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Field evaluation of *Desi* and *Kabuli* chickpea genotypes under irrigated and rainfed conditions

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Abstract
The present study was conducted during *Rabi* 2015-16 and 2016-17 on fourteen desi and kabuli chickpea genotypes under irrigated and rainfed conditions respectively. The morpho-physiological observations and water status (relative water content) were recorded at pod initiation stage to evaluate the channelization of photosynthates in terms of photosynthetic rate and ameliorate the effect of rainfed conditions regarding plant height, biomass accumulation and specific leaf weight. Water limited conditions at pod initiation stage enforced an overall negative trend in photosynthetic rate and relative water content but desi genotypes GL 29098 and ICC 4958 depicted drought tolerance by recording a decline of 3.61% and 3.46% respectively.

Keywords: Chickpea genotypes, rainfed conditions, pod initiation stage and photosynthetic rate

Introduction
In an overpopulated nation where quantity overrules quality, the main aim is to cope up with the demands of food and feed. Agricultural area occupied by the crops has decreased in the last few years due to the occupancy by industries and urban societies. Agricultural mechanization has advanced but the natural catastrophes like flood, drought, salinity, heat have overpowered the same. These disasters destroy the present status of crops as well as make the soil rendered infertile for the future too. The problem further amplifies when the remaining area is limited and the same is used for subsequent cropping system as in case of wheat and rice. This distorts the mineral nutrition and water strata of the soil making it water deficit and infertile. The adversity of these stresses on crop plants is calculated by the changes in physiological and morphological aspects of the plant growth and physiology (Mathur *et al.* 2008) [8].
Chickpea production is very crucial for India as is evident from the fact that India accounts for 70.7% of the total world production solely followed by Australia (4.4%), Pakistan (4.3%), Turkey (4.2%), Myanmar (4.0%), Ethiopia (2.8%), Iran (2.5%), USA (0.84%), Canada (0.78%), and Mexico (0.62%) (Upadhyaya *et al.* 2013) [16]. Chickpea is divided into two groups namely desi and kabuli, differentiated in terms of the deposition of Anthocyanin pigments (Thudi *et al.* 2017) [15] that are visible on one or other parts of the desi chickpea whereas anthocyanin pigments are absent in kabuli types.
The frequency of abiotic stress is readily increasing with the passage of time due to change in global precipitation levels. Increasing temperature due to global warming and decline in the water strata has immensely added to the adversity. This all has fabricated a water deficit condition in soil, whose prevailing consistency over a longer period of time alters the normal physiology of plant's growth and development and leads to a condition known as drought (Pryor *et al.* 2013) [10]. Drought, main agenda in the arid and semi-arid areas, has also affected the most fertile plains due to the changing global precipitation patterns (Awasthi *et al.* 2014) [2]. Water deficit condition mainly deteriorates the cropping system, but the effect is more pronounced in drought sensitive species. Chickpea production is estimated to be reduced by 33% on a global level (Kashiwagi *et al.* 2015) [7]. Drought affects the growth and development at almost every stage of the plant, but the most affected stage is the flowering and pod filling stage which leads to decline in the final yield of the plant (Hamidou *et al.* 2013) [6].

Sinclair and Muchow (2001) [14] analyzed many physiological and morphological traits that could contribute to an increase in grain yield in drought situations. The partitioning of dry matter to the pods is critical in the process of yield determination in water-stressed plants (Chimneti *et al*, 2002) [4]. Screening of superior chickpea genotypes conducted in the present study might confront the drought conditions that are efficient to survive in the forthcoming schema.

Materials and Methods

Fourteen genotypes (Kabuli and Desi) were procured from the Department of plant breeding & genetics and were subjected to irrigated and rainfed conditions. Irrigation of field was done prior to sowing against rainfed treatment and sowing was done as per the instructions of package of practices. The irrigated plot was having two water channels on the alternate sides. The plot size for field trails for each genotype during *Rabi* 2015-16 and 2016-17 was 3m*3rows in a randomized block design. The following morph physiological traits were recorded at reproductive phase (pod initiation) stage:

The plant height (cm) was recorded during the pod initiation. Data was recorded from three plants from each replication.

The plant at the harvestable maturity were taken into account for the biomass accumulation (g).

The specific leaf weight indicates the leaf thickness and was determined by the method of Radford (1967). It was expressed as gm^{-2}.

