Heat Tolerance Responses of Chickpea (*Cicer arietinum* L.) Genotypes in the Thermal Zone of Ethiopia, a Case of Werer Station

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Abstract

*Chickpea (***Cicer arietinum** *L.) is an important cool season food legumes with indeterminate growth habit. The crop is valued for its nutritive seeds and use as animal feed in many developing countries. The productivity of the crop is constrained by several abiotic stresses, among which high temperature is one of the key determinants of crop. The present study was conducted to screen, evaluate and select Chickpea genotypes possessing high yield potential under heat stress condition at Werer Agricultural Research Center. The experiment was laid in RCBD of three replications using eighteen early maturing chickpea genotypes of ICRISAT in 2015. Two times planting (i. e. 23 Jan and 24 February) was done each on 4.8m*^{2} *plot with 30cm and 10 cm spacing, and data was determined on the two central rows. Growth period maximum temperature of* $\geq 35^{O}$*C, considered threshold for heat assessment, was sufficiently interfaced in both planting days. Combined analysis of variance revealed existence of highly significant differences among the tested genotypes for most of the agronomic traits. The top 3 best performing lines with extra early phenology were ICCV 09309 (1187 kg/ha), ICCV 10103 (1035 kg/ha) and ICCV 10108 (1014 kg/ha). Delayed planting posed more stress on the crop and yield, possibly the increasingly progressing temperature interfered beyond physiological adjustment of the crop. Heat tolerance indices like STI, TOL, SSI, MP and GMP calculated on the basis of grain yield, and genotypes ICCV-10102, ICCV-09309, DZ-2012-CK-0034 and DZ-2012-CK-0041 showed lower TOL and higher STI values indicating as tolerant genotypes relative to others*

Keywords: Chickpea, heat stress, tolerance, phenology, Yield

Introduction

Chickpea (*Cicer arietinum* L.) is annual crop belongs to family *leguminaceae*, subfamily *papilionacea* and genus *cicer* (Van der Maesen, 1987). Among the global pulse crops, chickpea has consistently maintained a much more significant status, ranking second in area of production (15.3%) after common bean and third in production (14.6%) after common bean (*Phaseolus vulgaris* L.) and field pea (*Pisum sativum* L.) (Knights *et al.*, 2007; FAO, 2008; Gaur *et al.*, 2010). The crop is one of the first grain legumes domesticated in old world.

The crop faces various abiotic stresses among which heat stress is progressively posing major production constraint in warmer short-season environments. High temperature often occurs in combination with high solar irradiance, drought, and strong wind, all of which can aggravate plant injury even in well watered plants (Hall, 1992). For example, exposure of chickpea plants to high temperature 30–35°C at flowering stage can cause substantial yield loss (Summerfield and Wein, 1980; Saxena *et al.*, 1988) as it interferes with reproductive biology of the crop. High temperature during the grain filling period can reduce the individual seed size as it might interfere with assimilate translocation period to sink at maturity which may lower grain yield per plant (Ong 1983). Grain yield was reduced by 53-330 kg/ha for every 1°C seasonal temperature rise in India (Kalra *et al*. 2008). In spring sown crops, the mean grain yield decreased compared with autumn sown materials due to seasonal temperature fluctuations (26-38°C) during the reproductive stage (Ozdemir and Karadavut 2003). In Bangladesh, a six week delay in sowing from the optimum period was observed to reduce the grain yield by 40% and flowering and maturity was also accelerated (Ahmed *et al*. 2011) as it coincides with increasingly aggressive thermal condition.

Heat stress is a function of plant genotype, high temperature, and water status and soil type. The occurrence and severity of heat stress varies in different regions from year to year. Depending on timing, duration and interaction, observed heat stress can be grouped into chronic and acute, each of which involve different coping mechanisms, adaptation strategies and ultimately, breeding techniques (Blum, 1988; Wery et al., 1993). A simple but effective field screening technique for heat tolerance at the reproductive stage in chickpea has been developed at ICRISAT (Gaur *et al.,* 2013, 2014). It involves advancing sowing date to synchronize the reproductive phase of the crop with the occurrence of higher temperatures (≥35°C). This method was effective in identifying heat tolerant germplasm at ICRISAT and several other locations in the world (Gaur *et al.,* 2013, 2014). So far no effective screening technique has been developed to tackle this problem in Ethiopia. Heat tolerance is therefore important under Ethiopian condition where temperature is high.

