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9. Climate Change Impact on Quality Seed Production

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Abstract:

Climate variation is a genuine and unavoidable phenomenon that continuously risk the terrestrial environment and global food security. Few studies have examined how climate change may affect the development of advanced-quality seeds, which are the primary source for production, despite influence of the phenomenon on crop productivity and the environment get a lot of attention in recent years. As the main component used in crop cultivation, seeds deliver the majority of advanced agricultural technologies to the field. Periodic variations in temperature have an impact on several plant growth phases, which both directly and indirectly lower the quality of seeds. While climatic anomalies that arise during the harvest and post- harvest stages may not necessarily have a significant effect on seed production, they can lower the quality of the seed lot's physiology, morphology, and biochemistry, which in turn lowers its field performance and germination rate. Increased temperatures overall, more frequent dry spells and droughts, strong winds, rising carbon dioxide concentrations, ozone impacts, heavy precipitation, and unpredictable rainfall are all examples of climate change. The impact of climate variations on the production of improved-quality seeds could be lessened with the help of genetic breeding of more resilient and adaptable varieties, the development of agronomic techniques, and accurate crop and climatic factor monitoring. This chapter examines the climatic elements that affect seed quality and deals with seed quality.

9.1 Introduction:

In practical terms, "seed quality" refers to a seed lot's total worth for the purpose for which it was designed (Hampton 2002). This value encompasses various factors such as the species composition, weight, size, and form of the seed, its vigor, health, physical purity, genetic purity,and viability. A number of Asian and African nations face the possibility of losing over 280 million tons of their potential cereal production due to the effects of climate change, specifically elevated temperatures, extended periods of drought, and irregular precipitation. Under various socio-economic and climatic change scenarios, the agricultural productivity of emerging nations in Asia is expected to fall by approximately 4% to 10%. These are the most important negative effects. The amount of arable land will decrease due to rising temperatures; by 2050, it is predicted that the amount of maize and wheat farmed will have decreased by 6 to 23% and 40% and 45%, respectively (Andreev et al., 2013; IPCC, 2013, 2014a). The consumption of seeds from grain crops—wheat, rice, maize, soybean, barley, and sorghum—which are most susceptible to climate change, provides the majority of the world's food supply.

The majority of farmland area—nearly 60%—will be affected by climate change primarily by rain-fed crops. Sub-Saharan Africa and South Asia are expected to be particularly vulnerable to climate change. Using high-yielding, stress-tolerant varieties of high-quality seeds in conjunction with prudent management of inputs—especially water and nutrients—can boost crop productivity.

The phenology, reproduction, flowering, anthesis/pollen viability, pollination/fertilization, length of seed-filling duration, seed setting, seed size, seed dormancy, seed yield, and eventually seed quality of the seed crop are all impacted by climate change. Therefore, due to operational scheduling, land and water management, herbicide/insecticide applications, pollination management, and post-harvest seed management, the cost of seed production is anticipated to increase in a changing environment.

One of the most important things to agricultural societies' means of subsistence is seed. It is the genetic potential stored in crop species and their variants as a result of generations of selection and continuous improvement. Farmers are generally aware of the potential advantages of using more high-quality seeds from a variety of crop kinds, as this improves agricultural yield and boosts food security (FAO, 2009).

A vital part of the agricultural production system is the timely availability of high-quality seeds of enhanced varieties that are suited to thrive in various growing environments. Using high- yielding varieties' quality seed is thought to boost crop output by 15% to 20%, assuming all other variables stay the same (Agarwal, 2011). High temperature and moisture stress on the seed crop has been found to affect not just the seed yield but also the quality and performance of the resulting crop, among other climatic aspects. In general, delayed development resulting from one or more environmental conditions significantly lowers the quality of the seed. Genetic diversity, pollinator biodiversity loss, and crop/weed interactions all have an impact on the generation of high-quality seeds.

