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Short Communication

Physiological traits in relation to yield improvement in chickpea (*Cicer arietinum* L.) under depleting soil moisture environment

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Abstract

The chickpea genotypes along with F_4 progeny lines differing in their behavior towards drought were evaluated for seed yield, yield attributes and physiological traits. Drought decreased the leaf water potential, leaf osmotic potential and relative water content in both parents and progeny lines. The parent RSG 931 had more plant water status as compared to HC 1 under drought condition. The progeny lines G11, G10, G 04 and G 05 showed the similar results. Leaf water potential, osmotic potential and RWC had a significant association with seed yield (r = 0.86, 0.95 and 0.92, respectively). The seed yield decreased in drought stress condition but decrease in yield of RSG 931 (19.27%) was less than HC 1 (37.32%). The parent RSG 931 and the progeny lines G11, G10, G 04 and G 05 had better plant water status, CTD and photochemical efficiency and these traits were directly associated with seed yield.

Key words: Plant water status, yield, drought, chickpea

Chickpea (*Cicer arietinum* L.) is an important self-pollinated grain legume crop, which plays an important role in the maintenance of soil fertility, particularly in the dry and rainfed areas besides being an important source of human and animal food. About 90% of world's chickpea is grown under rainfed conditions where the crop grows and matures on a progressively depleting soil moisture profile and generally experiences terminal drought (Kashiwagi et al. 2013). Terminal drought is one of the major constraints limiting chickpea productivity and yield stability. It reduces the productivity by alteration in morpho-physiological metabolism in plant. Moisture deficit affects plant establishment in the field, photosynthetic ability and osmotic behavior of cells. However, species and genotypes vary in their capacity to tolerate water stress (Ulemale et al. 2013). There is a need to develop drought-tolerant genotypes with enhanced and stable yield under terminal drought stress. Plants adopt various defense mechanisms in response to terminal drought which were accomplished by regulating internal plant water status represents an easy measure of water deficit and provides best sensor for stress. Therefore, crosses were made using parents HC 1 and RSG 931 to obtain improved chickpea progeny lines for better plant water status and high yield in drought prone areas.

The experiment was conducted during the rabi season in drought plots with rainout shelters at CCS Haryana Agricultural University, Hisar. The cross of HC 1 and RSG 931 was made in 2009-10 and progeny rows were grown to get F_4 generation. The F_4 progeny lines along with parents (HC 1 and RSG 931) were planted in drought plots (6 m long, 1 m wide and 1.5 m deep) filled with sandy soil and irrigated up to field capacity. Both the parents were under two environments, namely irrigated (I: two irrigations of 6 cm depth each at pre flowering and pod filling) and drought (D: one irrigation of 30 mm equal to long-term average seasonal rainfall at pre flowering stage). The experiment was conducted in a randomized block design (RBD) with three replications. Eighteen F_4 progenies derived from the cross HC 1 × RSG 931 were grown in drought conditions as in case of parents.

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The soil moisture content at the time of sowing was 12.3% upto 15 cm depth. The soil moisture content in the depth range of 45-135 cm was 9.04% in irrigated plots and 6.42% under drought conditions at the time of observations. The plant water relation traits and other characters were recorded on third fully expanded leaf from top between 11.0-12.0 hrs at 50% flowering stage i.e. 96-102 days in irrigated and 83-97 days under drought conditions after sowing. The leaf water potential (LWP) was measured by Pressure Chamber (PMS Instrument Co., Oregon, USA), leaf osmotic potential (LOP) by Vapor Pressure Osmometer (Model 5100-B, Wescor, Logan, USA), leaf relative water content (RWC) was calculated by the method of Kumar and Elaston (1992), relative stress injury (RSI %) by the method Sullivan and Ross (1979), canopy temperature depression (CTD^{0}C) using infra-red thermometer (Model AG-42 Tele-temp Corp, California, USA), photochemical efficiency (F_v / F_m) by an OS-30P chlorophyll flurometer (Opti-Science, Inc., Hudson, NY, USA). The phenological observations, yield attributes and seed yield of both parents under irrigated and drought conditions and all eighteen F_4 progeny lines under drought condition were recorded.

