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# Quantitative phenotyping in plant research

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***Introduction:*** **Global population is going to reach 9.2 billion by 2050, hence to feed this growing population crop production need to be doubled. This is one of the major targets on our crop researchers. Phenotyping the plants is the most crucial step in plant science research. Speed of plant breeding depends on the quality of phenotyping. Plant phenotype is the product of interaction between genetic architecture of a plant and the environment, where it grows. Generally, this interaction affects plant functional and structural characters that determine its performance for example biomass and yield. Plant phenotyping is the determination of different plant physiological traits such as growth, development, yield, ecology, resistance and also the complex characters like fruit characteristic, root morphology, biomass, photosynthetic efficiency and stress response.**

## Quantitative phenotyping

Quantitative phenotyping is the high throughput and intensive recording of plant growth and development under different situation including controlled or natural conditions with the help of robust sensing technologies. Here in quantitative phenotyping different parameters are measured such as Growth pattern, Photosynthetic behaviour of the plants, Response to stress factors like Diseases &pests' reaction and radiation response. Quantitative phenotyping is useful over conventional phenotyping in the following aspects:

- ✓ Non-destructive measurements.
- ✓ Can handle large population
- ✓ Continuous methods.
- ✓ Relatively low error rate.
- ✓ Identification of critical faces is easy

## Plant and environment interaction

Plant interacts in several ways with different environmental constituents such as light, soil, water and temperature factor etc. Although all of these key components are not fully independent but their role can be examined independently for better understanding. Plant interact with different wavelength of solar radiation, mainly in 4 different types such as scattering, reflection, transmission, heat accumulation. Reflection of light happens at plant leaf surface layer but scattering happens at below the leaf surface. General reflectance pattern is more in near infrared region (NIR) and least at visible region (VR) of light. Among the VR reflectance peak occurs at green region hence plant appears green colour. Water influences different plant traits based on its availability (*i.e*, abundance and shortage). When there is abundance of water then the transpiration rate increases because of opening of stomata and leading to increase in rate of photosynthesis. Soil has various physical, chemical, and biological properties that affect the plant growth parameters in different ways. Soil microbes help in plant nutrient availability and hence influence plant growth. Role of temperature in plants is in various ways starting from seed germination, water availability, rate of photosynthesis, crop, growth and development, quality and yields. Typically, all the components are interdependent and several phenotyping techniques were developed to examine their role in plants.

- ✓ Visible light imaging
- ✓ Near infrared imaging
- ✓ Thermal imaging
- ✓ Hyperspectral imaging
- ✓ Fluorescence imaging
- ✓ Laser imaging
- ✓ 3D imaging
- ✓ MRI (Nuclear Magnetic Resonance Imaging)
- ✓ PET (Positron emission tomography)

| Imaging Techniques | Applications |
|---|---|
| Visible light (VR) imaging | Growth dynamics, Imbibition and germination rates, coleoptile length, Shoot biomass, Panicle traits, seedling vigour, leaf morphology, Root architecture, biomass at anthesis, seed morphology and Yield traits, |
| Fluorescence (FR) imaging | Indirect measurement of biotic or abiotic stress, Photosynthetic status, |
| Thermal imaging | Stomatal conductance, Surface temperature; water stress induced by biotic or abiotic factors |
| Light Detection and Ranging (LiDAR) | Crop volume and biomass, Canopy height and architecture; estimation of LAI; |
| Imaging spectroscopy | Leaf area index (LAI), water content composition parameters for seeds; health status of Leaf, canopy and panicle, leaf growth; Coverage density |

## High throughput phenotyping (HTP)

By joining advances in remote sensing, artificial intelligence, aeronautics and high-performing computing systems researchers were able to develop High throughput phenotyping platforms (HTPPs). High throughput phenotyping (HTP) is of two types - Inhouse phenotyping and Field based phenotyping. Inhouse phenotyping are nothing but the phenomics centres that is in control environment and the field-based platforms include ground-based and aerial-based methods. Ground-based phenotyping includes modified vehicles equipped with a GPS navigation device and sensors often referred to as 'phenomobiles'. Here data to be captured at individual plant level/plot level. Aerial-based methods incudes phenotowers, blimps, unmanned aerial platforms (UAPs) such as polycopters & airplanes and here data to be captured at individual plant level/plot/field level. Key parametres continuously monitored in HTPs-

- ✓ Plant Height
- ✓ Plant 3D structure
- ✓ Internode length
- ✓ Leaf area index
- ✓ Leaf angle
- ✓ Yield prediction
- ✓ Rate of temperature change
- ✓ Tissue water content
- ✓ Soil water content
- ✓ Fv/Fm (Efficiency of photosynthesis)
- ✓ Internal infestation
- ✓ Biomass
- ✓ Canopy width
- ✓ Rate of growth
- ✓ Rate of senescence
- ✓ Grain filling status
- ✓ Grain quality
- ✓ Chemical composition
- ✓ PAR-absorptivity
- ✓ Photosynthetic electron transport rate
- ✓ Soil water content
- ✓ Relative chlorophyll content
- ✓ Canopy temperature
- ✓ Plant water content
- ✓ Moisture content

- ✓ Pathogen infestation
- ✓ Leaf vegetation Index
- ✓ NDVI
- ✓ Root volume
- ✓ Root length
- ✓ Root 3D structure
- ✓ Secondary root numbers

## Conclusion

Current phenotyping strategy is largely extensive approach but it is necessary to convert into intensive approach. Suitable statistical models need to be developed and standardized according to need of researcher. Automated data analysis methodologies including use of new generation artificial intelligence and software need to be developed.

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