Rapid screening technique for canopy temperature status and its relevance to drought tolerance improvement in chickpea

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Drought is one of the most important constraints for chickpea (*Cicer arietinum*) productivity, and there is a scope to avert large portion of these productivity losses through crop improvements. Analytically, the seed yield under water scarce environments is a function of three independent component traits, viz, transpiration, transpiration efficiency and harvest index (Passioura 1977). This implies that the crop productivity under drought environments could be enhanced by improving any of these traits. One of the strategies could be to improve each component trait separately and then combine them through multiple crosses. It is, however, crucial and first step to establish the rapid and reliable field-based screening methods to identify superior genotypes among the large germplasm resources for a targeted trait (Richards et al. 2002, Stoddard et al. 2006). Among the three components in the formula, an effective and rapid method for estimating transpiration efficiency has already been developed such as the carbon isotope discrimination method (Farquhar et al. 1982), and the conventional gravimetric measurements for harvest index. On the other hand, no such high throughput screening method for measuring the total transpiration has been established yet to cope with larger population size. The thermal imagery system would be one of the potential high throughput methods that can allow large-scale field screening for the total transpiration.

As long as the plants continue to transpire through open stomata the canopy temperatures could be maintained at metabolically comfortable range otherwise higher temperature would destroy the vital enzyme activities. Stomatal closures for a considerable period of time are known to increase the leaf temperature. The thermal imagery system is a powerful tool as it can capture the temperature differences of plant canopies fairly quickly and instantly. In addition, the thermal images capture the whole crop canopies of many plants in a plot thereby reducing the sampling errors compared to screenings based on a single leaf, eg, steady state porometer. The main objectives of this study were to evaluate the use of thermal imagery systems for capturing the genotypic differences in canopy temperature, and to optimize the system for the development of a simple screening method to screen for drought tolerance based on better transpiration in chickpea.

Sixteen diverse chickpea germplasm accessions for drought tolerance and seed yield (ICC 67, ICC 867, ICC 898, ICC 3325, ICC 3776, ICC 4958, ICC 7184, ICC 7272, ICC 7323, ICC 8058, ICC 14199, ICC 14402, ICC 14778, ICC 14799, ICC 16796 and Annigeri) were grown in a precision Vertisol field at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India under rainfed condition in 2006/07 postrainy season. The experiment was conducted in randomized block design with three replications. The thermal images of plant canopies were captured at 70 days after sowing, at which all genotypes reached early flowering stage, by an infrared camera, IR FLEXCAM (Infrared Solutions, Inc, USA) between 1400 and 1430 hrs. As maximum plant height of chickpea was approximately 40 cm, the top view of the thermal images were captured. The target area of the image captured was about 30 cm × 20 cm at the center of each plot, and the images were captured from north to avoid shading of the target area. The original thermal images comprised sequential color gradients and it was difficult to extract the numerical thermal data from these. Therefore, the color contrast intensity was increased two times more than the original. With this treatment, the images could be easily classified into 7 colors, viz, white (very hot temperature = VH, ca. ≥40.0°C), red (hot temperature = H, ca. 35.9°C to 39.9°C), yellow (relatively hot temperature = RH, ca. 32.6°C to 35.8°C), green (moderate temperature = MD, ca. 32.2°C to 32.5°C), light blue (relatively cool temperature = RC, ca. 29.1°C to 32.1°C), blue (cool temperature = C, ca. 25.5°C to 29.0°C), and black (very cool temperature = VC, ca. ≤25.4°C). The modified thermal images were analyzed by using color analysis function of image analysis software WinRhizo (Regent Instruments Inc, Canada) to compute the ratio of plant canopy area occupied by each color to the total plant canopy area.

Each thermal image of chickpea canopy could be captured by the thermal imagery systems within about one minute. As it was expected, this is very quick compared to the porometer measurement by which it would take 10–15 min for one measurement as practical difficulty, viz, the chickpea leaflet is too small to be put on the thermal sensor properly and clipped/held within the chamber of the porometer. Moreover, the system could show the variability within a canopy. It would allow us to have better judgment on the drought response rather than depending upon a single leaflet measurement.

