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Improving Selection Efficiency of Crop Genotypes through Precise Time Scale Capturing of Images and Artificial Intelligence Tools

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Introduction

Plant breeding is a continuous process across the world irrespective of the economic status of the countries. Agrarian country like India, where more than 60% of the population totally depends upon farming as the sole income generating avenue. Novel crop varieties combined with yield better adaptations and consumer preference are being routinely developed and popularised for cultivation. Plant breeding by any innovative approaches or conventional approaches are always labor intensive and require special skills oriented operations for evaluation of parental lines and selecting superior sergeants in the unstable segregating populations. Basic Steps in plant breeding are as follows 1) Evaluation of parental lines 2) Diversity analysis of parental lines and identification of extreme genotypes with divergence 3) Crossing of selected parents in a suitable mating design and studying the inheritance pattern of yield and yield attributing traits 4) Selection of superior lines from segregating populations by several cycles of screening and development of stable lines with homozygosity 5) Release of variety by following suitable yield trials.

Though the advances in molecular breeding tools and speed breeding techniques considerably reduce the huge tasks of screening and selection procedures to obtain stabilized homozygous lines, still it is a difficult and skill oriented task to screen the larger number of germplasm lines under the context of pre breeding. Germplasm lines consist of local land races, traditional varieties, pre-release cultures, reconstitutional lines and popular varieties (checks). Germplasm lines need to be characterized by screening for particular traits of interest to be incorporated for the current breeding objective of the programme. Whether it is conventional breeding or molecular breeding tools like mapping of QTLs through association mapping or through development of recombinant inbred lines or near isogenic lines, phenotyping of larger numbers of germplasm lines with multiple traits is must. Precise phenotyping should be done for mapping works for linking with genetic regions regulating the traits.

Larger numbers of germplasm lines are pooled and raised in a particular design and screened for various traits viz., biotic and abiotic stresses, water use efficiency, nutrient responses, nutrient use efficiency, photosynthetic efficiency, seedling vigour etc. They are regulated by different genomic regions and to be screened under different platforms under varied growth and development phases. Precise phenotyping of these complex traits to constitute the whole genomic structural studies is a skill oriented, labour intensive and time consuming process. After phenotyping, traits are linked to markers which are amplified in the genomic regions. Based on the traits linked with markers, multiple traits of interest are incorporated into a variety of interest based on phenotyping and genotyping in backcross/segregating populations. Screening a larger number of segregating and introgressed lines to identify superior genotypes is again laborious and skilled oriented operations involving trained man force and computation. Phenotyping needs to be precise and high throughput automation processes are required for handling larger numbers of germplasm lines with multiple traits in a given period of time for different growth periods. Screening germplasm lines is a continuous process in every cropping season as the breeding objectives have long term futuristic goals, also the structural genomic studies for genome wide association studies.

Scope of Automations based image Capturing on Phenotyping

Time scale capture of images of different growth stages of genotypes for phenotypic scoring, phenotypic scoring should be converted into a numerical data using image analysis programs. Thermal imaging using efficient capturing tools supported by drones can capture images of genotypes in all directions, smaller cameras can capture closely even the floral structures, leaf morphology and pigmentations. Capturing will be precise at different heights, different directions, close up macro level capturing for the genotypes raised in the field under different screening platforms for different traits.

Traits to be captured on time scale levels

1. **Seedling parameters:** germination, seedling growth (root and shoot height), Seedling vigour
2. **Early vegetative phase:** micro nutrients deficiency, Sucking pests (populations, symptoms, levels of damage), damping off, metal toxicity, salinity, alkalinity, and submergence: for these parameters, colour changes in leaf, height of the plants, malformations in leaf, etc should be included and converted into a numerical data. Validations should be with standard manual scoring and calibrations should be made for the accuracy of image captures and manual scoring.
3. **Active Vegetative phase:** Growth parameters like plant height, no of branches/tillers can be captured, essentially yield and yield attributing traits of active vegetative phase.
4. **Reproductive Phase:** Panicle emergence, anthesis and pollination, Flowering habits, pests and diseases scoring, plant height, photosynthetic efficiency, leaf area
5. **Maturity Phase:** Yield parameters, pests and diseases scoring, cold tolerance, spikelet sterility, Maturity levels.

All these different periods and levels of captures for each trait of screening should be validated with regular screening methods. If there are any discrepancies, calibrations need to be made for accuracy. Numerical data can be validated from the image analysis and regular methods. The trials should be reproducible and should be performed across locations for consecutive seasons. Standard checks should be used for validations. Numerical data of image capturing and phenotypic scoring should be identical without any deviations.

Requirements of Experimental Plots for Digitalization of Data

1. **Tillage:** Proper levelling, plots and sub plots precisely formed for accuracy in crop growth and development. Drainage, wetting and drying, submergence are to be automated and precisely controlled.
2. **Fertility Gradients**: Fertility levels should be controlled by reliable and efficient management techniques. Deficiency conditions should be precisely maintained for each nutrient and should be validated thoroughly. For nutrient response studies, optimum levels and application methods should be standardized.

3. **Formation of Grids:** Field should be divided into grid like smaller structures by precise and uniform planting of genotypes in wider spacing for precise capturing of images at different periods.

Advantages of Artificial Intelligence Tools for Genotypic/Phenotypic analysis

Digital data of phenotyping generated through automated image capturing and selection parameters should be applied for the integration of data and identification of desired phenotype in a larger number of germplasm lines.

For evolving efficient genotypes with desired traits, integration of phenotypic and genotypic data should be precise and should be validated in the genotype performance. it is a difficult process, there are many bottlenecks to overcome for the integration viz., accelerated growth of data, data silos, incompleteness, inaccuracies and heterogeneity within and across data sets.

A big advantage of precision machine informatics is handling big data sets and accuracies in integrating data. Machine learning is integrated by physical knowledge tools as numerical output for the generation of integrating phenotype and genotype. Crop genotype selection models for each trait should be embedded in the knowledge system for each crops viz., germplasm data, genotypic data, sequencing data, disease resistance scores, nutrients responses, water use efficiency and quality traits. The knowledge created should be validated with successful models. AI tools for improving the selection efficiency will result in development of larger number of desirable varieties in quicker period with stability. New crop varieties will intensify the crop genetic variability in agro ecological zone. At present, few varieties of a crop grown in larger geographical area across the states which result in narrowing down in genetic variability. Each geographical location can have desirable varieties highly suited to the local conditions.

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