JFL

Journal of Food Legumes 33(2): 77-81, 2020

Comparative agroclimatic indices of desi and kabuli chickpea genotypes under irrigated and rainfed conditions

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Received: *6 April, 2020*
Accepted: *31 August, 2020*

Handling Editor:
Dr. Amarender Reddy, ICAR-CRIDA, Hyderabad

ABSTRACT

The present study was conducted in relation to agroclimatic indices i.e. accumulated growing degree days (AGDD), accumulated photothermal units (APTU) and accumulated heliothermal units (AHTU) on eight desi and four kabuli chickpea genotypes under irrigated and rainfed conditions at transitional phenophases of flower initiation, pod initiation and at maturity. Significant differences in AGDD, APTU and AHTU at different phenophases were recorded but no significant difference was observed amongst desi and kabuli genotypes. Genotypes pooled higher photothermal units under irrigated conditions; however, earliness in flowering reduced the accumulation window of heat units under rainfed conditions. Desi genotype PBG 7 and kabuli genotype IPCK-2009-165 recorded high HUE (heat use efficiency) values and displayed low dip (6.90 and 0.54 % respectively) in yield. Agroclimatic indices i.e. AGDD, APTU and AHTU in kabuli and desi genotypes significantly pooled to final high yields (P=0.78, P=0.82 and P=0.77 respectively) under irrigated conditions at maturity.

Key words: Chickpea, Heat units, Path coefficient analysis, Phenophases, Rainfed crops.

INTRODUCTION

In rainfed areas, crops with low water requirement are considered effective for improving water strata and nutrient balance of soil for climate resilience agriculture. Rainfed legume crops such as pearl millet (*Pennisetum glaucum*), blackgram (*Vigna mungo* L. Hepper), pigeon pea (*Cajanus cajan* L. Millsp) and chickpea (*Cicer arietinum* L.) (Vanaja *et al.* 2017) seems to be an effective alternative than non-legumes for the inclusion in crop diversifications due to reduced water requirement and their ability in elevating the nitrogen requirement of the soil (Oliveira *et al.* 2019). However, persistently low rainfall in these rainfed crops leads to drought like condition.

Chickpea ranks third amongst the pulse crops grown worldwide with India being the main contributor of approximately 75% to this production (Ahsan *et al.* 2018). Chickpea is an important protein dietary source particularly for vegetarian people and also enhance the nutritional status of soil due to its nitrogen fixing potential. The rainfed crop, though requires low rainfall for its growth and development, but faces drought stress during reproductive phases especially during pod formation. Drought affects chickpea production in India and the severity of the stress accounts for approximately 33% damage to the total production (Kashiwagi *et al.* 2015). The final yield of chickpea genotype is an output of individual factors and their individual capacity to cope up with abiotic and biotic stress conditions thus pooling to the end result of productivity.

During drought stress or water scarce conditions, apart from declining soil water levels, abiotic agroclimatic indices *viz.*, AGDD, APTU and AHTU that are accumulated over the life cycle of chickpea contribute their share towards total yield (Johal *et al.* 2018). The influence of these agroclimatic indices vary with stage i.e. vegetative, reproductive and maturity and thus affect the final yield (Qiao-yan *et al*. 2012). This is evident from the fact that a delay in sowing in *Brassica juncea* (Bio-92) reduced the GDD and HTU thus negatively affecting productivity (Solanki and Mundra 2015).

Drought stress influences the phenological attributes i.e. days to flower initiation, pod formation and maturity. The change in the phenological development affects the agroclimatic indices and thus the yield characteristics. The present study validates the contribution of agroclimatic indices in desi and kabuli (two sub types of chickpea differing in the deposition of anthocyanin pigments) genotypes (Thudi *et al.* 2017) under irrigated and rainfed treatments in field conditions. Moreover phenological attributes i.e. days to flower initiation, days to pod initiation and days to maturity have been correlated with grain yield via path coefficient analysis.

