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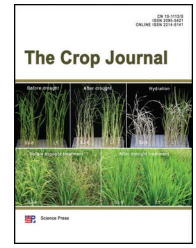

Integrated physiological and molecular approaches to improvement of abiotic stress tolerance in two pulse crops of the semi-arid tropics

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ABSTRACT

Chickpea (*Cicer arietinum* L.) and pigeonpea [*Cajanus cajan* L. (Millsp.)] play an important role in mitigating protein malnutrition for millions of poor vegetarians living in regions of the semi-arid tropics. Abiotic stresses such as excess and limited soil moisture (water-logging and drought), heat and chilling (high and low temperature stresses), soil salinity, and acidity are major yield constraints, as these two crops are grown mostly under rainfed conditions in risk-prone marginal and degraded lands with few or no inputs. Losses due to such stresses vary from 30% to 100% depending on their severity. The literature abounds in basic information concerning screening techniques, physiological mechanisms, and genetics of traits associated with resistance/tolerance to abiotic stresses in these two crops. However, the final outcome in terms of resistant/tolerant varieties has been far from satisfactory. This situation calls for improving selection efficiency through precise phenotyping and genotyping under high-throughput controlled conditions using modern tools of genomics. In this review, we suggest that an integrated approach combining advances from genetics, physiology, and biotechnology needs to be used for higher precision and efficiency of breeding programs aimed at improving abiotic stress tolerance in both chickpea and pigeonpea.

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Contents

1. Introduction

In several developing nations of the world, pulses are the major source of dietary protein for millions of people who are vegetarians either by choice or by religion [1], and thereby play an important role in mitigating protein malnutrition. However, year-to-year fluctuations in pulse production and productivity, owing mainly to abiotic stresses, often place global nutritional security in jeopardy. At the farmer level, cereals always take the front seat in filling families' basic energy requirements. This priority relegates the cultivation of pulses to less productive or risk-prone marginal lands of the semi-arid tropics (SAT) receiving <500 mm annual rainfall. SAT regions cover as many as 55 countries in Asia and sub-Saharan Africa. Among grain legumes serving as the major source of daily protein intake for the poor in parts of sub-Saharan Africa and south Asia, chickpea (*Cicer arietinum* L.) and pigeonpea [*Cajanus cajan* (L.) Millsp.] are the most important. The major abiotic stresses affecting their production are extremes of moisture stress (sufficiency or deficiency) and temperature (high or low), salinity/alkalinity, and acidity [2]. Instability in production and productivity of these two pulses greatly affects nutritional security in SAT regions.

Trait-specific indices have been used in many field crops for selecting high-yielding genotypes with tolerance/resistance to abiotic stresses. Several indices or parameters such as stress susceptibility index (SSI) [3], stress tolerance (TOL) [4], stress-tolerance index (STI) [5], and geometric mean productivity (GMP) [6] based on yield under both stress and non-stress conditions have been applied to identify better-performing cultivars. Similarly, recent advances in the development of molecular markers, marker–trait association, and marker-assisted breeding (MAB) have made it possible to realize higher genetic gain while breeding for abiotic stresses in other crops [7]. To improve selection efficiency for abiotic stress tolerance (AST) of these two SAT pulse crops, it is imperative to identify and validate morphological markers, physiological processes, and indices using high-throughput controlled conditions and/or natural stress conditions for use as selection criteria in conventional and/or molecular breeding. In recent years, several reviews dealing with abiotic stresses in pulses have appeared. However, most such reviews are specific either to an individual pulse crop [8,9] or to a specific abiotic stress within the crop [10,11]. Some reviews have focused on physiological approaches [12], while others have addressed the issue exclusively through molecular approaches [13]. The present review is an attempt to address the issue of abiotic stresses collectively in both chickpea and pigeonpea through integration of physiological and molecular approaches.

2. Major abiotic stresses affecting chickpea and pigeonpea productivity

2.1. Chickpea

Chickpea is a cool-season pulse crop of SAT regions that serves as the major source of protein for millions of farm families. In India, chickpea is grown over 9.92 Mha, with production of 9.88 Mt and productivity of 995.3 kg ha^{-1} [14]. It is cultivated in all the five diverse agro-climatic zones of India (central, south, northwest plain, northeast plain, and north hill zones). The central (parts of Rajasthan, Madhya Pradesh, Chhattisgarh, Gujarat, and Maharashtra) and south (Andhra Pradesh, Telangana, Karnataka, and Tamil Nadu) zones account for over 80% of the total chickpea area in India. SAT regions are scattered over two thirds of the area of these two zones. The cultivation of chickpea on such marginal lands with residual moisture and limited inputs leads to poor realization of the potential yield of improved cultivars.

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