Previous chickpea improvement efforts by centers under Ethiopian Institute of Agricultural Research (EIAR) focused on developing high yielding and drought tolerant varieties. As a result, about twenty-two improved chickpea varieties for increased yield and drought tolerance were released and some of which are currently under cultivation (Asnake, 2014). However, no variety has been released so far in Ethiopia for high temperature (heat) stress tolerance, despite global warming is on alert and some signals are evidenced in Ethiopia, at national level, and neither population thematized effort being attempted by the national improvement program. Therefore, the objective of this experiment is to assess variability among genotypes for heat tolerant and high potential yield under thermal zone of Ethiopia by screening in hot spot location.

Materials and Methods

Description of the study area

The study was conducted at Werer Agricultural Research Center, found in Afar National Regional State. The center is located at 9°20’31" N latitude and 40°10’11" E longitude in the Middle Awash Rift valley 280 km far from Addis Ababa. The station is delimited at 740 masl. The climate is semi-arid with a bimodal rainfall of 533mm annually. The long rainy season occurring from July to September accounts for 264 mm rainfall and the short rainy season from February to April accounts 156 mm. The minimum/maximum annual temperatures are $18.9^{O}C/38^{O}C$, while the average annual temperature is $28.4^{O}C$. The area receives the average daily sunshine of 8.5 hours with an average solar radiation of 536 calories per square centimeter day^{-1} ($cal/cm^2/day$) (Girma Menkir and Awulachew Sileshi 2007). The soils of the study area is predominantly fluvisol followed by Vertisols (Wondimagegne and Abere, 2012). The Fluvisol soils are coarser in texture than Vertisols and their textural classes range between clay and silt loams. The soils are brown in color and turn to dark brown when moist. The pH of the soil is slightly alkaline and ranges from 7.2 to 8.5.

Experimental Procedure

Field evaluation of 18 early maturing chickpea (*Cicer arietinum* L.) germplasms (Table 1) including both kabuli and desi types was conducted during 2015 off season adapting Gaur et al. (2013 and 2014), using two planting dates of 23 January and 24th February. It involves advancing sowing date to synchronize the reproductive phase of the crop with the occurrence of higher temperatures (≥35°C). This method was employed to optimize planting date and to effectively identify heat tolerant germplasm.

Table 1. List of plant materials (genotypes) used in experiment. K=Kabuli, D=Desi, €=indicating standard check

ICCV-10409 (K)	ICCV-07313 (K)	ICCV-10307 (K)
ICCV-09315 (K)	ICCV-09311 (K)	DZ-10-11 (D)€
DZ-2012-CK-0034 (D)	ICCV-10102 (K)	ICCV-09304 (K)
ICCV-09309 (D)	ARERTI (K)€	DZ-2012-CK-0044 (D)
ICCV-10107 (D)	DZ-10-4 (K)€	ICCV-10311 (K)
ICCV-10404 (K)	ICCV-09301 (K)	ICCV-09307 (K)
ICCV-10108 (D)	ICCV-10103 (D)	DZ-2012-CK-0041 (D)

The treatments were laid in RCBD with three replication. Both dates of planting of the 18 chickpea genotypes including the standard checks were sown when temperature rises above 30 ^{o}C. The gross plot size was 4.8m^{2} (4mx1.2m) accommodating 4 rows of 4m length. Spacing of 30cm between rows and10cm between plants were used and harvesting was done from two central rows of each plot (2.4m^{2}).

