Krishi Netra

Speed Breeding: Redefining Agricultural Timelines For Global Food Security

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Manuscript No: KN-V2-01/014

Abstract:

Plant breeding is crucial in addressing agricultural challenges and boosting food production for a growing population. Traditional and modern genomic tools like genotyping, genome editing, and marker-assisted selection aid breeders in swiftly identifying and integrating traits. However, these methods often involve lengthy generation times. To overcome this, researchers introduced "speed breeding," a novel concept enabling faster generation cycling and greater genetic advancements for accelerated varietal development. By reducing the breeding cycle of the crops, speed breeding has successfully achieved a higher genetic gain for crops. The rate of plant improvement has increased, and speed breeding focuses mainly on photoperiod extension, temperature control, land, and early harvest. The development of improved crop types through plant breeding is hampered by the exceptionally extended crop duration. Numerous molecular techniques, such as genetic selection, mutagenic breeding, somaclonal variations, whole-genome sequence-based approaches, physical maps, and functional genomic tools, have been used to improve agronomic attributes associated with production, quality, and resilience to biotic and abiotic challenges in crop plants.

Key words: Speed breeding, photoperiod, breeding cycle, generations

Introduction:

Inrecentyears,therateofglobalurbanizationandpopulationgrowthhasincreasedrapidly,whiletheratiooffoodproductiontoconsumptionhasdeclinedsignificantly. Sincetheearly20thcentury,plantbreedinghasplayedanimportantroleinensuringfoodsecurityandhashadadramaticimpactonfoodproductionaroundtheworld. However,inrecentyears,issuesregardingfoodqualityandquantityhavesurfacedaroundtheworldasfooddemandisunsustainablefortherapidlyincreasinghumanpopulation. Additionally,rapidweatherfluctuationsduetoglobalclimatechangeareleadingtoheatanddroughtstress,resultinginsignificantproductionlossesforfarmersaroundtheworld.

Since the 1940s, plant breeding techniques like single-seed descent and shuttle breeding aimed to modify the plant lifecycle pace. Recently, scientists have prolonged plant lifespans by manipulating controlled-environment growth conditions. Speed breeding encompasses methods such as accelerated single-seed descent (aSSD), rapid generation cycling (RGC) with DNA marker tech, fast generation cycling (FGC) via stressed conditions and in vitro embryo culture, and rapid generation turnover (RGT) using immature seed harvest and photoperiod response.

Researchers at the University of Queensland first used the term "speed breeding" in 2003 to refer to a set of procedures designed to expedite the breeding of wheat. By using optimal light intensity, temperature, and daily duration regulation (22 h light, 22 °C day/17 °C night, and high light intensity), speed breeding aims to improve photosynthesis and shorten the generation time by directly boosting early flowering. Annual seed harvesting is also a key component of this strategy. The wavelength and intensity of the light play a significant role in controlling blooming. In recent times, there has been a notable decline in the ratio of food production to consumption, concurrent with a surge in global urbanization and demographic growth.

Traditional breeding methods have limitations in enhancing plant genomes for new varieties. Molecular markers, employed since the 1990s, aid in selecting superior hybrid lines. Plant breeders often prioritize diploid-like crops, such as maize and tomatoes, over polyploid crops like alfalfa and potatoes due to their simpler genetics. Shorter reproductive cycles in crops enable quicker production of desired traits through artificial breeding. Combining plant breeding with genome studies enhances accuracy and expedites the process, leveraging plants' genetic manipulability, shorter generation times, and larger population sizes. Efforts like NASA's collaboration with Utah State University in the 1980s led to the development of "USU-Apogee," a dwarf wheat line designed for rapid cycling in space. Recently, Lee Hickey and colleagues introduced "speed breeding," a non-GMO approach facilitating faster turnover of generations and selection of desired plant traits by regulating environmental conditions and extending photoperiods. This method achieves between four and six generations per year for long-duration crops like wheat, barley, and canola.

Speed breeding conditions

Light: For the purposes of speed breeding, any light that generates a spectrum encompassing the Photosynthetic Active (PAR) region (400-700 nm) with an emphasis on the blue, red, and far-red ranges is appropriate.

Photoperiod: For speed breeding, a photoperiod consisting of two hours of darkness and twenty-two hours of daylight has been found to be beneficial.

