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Dnyaneshwar A Raut
Ph.D. Research Scholar,
Department of Plant Physiology,
Mahatma Phule Krishi
Vidyapeeth, Rahuri,
Maharashtra, India

Sharad R Gadakh
Vice-Chancellor, Dr. Panjabrao
Deshmukh Krishi Vidyapeeth,
Akola, Maharashtra, India

A Blesseena
Ph.D. Research Scholar,
Department of Plant Physiology,
Mahatma Phule Krishi
Vidyapeeth, Rahuri,
Maharashtra, India

Corresponding Author:
Dnyaneshwar A Raut
Ph.D. Research Scholar,
Department of Plant Physiology,
Mahatma Phule Krishi
Vidyapeeth, Rahuri,
Maharashtra, India

Evaluation of chickpea drought tolerance by photosynthetic efficiency under soil moisture depletion

Dnyaneshwar A Raut, Sharad R Gadakh and A Blesseena

Abstract

Numerous metabolic functions, including photosynthesis, endure detrimental consequences under drought-stress conditions. As a fact, water scarcity harms the plants' fundamental components, which prevents carbon assimilation and harms the photosynthetic machinery. In this regard, the present research was conducted to study chickpeas' photosynthetic efficiency (PSII efficiency) under restricted moisture levels. We found that six chickpea genotypes differing in their behavior towards depleting soil moisture levels *viz.*, 60, 50, 40, 30, and 20% FC evaluated for PSII efficiency. Water stress substantially decreased the leaf PSII efficiency in all the genotypes under soil moisture depletions. The G1 had more PSII efficiency than the other genotypes under severe soil moisture depletion. However, at the same moisture level, the G4 genotype had lower PSII efficiency than the rest of the genotypes.

Keywords: PSII efficiency, chickpea, soil moisture depletion, plant phenomics facility

Introduction

Chickpea is an excellent season crop (Cerna *et al.*, 2022) [1] and is widely cultivated in India (Halder *et al.*, 2022) [5]. India is the world's largest consumer of chickpeas, accounting for 76% of total production (Mathew *et al.*, 2022) [11]. It is the world's second most extensively cultivated pulse crop and India is the world's leading producer, accounting for 75% of global production (Rani *et al.*, 2020) [20]. Chickpeas protein has a higher bioavailability in the human body than other pulses (Kaur and Prasad, 2021) [7]. Considering the significance of chickpeas as a protein source and in addition to the irrevocable damage caused by drought stress to chickpea production, it is critical to implement approaches that can increase tolerance in plants to drought stress (Zamani *et al.*, 2022) [24].

The impacts of drought frequently affect the agriculture and water resource industries. They may significantly reduce agricultural production and completely ruin crops in developed countries, resulting in significant economic losses (Sweet *et al.*, 2017; Tian *et al.*, 2018) [22, 23]. Insufficient soil moisture at sowing leads to poor germination rate, germination speed, potential and seedling growth in chickpeas (Chauhan *et al.*, 2022) [2]. There have been numerous investigations into how different chickpea traits are impacted by drought, including shoot biomass (Purushothaman *et al.*, 2016; Istanbul *et al.*, 2022) [18, 6], and morphological (Kobru *et al.*, 2022; Sachdeva *et al.*, 2022) [8, 21], physiological (Rahbarian *et al.*, 2012) [14], biochemical (Mafakheri *et al.*, 2010) [10] and molecular traits (Garg *et al.*, 2016) [4]. Critical physiological and biochemical processes in chickpeas, such as photosynthesis, CO_2 availability, respiration, cell growth and other crucial cellular metabolisms, are all negatively impacted by drought stress (Chaves *et al.*, 2009; Pinheiro and Chaves, 2011) [3, 17]. Drought stress decreases nodules' quantity, size, and vigor, leading to less effective nitrogen fixation in chickpeas (Muruiki *et al.*, 2018) [13].

The major focus of the present investigation was on the PSII sensitivity of six chickpea genotypes under depleting soil moisture stress. It was our goal to determine which chickpea candidates were stress-tolerant or stress-sensitive to based on the PSII efficiency performance at the flowering stage.

Materials and Methods

During the *Rabi* season of 2021–2022, the experiment was conducted at the National Institute of Abiotic Stress Management (NIASM), Baramati (MS), India. The following six chickpea genotypes were used in the pot experiment, G1: BDNG-2018-15, G2: PG-1201-20, G3: Vijay, C-19159, C-19294, and G6: Vishal, which was run in a controlled environment. Twelve-inch-diameter plastic pots containing 13 kg of clay loam soil in which seven seeds each were planted. Six genotypes were grown for 24 days in an open environment before being moved to the National Plant Phenomics Facility to monitor the loss of soil moisture every day. Inside the phenomics, there was an automated provision employed to maintain the required soil moisture levels in the respective pots. In the present investigation, 24 days old seedlings of all the genotypes were subjected to 60% (well watered), 50%, 40%, 30%, and 20% (severe water stress) field capacity (FC). Four pots each for well-watered and water-stressed treatment were maintained (as replicates) for each genotype throughout the experiment.

