Identification of New Genetic Resources Under Drought Stress in Response to Roots and Nodules in chickpea

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Abstract

Ten high nodulation and two poor nodulation chickpea genotypes were selected from the previous field experiment to study the effect of drought stress on various nodules, root characteristics, and physiological traits of chickpea. The experiment was conducted under greenhouse conditions as a split factorial plot design with two replications. The main plot (spilt) included two levels of water stress: well-watered and severe stress. The factorial plot included genotypes and three treatments: a combination of two rhizobia strains (ICARDA36, NIF1148), ammonium nitrate, and a control. The result indicated that drought stress had a significant effect on nodule biomass (NB), nodule dry weight (NDW), root biomass (RB), root dry weight (RDW), chlorophyll content (Chl), relative water content (RWC), stomatal conductance (*gs*), grain yield (GY), 100 seed weight (100SW), and pod number (PN), but was not significant in the number of empty pods (EPN). In general, inoculation by Rhizobia strains increased the value of all the studied parameters under both water treatments. The highest regression relationship between grain yield and root biomass, 100 seed weight was found in rhizobia treatments (R^2=0.60, 0,74) respectively. The four genotypes (Genesis090, IG13032, IG70270, IG70272) produced the highest nodules, root biomass, and yield under drought conditions. This result will help the breeders to develop new chickpea varieties with better nodulation under drought conditions.

Introduction

Chickpea (*Cicer arietinum* L.) is the second most important grain legume (pulse) globally, occupying 15 Mha (FAO, 2021), it is a leguminous plant known for its high nutritional properties and is an important source of food, feed, and fodder. Chickpea plays an integral part in diversifying the cereal-based cropping system because of its ability to add 60–103 kg/ha nitrogen to the soil through symbiotic nitrogen fixation (SNF) by fixing 140 kg of atmospheric N_2 ha^{-1}. Environmental stresses, such as drought limit symbiotic nitrogen fixation in legumes, resulting in decreased yielding capacity. Drought is the major abiotic stress and the most important constraint limiting yield potential in cereal and legume crops, which can cause more than 70% yield loss in chickpea. Thus, an understanding of SNF responses to drought stress and the identification of factors that affect the rate of SNF in chickpea nodules and roots are crucial for enhancing the productivity of this crop.

Materials and Methods

The experiment was conducted in ICARDA greenhouse at Terbol station, Lebanon, during the 2018-2019 season. The best ten genotypes in N_2-fixation and two genotypes that are poor in N_2-fixation have been selected from field experiments depending on N_2-fixation results (Istanbuli *et al*., 2022). Twelve genotypes have been selected from field experiments depending on nodulation observation and drought tolerance score. The greenhouse experiment was planted in a split factorial design with two replications under two water stress conditions, drought stress 10% from the available water content and well-watered 70% from the available water content (Figure 1).

Figure 1. Greenhouse experiment under two water levels, three plant treatments, and two replications.

The first set was inoculated with two kinds of *Rhizobium* strains (ICARDA-CP-36, ICARDA-CP-39) just before planting, the second set with ammonium nitrate, and the third set as a control (without inoculation). Several reliable physiological parameters, nodules, root characteristics, and yield components were used for evaluating drought-tolerant chickpea genotypes (Figure 2).

Figure 2. Measuring physiological parameters under two water and three plant treatments in the greenhouse.

Result and Conclusion

Drought stress caused significant (P < 0.05) changes in physiological traits and yield components but was not significant in EPN. Drought stress reduced RB, RDW, NB, and NDW (56%, 46%, 48%, and 48%), respectively, under water stress compared to well-watered (Table 1).

Table 1. Mean comparison ± standard errors for morpho-physiological traits under two water treatments (W).