MATERIAL AND METHODS

Twelve genotypes bifurcated into desi and kabuli were subjected to two treatments i.e. irrigated (lined with water channels on two sides) and rainfed (no irrigation) in the experimental area of Pulses section, Department of Plant Breeding & Genetics, Punjab Agricultural University, Ludhiana during *Rabi* 2016-17 and 2017-18 seasons. Irrigation of field was done prior to sowing against rainfed treatment and sowing was done as per the instructions of package of practices in randomized block design. Data for phenological attributes in terms of days to flower initiation, days to pod initiation and days to maturity were recorded from three replications with five plants tagged in each replication. School of Climate Change and Agrometeorology, Punjab Agricultural University, Ludhiana provided the meteorological data and agroclimatic indices were calculated as below with base temperature of chickpea taken into consideration as 5^0C (Roberts *et al*. 1985):

GDD (^{0}C)= (Max. Temp. + Min. Temp.)/2–Base Temp. (Tb)

PTU=GDD X Day length

HTU= GDD X Actual Sunshine

HUE= Grain yield/GDD (Aggarwal *et al.* 2016).

Accumulated GDD, HTU and PTU were calculated (Singh *et al.* 1990 and Nuttonson 1957) from the duration of initiation of one phenophase onto the completion of it.

Statistical analysis

Mean value of genotypes from both the *Rabi* trials and calculated values were subjected to SPSS 16.0 software Tukey's post hoc test (Wragg *et al.* 2000) to test the difference between treatments and genotypes. Path coefficient analysis (Dewey and Lu 1959) including correlation and polynomial regression coefficients between agroclimatic indices and yield were analysed using Microsoft office Excel version 2010. Mean fold/percent increase or decrease data was calculated in rainfed plants against irrigated ones.

RESULTS AND DISCUSSION

Phenology and agro climatic indices

Plant's transitional processes hastened under rainfed conditions at flower initiation, pod initiation and maturity stage in comparison to irrigated conditions in both desi and kabuli genotypes (Table 1 and 2). Two kabuli genotypes GNG 2285 (20.39, 10.21 and 9.15%) and BG 3057 (43.46, 12.07 and 6.57%) showed maximum rapidity to escape drought stress and complete their days to flower initiation, pod initiation and maturity respectively under rainfed conditions in comparison to irrigated one. The reason for rapidity is attributed to early completion of life cycle that acts as an important strategy to evade drought conditions. This hypothesis was proved by Ulemale *et al* (2013) which demonstrated that yield potential and early flowering are two major components of drought escape in lentil and chickpea.

Kabuli and desi genotypes depicted significant differences in terms of AGDD, APTU and AHTU at flower initiation, pod initiation and maturity stages under irrigated and rainfed conditions. The mean value of

Table 1. Duration and agroclimatic indices at different phenophases of desi and kabuli chickpea genotypes under irrigated conditions.