The chickpea parental genotypes matured earlier in drought than in irrigated conditions. The parent HC 1 showed early flowering and maturity (83 and 124 DAS) than RSG 931(87 and 145 DAS) but yield response was reverse under both growing environments. Therefore, the crosses were made to induce earliness, improved plant water status with

Table 1. Plant water status, relative stress injury, and chlorophyll fluorescence of parents and progeny lines of chickpea

Genotype/ progeny lines	Water potential (-MPa)	Osmotic potential (-MPa)	Relative water content (%)	Relative stress injury (%)	Canopy temperature depression (^{0}C)	Photochemical efficiency (F_v/F_m)
HC 1 (Irrigated)	0.80	1.15	78.7	16.4	-0.4	0.624
HC 1 (Drought)	1.20	1.31	59.2	31.3	2.1	0.429
RSG 931 (Irrigated)	0.76	1.22	75.9	21.5	-1.6	0.655
RSG 931 (Drought)	1.19	1.42	62.2	29.7	0.2	0.500
LSD (0.05%)	0.21	0.06	3.12	4.65	0.51	0.14
F4 Progeny lines (HC 1× RSG931)						
G 01	0.95	1.24	68.5	28.8	-1.3	0.614
G 02	0.80	1.11	72.0	24.6	-1.5	0.700
G 03	0.88	1.20	68.9	27.9	-1.3	0.619
G 04	0.78	1.02	74.3	21.1	-1.7	0.552
G 05	0.80	1.10	74.3	24.5	-1.6	0.498
G 06	0.82	1.12	70.7	24.9	-1.5	0.644
G 07	0.98	1.30	68.0	30.0	-1.0	0.703
G 08	0.85	1.20	69.0	25.3	-1.3	0.625
G 09	0.84	1.19	69.7	25.0	-1.4	0.435
G 10	0.77	1.00	74.9	20.3	-2.0	0.509
G 11	0.72	0.87	77.8	20.3	-2.3	0.627
G 12	1.43	1.53	57.2	37.7	0.7	0.555
G 13	1.34	1.45	59.3	37.3	0.6	0.471
G 14	0.88	1.22	68.8	28.0	-1.3	0.421
G 15	1.10	1.38	65.4	33.9	-0.7	0.520
G 16	1.07	1.32	66.9	31.9	-0.7	0.608
G 17	1.02	1.31	67.4	30.1	-1.0	0.617
G 18	1.15	1.44	62.8	34.5	-0.7	0.658
LSD (0.05%)	0.24	0.18	3.67	3.14	0.11	0.34

higher yield using these parents. The range for 50% flowering and poding along with physiological maturity in F_4 progenies varies from 82-97 days, 97-123 days and 120-160 days, respectively. Early maturity and poding are important traits to avoid higher yield losses from drought. The differential genotypic response to drought stress, as a result of variation in physiological parameters has also been reported (Gunes et al. 2008; Talebi et al. 2013).

The plant water status was evaluated as drought tolerance selection criteria. The results showed that under drought stress there is decrease in water potential, osmotic potential and relative water content (Table 1). The leaf water potential and osmotic potential decreased from -0.8 and –1.15 MPa under irrigated to –1.20 and 1.31MPa, respectively under drought in HC 1 and from –0.76 and –1.22 MPa (Irrigated) to –1.19 and –1.42 MPa (Drought), respectively in RSG 931. The decrease in osmotic potential of drought resistant genotype (RSG 931) was higher probably because it may accumulate higher amount of solutes under drought as compared to HC 1. These osmoregulatory activities help the plant to cope up with moisture stress (Khodadadi 2013). The percent decrease in relative water content in parent RSG 931 was less (13.7%) than in HC 1 (19.5%) at 50% flowering. Variation in RWC is caused by differences in plant ability to absorb water from soil by developing a high water potential gradient from soil to plant, extending rooting depth or ability to control water loss through stomata (Kumar et al. 2012). In F_4 progeny lines LWP, LOP and RWC ranges from –0.72 to –1.43 MPa, –0.87 to –1.53 MPa and 57.2% to 77.8% respectively (Table 1). Among the F_4 progeny lines G 11 recorded highest plant water status with LWP at –0.72 MPa, LOP at –0.87 MPa and RWC at 77.80% followed by G 10 and G 04 whereas lowest plant water status was recorded in