The size of each individual seed, the content or nutritional quality of the seed, and the seed's capacity to germinate and thrive are the three main factors that determine the quality of a seed. A seed's growth environment affects each of the three dimensions of quality. Due to their effects on nutrient uptake, assimilate supply, partitioning, and remobilization, heat stress and drought can have a significant effect on the seed quality of cereals and legumes (Prasad et al., 2008).

A large portion of the variance in seed quality between seed lots can be attributed, either directly or indirectly, to variations in the weather before to or during harvest; hot, dry spells are typically associated with high-quality seed (Austin, 1972). It has been demonstrated that high temperatures following anthesis lower the quality of rice and bean seeds.

Between the conclusion of the seed-filling phase, also known as mass maturity, and harvest maturity, when cereal seed harvests have naturally dried to a moisture content of roughly 15%, the quality of cereal seeds, including wheat and barley, increases. The quality of seeds produced by soybean plants that are subjected to abnormally high temperatures during seed filling—that is, seeds that are wrinkled, flattened, and have depressions in the seed coat—is frequently significantly poorer than that of seeds that are flawless.

With the exception of mechanical damage, the main factors affecting seed quality at harvest are moisture, temperature, and disease (P. longicolla-caused pod and stem blight). Drought and/or heat stress can reduce the viability of the harvested seeds along with reducing size of seed and its constituents. The germination rate of peanut seeds grown under drought stress was decreased. The quality of planting stock is greatly influenced by the quality of the seeds. The greatest seed quality is typically thought to be reached during field crop growth at physiological maturity, or the conclusion of seed filling. Compared to normal germination, seed vigor was frequently more susceptible to high temperatures. Wetzel's findings regarding the relationships between seed quality and size in soybeans can be applied to the majority of seed types: Larger seeds in a population have better qualities in terms of germinability, stand establishment, and survival; this link between seed size and quality is most stable within a lot or population of seeds (Wood et al., 1977). When seeds have dried to a moisture content that permits harvesting without causing considerable damage, the crop is harvested at harvest maturity. It's possible that the seed quality has already declined by then. There are variations in the time at which individual seeds reach physiological maturity due to uneven seed development within a crop. Pathogens before physiological maturity, pre-harvest weathering, mechanical damage during and after harvest, and deterioration during storage can all contribute to poor seed quality. Poor quality might also arise from hot, dry weather when seeds are maturing (FAO, 1994). Pollen and seed set functioning is impacted by environmental stresses that exist during pollen development, germination, and pollen tube growth (Thuzar et al., 2010), which in turn affects the quantity and quality of seeds produced.

9.2 Impacts of Climate Change on Production and Quality of Seed:

From the earliest phases of plant growth, such as germination, until the start of reproductive growth in plants, climate change can affect seed production and quality. Various stages of plant life are affected by climate change, including seed development and maturation, flowering, pollination, fertilization, harvesting and threshing, processing, storage, and transportation. Among these, the impact on seed quality is negative during the reproductive stage, harvesting, and post-harvest phases.

9.2.1 Germination:

The annual rise in temperature is one aspect of the changing climate. Temperature increases up to 35 °C have a beneficial influence on germination; that is, whereas even high temperatures might damage the fragile embryonic tissues, in this case, the germination percentage is either increased or unaffected. A tendency toward higher temperatures can lengthen seed dormancy and lower the rate of germination, particularly in crops where lower temperatures are necessary for seedling establishment and germination.

9.2.2 Vegetative Growth:

Most responses differ within species as well as between species and are dependent on developmental stage. In poplar and soybean, higher temperatures and CO2 levels are linked to larger average leaf sizes, which promote vegetative development (Dermody et al., 2006; Taylor et al., 2003).

In leaves, there are species-specific, temporally specific, and spatially specific reactions to increased CO2. The rate of leaf start, expansion, and longevity increases linearly with temperature in the 6–26 °C temperature range. Depending on the stage of leaf formation, drought stress typically causes decreased leaf expansion in many species. Regular cell division activities throughout the early stages of growth are necessary for the leaf to reach its ultimate size; if cell division is stopped at this point, the future leaf size cannot rise.