Genotypes	Days to flower initiation				Days to pod initiation				Days to maturity			
Desi	**DAS**	**AGDD**	**APTU**	**AHTU**	**DAS**	**AGDD**	**APTU**	**AHTU**	**DAS**	**AGDD**	**APTU**	**AHTU**
GL 12020	93.00^{ab}	944.65^{cd}	9677.46^{cd}	4642.07^{c}	111.00^{c}	1158.98^{c}	12063.15^{c}	6324.32^{b}	144.00^{abc}	1683.95^{abc}	17916.18^{abc}	10974.37^{ab}
GL 13029	94.50^{ab}	959.18^{bc}	9835.14^{bc}	4754.74^{abc}	112.00^{bc}	1172.98^{bc}	12221.45^{bc}	6426.96^{b}	147.00^{ab}	1752.13^{ab}	18756.83^{ab}	11364.37^{a}
GL 29078	91.00^{b}	925.80^{d}	9478.38^{d}	4507.56^{d}	115.00^{abc}	1215.08^{abc}	12698.68^{abc}	6800.19^{ab}	146.00^{abc}	1728.80^{abc}	18468.85^{abc}	11258.68^{a}
GL 29098	95.50^{a}	968.85^{abc}	9941.68^{abc}	4801.11^{ab}	111.50^{c}	1166.18^{c}	12144.68^{c}	6392.45^{b}	144.50^{abc}	1694.65^{abc}	18047.74^{abc}	11075.47^{ab}
GNG 1581	94.00^{ab}	954.15^{c}	9779.84^{c}	4719.66^{bc}	113.50^{abc}	1194.03^{abc}	12459.95^{abc}	6607.26^{ab}	143.50^{bc}	1672.90^{bc}	17780.09^{bc}	10873.06^{ab}
PBG 5	95.50^{a}	968.85^{abc}	9941.68^{abc}	4801.11^{ab}	114.00^{abc}	1201.23^{abc}	12541.48^{abc}	6675.39^{ab}	148.50^{a}	1784.73^{a}	19159.92^{a}	11492.81^{a}
PBG 7	94.50^{ab}	959.18^{bc}	9835.14^{bc}	4754.74^{abc}	115.50^{abc}	1222.20^{abc}	12779.53^{abc}	6860.69^{ab}	143.50^{bc}	1672.90^{bc}	17780.09^{bc}	10873.06^{ab}
PDG 4	91.00^{b}	925.80^{d}	9478.38^{d}	4507.56^{d}	117.50^{ab}	1250.80^{ab}	13105.20^{ab}	7103.02^{a}	145.00^{abc}	1706.65^{abc}	18195.70^{abc}	11130.24^{ab}
Kabuli												
HK-10-103	97.00^{a}	984.25^{a}	10111.64^{a}	4896.32^{a}	119.00^{a}	1271.13^{a}	13337.45^{a}	7240.71^{a}	142.00^{c}	1639.08^{c}	17364.67^{c}	10524.67^{b}
IPCK-2009-165	96.50^{a}	979.60^{ab}	10060.40^{ab}	4885.02^{a}	115.50^{abc}	1222.20^{abc}	12779.53^{abc}	6860.69^{ab}	146.50^{abc}	1740.13^{abc}	18608.87^{abc}	11309.60^{a}
BG 3057	95.50^{a}	968.85^{abc}	9941.68^{abc}	4801.11^{ab}	116.00^{abc}	1229.10^{abc}	12857.96^{abc}	6927.97^{ab}	144.50^{abc}	1694.65^{abc}	18047.74^{abc}	11075.47^{ab}
GNG 2285	93.00^{ab}	944.65^{cd}	9677.46^{cd}	4642.07^{c}	117.50^{ab}	1250.63^{ab}	13103.51^{ab}	7084.23^{a}	147.50^{ab}	1763.23^{ab}	18893.88^{ab}	11391.50^{a}
Mean	**94.25**	**956.98**	**9813.24**	**4726.09**	**114.83**	**1212.88**	**12674.38**	**6775.32**	**145.21**	**1711.15**	**18251.71**	**11111.94**

Mean values marked with same alphabets are significantly not different
DAS- Days after sowing
(Data pooled for both years)

Table 2. Duration and agroclimatic indices at different phenophases of desi and kabuli chickpea genotypes under rainfed conditions.