Table 2. Yield and yield attributes of parents and progeny lines of chickpea

Genotype/ progeny lines	# Branches plant^{-1}	# Pods plant^{-1}	100-seed weight (g)	Biological yield plant^{-1} (g)	Seed yield plant^{-1} (g)	Harvest index (%)
HC 1 (Irrigated)	4.4	49.8	14.7	39.6	11.1	28.1
HC 1 (Drought)	3.6	40.4	11.5	24.3	6.9	28.3
RSG 931(Irrigated)	6.1	51.6	15.3	43.4	12.1	27.9
RSG 931(Drought)	5.3	44.8	12.5	33.8	9.8	28.9
LSD (0.05%)	0.35	3.57	1.24	6.87	3.54	0.21
F_4 Progeny lines (HC 1× RSG 931)						
G 01	5.3	42.7	12.6	27.8	8.3	29.9
G 02	5.7	50.3	14.9	36.1	9.6	26.5
G 03	5.0	42.7	17.0	28.5	8.4	29.3
G 04	6.3	55.7	18.0	36.2	10.4	28.7
G 05	6.7	58.0	13.7	35.6	10.3	28.9
G 06	5.0	52.7	14.2	37.4	9.5	25.4
G 07	5.3	48.7	14.7	40.6	8.3	20.3
G 08	5.0	52.7	14.3	36.2	9.3	25.6
G 09	5.7	54.0	13.6	30.9	9.3	30.3
G 10	6.7	66.0	15.8	34.1	10.7	31.5
G 11	6.0	61.7	16.0	37.4	10.9	29.1
G 12	4.8	42.0	14.4	24.3	7.2	29.6
G 13	5.0	45.0	14.8	24.6	7.5	30.4
G 14	7.8	50.7	12.4	34.3	8.3	24.2
G 15	6.0	44.3	15.0	26.1	7.8	30.0
G 16	7.3	40.3	13.4	27.1	7.9	29.1
G 17	5.3	48.0	14.4	31.8	8.0	25.2
G 18	7.3	49.7	12.8	31.1	7.6	24.5
LSD (0.05%)	0.54	3.83	2.46	6.74	2.68	1.64

progenies G 12 followed by G 13 and G 18, respectively. In parent (HC 1) relative stress injury was 16.4% under irrigated whereas 31.3% under drought condition. Whereas in RSG 931, RSI was recorded 21.5% under irrigated and 29.7% under drought conditions (Table 1). In progeny lines RSI ranges from 20.35% to 37.74%. Out of progeny lines the lowest stress injury was recorded in highest seed yielding progeny i.e. G11 (20.35%). It had been reported that tolerant and intermediate genotypes were superior to susceptible ones in maintaining membrane stability and lower membrane injury under drought stress condition (Pouresmael et al. 2013). Canopy temperature depression of RSG 931 increased from –1.6 under irrigated to 0.2 under drought and maintained cooler canopy as compared to HC 1. In progeny lines, CTD ranges from –2.30 to 0.67°C. The parent RSG 931 maintained higher F_v/F_m ratio than HC 1 in both irrigated and drought conditions. The photochemical efficiency was recorded in range of 0.421 to 0.703 for progeny lines under drought. The photosynthetic efficiency, transpiration and the values of relative stress injury declined under drought conditions (Kumar et al. 2012; Ulemale et al. 2013).

Drought stress reduces the seed yield of both parental genotypes and F_4 progeny lines (Table 2). The yield of HC 1 and RSG 931 were decreased in drought stress condition but decrease in yield of RSG 931 (19.27%) was less as compared to HC 1 (37.32%). Drought stress decreases number of pods in both parents under drought as well as irrigated condition. HC 1 produced 49.9 pods plant^{-1} in irrigated and 40.4 in drought condition while RSG 931 had 51.6 pods plant^{-1} in irrigated and 44.78 under drought stress. Number of pods plant^{-1}, 100 seed weight and seed yield of RSG 931 was more than HC 1 in irrigated as well as drought conditions. Among the progeny lines the maximum seed yield was recorded in G 11 with highest number of branches, number of pods, 100 seed weight and biological yield. A significant pod abortion under severe moisture stress and high temperature especially during commencement of pod set resulted in yield loss has been reported by Leport et al. (2006). The correlation of parents and progeny lines showed that leaf water potential (r = 0.86), osmotic potential (r = 0.87) and RWC (r = 0.92) had a significant positive correlation with seed yield. The negative correlation of RSI and CTD with plant water status traits and seed yield indicated that parent and progeny lines maintained higher plant water status and lower membrane injury alonwith cooler canopy helped in maintaining higher seed yield under drought. The results of this study showed that RSG 931 alongwith progeny lines G11, G10, G 04 and G 05 were more promising with better plant water status, low membrane injury and cooler canopy temperature and higher yield attributes under drought conditions. These progeny lines could be utilized in chickpea crop improvement programmes as source of drought tolerance.

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