Traits	W	Mean	Minimum	Maximum
Root biomass	Water Stress	3.986 ± 0.45 a	0.6667	8
	Well Watered	9.148 ± 0.7 b	1.667	17
Root dry weight	Water Stress	0.4425 ± 0.053 a	0.1133	0.98
	Well Watered	0.8144 ± 0.061 b	0.1867	1.493
Nodule biomass	Water Stress	0.6692 ± 0.076 a	0.23	1.45
	Well Watered	1.283 ± 0.097 b	0.35	1.985
Nodule dry weight	Water Stress	0.1326 ± 0.019 a	0.02	0.32
	Well Watered	0.2532 ± 0.021 b	0.02	0.445
Chlorophyll content	Water Stress	31.5 ± 2 a	16	47.6
	Well Watered	72.4 ± 2.4 b	54	92
Stomatal conductance	Water Stress	15.85 ± 1.910 a	4.6	39.6
	Well Watered	39.20 ± 2.362 b	16.2	64.5
Relative water content%	Water Stress	47.6 ± 1.3 a	31	60
	Well Watered	77.4 ± 1.7 b	54.55	94
Grain yield (GY)	Water Stress	3.81 ± 0.293 a	0.8	8.233
	Well Watered	7.49 ± 0.449 b	2.067	12.57
100 seed weight (100SW)	Water Stress	30.67 ± 0.98 a	9.744	44.58
	Well Watered	33.79 ± 1.01 b	10.92	49.82
Pod number (PN)	Water Stress	15.06 ± 1.1 a	5	30
	Well Watered	21 ± 1.8 b	10.67	35.33
Empty pod number (EPN)	Water Stress	2.31 ± 0.3 a	1	5.667
	Well Watered	2.03 ± 0.4 a	0	9

The linear regression analysis showed the positive and highest relationship between grain yield and root biomass, 100 seed weight was found in rhizobia treatments (R^2=0.60, 0,74) respectively (Figure 3).

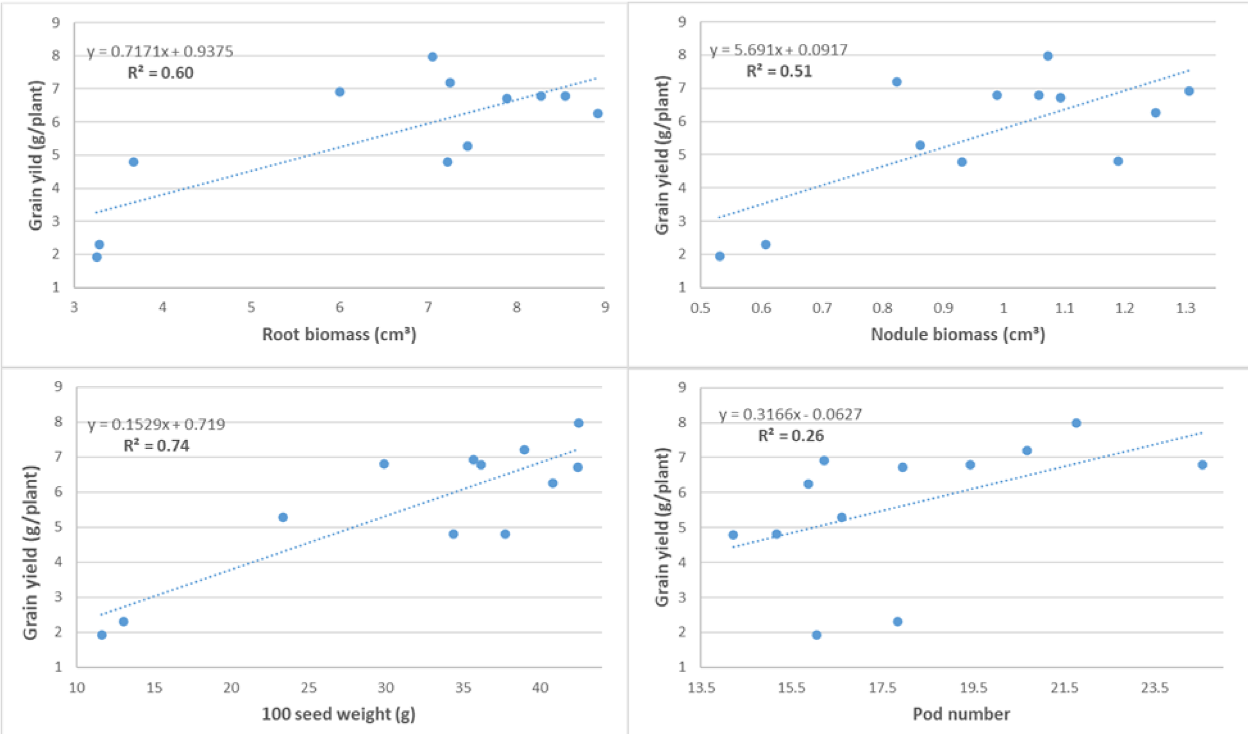

Figure 3. Relationship between grain yield and some root biomass and nodule biomass, 100 seed weight, and empty pod number.

