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Seed set variability under high temperatures during flowering period in pearl millet (*Pennisetum glaucum* L. (R.) Br.)

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ABSTRACT

Pearl millet has recently emerged as a significant irrigated summer season cereal crop in north-western India. But its flowering coincides with air temperatures of ≥40 °C, leading to reduced seed set and poor grain yield in most of the available hybrids, although a few hybrids with good seed set and high yield potential are widely cultivated. Under a recent initiative to diversify the genetic base of heat tolerant hybrids, field screening of 221 hybrid parental lines (both B- and R-lines), 53 germplasm accessions and 4 improved populations over four-year period revealed large genetic variability in seed set at daily maximum air-temperature of ≥42 °C during flowering. Two locations data on 46 medium maturing genotypes screened during summer 2009 showed that seed set in pearl millet started declining when maximum air temperatures reached 42 °C and decreased in curvilinear fashion to 20 percent at 46 °C. Similar relationship of seed set with minimum and mean temperature was observed with threshold values of 26.4 °C and 34.2 °C, respectively. Similarly, the relationship of percent seed set with vapor pressure deficit (VPD) showed threshold value of 6.2 kPa for maximum VPD, 1.2 kPa for minimum VPD and 3.7 kPa for mean VPD. Seed set on 2 each of heat tolerant and susceptible genotypes fitted well on the seed set-temperature response curve for the maximum, minimum and mean air temperatures. Based on 3 to 4 year field screening (2009–2012), five hybrid seed parents (ICMB 92777, ICMB 05666, ICMB 00333, ICMB 02333 and ICMB 03555) and a germplasm accession IP 19877 with 61 to 69% seed set as compared to 71% seed set in a heat tolerant commercial hybrid 9444 (used as a control) was identified. Intra-population variability for heat tolerance was observed in four populations, and highly heat tolerant progenies from two of them were identified. Evaluation of six hybrid parents under controlled environment (maximum temperature of 43 °C and minimum temperature of 22 °C) revealed boot-leaf stage of pearl millet plant to be more heat sensitive than panicle-emergence stage, and investigations on 6 A-/B-pairs under controlled environment (max. temperature of 44 °C and min. temperature of 22 °C) revealed female reproductive system of pearl millet to be more heat sensitive than pollen. Comparison of 23 hybrids and their parents for seed set at high air temperature (>42 °C) showed heat tolerance as a dominant trait, implying heat tolerance in one parent would be adequate to produce heat tolerant hybrids in pearl millet. Heat tolerant composite developed using identified lines showed high mean seed set under high air temperatures during flowering.

Abbreviations: CSIRO, Commonwealth Scientific and Industrial Research Organization; ICMB, ICRISAT millet B-line; ICRISAT, International Crops Research Institute for the Semi-Arid Tropics; IMD, India Meteorological Department; kPa, kilopascals; NCAR, National Center for Atmospheric Research; R-line, restorer line; RH, relative humidity; S, sensitive; SS, seed set; SSC, seed set class; T, tolerant; VPD, vapor pressure deficit; WANA, western Asia and northern Africa; WCA, western and central Africa.

