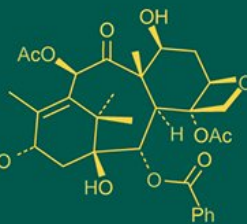
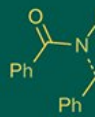


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Character association studies among physiological traits and seed yield in chickpea (*Cicer arietinum* L.)

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Abstract

Identifying genetic variability and trait associations is essential for the selection of physiologically efficient chickpea genotypes and the development of effective breeding strategies. The present study evaluated genetic variation and relationships among chlorophyll content, canopy temperature, photosynthetic rate, stomatal conductance and single-plant yield in a diverse chickpea collection. A total of 400 genotypes and six check varieties were evaluated during the 2023-24 Rabi season at the Seed and Research Farm of Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, using an augmented block design. Analysis of variance revealed significant genotypic variation for chlorophyll content, canopy temperature and single-plant yield, whereas photosynthetic rate and stomatal conductance showed comparatively limited genotypic variation under the experimental conditions. Frequency distributions further indicated substantial variability for chlorophyll content, canopy temperature and single-plant yield. Pearson correlation analysis showed that single-plant yield was positively associated with photosynthetic rate ($r = 0.434$), chlorophyll content ($r = 0.418$) and stomatal conductance ($r = 0.391$). Photosynthetic rate also showed positive associations with stomatal conductance ($r = 0.479$) and chlorophyll content ($r = 0.466$). In contrast, canopy temperature was negatively associated with chlorophyll content ($r = -0.316$), photosynthetic rate ($r = -0.333$), stomatal conductance ($r = -0.303$) and single-plant yield ($r = -0.333$). These findings indicate that improved photosynthetic activity, chlorophyll retention and stomatal regulation are associated with greater yield potential, whereas higher canopy temperature may be detrimental to physiological efficiency and yield. The identified trait relationships can support the selection of promising chickpea genotypes for breeding programmes targeting improved physiological efficiency and productivity.

Keywords: Chickpea, genetic variability, physiological traits, seed yield, correlation analysis

Introduction

Chickpea (*Cicer arietinum* L.) is an important grain legume cultivated widely for human consumption and livestock feed. It is a self-pollinated, diploid crop with two major market classes, desi and kabuli, and is particularly important in the rainfed production systems of India. The crop contributes substantially to dietary protein and provides minerals and other nutritional components, while biological nitrogen fixation contributes to soil fertility. Consequently, improvement of chickpea productivity remains an important breeding objective.

Seed yield is a complex quantitative trait governed by the cumulative effects of several morphological, physiological and environmental factors. Physiological traits such as chlorophyll content, photosynthetic rate, stomatal conductance and canopy temperature provide information on the functional status of plants and their ability to capture carbon, regulate water loss and maintain productive growth. Chlorophyll content is associated with light interception and photosynthetic capacity, while stomatal conductance regulates the diffusion of carbon dioxide into leaves and water loss. Canopy temperature provides an indirect indication of plant water status and the balance between transpiration and heat dissipation.

Variation in these physiological attributes can therefore contribute to differences in biomass accumulation, reproductive success and final seed yield.

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Understanding the associations among physiological traits and yield can help identify useful indirect selection criteria, particularly when direct selection for yield is influenced strongly by the environment. Correlation analysis provides a simple approach for assessing the direction and strength of these relationships and can complement the evaluation of large germplasm collections.

The present investigation was undertaken to assess genetic variability for selected physiological traits and single-plant yield in a diverse chickpea collection and to determine the relationships among these traits. The study was specifically aimed at identifying physiological attributes that could assist the selection of high-yielding and physiologically efficient chickpea genotypes for use in breeding programmes.

Materials and Methods

The experimental material comprised 400 diverse chickpea (*Cicer arietinum* L.) genotypes and six check varieties, namely IPC-2005-62, IPC-7006-77, BG-3062, BGM-10216, JG-14 and RLBGK-1. The germplasm was obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India.

Field evaluation was conducted during the *Rabi* season of 2023-24 at the Seed and Research Farm of Rani Lakshmi Bai Central Agricultural University, Jhansi, Uttar Pradesh, India. The experiment followed an augmented block design in which test genotypes were unreplicated and check varieties were replicated in each block. Each genotype was grown in two rows of 2 m length, with 30 cm row spacing and 10 cm spacing between plants. Seeds were sown manually at a depth of approximately 5 cm, and recommended crop-establishment and management practices were followed throughout the crop season.

Five traits were recorded at the appropriate crop growth stages: chlorophyll content (CC), photosynthetic rate (PR), canopy temperature (CT), stomatal conductance (SC) and single-plant yield (SPY). Observations were recorded from five randomly selected plants per genotype, and mean values were used for statistical analysis.

Analysis of variance for the augmented design and Pearson correlation analysis among the studied traits were performed using the augmentedRCBD package in R software (version 4.5.2). Statistical significance was interpreted according to the probability levels obtained from the analyses.