SLW = Leaf dry weight (g)/Leaf area (m^2)

Leaf area (m^2 $plant^{-1}$) The leaves from plants selected for growth analysis from each treatment were used for the estimation of leaf area. Leaf area was computed by graphic method and expressed as m^2 $plant^{-1}$.

Randomly selected five leaf plant samples were dried in oven at 80ºC until constant weight was obtained.

Photosynthetic rate was recorded as µmole $CO_2 m^{-2} s^{-1}$ by using Portable Photosynthesis System (LI-6400XT, LICOR).

Leaf samples were collected at pod initiation phase. Fresh weight was recorded and the leaves were kept in 15 ml distilled water for 24h for saturated weight. The saturated leaves were kept in an oven for 72 h at 80ºC and dry weight was recorded.

$$\text{RWC (Weatherly 1950)} = \frac{\text{Fresh weight - Dry weight}}{\text{Saturated Weight-Dry weight}}$$

Statistical analysis

Mean value of each genotype was calculated from both the *Rabi* trials and calculated values were subjected to SPSS 16.0 software Tukey's post hoc test to test the difference between treatments and genotypes. Mean fold/percent increase or decrease data was calculated in rainfed plants against irrigated ones.

Results and Discussion

Plant height (cm)

Plant height is a morphological parameter that is affected under rainfed conditions. The plant height recorded an overall significant reduction of 16.01% among genotypes and 21.24% among accessions under rainfed conditions over irrigated one (Table 1). Desi genotype GL 13029 and kabuli genotype GNG 2285 showcased maximum reduction of 24.62 and 30.30% under rainfed condition. ICC 4958 embarked minimum effect of rainfed conditions by depicting a decline of 4.29% under rainfed conditions.

The results are in agreement with the reports of Aslam *et al.* (2015) [1] where maize hybrids exhibited drought tolerance at 50% field capacity by adhering to low decline in plant height. Sah and Zamora (2005) [13] found that water stress significantly reduced the plant height at vegetative stage by arresting the growth of plant via altering phenology and development of plant to considerable level.

Biomass accumulation (g)

The accumulation of biomass in terms of dry weight is an evidence of restoring the photosynthates under rainfed conditions. The ability of maximum restoration will also be efficient in channelizing its nutrients into seeds at maturity. Genotypes and wild accessions witnessed an overall decline of 37.83 and 16.80% respectively under rainfed conditions (Table 1). GL 29078 recorded minimal decline of 12.85% under rainfed conditions showing efficient storage capacity. Adverse effects were documented in genotypes GNG 2285, PBG 5, BG 3057 by reducing 73.33, 68.91 and 35.18% of biomass under rainfed conditions in comparison to irrigated conditions.

Rosales-Serna *et al.* (2004) [12] recorded a negative significant relationship of biomass reduction and seed yield, thus concluding its importance in drought tolerance. In another study, two sesame cultivars when exposed to drought also suffered a shrunk in biomass of leaves and root (Fazeli *et al.* 2007) [5]. The disruption in remobilization of photosynthates in common bean towards vegetative structures under rainfed conditions has been reported by Polania *et al.* (2017) [9] confirming the reduction in biomass in the present study.

Specific leaf weight (gm^{-2})

Specific leaf weight is a measure of leaf thickness that gets affected under drought condition. Rainfed treatment inhibited the SLW in all the accessions, by marking an overall significant decline of 6.22% in genotypes and 9.20% in wild accessions (Table 1). The maximal decline in SLW was observed in genotype GL 12020 (11.09%), PBG 5 (10.69%) followed by PDG 4 (14.75%) and CSJ 513 (10.77%) under rainfed conditions. Kabuli genotype IPCK-2009-165 exhibited lowest percent decline of 2.44 in SLW under rainfed conditions.

There was decline in SLW of all chickpea accessions under rainfed conditions and the results are in corroboration with the reports of Vanaja *et al.* (2011) [17]. Differences in decline of SLW under drought among sunflower cultivars (Canavar *et al.* 2014) [3] are correlated to differences in photosynthetic capacity, because of the fact that they held strong relationships among the values of water use efficiency, leaf area, total dry weight and relative water content.