Genotypes	Days to flower initiation				Days to pod initiation				Days to maturity			
Desi	**DAS**	**AGDD**	**APTU**	**AHTU**	**DAS**	**AGDD**	**APTU**	**AHTU**	**DAS**	**AGDD**	**APTU**	**AHTU**
GL 12020	86.50^{a}	884.65^{a}	9046.01^{a}	4282.89^{a}	105.00^{ab}	1084.78^{bcd}	11228.97^{bcd}	5615.48^{bcd}	136.50^{ab}	1527.40^{abc}	16326.68^{ab}	9387.35^{abc}
GL 13029	91.50^{a}	930.45^{a}	9527.56^{a}	4549.17^{a}	104.00^{ab}	1072.03^{cd}	11086.58^{cd}	5508.24^{cd}	138.00^{ab}	1556.58^{a}	16538.08^{a}	9653.04^{a}
GL 29078	87.00^{a}	888.90^{a}	9090.43^{a}	4309.67^{a}	104.00^{ab}	1073.35^{cd}	11101.24^{cd}	5496.71^{cd}	136.00^{ab}	1518.70^{abc}	16221.06^{ab}	9293.74^{abc}
GL 29098	91.00^{a}	925.80^{a}	9478.38^{a}	4507.56^{a}	107.00^{a}	1107.78^{ab}	11486.56^{ab}	5853.95^{ab}	137.00^{ab}	1537.10^{abc}	16393.34^{ab}	9475.33^{abc}
GNG 1581	89.00^{a}	907.53^{a}	9285.93^{a}	4402.59^{a}	108.00^{a}	1119.35^{a}	11616.43^{a}	5973.65^{a}	137.00^{ab}	1536.85^{abc}	16394.34^{ab}	9458.70^{abc}
PBG 5	88.00^{a}	898.10^{a}	9186.92^{a}	4348.02^{a}	106.50^{a}	1101.68^{abc}	11418.06^{abc}	5792.50^{abc}	134.50^{b}	1492.30^{bc}	15947.75^{ab}	9036.87^{bc}
PBG 7	91.50^{a}	930.45^{a}	9527.56^{a}	4549.17^{a}	104.00^{ab}	1072.03^{cd}	11086.58^{cd}	5508.24^{cd}	136.50^{ab}	1527.40^{abc}	16326.68^{ab}	9387.35^{abc}
PDG 4	89.50^{a}	912.13^{a}	9334.25^{a}	4422.30^{a}	106.00^{ab}	1096.20^{abc}	11356.69^{abc}	5734.25^{abcd}	138.00^{ab}	1556.58^{a}	16538.08^{a}	9653.04^{a}
Kabuli												
HK-10-103	92.00^{a}	935.65^{a}	9582.36^{a}	4566.53^{a}	104.00^{ab}	1072.03^{cd}	11086.58^{cd}	5508.24^{cd}	139.00^{a}	1558.15^{a}	16551.42^{a}	9688.67^{a}
IPCK-2009-165	92.00^{a}	935.65^{a}	9582.36^{a}	4566.53^{a}	106.50^{a}	1101.68^{abc}	11418.06^{abc}	5792.50^{abc}	138.00^{ab}	1542.78^{ab}	16415.52^{ab}	9555.25^{ab}
BG 3057	64.00^{b}	719.68^{b}	7341.52^{b}	3717.42^{b}	102.00^{b}	1063.83^{d}	10995.39^{d}	5469.30^{d}	135.00^{ab}	1501.00^{abc}	16053.38^{ab}	9130.49^{abc}
GNG 2285	91.50^{a}	930.45^{a}	9527.56^{a}	4549.17^{a}	105.50^{ab}	1083.75^{bcd}	11217.66^{bcd}	5616.34^{bcd}	134.00^{b}	1483.60^{c}	15842.43^{b}	8951.70^{c}
Mean	**87.79**	**899.95**	**9209.24**	**4397.58**	**105.21**	**1087.37**	**11258.23**	**5655.78**	**136.63**	**1528.20**	**16295.73**	**9389.29**

Mean values marked with same alphabets are significantly not different at 0.05 level
DAS- Days after sowing
(Data pooled for both years)

increase in agroclimatic indices i.e. AGDD, APTU and AHTU transcended from days to flower initiation (1.06, 1.06 and 1.07 folds respectively) to days to pod initiation (1.11, 1.11 and 1.20 folds respectively) and finally to maturity (1.12, 1.12 and 1.1.8 folds respectively) under irrigated conditions in comparison to rainfed treatment. The accumulation of higher photothermal and heliothermal units till vegetative stage directly corresponded to an increased yield in irrigated conditions against rainfed treatment. However, under rainfed condition the earliness in flowering accumulated lower proportion of photo and heliothermal units till vegetative stage those were insufficient to accumulate photosynthates ultimately leading to a decline in final yield. The finding is in confirmation with Jain and Sandhu 2018 who revealed that the early sown Brassica genotypes accumulated more GDD, HTU and PTU along the cropping period thus showing significantly higher yield attributes in comparison to late sown genotypes that were unable to gather photo-units in the same duration.

The time interval in terms of AGDD and grain yield was explored by the heat use efficiency (Table 3). Among the desi genotypes,

Table 3. Heat use efficiency (HUE) of desi and kabuli chickpea genotypes under rainfed conditions at maturity.