Measurements of growth and yield parameters

This study used measure of plant growth, yield traits and temperature prediction at different developmental stages of chickpea as tools for heat tolerance screening. Days to first flowering (DFF), days to 50% flowering (D50%F), days to first podding (DFP), days to end of podding (DEP) and days to maturity (DM) were recorded for each genotype. At physiological maturity, five plants were randomly selected and plant height (cm) and first pod height (cm) was determined. Grain yield was collected from two central rows of each plot (2.4m^{2}) and the aerial parts of the plants from 2 central rows were air dried at 38^{0}C for 48 h to determine shoot dry weight. At harvest, five plants were randomly collected and yield components (pod number per plant, seed number per plant and hundred seed weight) were recorded. Harvest Index (%) was calculated as (grain yield/total shoot dry weight) x 100.

The plant growing days at different developmental stages were also calculated following the procedure of Vargas (1998). Vegetative period (VP) was defined as the number of days from sowing to one day before flowering date was recorded for the plot. The days from first flower to first pod was considered the flowering period (FP). The grain filling period (GFP) was defined as the number of days from first pod to maturity and, Maturity period (MP) was defined as the number of days from first flowering to maturity. Then, the average maximum and minimum temperatures were calculated at different developmental stages (VMax; VMin; FMax; FMin; GFMax ; GFMin; Mmax; Mmin). Grain yield was considered as the dependent variable and the influence of temperature was determined from different developmental stages (Vargas *et al*. 1998). All measured parameters (plant phenology, growth parameters, yield and yield components) were subjected to analysis of variance (ANOVA) using

PROC GLM of SAS software version 9.1 (Anonymous, 2002) and mean separation was done using LSD (0.05).

Estimation of Heat Indices

Heat indices including stress susceptibility index (SSI) ($\frac{1-(Yp/Ys)}{1-(\bar{Y}s/\bar{Y}p)}$) (Fischer and Maurer, 1978), stress tolerance (TOL) (Yp-Ys) (Rosielle and Hamblin, 1981), mean productivity (MP) (Ys+Yp)/2 (Rosielle and Hamblin, 1981) stress tolerance index (STI) = $\frac{(Yp)(Ys)}{(\bar{Y}p)2}$(Fernandez, 1992) and geometric mean productivity (GMP) ($\sqrt{(Ys \times Yp)}$) (Fernandez, 1992) were calculated using the formula indicated in their respective references, where "Ys" is the yield of genotype under stress, "Yp" is the yield of genotype under irrigated conditions, " Ys "and " Yp " are the mean yields of all genotypes under stressed and non-stressed conditions, respectively, and "$1-(\bar{Y}s/\bar{Y}p)$" is the stress intensity.

Result and Discussion

Variation in atmospheric temperature

The maximum/minimum sowing air temperatures during the first planting was 31^{o}C/9.3^{O}C and maximum temperature reached the threshold level of 35^{O}C at 12 days after sowing. For the second planting, Maximum/minimum sowing temperatures were 33.5^{o}C/ 12.5^{O}C and maximum temperature raised to 36 ^{O}C at 2 days after sowing (Fig 1). This is an indication for the rapid increment of temperature during the chickpea growing period, which might have posed greater factor of yield reduction, possibly from physiological interference beyond adjustment, in the second date sown chickpea. In this study, the average grain yield of chickpea genotypes reduced by half during the second planting (430 kg/ha) as compared to first planting (860 kg/ha) (Table 5). Similar report by Singh *et al.* (1982) indicated that, peak photosynthetic rate was observed at 22^{O}C in chickpea, but the net photosynthetic rate showed to be reduced at 28^{O}C.

