Journal of Cotton Research

LETTER

Open Access

Karachi provides a good opportunity for low-cost generation advancement of cotton for breeding and seed purity

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Cotton is said to be the backbone of Pakistan's economy. Cotton production is facing many challenges such as climate change, pests and diseases, and competition from food crops (Ali et al., 2019). One of the major issues faced by cotton production is seed purity, as cotton is often cross-pollinated, therefore breeders are hard to maintain seed purity. For example, non-*Bt* cotton varieties are often contaminated with *Bt* seeds which is an important limiting factor. Another important consideration in cotton breeding is rapid generation advancement. The speed breeding for crops such as wheat and chickpea have been optimized (Watson et al., 2018), and the use of speed breeding technology has allowed us to overcome this challenge. However, the speed breeding concept is still challenging for crops such as cotton that flower in a short day. The rate of genetic gain (ΔG) in breeding depends on the number of generations required to develop stable varieties. Rate of genetic gain is estimated using the following formula proposed by Cobb et al. (2019),

$$\Delta G = \frac{(\sigma_a)(i)(r)}{L}$$

Where, L represents the number of years per cycle, thus the greater the number of crop cycles in a year, the greater be genetic gain (Cobb et al., 2019). The other parameters are additive genetic variation within the population (σ_a), selection intensity (i), and selection accuracy (r).

Based on the above facts, we explored the possibility of growing cotton at the International Center for Chemical and Biological Sciences (ICCBS), University of Karachi, Pakistan to address the issue. The open-field experiments were conducted at ICCBS during 2022–2023. The climate of the city is predominantly dry, with minimal rainfall. The summer season is the most prolonged throughout the year. Winter temperature occasionally drop below 10 °C, while day time temperature typically reach around 26 °C (Fig. 1). Seeds of nine approved cotton varieties namely, Reshmi, Sohni, Ufaq, Kiran, USG-13-1607, FH-490, FH-492, VH-327, and NIAB-112 were collected from five cotton research centres, which include: Nuclear Institute of Agriculture (NIA), Tando Jam; Ayub Agricultural Research Institute (AARI), Faisalabad; Central Cotton Research Institute Multan (CCRI), Multan; Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad; Cotton Research Institute, Government of Sindh, Tando Jam. For the experiment, pots sized 12 cm in height and 10 cm in width were used and filled with approximately 3 kg sandy loam soil (pH ranging from 5.5 to 7.5). In each pot, the seeds were planted 2 cm deep. Five cotton seeds were planted in each pot and 10 pots of each variety to attain the optimal density. Following germination, all other plants were removed, and just one plant was maintained for observations. Agronomic procedures

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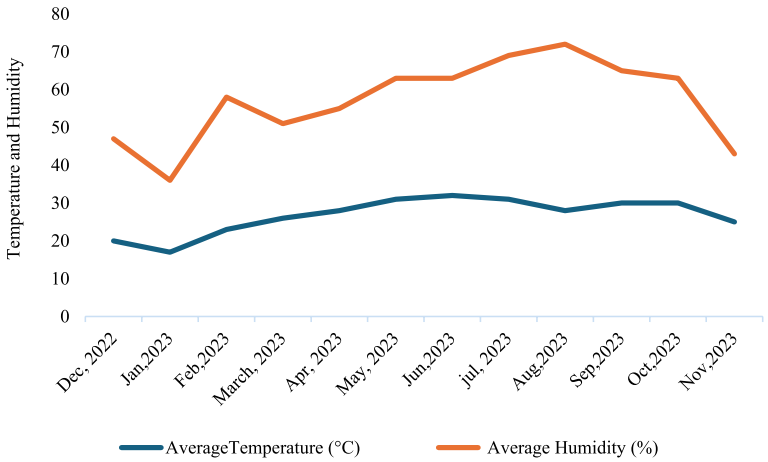

Fig. 1 Average temperature and humidity during December 2022 to November 2023 in Karachi (Pakistan)

were implemented following the recommendations under cotton field conditions.

In this study, the first generation of cotton plants was cultivated between December 2022 and January 2023 within a glasshouse environment with temperature between 30 to 40 ℃, and humidity level between 70% to 80%, without the need for supplementary lighting. Once weather conditions improved in February 2023, the pots were shifted outdoors for further growth, maintaining the same conditions to ensure consistency across our trials. Subsequently, rapid flowering and boll opening were observed in April 2023. A second generation of cotton was cultivated in May 2023 in open fields, and seeds were harvested at the first week of August in 2023. Following this, a third generation was also planted in open field in August 2023, and seeds were harvested in November and December of the same year. Notably, the crop did not suffer from severe attacks by major pests, and no pesticide spraying was required. Pure, non-*Bt* seeds of approved cotton varieties were obtained in the third generation, and the process of generation advancement was successfully achieved. This method has facilitated the advancement of three generations of cotton in a year.

The experiments described above demonstrated the feasibility of achieving three cotton generations within a single year through a cost-effective approach. Cotton cultivation thrives in warm and humid climates, where there are extended periods without frost, and abundant sunlight and heat. Throughout the active growth period, cotton thrives best within the temperature range of 21 to 37 °C. Karachi's mild tropical climate facilitates cotton cultivation (Fig. 1), enabling the growth of three cotton generations within a single year.

Thus, the mild tropical environment of Karachi offers a great opportunity for generation advancement to reduce the time required for breeding of new cotton varieties. Moreover, the purity of seeds can be maintained, as no cotton is grown in the area compared with other areas, and no electricity was used in off-season cotton growth due to mild climatic conditions. The rapid progression of generations enables extensive phenotypic screening, facilitating the precise identification of superior genotypes. This heightened efficiency in breeding programs expedites the introduction of improved crop varieties. Thus, Karachi offers a great opportunity to cotton breeders, research institutes, seed companies, and other stakeholders.

Acknowledgements
The authors are highly grateful to the reviewers for the critical review and thankful to all of the collaborators for making productive contributions to preparing this article.

Authors' contributions
Nizam F, Javed A, and Rehman K performed the experiments, analyzed the data, prepared tables, drafted the manuscript. Mansoor S and Azhar MT reviewed the manuscript and approved the final draft before submission.

Funding
The authors are thankful to the Research Project at International Center for Chemical and Biological Sciences, University of Karachi, Karachi, Pakistan.

Availability of data and materials
Not applicable.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
All authors declare no competing interests. Author Azhar MT is a member of the Editorial Board of Journal of Cotton Research, he was not involved in the journal's review or decision related to this manuscript.

Received: 3 July 2024 Accepted: 19 September 2024
Published online: 10 October 2024

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