9.2.3 Reproductive Growth Physiology:

The impact of climate change on plant reproductive performance affects the sequencing of numerous plant reproductive phases, including flowering, seed production, and viability, as well as the web of interactions among them. These effects are expected to respond to various components of climate change, including temperature and water availability, and they might be susceptible to changes in the phenology of the species.

Because high temperatures and CO2 can change the physiological processes involved in flowering, the reproductive stage is extremely vulnerable to environmental challenges and can fail to produce seeds and develop in a timely manner (Jagadish et al., 2007, 2016; Singh et al., 2013). As high degrees of heat hasten maturation and shorten crop duration, cool temperatures during the vegetative stage of crop may lengthen its duration. It has been discovered that a plant growing in high CO2 increases photosynthesis, allocating more resources to seed laying and bloom growth. Furthermore, by raising the plants' relative growth rates and size at blooming, the higher temperatures and CO2 levels have an impact on the physiological underpinnings of flowering. Temperature and precipitation variations can have a direct or indirect effect on plant phenology (Inouye, 2008), the development of reproductive structures (Day et al., 1999, Miranda et al., 2009), or both. Disruptions to plant-plant or plant-animal interactions are possible (Brooker, 2006; Memmott et al., 2007); changes to plant size and population are also possible (Knight, 2003).

A. Flowering Time:

According to Jagadish et al. (2016), flowering time is a crucial element in regulating plant reproductive performance and seed set. Depending on the types and conditions for plant growth, more CO2 and air temperature can either delay or change the flowering cycle. Variations in temperature and rainfall seem to have a major impact on the phenology of flowering and reproductive output changes associated with climate change (Ratchke and Lacey, 1985). Specifically, there is a strong relationship between the amount of water available and the development and upkeep of floral organs as well as the quantity of fruits, seeds, and flowers (e.g. Herrera, 1991).

A crop's ability to delay flowering due to heat stress varies by species. Faster flowering can cause the plant to develop reproductively before it has enough biomass to produce a larger seed yield. Certain perennial species have seen an advancement in flowering time due to the cumulative influence of slow climatic change; nevertheless, variations in the flowering period of annual plants should be taken cautiously. The alteration in blooming time has been limited by the regular breeding method used in commercial crops to achieve synchrinous flowering within a specific period of time.

On other hand, it is stated that the high temperature, CO2, and their dynamic interaction affect flowering time in both good and negative ways. It has also been documented to have an impact on the rise in nectar production. Additionally, the effect of heat stress was found to be associated with a decrease in floral organ size and number (Hoover et al., 2012).

B. Pollen Biology and Dispersal:

The exposure of pollen grains to the environment is a crucial stage in the reproductive cycle of higher plants.It is recognized that a number of environmental stressors, including heat, drought, cold, and humidity, can impact pollen viability and production. When the mother plant is stressed, the pollen grains will get a signal that will affect the time and planning of the pollen dispersal process. Therefore, the discharge of pollen is determined by the equilibrium between the environment and the physiological state of the sporophyte. Throughout its growth phases, pollen is extremely susceptible to heat stress. Because elevated temperature quickens flowering, the crop plants must start the flowering phase before enough inputs have accumulated. Pollen production is usually unaffected by elevated CO2 levels; however, it may experience reduced viability and germination. The decrease in nutrient availability, particularly for nitrogen and phosphorus, as a result of elevated CO2 levels may be the cause of the decline in pollen viability and quality. Heat stress is frequently reported to have a detrimental impact on the morphology, total amount of pollen generated, architecture of the pollen wall, viability of the pollen, germinability, and expansion of the pollen tube. One important factor in the mechanism of pollen tube growth is temperature. Grain mass, seed laying, and pollen viability all decrease after brief exposure to high temperatures (Prasad et al., 2002). As a result, short-term temperature stress can cause infertility; high temperatures also affect the chemical composition and metabolisms of pollen, as well as pollen load, morphology, anther dehiscence, and wall architecture. Similar to heat stress, dry spells during flowering have an impact on pollination or reproductive growth.