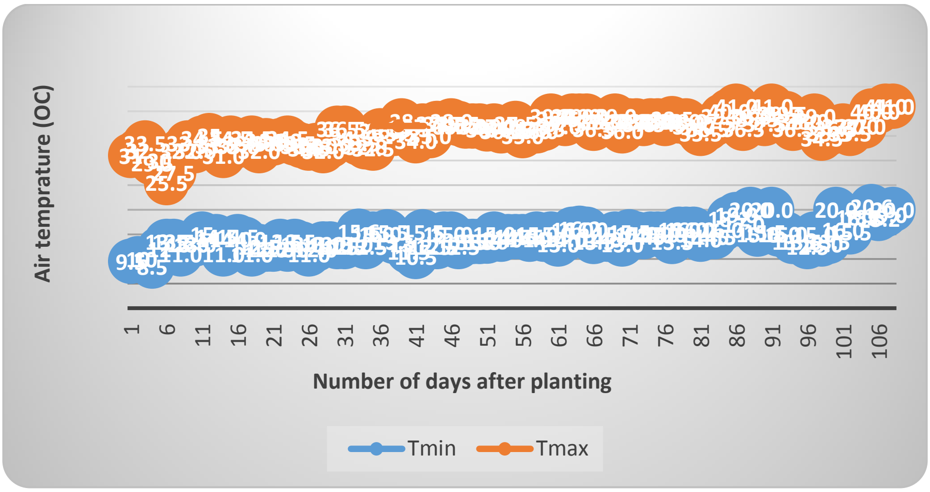

Fig 1. Maximum and minimum air temperatures at WARC during the chickpea growing season

Thus, observations in the present study suggested that, the experimental location is suitable site for screening heat stress tolerance of chickpea and the performance of genotypes to the existing temperature would result in screening and identification of genotypes tolerant to heat stress.

Effect of atmospheric temperature on developmental stages of chickpea

The result of this study indicated that high temperature significantly reduced the vegetative, flowering, grain filling and maturity periods of chickpea as planting delayed from Jan 23 to Feb 24 (Table 2). The overall vegetative period (VP), flowering period (FP), grain filling period (GFP) and maturity period (MP) was reduced from 33 to 31, 16 to 13, 33 to 30 and 49 to 43 days at late sown chickpea (Table 2).

The calculated average maximum and minimum temperature at different developmental stage V*max*, V*min;* F*max*, F*min;* GF*max*, GF*min* and M*max*, M*min* were considerably higher during the second planting as compared to the first planting (Table 3).

Table 2. Mean number of days for different chickpea developmental stages during P1 and P2.

Planting dates	Chickpea developmental stages			
	VP	**FP**	**GFP**	**MP**
P1	33	16.1	33.2	49.2
LSD(0.05)	2.0	4.0	8.9	9.1
P2	31.3	13.2	30.3	43
LSD(0.05)	1.8	2.89	6.4	8.8

Key: VP = one day before first flower – sowing date; **FP**= days to first pod – days to first flower; **GFP**= maturity date – one day after pod formation: **MP**=maturity date-days to first flower

Table 3. The average maximum and minimum temperatures for each developmental stages.

Planting	Average maximum and minimum temperature of chickpea developmental stages					
	V*max*	V*min*	F*max*	F*min*	GF*max*	GF*min*
P1	32.8	12.5	36.4	13.6	37.5	14.7
P2	36.7	14.2	37.8	14.5	38.1	16.4

Key: Vmax = Average maximum temperature during vegetative period, Vmin = Average minimum temperature during vegetative period, Fmax= Average maximum temperature during flowering period, Fmin= Average mimimum temprature during flowering period, GFmax = Average maximum temperature during grain filling period, GFmin = Average minimum temperature during grain filling period

The VP exposed to max/min temperature of 39^0C/8.5^0C and 41^0C/10.5^0C during first and second planting, respectively. The FP experienced max/min temperature of 40^0C/10.5^0C and 40^0C/11.5^0C during first and second planting, respectively. Whereas, the GF exposed to max/min temperature of 39^0C/11°C and 41/12°C of during first and second planting, respectively. This indicates late sowing exposed the chickpea plant to high temperature and reduced the length of vegetative growth stage causing flowering earlier. This might be the reason for yield reduction during second planting as compared to the first (Table 5).

The current result is supported by old reports of Saxena *et al*., *(*1988), indicated that exposure of chickpea plants to high temperature of 30^0C-35^0C at flowering and grain filling stage caused substantial yield loss.