Photosynthetic rate (µmol $m^{-2}s^{-1}$)

Photosynthetic efficiency is a measure of the efficient working of photosystems and finally channelizing the photosynthates and converting the former into final yield. Photosynthesis rate is severely compromised under drought conditions as is evident by an overall significant decline of 23.91 and 36.39% in genotypes and wild accessions respectively (Table 2). Among desi genotypes GNG 1581 was critically negatively altered by 50.75 under rainfed conditions followed by PDG 4 (48.93%). However, genotype GL 29098 absconded rainfed situation by witnessing a dip of only 3.61%

in comparison to irrigated one. Among kabuli genotypes, IPCK-2009-165 recorded minimal decline of 8.72% in photosynthesis rate under rainfed conditions. BG 3057 suffered drastic consequences under rainfed conditions by reducing the photosynthetic rate by 52.17 % in comparison to irrigated ones. Drought stress portrayed inhibitory effect on the soybeans in the seedling stage through stomatal limitation and thus damaging the photosynthetic system (Wang *et al.* 2018) [18].

Table 1: Morpho-physiological traits of Chickpea genotypes under irrigated and rainfed conditions.

	Irrigated			Rainfed		
Genotypes	**Plant height pl^{-1} (cm)**	**Biomass accumulation pl^{-1} (g)**	**SLW pl^{-1} (gm^{-2})**	**Plant height pl^{-1} (cm)**	**Biomass accumulation pl^{-1} (g)**	**SLW pl^{-1} (gm^{-2})**
GL 29078 (Desi)	44.17±4.01^{ab}	13.28±0.69^{ef}	5.61±0.06^{d}	34.96±5.24^{bc}	11.57±0.53^{cd}	5.24±0.13^{b}
GL 13029(Desi)	49.42±2.95^{ab}	23.72±0.91^{abc}	5.90±0.08^{bc}	37.25±1.77^{bc}	16.19±0.55^{abc}	5.65±0.14^{b}
GL 29098(Desi)	38.42±0.59^{b}	19.63±1.27^{b-e}	5.77±0.08^{c}	32.83±0.47^{bc}	14.95±2.85^{bc}	5.18±0.03^{cd}
GL 12020(Desi)	56.96±3.24^{a}	22.53±2.73^{a-d}	6.81±0.12^{a}	46.71±1.47^{a}	19.13±1.38^{ab}	6.05±0.04^{a}
CSJ 513(Desi)	40.75±0.35^{b}	17.24±2.37^{cde}	4.83±0.04^{e}	39.00±0.71^{bc}	11.60±1.85^{cd}	4.31±0.14^{d}
ICC 4958(Desi)	41.71±6.42^{b}	20.49±2.06^{b-e}	5.72±0.01^{c}	37.50±2.12^{bc}	12.23±1.18^{cd}	5.25±0.14^{cd}
PBG 7(Desi)	46.63±0.88^{ab}	8.09±1.10^{f}	4.15±0.02^{h}	39.17±1.18^{bc}	5.08±0.12^{e}	4.08±0.02^{d}
PBG 5(Desi)	41.63±0.53^{b}	24.67±1.36^{abc}	4.77±0.10^{ef}	41.00±2.83^{ab}	7.67±0.18^{de}	4.26±0.10^{d}
PDG 4(Desi)	43.42±1.53^{ab}	21.91±1.67^{bcd}	5.90±0.16^{bc}	31.42±0.59^{c}	12.86±1.78^{cd}	5.03±0.03^{d}
GNG 1581(Desi)	39.25±6.72^{b}	29.94±1.81^{a}	4.40±0.02^{g}	35.29±2.18^{bc}	21.46±2.13^{a}	4.20±0.04^{d}
GNG 2285 (Kabuli)	47.17±1.18^{ab}	15.26±2.36^{de}	5.38±0.11^{d}	32.88±2.30^{bc}	4.07±0.66^{e}	5.33±0.10^{bc}
IPCK-2009-165(Kabuli)	38.54±6.07^{b}	27.30±5.37^{ab}	6.15±0.03^{b}	35.38±1.94^{bc}	17.31±2.68^{abc}	6.00±0.03^{d}
BG 3057(Kabuli)	41.71±6.31^{b}	24.90±0.10^{abc}	4.61±0.03^{efg}	38.33±0.47^{bc}	16.14±2.39^{abc}	4.35±0.06^{d}
HK-10-103(Kabuli)	46.50±1.41^{ab}	24.53±0.14^{abc}	4.56±0.05^{fg}	35.88±0.88^{bc}	12.23±0.34^{cd}	4.16±0.04^{d}
Mean	44.02	20.97	5.29	36.97	13.03	4.96

Mean values are represented as ±S.D. Values marked with same alphabet are non-significant at alpha 0.05 level. Pooled data for *Rabi* 2015-16 and 2016-17.