The soil surface area without exception was either seen as VH (white) or H (red) areas in the thermal images and was easily removed from the total area captured to

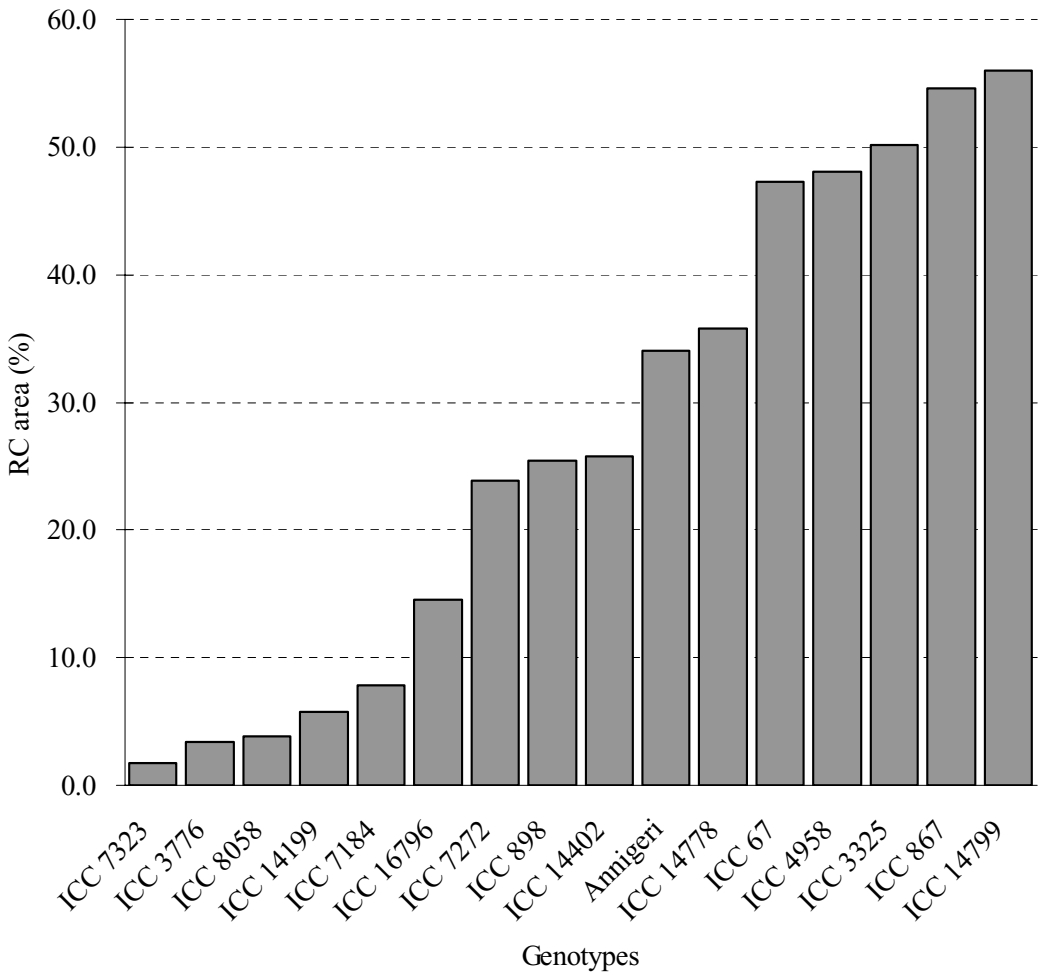

Figure 1. Ranking of chickpea genotypes in area occupied by relatively cool (RC) canopy temperature.

Table 1. ANOVA for grand cover rate and areas occupied by different thermal ranges in chickpea genotypes.

Description	Mean	Mean of square		F-predicted	Probability
		Genotype	Residual		
Ground cover rate	87.9	218.8	170.8	1.28	0.270
Thermal range					
Relatively hot	61.9	1739.2	440.6	3.95	0.001
Moderate	5.3	17.4	11.9	1.46	0.178
Relatively cool	27.4	1166.9	398.3	2.93	0.005
Cool	2.5	121.0	122.0	0.99	0.486
Very cool	2.9	7.2	7.1	1.02	0.461