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1. Introduction

Pearl millet (*Pennisetum glaucum* L. (R.) Br.) is an important coarse grain cereal cultivated for grain and fodder on about 30 million hectares worldwide. India is the largest producer of this crop with 9.5 million tons of grain from 9.3 million hectares area (Yadav et al., 2012). It is primarily cultivated in rainy season of dry tropics with an average grain yield of about 800–1000 kg ha^{-1}, but in the past decade it has also occupied large areas (>500,000 ha) in the hot-dry post rainy season (February to June), locally referred as "summer", in the northern and western parts of India (Fig. 1). In this summer crop of about 80–85 days, under well irrigated and well-managed conditions, pearl millet yields about 4–5 t ha^{-1} of grain and 8–10 t ha^{-1} of dry fodder (AICPMIP, 2013). This grain yield advantage and with better grain quality from summer crop has shifted pearl millet cultivation in Gujarat state from rainy season to summer season (Reddy et al., 2013). In these parts of India, maximum air temperatures in the range of 40 °C to 48 °C are prevalent during the months of April–May. Thus, owing to high air temperatures (often >40 °C) coinciding with flowering of pearl millet crop, the summer crop suffers from reproductive sterility leading to drastic reduction in grain yield (Fig. 2.1, 2.2). Very few hybrids with high yield potential have shown good seed set under such high temperature conditions, leaving limited cultivar choice for farmers. With this limited genetic variability, there is always a risk of such hybrids breaking down to downy mildew (*Sclerospora graminicola* (Sacc.) J. Schrot) disease, which is the greatest biotic constraint of pearl millet hybrids in India. Thus, there is need to strengthen breeding of pearl millet for tolerance to heat stress during flowering period to increase genetic diversity of hybrids suitable for summer season cultivation in north–western India. Moreover, pearl millet is being experimented as a summer season crop in western Asia and north African (WANA) region, in central Asian countries and in western and central African countries (WCA) where high temperatures during flowering period is a major constraint (pers. commun. Kristina Toderich, International Center on Biosaline Agriculture—Central Asia and South Caucasus; and C.T. Hash, ICRISAT, Niger). Also, yield stability has gained more importance because of the potential adverse effects of climate changes, and high temperature is especially considered as key stress factor with potentials impact on grain yield. Nelson et al. (2009) reported 8.4% and 7.0% reduction in projected global yields of millets by 2050 using CSIRO (Commonwealth Scientific and Industrial Research Organization, Australia) and NCAR (National Center for Atmospheric Research, USA) models, respectively, under climate change scenario. Hence, higher levels of high temperature tolerance during flowering period in pearl millet will not only have global implications to diversify cropping patterns in ecologies with existing high temperatures but will also ensure stable crop production in future high temperature scenarios. This paper present results on the seed set response at different temperatures and vapor pressure deficits, magnitude of variability for seed set under high temperatures during flowering period in pearl millet, on the identification of heat tolerant sources and examines most heat sensitive stages during the crop development and whether there would be a need to breed heat tolerance in both parental lines to develop heat tolerant hybrids to further enhance the prospects of breeding flowering-period heat tolerant cultivars in pearl millet.

2. Material and methods

2.1. Field screening

Field screening for flowering-period heat tolerance in pearl millet require locations having crop season of about 80 days with good irrigation facilities, and rainfall-free days from boot-leaf stage (40–45 days after sowing) to seed set stage (about 15–20 days after

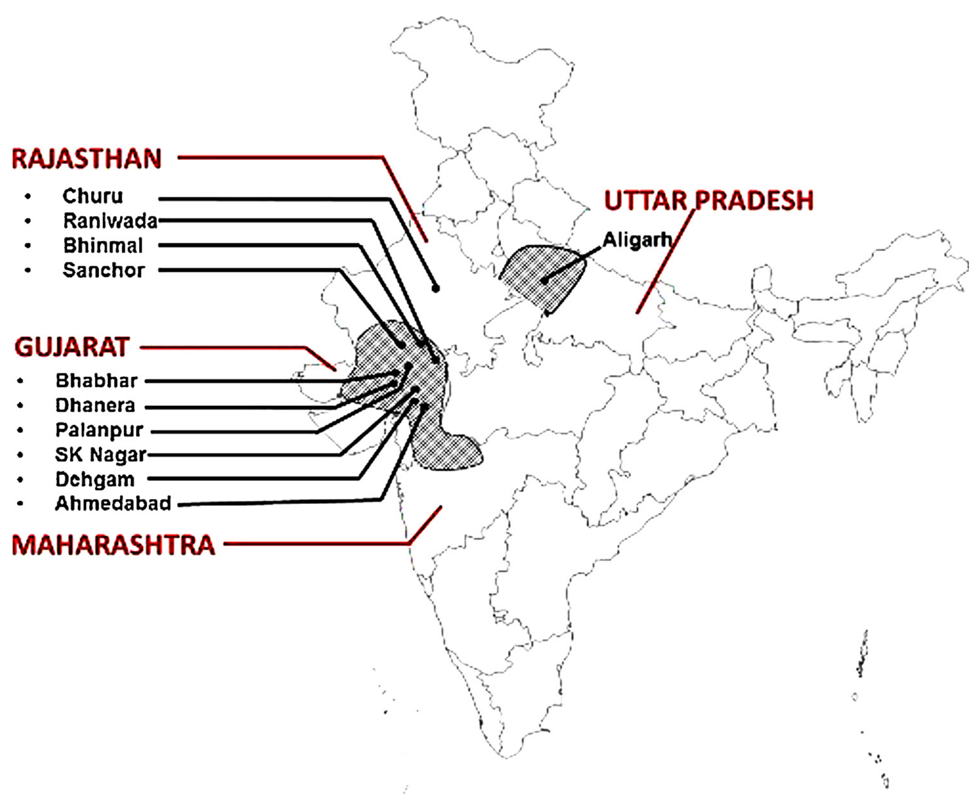

Fig. 1. Summer crop of pearl millet in India (shown as marked area), and testing locations used for screening pearl millet for high heat stress during flowering period in present study.