C. Stigma Receptivity:

The pollen grain initially comes into contact with the stigmatic surface of the pistil. Numerous studies suggest that temperature affects spikelet fertility and stigmatic receptivity in a variety of crops, including Indian mustard, rice, sorghum, and many more (Maity et al., 2019), Rang et al., 2011, Jagadish et al., 2010). The stigmas lost their capacity to hold pollen tubes in place when they entered the transmitting tissue, to keep germination going, and to permit pollen grains to adhere. Reproductive failure results from any meteorological anomalies that occur during any of these phases. In the end, this results in the generation of tiny seeds, which are lower quality.

D. Pollinating Agents:

Insects are essential to the success of pollination in most cross-pollinated species, including those that cross-polinate often. Climate change has a significant impact on insect pollination, particularly on temperature extremes (both hot and cold), which endangers the world's food supply (Forrest, 2017). Any change in temperature, drought, or CO2 levels that affects the generation of pollen and nectar has a adverse impact on pollinator activity, which in turn has a negative impact on crop growth and productivity. Because the reproductive stage of the bee experiences different environmental conditions than usual, a change in planting time may result in lesser pollination activity of the bee population. Because of the change in the hexose to sucrose ratio in nectar, a higher concentration of CO2 has a detrimental effect on the population of bumble bees (Bombus terrestris L.) (Hoover et al., 2012). Increased atmospheric CO2 levels lengthen bloom life and number in many species, which affects pollinator activity. The Apis mellifera bees' foraging activity at 6.57° celsius was shown to be lowest above 40° celsius or below 10° celsius, with the highest action occurring approximately at 20° celsius. There is generally a substantial negative correlation between foraging behavior and temperature, suggesting that in cases where climate change affects seed set and quality, bee foraging may be restricted.

E. Seed Yield:

The majority of India's crop production area is made up of rain-fed crops, such as pulses, which are particularly vulnerable to the effects of climate change (Basu et al., 2009). Numerous factors, including climate change, might affect seed output. Increased atmospheric CO2 increases seed output in C3 plants, while it decreases seed yield in C4 plants, including maize and sugarcane, according to current research in crops like cotton, soybean, rice, and peanut. Because there are fewer completely developed seeds in water-stressed plants, both C3 and C4 plants may produce less seed. Because less photosynthate accumulates in seeds during the peak stage of seed development, a slight increase in temperature can have a substantial negative impact on seed output. Raising the temperature has a negative effect on the pace, duration, and timing of seed filling, which reduces the mass of the seed. Several research on vegetable crops showed that higher temperatures doubled the vegetative biomass, and that increased CO2 can impact the vegetative growth of the carrot plant. Wild radish produced more seeds and flowers when atmospheric CO2 levels were higher. In carrots, warmer temperatures increased the quantity of umbels per plant. Individual seed size and weight may be attained, even though the quantity of seeds may grow. Pre-harvest sprouting, decreased seed quality, and shorter storage shelf life are all caused by irregular rainfall throughout the seed ripening stage.

F. Seed Biochemical Composition:

Adversities in the weather have the potential to lower seed yield as well as change the biochemical makeup, which can lower seed quality in the end. Seed viability, germination, dormancy, and seed and storage abilities are significantly impacted by components such polyphenolics and the fatty acid composition of oil content in seed (Kaymak,2012). Therefore, there may be negative effects of climate change on the biochemical makeup of seeds, which could lower the quality of those seeds. Proline is an essential amino acid that gives plants and seeds stress tolerance. Environmental conditions also affect the enzymes involved in the synthesis of proline, including pyroline-5- carboxylate synthetase (P5CS), proline dehydrogenase (PDH), and ornithine amino transferase (OAT). The development and maturation of high-quality seeds depend on the activity of several key enzymes, including callase (ß-1, 3-D-glucanase), sucrose and starch synthase, hydrogenase, α- and β-amylase, invertase, protease, lipase, and mannose, as well as plant growth regulators (PGR) like ABA, GA, ET, cytokinins, auxin, and brassino steroids (BR). However, sensitivity of any of these enzymes to environmental stressors can affect the quality of the seed.

