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Speed Breeding: An Accelerating tool for Crop Improvement

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The increasing global population and changing environment have raised significant concern for global food security and it is projected that by 2050, the present agricultural advancement will not be adequate to provide food for the expanding global population. Hence need to improve the current rate of crop improvement (Anjum et.al., 2017). The traditional breeding techniques used for developing new crop varieties are time-consuming and cannot keep up with the exponentially rising demand for food production. However, with the advancement of technologies and breakthroughs, researchers and breeders are able to accelerate the advancement of novel varieties. Speed Breeding is one such technique that can significantly increase the progress toward combating challenges associated with food security. Speed breeding utilizes controlled environments, which promotes rapid and accelerated growth and development from the vegetative stage to the reproductive stage. Speed breeding shorten the breeding cycle by accelerating the plant growth, flowering and seed maturation time by controlling all environmental conditions including photoperiod, temperature, soil temperature and light intensity from seedling to maturity.

History

Use of carbon arc lamp, an artificial light for growing plants dates back 150 years ago. Utah State University collaborated with the National Aeronautics and Space Administration (NASA) conducted a research to develop dwarf wheat varieties for fast growth and development using perpetual light environment. Thereafter the effect of LED on plant development was studied by researchers during 1990s. Researchers at the University of Queensland named this technology 'speed breeding' and used it in 2003 for wheat breeding. Later, many plant scientists became interested in comprehending more in this and now it is successful in Wheat, Barley, Chickpea, pea and oilseed rape. Speed breeding helps to achieve six generations of wheat, durum wheat, barley, pea and chickpea per year while four generations of canola per year. In addition to reduce the generation time, it provides the rapid generation cycle through SSD and the opportunity for adaptation to larger scale agricultural improvement efforts.

Requirements

Glasshouse chambers with controlled environment required for speed breeding. A controlled environment with specific air and soil temperature, light intensity, humidity, light hours is provided to speed up the growth stages. Enhancing growth, development, flowering, and seed set in many crop species and genotypes requires manipulating photoperiod regime. According to some reports, certain photoperiod regimes can cause early blooming in crops like wheat, barley (Riaz, et. al., 2017 & Ribalta, 2017), chickpeas, grain amaranth (Rober et.al.,2021) etc. For the crops like Wheat, barley, and oats an ideal controlled environmental condition of 22h light and 2h dark, 22°C day/17°C night, humidity of 70%, and 360-380µmol/m2s light intensity were maintained. For a homemade growth room, designed for low-cost speed breeding, a room of 3×3×3m was made to accommodate 90 pots of 8-inch diameter with 5L volume (Watson et. al., 2018). A photoperiod of 12h light and 12h darkness was maintained for the first four weeks; later the photoperiod was increased to 18h light and 6-hour dark period. These speed breeding protocols vary crop wise.

Selection Methods

In plant breeding there are different selection methods like pure line, bulk, mass selection, recurrent and pedigree selection. As these selection methods are lengthy and require extended cycles of selection, they are unsuitable for speed breeding. These traditional methods do not align with speed breeding requirements. Some breeding methods like SPS (Single Plant Selection) and SSD (Single Seed Descent) can suitably align with principles and requirements of speed breeding. These breeding methods require less cultivation area and labors at initial generations. Hence these methods facilitate growing the plants in growth chambers and in HDP (High Density Planting) conditions. Speed breeding using SSD is highly efficient especially for cereal crops like wheat and barley. Higher sowing densities in speed breeding allowed rapid cycling of multiple generations annually. SSD has been practiced in legume breeding, offering practical applications in biotechnological tools for enhancing legume crops (Croser et.al., 2016) SSD has been applied to create recombinant inbred lines in chickpeas, focusing on salinity tolerance. Similar approaches have been used in peanut breeding research, where controlled conditions, continuous light, optimal temperature, and SSD were combined in a greenhouse setting.

Advantages

Speed breeding is suitable for long-duration crops. It enables rapid generation cycles and overcomes the limitation of seasons. Speed breeding saves labor, cost, and time of researchers as it fetches only light-emitting diode (LED) and other regulators. It facilitates development of new varieties when aligned with modern techniques like CRISPR, high throughput phenotyping, genome editing and genomic selection etc. It is highly cost-effective than single seed descent (SSD) and double haploids (DHs). It is efficient for gene insertion of distinct phenotypes followed by marker-assisted selection (MAS). It employs breeders to expedite genetic improvements such as yield gain, disease resistance and climate resilience in certain crops. It can significantly increase the progress toward combating challenges associated with food security through the development of genetic gain, especially in areas with harsh environmental conditions.

Limitations

There are some limitations to speed breeding. It is not far more suitable for short day plants or plants that require vernalization. The protocol needs to be customized according to the crop, the species, temperature, and lighting conditions since the photoperiod is independent of the crops and their agro-climatic conditions. It requires an artificial environment that requires a specific structure which differs greatly from field conditions where crop production actually takes place.

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