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ORIGINAL ARTICLE

Evaluation of wheat genotypes for heat stress tolerance and identification of early stress indicators

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Abstract Heat stress is an abiotic factor that reduces wheat yields. This study assessed the morphological and physiological traits essential for early detection of heat tolerance in wheat and identified suitable genotypes for specific agro-ecologies prone to heat stress in Zambia. Twelve wheat genotypes were evaluated in a heat-stress environment (Chakanka) and a non-stress heat environment (UNZA). Early heat stress indicators like leaf thickness and chlorophyll content had a 92% and 90% relationship with the yields of heat-tolerant genotypes, respectively. An increase in either or both parameters improved the yields of heat-tolerant genotypes relative to the susceptible ones. Among the heat-tolerant genotypes, Entry 48 had the highest yield (5866.5 kg ha^{-1}) at the heat-stress site; this yield was 51.2% higher than that of the most susceptible genotype, Kwale (2864.0 kg ha^{-1}). Entry 48 was more adapted to heat stress and yielded better than others due to early flowering (53.8 days to 50% flowering) and longer grain-filling duration (40.3 days). Entry 48 possessed traits of a climate-smart variety and could be a candidate for breeding future heat-tolerant and high-yielding wheat varieties.

Keywords Heat tolerance · Heat susceptible · Zambia · Stress indicators · Leaf thickness · Breeding

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Introduction

Heat stress is an abiotic factor that reduces global crop production. It is further exacerbated by global warming. A global atmospheric temperature rise of 2 °C could lead to an increase in yields of adapted crops such as wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.) and maize (*Zea mays* L.), but each subsequent increase in temperature could reduce yields (Challinor et al., 2014). In wheat, yield declines by 6% for each degree increase in atmospheric temperature above the optimum temperature of 25 °C (Asseng et al., 2015).

Depending on the wheat variety, heat stress can decrease the number of grains, yield and straw mass by up to 28%, 25%, and 25%, respectively (Mahrookashani et al., 2017). In addition, flowering, CO_2 assimilation by wheat, seed set, kernel weight, starch and protein content of grains are all lowered by heat stress (Aiqing et al., 2018). Also, grain starch characteristics such as grain starch area, length and volume are reduced (Chaubey et al., 2021). Even the days to anthesis and days to maturity are reduced by 16% and 20%, respectively. The early anthesis causes a further decline in leaf area, above-ground biomass, panicle length, and tillers per plant (Qaseem et al., 2019). Furthermore, heat-stress has been shown to reduce chlorophyll by 19% during anthesis and 25% during grain filling. Similarly, photosynthesis rate declined by 17% and 25% during anthesis and grain filling, respectively (Djanaguiraman et al., 2020). Conversely, fluorescence, stomatal conductance and less-unsaturated lipid species were elevated under heat stress (Djanaguiraman et al., 2020). Despite all these negative effects of heat stress that eventually lower wheat yield, there are concerted efforts to mitigate these, from irrigation to improve transpiration and thus reduce the plant temperature, to growing adapted varieties, priming of seeds with salicylic acid

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