Table 2: Photosynthetic rate (PR) and relative water content (RWC) in Chickpea genotypes under irrigated and rainfed conditions.

	Irrigated		Rainfed	
Genotypes	PR (μmolCO$_2$m^{-2})	RWC (%)	PR (μmolCO$_2$m^{-2})	RWC (%)
GL 29078 (Desi)	19.80±1.27^{a}	75.25±3.04^{c-f}	14.75±1.34^{bc}	70.45±1.06^{d}
GL 13029(Desi)	16.70±2.12^{abc}	76.22±5.49^{cde}	15.75±0.49^{bc}	71.05±0.21^{d}
GL 29098(Desi)	22.15±2.76^{a}	87.50±2.97^{ab}	21.35±0.64^{a}	83.20±1.56^{ab}
GL 12020(Desi)	16.65±1.77^{abc}	84.25±2.05^{abc}	14.00±1.13^{c}	75.65±0.64^{c}
CSJ 513(Desi)	7.30±1.27^{e}	64.45±0.35^{g}	3.95±0.78^{e}	58.85±0.49^{ef}
ICC 4958(Desi)	17.85±1.34^{ab}	85.25±1.91^{abc}	14.25±0.78^{c}	82.30±0.57^{b}
PBG 7(Desi)	16.90±0.28^{ab}	79.00±1.56^{bcd}	14.65±0.49^{bc}	74.40±1.70^{c}
PBG 5(Desi)	9.95±0.35^{de}	47.00±3.68^{h}	4.90±0.42^{e}	42.05±1.63^{h}
PDG 4(Desi)	11.65±2.05^{cde}	74.00±2.69^{d-g}	5.95±0.49^{de}	69.45±0.92^{d}
GNG 1581(Desi)	13.95±1.34^{bcd}	67.45±3.32^{efg}	8.05±0.64^{d}	61.55±1.20^{e}
GNG 2285 (Kabuli)	10.95±0.21^{de}	65.95±2.62^{fg}	6.05±0.92^{de}	55.98±0.34^{f}
IPCK-2009-165(Kabuli)	21.80±1.27^{a}	91.40±1.84^{a}	19.90±0.14^{a}	86.40±1.70^{a}
BG 3057(Kabuli)	10.35±1.20^{de}	53.25±2.47^{h}	4.95±0.35^{e}	49.25±0.78^{g}
HK-10-103(Kabuli)	21.45±0.92^{a}	86.60±3.11^{ab}	16.95±0.21^{b}	80.75±0.78^{b}
Mean	15.53	74.11	11.82	68.67

Mean values are represented as ±S.D. Values marked with same alphabet are non-significant at alpha 0.05 level. Pooled data for *Rabi* 2015-16 and 2016-17.

Relative water content (RWC) (%)

RWC quantifies the amount of water withheld in a particular tissue. RWC was negatively influenced under drought stress conditions in all the chickpea accessions. There was a significant average decline i.e. 7.35 and 8.50% in RWC amongst all the chickpea genotypes and wild accessions under rainfed conditions (Table 2). The highest reduction (15.12%) in RWC was observed in kabuli genotype GNG 2285 followed by desi genotype PBG 5 (10.53%) and GL 12020 (10.21%) under rainfed conditions. The ability of more water absorption of the genotype ICC 4958 was recorded under rainfed situation by recording a dip of only 3.46% over irrigated conditions. This could be attributed to reduction in transpiration via stomata that withheld water in leaves under rainfed conditions. Sunflower variety 'Sanbro' retained high RWC that act as feasible parameter in imparting tolerance under drought conditions. The relation of RWC to cell volume and increased tissue elasticity can act synergistically on the symplastic volume, providing an increased gradient for the influx of water. Thus, in conclusion reductions in the rigidity of leaves occurs on account of changes in the extensibility of the tissue and absorptive capacity of the cell wall (Canavar *et al.* 2014) [3].

In conclusion rainfed (decline in water strata) conditions imposed a dip in the morph physiological characteristics *viz*., plant height, biomass accumulation, specific leaf weight, photosynthetic rate that were reduced on account of declined production of photosynthates or side-lining of channelization of photosynthates to growing tissues and mobilization against water stress. Relative water content an important parameter for screening of drought stress also pertained without drastic changes in rainfed conditions in desi genotype ICC 4958 and kabuli genotype IPCK-2009-165.

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