Results

Analysis of variance under the augmented design revealed significant treatment effects for chlorophyll content, canopy temperature and single-plant yield, indicating appreciable variation among the evaluated genotypes for these traits. In contrast, photosynthetic rate and stomatal conductance showed non-significant treatment effects, suggesting comparatively limited genotypic variation under the prevailing experimental conditions. Block effects were non-significant for the studied traits, indicating that variation among blocks did not materially affect the observed responses.

Frequency distributions showed comparatively broad variation for chlorophyll content, canopy temperature and single-plant yield, with several test genotypes exceeding the performance range of the check varieties. Photosynthetic rate and stomatal conductance displayed narrower distributions. These patterns were consistent with the

analysis of variance and indicated greater scope for selection for chlorophyll content, canopy temperature and single-plant yield within the evaluated collection.

Pearson correlation analysis revealed significant positive associations of single-plant yield with photosynthetic rate ($r = 0.434$), chlorophyll content ($r = 0.418$) and stomatal conductance ($r = 0.391$). Among the physiological traits, photosynthetic rate showed the strongest positive association with stomatal conductance ($r = 0.479$), followed by chlorophyll content ($r = 0.466$). Chlorophyll content was also positively associated with stomatal conductance ($r = 0.355$).

Canopy temperature showed significant negative correlations with chlorophyll content ($r = -0.316$), photosynthetic rate ($r = -0.333$), stomatal conductance ($r = -0.303$) and single-plant yield ($r = -0.333$). Thus, genotypes with comparatively lower canopy temperature tended to exhibit more favourable physiological attributes and higher single-plant yield under the conditions of the experiment.

Discussion

The observed genotypic variation for chlorophyll content, canopy temperature and single-plant yield demonstrates the presence of useful diversity within the evaluated chickpea collection. Such variation is valuable for breeding because physiological traits can reflect mechanisms contributing to productivity and adaptation. The relatively limited variation observed for photosynthetic rate and stomatal conductance may have resulted from environmental effects during measurement or from a narrower genetic range for these traits within the material evaluated.

The positive association of single-plant yield with photosynthetic rate indicates that greater carbon assimilation may contribute to improved reproductive productivity. The positive relationships of yield with chlorophyll content and stomatal conductance further suggest that maintenance of photosynthetic machinery and effective stomatal regulation may support assimilate production and translocation towards developing seeds. The positive correlations among photosynthetic rate, chlorophyll content and stomatal conductance also indicate coordinated physiological functioning.

The negative association between canopy temperature and the other physiological traits is consistent with the role of transpirational cooling in maintaining leaf and canopy temperature. Genotypes capable of sustaining effective stomatal activity may dissipate more heat through transpiration and consequently maintain a comparatively cooler canopy. The negative association of canopy temperature with single-plant yield further suggests that canopy temperature could serve as a useful secondary trait when screening chickpea material for physiological efficiency, particularly under environments where heat and water limitation constrain productivity.

Although correlation identifies useful associations, it does not establish causality. Therefore, the physiological traits identified here should be evaluated across seasons and environments, preferably with replicated trials and complementary genetic analyses, before being used as definitive selection criteria. Combining physiological phenotyping with genomic information could further facilitate the identification and validation of genomic regions controlling yield-related physiological adaptation.

Table 1: Analysis of variance for physiological traits and single-plant yield in chickpea

Source	Df	CC	CT	PR	SC	SPY
Block (ignoring treatments)	7	1.45	427.44	9.31 ns	0.51 ns	7.82
Treatment (eliminating blocks)	405	0.23 **	76.42 *	10.37 ns	0.49 ns	3.16 **
Treatment: Check	5	0.19 **	87.58 ns	10.29 ns	0.48 ns	0.53 ns
Treatment: Test and Test vs. Check	400	0.23 **	76.28 *	10.37 ns	0.49 ns	3.19 **
Residuals	35	0.04	43.59	9.65	0.47	0.60

Note: CC, chlorophyll content; CT, canopy temperature; PR, photosynthetic rate; SC, stomatal conductance; SPY, single-plant yield. ns, non-significant; * and ** indicate significance at the 5% and 1% probability levels, respectively.