9.2.4 Harvesting and threshing:

Unseasonal rainfall during harvest negatively impacts seed quality and yield. The inability to follow harvesting procedures and the higher moisture percentage in seeds cause fungal pathogen infection, which results in the production of low- quality seeds. Fruit and vegetable harvesting takes place at different periods of the year based on a variety of pre-harvest parameters, including maturation index, temperature control, pest control, cultural methods, exposure to direct sunshine, and cultivar. Fruit and vegetable produce becomes more perishable in high temperatures. Strong winds during the harvest season cause plants to lodge, which results in the loss of high-quality product.

In order to maintain the quality of the harvest, respiration is the primary process that must be controlled after harvesting (Saltveit, 2002). Nevertheless, because respiration is highly dependent on the unique qualities of the product, managing it has become more challenging in an environment where climate change is an ongoing issue.Excessively dry grain has low viability, which results in large losses in the grain quality. It also becomes brittle and can break after threshing or during milling. Increased temperatures and atmospheric CO2 levels promote the growth of weeds, which has two negative effects: they compete with crop plants, causing them to mature earlier and generate lower-quality seeds, and they contaminate crop product with weed seeds, reducing its physical purity.

9.2.5 Storage:

Climate change will cause higher temperatures to shorten the shelf life of things that are stored, whereas lower temperatures will increase the same product's shelf life.Elevated temperature and humidity levels have the potential to diminish the efficacy of certain commercial grain protectants' active components, as well as accelerate the crop's chemical and biological deterioration (Stathers et al., 2013). Shorter shelf lives could result from these climate change events as well as an increase in the chemical and biological deterioration of stored goods. All crops will be seriously impacted after harvest by this, particularly perishable goods that quickly deteriorate in hot weather. Furthermore, rising temperatures can accelerate the spread of pests and crop diseases, which is a serious risk to efficient storage (FAO 2008). The ideal criteria for produce quality in terms of grading, packing, and storage are determined by the growth period's temperature and CO2 concentration.

9.3 Interactions:

i. Unseasonal Rainfall and Seed Quality:

Approximately one- third of the global population lives in areas that are severely water-stressed. With global warming, the hydrological regimes in which crops flourish will undoubtedly alter. The availability of water is a significant factor in agricultural output variability between environments. The main factor influencing inter-annual variations in agricultural productivity is typically the quantity and timing of rainfall. Over-rainfall during the vegetative and reproductive stages creates conditions similar to flooding, while insufficient rainfall creates conditions similar to droughts, which have a significant impact on disease infestation, germination, seedling growth, and crop physiology. There are several variables that affect seedling emergence, but one important one is the availability of water. Rainfall affects the development of superior seeds in a number of ways. Reproductive structures are not prepared for optimal pollination and fertilization when rain falls during the peak pollination time. Even in the case of modest rainfall, inflorescence is not entirely completed, as the stigma is not at completely receptive in nature, and low activity of pollinators. Even in cases where rain does not impede crop pollination in its early stages, it has a significant impact on seed growth and maturity stages. There are obstacles to the biological processes required for the development of premium seeds leading to decreased crop yield in terms of quantity and quality due to the unseasonal rainfall brought on by climate variation that happen at unintended times during the crop development.

ii. UV Radiation and Seed Quality:

Human activity has caused the protective ozone layer to thin, increasing the amount of UV radiation that reaches the earth's surface. UV radiation impacts a number of physiological and biochemical processes in plants, including abnormal carbon partitioning from source to sink, which reduces output by affecting crop phenology, photosynthesis, and reproductive organs.C3 plants don't produce as much soluble proteins and chlorophyll when exposed to high UV radiation levels. Increased UV-B radiation can lead to a decline in seed quality, specifically in terms of a reduction in protein content and total free amino acid content. UV rays cause disruptions to stomatal opening and shutting, which reduces gaseous exchange and the rate of transpiration. In addition, UV light causes hormonal abnormalities and changes the way cells divide.

9.4 Mitigation strategies:

A. Breeding Strategies:

The global breeding goal until recently was to generate crop cultivars that would provide large amounts of food while being resistant to pests and diseases. This approach has limited the variance in the gene pool and made it less able to adapt a wider extent of settings.

The seed coating serves as biochemical barrier that inhibits the growth of pathogens and insect infestation in addition to acting as a physical barrier that shields the embryo from the outside world. On the other hand, since phenols and tannins are thought to be anti-nutritional, efforts are undertaken to lower the concentrations. The susceptibility to adapting to the constantly shifting environment brought on by climate change has grown because of the significant decline in seed physical and chemical defense mechanisms. In the past, the C3/C4 pathways have exhibited a dynamic equilibrium in evolution. By accumulating genetic, physiological, and anatomical modifications to utilise higher temperatures and CO2 levels, the C4 system progressively evolved from the C3 system (Kalra et al., 2008). Many nations are concentrating their current breeding techniques on creating C4 variations in income crops in order to capitalize on the changing climate. The development of crop cultivars with stable seed quality features requires equal or more care. A lot of crops, including barley, soybean, lentil, common bean, and many more, are undergoing special breeding efforts to produce crop cultivars with superior seed quality features.

B. Agronomic Strategies:

Farmers have made adjustments to irrigation schemes, varied cropping patterns and intensities, and timing of planting and harvesting in an effort to mitigate the effects of climate change on crops (Singh et al., 2013). The techniques for reducing abiotic anomalies are practical, affordable, and simple to apply in the field. It has been discovered that these methods help in crop adaptability and management ease. Moving production of seed to a more advantageous ecological corner—either higher or lower in latitude and altitude—is required to prevent climatic stress from adversely influencing the quantity and quality of seeds produced. Some potential mitigation techniques include planting climate-resilient cultivars, developing novel varieties to lessen the impact of climatic variation, and working to bring minor or ignored species into widespread cultivation to ensure food and nutritional security. One method of adapting to climate change has been to move the date of seeding to escape the damaging effects of temperature stress during seed setting. Wheat would need to be sown six days earlier in northwest India for every degree Celsius that the temperature rises. Although delaying the sowing date could be a smart establishment tactic to reduce the impact of temperature stress on the quantity as well as quality of seeds, other factors like temperature of soil and length of the day must be taken into account. It is necessary to customize crop establishment techniques, that are irrigation intervals, ideal planting density, time and spacial-specific fertilizer scheduling, precise pesticide treatment, and routine crop scouting, to local cropping systems under particular environmental stressors. Using a dynamic crop rotation strategy, one may modify the impact of spatial distribution and the degree of change in climate. Pre-sowing maize and field crop rotation increased output somewhat, but they were unable to make up for losses brought on by climate change in warm, lowland regions. Water conservation can be achieved without sacrificing production by utilizing contemporary irrigation techniques like the evaporative canopy-cooling technique, which is an adaptation of modern, makeshift irrigation methods. In Italy, it was discovered that the method produced larger seed yields.

C. Seed Quality Improvement and Seed Treatment:

In field situations, enhancing the microclimate surrounding seeds may eradicate or lessen the chance of harm from natural disasters. To deal with unfavorable field circumstances, seed coating with thermostat polymer that can include the necessary insecticides and growth supplements (such as hormones or plant growth regulators) is a viable solution for high-value crops. Here, seeds are only permitted to sprout on the field during favorable temperatures. In regions where drought is a possibility, seed germination can be sustained by covering seeds with materials that have a high capacity to retain moisture.