The statistical analysis of data was carried out by the standard method and critical differences were calculated. Whenever the results were significant, critical differences (C.D.) at 5% significance were worked out. The data were analyzed in Factorial Randomized Block Design (FRBD).

Results

The result revealed that depleting soil moisture levels could markedly affect the PSII efficiency in all the genotypes. There was a great genotypic variation for PSII efficiency found under the depleting soil moisture levels. Irrespective of the soil moisture depletion, G2 had the highest (0.694) and G4 had the lowest (0.533) PSII efficiency compared to rest of the genotypes (Table-1).

Table 1: PS II efficiency as indicated by Fv/Fm under depleting soil moisture levels in chickpea genotypes.

Genotypes	**Depleting soil moisture levels in% field capacity**					
	60	**50**	**40**	**30**	**20**	**Mean**
G1	0.780	0.705	0.538	0.434	0.373	0.566
G2	0.864	0.807	0.722	0.597	0.479	0.694
G3	0.809	0.778	0.66	0.55	0.357	0.631
G4	0.735	0.672	0.525	0.377	0.357	0.533
G5	0.801	0.733	0.652	0.488	0.391	0.613
G6	0.844	0.753	0.687	0.341	0.326	0.590
Mean	0.806	0.741	0.631	0.464	0.381	0.604
Main factor- Depleting soil moisture levels		Subfactor – Genotypic variation		Interaction effect		
SE (m) ±	0.013	SE (m) ±	0.014	SE (m) ±	0.031	
CD at 5%	0.036	CD at 5%	0.040	CD at 5%	0.089	

All the genotypes at 60% FC (well-watered) had a significantly maximum PSII efficiency. When these genotypes gradually submitted to moisture depletions (50, 40, 30 and 20% FC), the PSII efficiency substantially declined. There was a progressive decrement in PSII efficiency by up to 40% FC. However, thereafter at severe stress, PSII efficiency significantly declined in all the genotypes (Table-1, Fig-1).

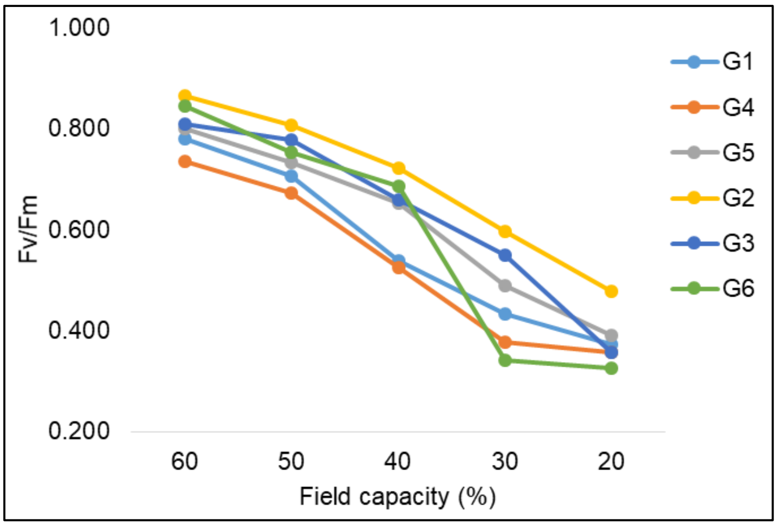

Fig 1: Response of PSII efficiency of chickpea genotypes to depleting soil moisture levels

Among the genotypes, G2 had the higher PSII efficiency under both well-watered and severe water-stress conditions. After the imposition of the water stress, the PSII efficiency of G2 gradually declined toward severe water stress condition. The intensity of declination was lower during the earlier period of the water stress; however, in later stages, it was drastically higher. In between, G2 maintained a significant difference over all the genotypes from 50% FC to 20% FC. At severe water stress, PSII efficiency in all the genotypes were not significantly distinguished. However, G2 was the only genotype that maintained significantly higher PSII efficiency than the rest of the genotypes (0.479) (Table-1, Fig-2).