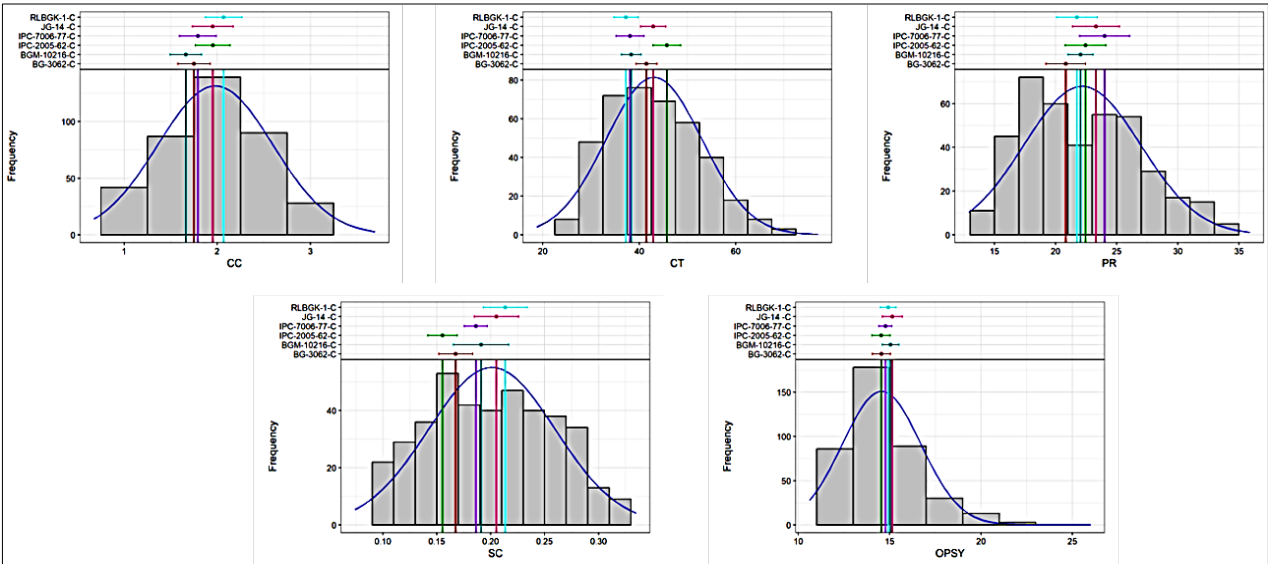


Fig 1: Frequency distributions of chickpea genotypes for chlorophyll content, canopy temperature, photosynthetic rate, stomatal conductance and single-plant yield under the augmented design.

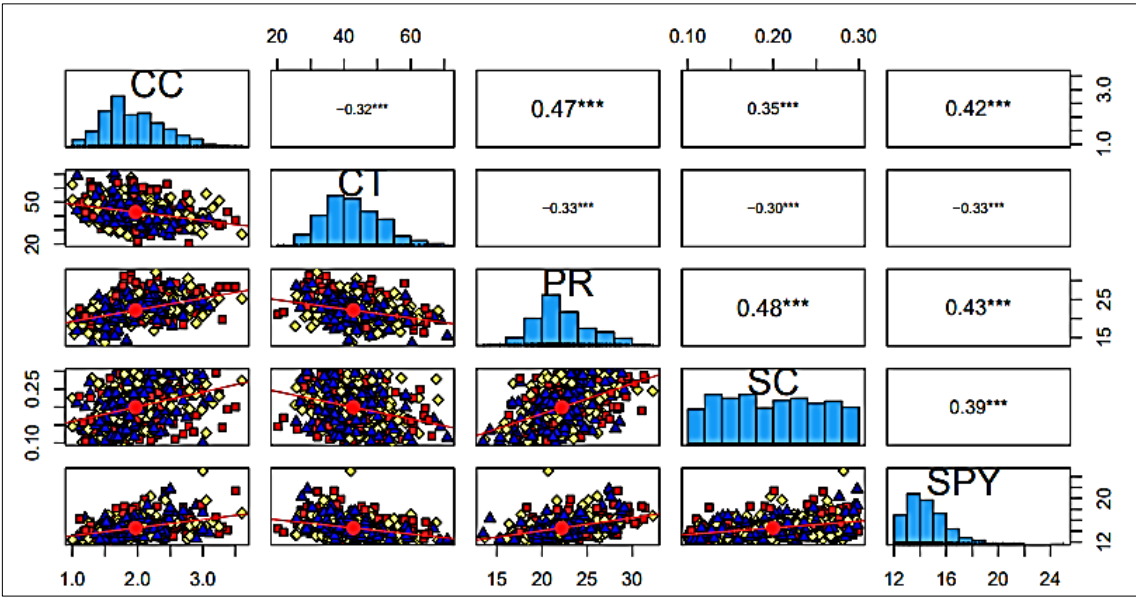


Fig 2: Pearson correlation matrix among chlorophyll content, canopy temperature, photosynthetic rate, stomatal conductance and single-plant yield in chickpea.

Conclusion

The study demonstrated substantial variation for chlorophyll content, canopy temperature and single-plant yield among the evaluated chickpea genotypes. Single-plant yield was positively associated with photosynthetic rate, chlorophyll content and stomatal conductance, whereas canopy temperature showed negative associations with these traits and with yield. The results indicate that efficient photosynthetic activity, chlorophyll retention and stomatal regulation may contribute to higher yield potential, while

lower canopy temperature may be associated with more favourable physiological performance. The identified relationships provide useful preliminary selection criteria for chickpea improvement; however, validation across environments and seasons is recommended before deployment in breeding programmes.

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Conflict of interest: The authors declare that there is no conflict of interest.

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