LeasyScan—an efficient phenotyping platform for identification of pre-breeding genetic stocks in maize

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Abstract: The huge genetic resources among all the crop species is still underutilized in meeting the worldwide challenges of agriculture production systems. In maize only 5% of world’s maize germplasm has been used. The utilization of the maize genetic resources, which hold the answers to most of the threats and challenges, would be enhanced by their precise characterization and evaluation. Also, the data needs to be generated at a faster rate to meet the onset challenges. In this study, we discussed and demonstrated the use of an imaging phenotyping platform- LeasyScan, coupled with lysimeters, to measure precise plant height and canopy traits viz., leaf area and leaf area index (LAI) affecting water use in six experimental and two released maize hybrids viz., 14746185, 8315622, 22525674, 18270413, 4695575, 783527, 900MG and 30V92. Of these, experimental hybrids 2 & 5 i.e 8315622, 4695575 showed promising 3D-leaf area and LAI. We conclude that LeasyScan—phenotyping platform can be effectively used in the identification of genotypes/germplasm lines with high vigour (Plant height), efficient 3D-leaf area and LAI at early stage of around one month old seedlings. Identification of such genetic stocks/germplasm lines can be an important step towards effective utilization of the genetic resources in pre-breeding programme.

Introduction

The challenges to the agricultural production systems across the globe are diverse and complex with the changing environmental conditions which impacts severely on the crop yields (Tester and Langridge, 2010). The agricultural approaches and practices that contribute to climate change adaptation and mitigation have been listed by FAO (2015). As the dual challenges of climate change and increased demand of food production for the rapidly growing population, are immense, therefore we need high throughput and efficient technologies in finding out ways and means for mitigating the challenges and meeting the basic food demands. A huge untapped potential is the underutilized genetic resources among all the crop species, for example, in maize only 5% of world’s maize germplasm has been used (Taba and Eberhart, 2004). The utilization of the genetic resources, which hold the answers to most of the threats and challenges, would be enhanced by their characterization and evaluation data (Drinic and Andjelkovic, 2012). The generation of data on huge genetic resources at the international level, for example over 7.4 lakh accessions conserved in 11 international gene banks; and total germplasm accessions conserved worldwide, viz., 7.4 million (Commission on Genetic Resources for Food and Agriculture, 2010) is highly desired. The data needs to be recorded as precisely and at a faster rate, as it involves huge germplasm collections. Further, broadening the genetic base of the crop species and use of the phenomics have been settled as the technologies to look up to in the changing world (Araus et al., 2012). The way to genetic gain is being increasingly seen through effective phenotyping and phenomics approaches, this necessitates the amalgamation of high throughput technologies such as phenotyping and the utilization of genetic resources. The use of imaging phenotyping platform- LeasyScan, coupled
with lysimeters, to measure canopy traits affecting water use, viz., leaf area, leaf area index, transpiration has been demonstrated in peanut, cowpea and pearl millet (Vadez et al., 2015).

In maize, most of the yield improvement (about 75%) has been attributed to genetic gain and remainder to the improvement in agronomic practices (Araus et al., 2012) further, interestingly, the genetic gain was not attributed to heterosis but to more stress tolerance (Duvick, 1999) relating to increased leaf area index and higher harvest index (Lee and Tollenaar, 2007). Bolaños and Edmeades (1996) concluded that yield variation explained more by the reproductive traits like HI than traits like leaf extension rate, canopy temperature, leaf erectness, leaf rolling, and leaf senescence which contributed to plant water status, water use and WUE. Leaf area and Leaf Area Index plays an important role in ultimate plant yield in maize as it has considerable influence on yield in maize (Lukeba et al., 2013). The use of LeasyScan-a phenotyping platform for measuring and validation of 3D leaf area and the destructive leaf area in pearl millet, cowpea and peanut have been demonstrated (Vadez et al., 2015). In this experiment using maize hybrids, we have attempted the use of LeasyScan phenotyping platform and to see if LAI can be used as a tool to identify potential early experimental hybrids for yield.

Materials and methods

Eight hybrids of maize, which included two released and six experimental hybrids, were made part of the LeasyScan phenotyping platform. The platform is equipped with a set of scanners (PlantEye F300, Phenospex, Heerlem, The Netherlands) which are made to slide above the plants using well established moving device that enabled the generation of 3D point clouds of the crop canopy structure. The leaf area and other parameters are derived through a process known as segmentation. The hybrids were sown as per the standard spacing of 60 × 20 cm in the lysimetric tubes fitted in the platform in a Replicated Block Design (RBD) with three replications. The sowing was done on 13th January 2016. The LeasyScan is equipped to record the plant height, total leaf area (which is called 3D-leaf area) and the projected leaf area which is the equivalent to Leaf Area Index using the eye camera. The details on working of LeasyScan were explained by Vadez et al. (2015). The data on the plant height, leaf area and projected 3D-leaf area were recorded at 3-day interval up to one month beginning from one week after sowing. The data was subjected to analysis using the Wasp 2 (Web Agri Stat Package 2.0) available online at http://www.ccari.res.in/wasp2.0/index.php.