Genotypes	Heat Use Efficiency	
Desi	**IRRIGATED**	**RAINFED**
GL 12020	0.68[d]	0.59[a]
GL 13029	0.74[c]	0.57[c]
GL 29078	0.70[cd]	0.44[d]
GL 29098	0.29[g]	0.21[h]
GNG 1581	0.26[h]	0.17[g]
PBG 5	0.39[f]	0.35[e]
PBG 7	0.29[g]	0.27[fg]
PDG 4	0.44[e]	0.37[e]
Kabuli		
HK-10-103	0.90[a]	0.89[a]
IPCK-2009-165	0.29[g]	0.20[h]
BG 3057	0.81[b]	0.70[b]
GNG 2285	0.39[f]	0.33[ef]
Mean	**0.57**	**0.39**

Mean values marked with same alphabets are significantly not different
(Data pooled for both years)

GL 29078 and GNG 1581 and kabuli genotype IPCK-2009-165 depicted maximum percent decline of 37.17 and 34.62 under rainfed conditions, highlighting the importance of growing degree days and accumulating higher quantity of accumulated photo and heliothermal units. Desi and kabuli genotypes PBG 7 and IPCK-2009-165 respectively displayed low influence of AGDD on the final yield by recording only 6.90 and 0.54% decrease in HUE under rainfed conditions. *C. judaicum* 212 a rainfed resistant wild chickpea cultivar also maintained high HUE under rainfed conditions on account of prolonged life cycle (Johal *et al.* 2018).

Correlation coefficient and path analysis

Path coefficient analysis was carried out between agroclimatic indices and grain yield at maturity (Table 4). A non-significant correlation was found between AGDD, APTU and AHTU with grain yield under rainfed conditions. Under high yielding irrigated conditions agroclimatic indices i.e. AGDD (P=0.78), APTU (P=0.82) and AHTU (P= 0.77) pooled directly to the final grain yield.

Table 4. Path coefficient analysis depicting the direct effects of accumulated growing degree days at maturity (AGDDM), accumulated photothermal units at maturity (APTUM), accumulated heliothermal units at maturity(AHTUM) on grain yield (GY) under irrigated and rainfed conditions.

	IRRIGATED			RAINFED		
Grain yield	**AGDD**	**APTU**	**AHTU**	**AGDD**	**APTU**	**AHTU**
P	0.78*	0.82*	0.77*	0.21	0.21	0.13
r	0.089	0.072	0.092	-0.38	-0.38	-0.46

*Significant at 0.05 level.

In conclusion, no significant difference was found in desi and kabuli genotypes. However irrigated and rainfed treatment depicted significant differences amongst final yield (Table 5) and agroclimatic indices at different phenophases. Agroclimatic indices i.e. AGDD, APTU and AHTU pooled their share in enhancing final grain yield under irrigated conditions in both desi and kabuli genotypes.

Table 5. Yield (Kg/ha) of desi and kabuli chickpea genotypes under rainfed and irrigated conditions.

Genotypes	Yield (kg/ha)	
Desi	**IRRIGATED**	**RAINFED**
GL 12020	1148.68	907.57
GL 13029	1302.29	881.32
GL 29078	1207.50	666.46
GL 29098	487.08	325.21
GNG 1581	489.24	399.58
PBG 5	700.00	525.49
PBG 7	456.46	438.47
PDG 4	749.10	568.75
Kabuli		
HK-10-103	1471.46	1391.25
IPCK-2009-165	505.07	315.49
BG 3057	1374.72	1056.32
GNG 2285	695.63	493.89
Mean	**865.60**	**664.15**

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit.*
Genotypes	2896711.81	11	263337.44	17.71	0.00*	2.82
Treatments	243498.77	1	243498.77	16.37	0.00*	4.84
Error	163608.736	11	14873.52			
Total	3303819.32	23				

ANOVA table for above data
*$p < 0.05$ level, Significant difference in yield between genotypes under rainfed and irrigated conditions.

ACKNOWLEDGEMENT

The authors duly acknowledge financial assistance provided by the UGC (Maulana Azad National Fellowship).

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