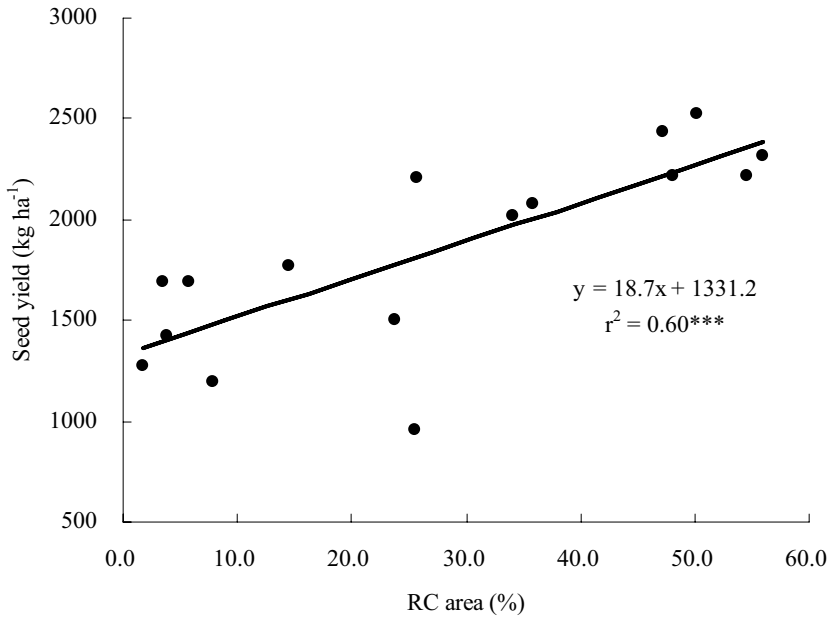

Figure 2. Relationship between the area occupied by relatively cool (RC) canopy temperature and seed yield of chickpea genotypes under rainfed conditions during postrainy season in 2006/07.

estimate the plant canopy area of each genotype. Thus, the ratio of plant canopy area occupied by each thermal range to the total plant canopy area was computed as the number of pixels occupied by each color range divided by the total number of pixels of entire image minus the number of pixels of the VH and H areas. At this early to late pod-fill stage, all the chickpea genotypes almost fully developed their canopies (Table 1), and the ground cover ratio ranged from 70.2% (ICC 7323) to 97.8% (ICC 3325). Most of the canopy areas had either exhibited temperature ranges of RH or RC. The significant differences among genotypes were also observed for the areas with the RH or RC. The rest of the temperature regimes occupied insignificant proportions and with insignificant genotypic differences (Table 1).

The 16 entries were ranked based on RC (Fig. 1). The genotype ICC 7323 showed the smallest RC area in the plant canopy among all the entries, while ICC 14799 showed the largest. There was no direct correlation between the RC area and the root biomass at 35 days after sowing in our previous study (Kashiwagi et al. 2005). It would be mainly because of the timing of the root characterization (35 days after sowing) of the chickpea mini-core germplasm in the previous study and the possibility of later growth contributing to the increased water uptake. However, ICC 4958, a well-known chickpea genotype with more prolific and deeper root system throughout its growth period stood 4th largest in RC area among the entries. It indicates the importance of prolific and deep root systems in keeping the canopy cooler for longer time likely due to better control of stomatal conductance extending through better part of the reproductive growth.

There was a significant positive correlation between the RC area and seed yield under rainfed conditions (P <0.001) (Fig. 2). This means that the chickpea genotypes transpiring more likely through better supply of water by roots at later growth stage have significant advantages for the reproductive growth leading to better seed yield. This result encourages further work in this direction and to proceed with a large-scale field-based germplasm screening for identification of accessions that are more efficient in transpiration at later stages of reproductive growth.

In conclusion, the thermal imagery systems offers a good scope for screening the transpiration status of the plant canopy in chickpea as it is rapid, high throughput amenable and the canopy area sampled is large. It indirectly measures the functional aspects of the root system which otherwise is expensive, difficult and time-consuming. As the trait plant canopy temperature is closely related to drought tolerance, it would be valuable for developing large-scale research projects. However, further optimization of the systems and standardization of the protocol, eg, confirming the relationship between the canopy temperature and the leaf water potential or the stomatal conductance, setting some reference temperature

markers in each pot, applying a wide-angle lens, etc would be needed to collect more reliable data for larger scale field screening.

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