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Speed Breeding: Techniques, Applications, and Challenges in Modern Crop Improvement

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Speed breeding is an innovative breeding process that allows for the development of crop varieties in a shorter period of time. This technique is essential to improve crops' ability to adapt to changing climatic conditions and meet global food demands. It uses longer photoperiods to accelerate plant development as well as harvesting and germination of immature seed, minimizing generation time.

Introduction

Speed breeding is a set of approaches that entail modifying the environmental conditions in which crop genotypes are produced in order to speed up flowering and seed development so that the next generations can be produced as quickly as possible. It works on the chromosome and provides optimal light quality, intensity, and temperature to promote photosynthesis, increase growth, and breeding. The generation cycle can be cut in half or three times the time necessary to create a new variety using traditional breeding procedures (8-10 years). Speed breeding has recently been implemented in the majority of over 100 plant species, including vegetables, legume crops, cereals, and other herbaceous vegetables. Speed breeding techniques have been established for a variety of long-day and short-day plants, including rice, soyabean, and Amaranthus.

Controlled Environmental Techniques in Speed Breeding

- **Artificial Control of Light Duration:** Plants' daily exposure time to scheduled light and dark regimes is adjusted to promote quick growth, development, flowering, and seed set.
- **Management of Thermal Conditions:** Adjusting soil and air temperatures affects germination and growth responses, resulting in rapid growth, flowering, seed set, and maturity.
- **Soil moisture regulation:** Soil moisture stress can significantly alter plant growth and development processes, altering plant height, days to flowering, seed set, and maturity.
- **Plant population density:** Because of light competition, high plant densities produce tall plants, resulting in a quick shift from vegetative to reproductive growth stages. This method is excellent for inducing early flowering and maturity, increasing the number of generations each year.
- **Modulation of CO_2 Environment:** Increased carbon dioxide levels may accelerate plant growth and the shift from vegetative to reproductive stages in some plants.
- **Use of plant nutrition and hormones:** When plant growth regulators are employed in controlled situations like greenhouses and growth chambers, where photoperiod and temperature can be monitored and regulated, they produce a varied response.

Applications of Speed Breeding in Crop Improvement

a. **Speed Breeding as a Tool for Crop Enhancement:** Speed breeding generates 3 to 9 generations each year, allowing for the rapid production of homozygous and stable

genotypes, as well as the rapid progression of generations. It additionally has the potential to coordinate the flowering of cultivated and wild crop species, increasing the variability in populations that breed and speeding up the achievement of breeding goals.

b. **Synergistic Use of Phenotyping and Speed Breeding to Boost Yields:** Plant phenotyping is defined more recently and comprehensively as the examination of complex plant properties such as growth, development, tolerance, resistance, physiology, and yield. Combining speed breeding and phenotyping will encourage root adaptation in changing settings, as well as water scarcity, to increase food crop yield.

c. **Integrating Gene Editing and Speed Breeding for Crop Enhancement:** Genome editing is a site-specific genetic alteration to a crop species to increase yield. A high-yielding variety can be created, but the process is time-consuming and labour-intensive. As a result, merging these two technologies has the potential to solve the dilemma, as numerous generations can be generated in a single year.

d. **Accelerating Genetic Gain through Speed Breeding and Genomic Selection:** Breeding techniques like as genomic selection, genetic engineering, and double haploid technology have reduced breeding cycles and increased genetic grain yields. When these technologies are combined with speed breeding, it is possible to progress generations quickly by cultivating plant populations under regulated photoperiod and temperature regimes to accelerate their growth and development. This method can produce higher-quality plant types in a shorter period of time, increasing genetic gain.

Limitations

- ✓ Lack of sophisticated environmentally controlled facilities can increase costs and limit accessibility, particularly in resource-poor countries.
- ✓ Risk of genetic loss due to difficult supervision of these expedited procedures.
- ✓ Excessive photoperiod can reduce plant growth and increase stress hormone levels.
- ✓ Problems in pest and disease control, as well as tracking individuals for gene discovery.
- ✓ Keeping plants alive beyond their physiological limits can be detrimental and lead to genetic loss.

Conclusion

Speed breeding can hasten the production of high-performing cultivars with market-favoured features by minimizing the amount of time, space, and money invested in the selection and genetic improvement of superior crop types. This method enables plant breeders to produce enhanced crop types more quickly. Integrating speed breeding with traditional, marker-assisted selection, and genetic engineering can improve the successful selection of elite genotypes and lines with innovative features such as greater yield and biotic and abiotic stress resistance.

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