Other contemporary technologies, such as nanotechnology and seed priming and hardening, also help preserve or enhance seed quality (Maity et al., 2016). It has been shown that a number of seed treatment techniques, including pelleting, polymer seed coating, and seed priming, reduce stress and boost seed production. Hydropriming, halopriming, osmopriming, solid matrix priming, biopriming, and magneto priming are some of the seed priming techniques. Salicylic acid (SA) seed priming has drawn attention recently as a way to reduce abiotic stress. An experiment on seed priming found that salicylic acid and ascorbic acid priming boosted the amylase, catalase, peroxidase, and superoxide dismutase activity which in turn increased rice seed germination at [CO2], thereby mitigating the influence of [CO2] on rice seed germination. As a defensive metabolite, salicylic acid stimulates gibberellic acid, a germination hormone, and inhibits abscisic acid, a dormant hormone (Li et al., 2017b).

D. Use of Traditional Cultivation:

Some of the areas that our ancestors focused on were variety selection for higher quality of seed attributes to natural means of conserving seeds for extended periods of time. "Mittikakotha" (mud grain storage structure) is one such promising grain storage construction. These are tried-and-true methods for managing seeds on a modest basis. Incorporating these technologies into contemporary seed storage projects that involve scientific improvement of the structures requires careful consideration (Maity et al., 2020).

E. Policy Efforts at Global Level:

Over 1,700 genebanks throughout the world have food crop seed collections. But many of these are also susceptible to preventable calamities, such inadequate funding or bad management, in addition to natural disasters and war. On the Norwegian island of Spitsbergen, the Svalbard Global Seed Vault was founded in 2006 to fight significant regional or global catastrophes in the age of climate change. With space for millions more, the Seed Vault protects duplicates of 1,145,693 seed kinds from nearly each nation on earth. Its goal is to safeguard the base of our future food supply by backing up genebank collections. Global cooperation of this magnitude is needed to protect the planet from impending climate risks.

F. Close Monitoring for Improved Stewardship Practices:

Farmers urgently need to adopt smart agriculture that takes advantage of cutting-edge crop production technologies as the environment continues to change. Commercial seed production processes will continue to use remote sensing-based crop monitoring and input application. Unmanned aerial vehicles should be used for disease-pest monitoring in order to promptly implement preventative actions. Local companies and seed growers should be encouraged to follow region-specific production and storage guidelines. Avoiding potential problems due to climate aberrations requires prior detection of dangers during production of seeds and pre-arrangements for post-harvest handling of produce.

9.5 Conclusion:

All of our terrestrial life has already been influenced by the reality of climate change. One of the main prerequisites for global agriculture is the delivery of higher-quality seeds in order to increase food output and satisfy present food production demands. While the negative effects of variations in climate on production of food grains are well known, there has been little discussion of how these effects affect the world's ability to produce and provide high-quality seeds. Variables related to climate can affect the biochemical makeup of seeds, which can lower productivity without always lowering lot quality. In order to maintain the global seed supply chain, stewardship procedures must be adjusted and systematic research and evaluation of the situation are urgently needed. Thankfully, recent studies have concentrated on adding characteristics related to seed quality as a criterion for crop breeding. It is crucial to investigate vast germplasm pools in an effort to identify improved and consistent seed quality features. Modern seed augmentation methods including as coating, priming, nanotechnology, and molecular approaches must be used as an intervention. Finding an appropriate geographic location for the production of high-quality seed requires both temporal and spatial movement of the seed production niche.

In order to create new technologies that are suited to the requirements of small-scale seed producers, it is imperative that the conventional methods of seed production and storage be reviewed. Every country should concentrate on concerted global initiatives.

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