The tolerant and high nodulation genotypes (Genesis90, IG70272, IG70270, IG132032, IG71832, IG114795, and IG8256) had an above-average value in GY compared to two susceptible and poor nodulation genotypes (IG115380 and IG70309) under water stress treatment (Figure 4).

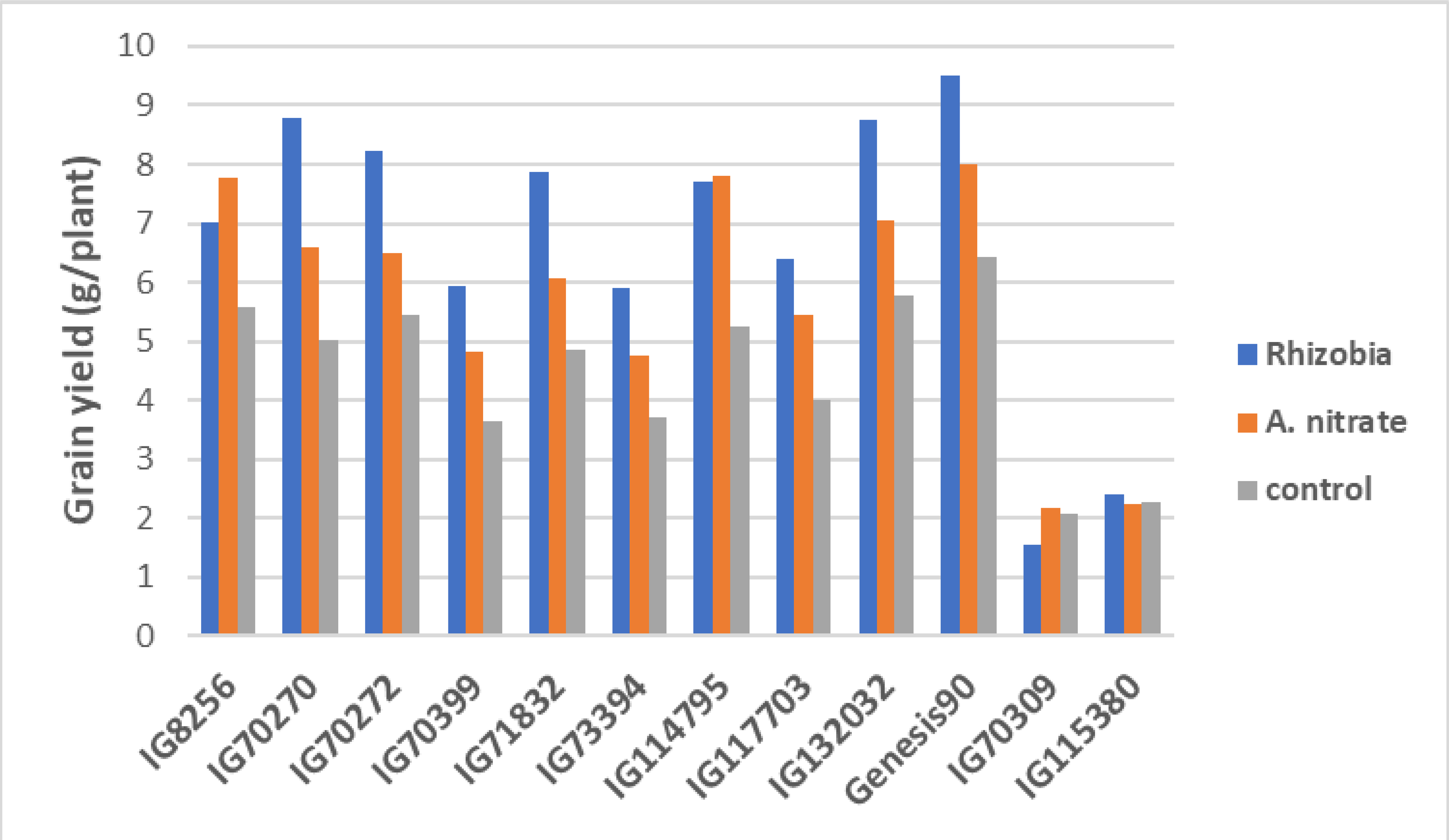

Figure 4. Effect of Rhizobium inoculation and ammonium nitrate on grain yield (g/plant^{-1}) under drought stress.

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