Results and discussion

The platform was designed, initially, with an aim to assess the range of genetic variation in leaf area, transpiration and transpiration rate (i.e. canopy conductance) for mapping and screening purposes (Vadez et al., 2015). The analysis of variance for the eight hybrids of maize has been presented in table 1. There was no significant difference (p > 0.05) in the plant height among the maize hybrids, whereas the 3D-Leaf area and Leaf area index values recorded significant variation (p < 0.05) among the hybrids. Taking the cue from the significant variation among the hybrids, we observed if there was any difference between the released hybrids—which are popular among the farming community for their high yield and unique leaf architecture. The leaf architecture of these hybrids also promotes high density planting resulting in high production.

**3D-Leaf area**

The two released hybrids, viz., 900MG and 30V92 were characterized by high 3D-Leaf area values (Figure 1a to 1h). The 900 MG recorded value of 111230.4 at the end of 30 DAS, whereas 30V92 recorded a value of 108945. All the other experimental hybrids, except hybrids 2 (No.8315622) and 5 (4695575) which recorded a 3D leaf area value of 109296 and 103174, respectively, recorded values lower than 100000 mm2. Hence, these two hybrids which recorded higher 3D-leaf area values may be selected as potential hybrids for promotion as they have fared on

| Table 1. Analysis of variance for different traits recorded in maize hybrids |
|---------------------|---------------------|---------------------|
| Source | df | Mean sum of squares |
| | Plant height | 3D-leaf area | Leaf area index |
| Replications | 2 | 967.24 | 189042024.64 | 16163.60 |
| Hybrids | 7 | 895.22 | 838171802.45 | 45573.18 |
| Error | 14 | 718.78 | 102191266.61 | 4710.60 |
par with the highly popular released hybrids in case of 3D leaf area.

Leaf area index

Leaf area Index, is the Specific Leaf Area, which is considered as the key determinant for the growth rate of the species and system productivity (Norberg et al., 2001) is one of the important agronomic traits that is used as an indirect measurement of yield. Asner et al. (2003) have termed LAI as the most important bio-physical factor in climatologically, meteorological, ecological, and agricultural modelling. It has also been used in yield forecasting using LAI based yield model (Baez-Gonzalez et al., 2005). Although, destructive assessment of LAI, involving manual collection of leaves and direct measurement by Planimeters, has been used to with accurate results, but its main drawback is, it is time-consuming, as a result, expensive and often limited to small areas (Jonckheere et al., 2004).

Consequently many indirect methods of measuring LAI, have been developed, grouped as in-situ and remote sensing approaches (Bauer et al., 2016).

As in the 3D-leaf area, the LAI values in the released hybrids were superior to the experimental hybrids (Figure 2a to 2h). The LAI values recorded in 900MG was 820 and in 30V92 it was 794; Two of the experimental hybrids, viz., Experimental hybrid 2 (No. 8315622) and 5 (No.4695575) recorded higher LAI. The LAI recorded in both these hybrids is more than 750. These hybrids may be selected as potential hybrids as they meet the higher LAI. A smaller leaf angle results in a more upright leaf orientation. This is beneficial for increasing the leaf area index, reducing maize shade syndrome and improving photosynthetic efficiency (Sakamoto et al., 2006). High Density planting also promoted LAI, which resulted in higher light interception, higher Dry Matter Accumulation (DMA) and hence higher yields (Shi et al., 2016). The QTLs (Li et al., 2015) and genes (Zhang et al., 2014) related to leaf angle in maize have been mapped and cloned. Identification of genotypes at an early stage, as with using the LeasyScan, can help us to identify genetic stock with good potential for high leaf area index through leaf angle. The benefits of high leaf area index post flowering, which is a result of delayed leaf senescence leading to improvements in maize grain yields have been reported in newer hybrids (Lee and Tollenaar, 2007). New methods like satellite based LAI yield forecasting have been attempted, although with error of 2-5%, but will prove useful in large areas avoiding laborious ground leaf area measurements (Baez-Gonzalez et al., 2005). The importance of LAI as the main driving force of net primary production, water and nutrient use, and carbon balance and the impact of canopy LAI on the understory communities especially in the soil were dealt by Bréda
Figure 2a to 2h: Variation observed for plant height and leaf area index in maize hybrids


Conclusion

The LeasyScan–phenotyping platform can be used in the identification of genotypes/germplasm lines with high vigour (Plant height), efficient 3D-leaf area and LAI. Identification of such genetic stocks/ germplasm lines forms the important pre-breeding steps towards the effective utilization of germplasm lines.

References