Temperature: In the speed breeding process, a temperature of 22 degrees Celsius during the day and 17 degrees Celsius at night has been utilized

Humidity: The speed breeding program has been running with a humidity of between 60 and 70 percent.

Achievements: Single-seed descent technique in speed breeding: To produce homozygous lines with fixed features, the single-seed descent technique is frequently applied on a large number of segregating populations for numerous generations. It's a crucial stage in the growth of the cultivar and calls for dense plantings. Increasing sowing density under Speed breeding will result in a rapid cycle of viable and healthy seeds. In spite of the high planting density, all plants generated a spike with enough seeds to carry out SSD, according to Watson and Ghosh's experiment with wheat and barley. The experiment's outcomes demonstrate the importance of high-density planting in SB environments to produce plants appropriate for a sizable and resource-efficient generation turnover in SSD operations.

Six generations are produced annually in plants including wheat, barley, and chickpeas without the need for embryo rescue. Uniform germination rates and robust plants arise more quickly from the early harvest of barley and wheat seeds grown under SB at two weeks post-anthesis, followed by a brief drying time. Design of an inexpensive bench-top growing cabinet for SB testing

Challenges and Limitations

SB is an effective technique for quickening the pace of genetic gain in several plant species, as previously mentioned; yet, it has drawbacks. Obtaining CE conditions that are appropriate for the target species' fast cycle is a major barrier. If advanced CE facilities are not easily accessible, SB settings become costly, and integrating SB with other methods like embryo rescue and MAS necessitates more resources and knowledge. Additional difficulties include maintaining a consistent temperature, particularly in the winter, and supplying electricity continuously. Routine SB usage for research and breeding is still difficult in resource-poor nations because of inadequate infrastructure, a lack of experience, and a lack of international organization collaboration. This problem is less severe in developed nations.

Once a specific breeding system (SB) is established, various species can show genetic differences in how they respond to intense growth conditions. These conditions often lead to limited seed yield, which can make it challenging to assess the plants in subsequent field trials. To tackle the issue of low seed numbers, employing advanced, limited-observation field trial setups can be beneficial. Extended exposure to light can restrict plant growth and might be linked to issues like excessive starch production, photo-oxidation, and heightened stress hormone levels. Harvesting seeds prematurely could also disrupt the accurate assessment of seed characteristics. The rush for quicker results pushes plants to their limits, and environments optimized for rapid growth can harm a plant's defense mechanisms. Careful management is crucial as such conditions can cause significant losses in valuable breeding material. To address this, adjusting conditions to identify optimal light saturation and temperature thresholds for each species, and sometimes even for different genotypes within a species, is vital. Additionally, keeping backup seeds from each plant generation serves as a safety net against genetic loss due to diseases, pests, or unexpected interruptions like power outages in. controlled environments or similar setups.

Conclusion:

Speed breeding has undeniably enhanced the yield performance of essential cereal crops such as wheat, barley, and chickpeas by significantly boosting genetic gain. Yet, its impact on common horticultural produce like fruits and vegetables remains a fascinating topic. Compared to genomic selection, speed breeding has shown more robust results, achieving a high rate of genetic gain in its cultivated plants. Addressing the formidable challenge of lengthy varietal development periods, speed breeding has instilled hope for innovative breeding strategies and program restructuring. Its approach aims to streamline challenges and capitalize on emerging opportunities in the field of plant breeding.

REFERENCES:

Devi, O. B., Haokip, S. W. and Singh, Y. S. 2023. Speed Breeding: An Effective Strategy for Breeding of Crop New Kinds and its Future Prospects. Vigyan Varta 4(7): 83-86.

Samantara K, Bohra A, Mohapatra SR, Prihatini R, Asibe F, Singh L, Reyes VP, Tiwari A, Maurya AK, Croser JS, Wani SH, Siddique KHM, Varshney RK. Breeding More Crops in Less Time: A Perspective on Speed Breeding. Biology (Basel). 2022 Feb 10;11(2):275. doi: 10.3390/biology11020275. PMID: 35205141; PMCID: PMC8869642.

S. Acharya et.al. (2021) Int. J. Grad. Res. Rev. Vol 7(1):11-16.

Sunny Ahmar, et.al. 2020 “Conventional and Molecular Techniques from Simple Breeding to Speed Breeding in Crop Plants: Recent Advances and Future Outlook”International Journal of Molecular Sciences 21(7).