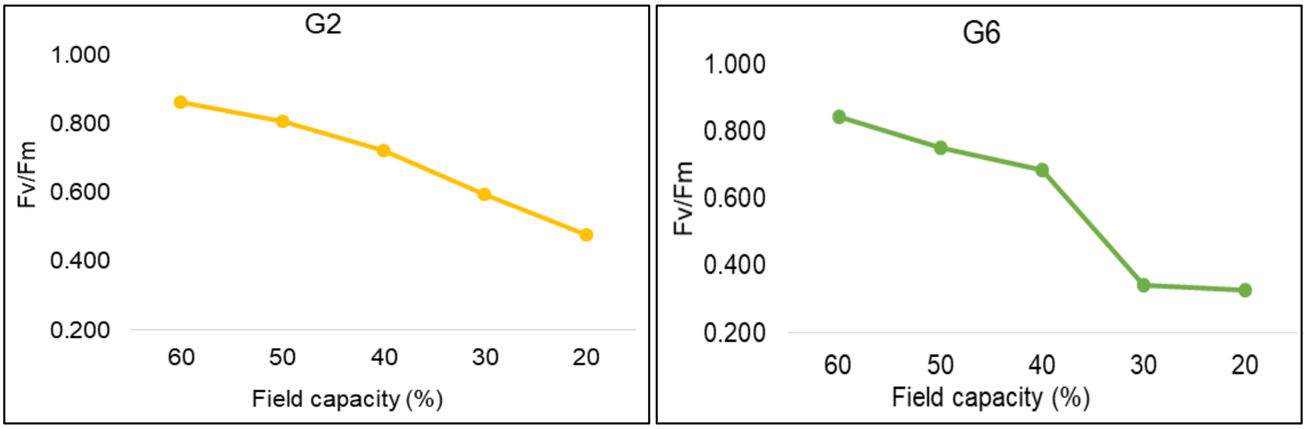

Fig 2: Response of PSII efficiency of G2 and G6 genotypes to depleting soil moisture levels

The G4 had significantly lower PSII efficiency than the rest of the genotypes under well-watered condition. Whereas, at severe water stress G6 exhibited a lower PSII efficiency than the rest of the genotypes. The PSII efficiency of G6 gradually decreased from well-watered to 40% FC; however, it drastically dropped between 40 - 30% FC. In the end, between 30- 20% FC, the PSII efficiency of G6 was almost the same. (Fig-2).

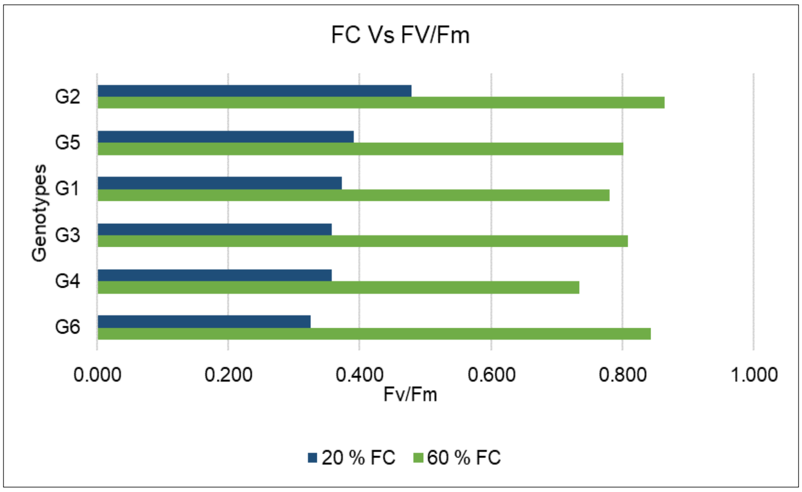

Fig 3: Response of PSII efficiency of chickpea genotypes to well watered (60%) and water severe water stressed (20%) FC conditions

The G2, G5, G4, G1, G3 and G6 had 1.80, 2.0, 2.1, 2.1, 2.3 and 2.6 folds lower PSII efficiency under severe water stress than well-watered conditions (Fig-3). However, G2 outperformed the other genotypes under severe water stress conditions in response to PSII efficiency.

Discussion

In the present investigation, the PSII efficiency of all the genotypes was markedly decreased by water stress impact. Seifikalhor *et al.* (2022) [25] revealed a similar result, noting that all chickpea plants PSII efficiency dropped as moisture levels declined (100, 60, 40, and 20% FC). There was a substantial genetic variation existed between the genotypes for PSII efficiency in the current study. In the severe water stress, G2 had the higher and G6 had the lower PSII efficiency. This might be that's not that G2 is drought tolerant and G6 is a drought intolerance genotype as drought tolerant plants can function better under water-stressed conditions than that drought intolerant plants (Meshram *et al.*, 2022) [12]. A similar finding was obtained by Rahbarian *et al.* (2012) [19], who found that under drought stress conditions (25% FC), PSII efficiency (Fv/Fm ratio) was higher in all the drought tolerant genotypes (MCC392, MCC877) than in drought-sensitive genotypes (MCC68, MCC448) at the seedling and pod initiation stages of chickpea. It has been demonstrated that drought stress inhibits PSII activity and has a detrimental effect on energy transfer pathways in mungbean (Batra *et al.*, 2014) [15]. Drought sensitive variety of chickpeas experienced a greater reduction (64%) than the tolerant variety (26%) (Khan *et al.*, 2019) [16].

Conclusion

Under both well-watered and severe water stress conditions, there was a substantial genetic variation in PSII efficiency. Under severe water stress conditions, the G2 genotype performed better. This can be explored for drought-tolerant identification. Genotypes with high PSII efficiency can lead to drought tolerance.

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