Combined Analysis of Variance

Results from combined analysis of variance revealed that there were significant genotypic differences among the tested chickpea genotypes for most of the traits considered in this study (Table 4). Except for days to maturity (DM), highly significant difference ($p \leq 0.01$) for all the studied phenological & growth parameters, such as days to first flowering (DFF), days to 50% flowering (DFFF), days to first podding (DFP) and number of primary branches (NBR) were observed among the tested chickpea genotypes under heat stressed environment (Table 4).

Table 5. Analysis of Variance for sum of squares of chickpea traits grown under heat stress at Werer for both planting date.

	Planting date 1						Planting date2				
	Source of variation						Source of variation				
Characters	Varieties (20)¥	Replication (2)	Error (40)	mean	CV	R2	Varieties 20)	Replication (2)	Error (40)	mean	CV (%)
DFF	71.09**	3.48	1.48	33.52	3.62	0.96	65.74**	1.33	1.38	32.38	3.63
DFFF	44.02**	6.78*	2.04	43.46	3.29	0.92	71.07**	0.33	2.70	39.33	4.18
DFP	47.3**	46.9*	5.9	49.4	5.09	0.68	30.2**	7.04	3.4	46.0	4.00
DM	33.02^{ns}	104.64*	24.60	82.54	6.01	0.47	24.75 ^{ns}	63.54	28.46	75.84	7.03
FPH	6.49**	4.12	2.17	17.86	8.25	0.61	33.48**	5.19	5.83	16.62	14.53
PPP	1574.21**	757.48	408.1	50.10	40.3	0.67	897.52**	251.44	194.31	36.68	38.00
SPP	2480.84**	1824.91*	482.5	60.57	36.2	0.73	1391.21**	277.48	291.11	43.24	39.46
HSW	368.46**	1.42	12.21	31.24	11.2	0.94	343.08**	4.01	5.55	29.00	8.12
YLD	225729.73**	66068.59	7706	860.0	32.3	0.60	207198.96**	30847.83	34399.89	430.92	43.04
BMY	557821.18**	151265.21	207584	1982	22.99	0.58	575546.07**	230512.00	112863.12	1243.33	27.02
HI	236.33**	87.01	87.61	42.65	21.9	0.58	556.40**	78.05	83.43	32.60	28.02

Key: *, **, ns indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively. ¥ =figures in parenthesis refer to degrees of freedom, CV coefficient of variation. DFF=Days to first flowering, DFFF=Days to fifty percent flowering, DFFP=Days to fifty percent podding, DEP=Days to end of podding, DM=Days to maturity, FPH=First pod height, PPP=Number of pods per plant, SPP=Number of seeds per plant, HSW=Hundred seed weight, YLD=Yield, BMY=Biomass yield, HI=Harvest index.

Table 4. Combined ANOVA for studied traits of chickpea genotypes under high temperature during the dry season of 2015 at Werer.

Sources of Variation							
S/No	CHARACTERS	Varieties (20)¥	Replication (2)	Planting Date (1)	Planting Date*Varieties (20)	Error	CV (%)
1	DFF	134.47**	3.88	41.143**	2.36	1.42	3.61
2	DFFF	109.74**	4.79	536.51**	5.34**	2.37	3.72
4	DFP	73.10**	44.9	346.7**	3.7	4.6	4.53
5	DM	40.02^{ns}	101.17	1413.37**	17.75	27.52	6.62
6	FPH	25.07 ^{ns}	8.16	48.91**	14.89	3.93	11.50
7	PPP	2334.91**	227.39	5666.87**	136.82	312.95	40.77
8	SPP	3617.21 ^{ns}	474.50	9464.00**	254.83	417.06	39.35
9	HSW	701.61**	0.34	158.01**	9.93	8.79	9.84
10	YLD	408721.67**	4051.52	5800294.89**	24207.02	56637.02	36.87
11	BMY	898336.69**	53624.41	17192467.06**	235030.56	164319.42	25.14
12	HI (%)	711.46**	86.47	3183.13**	81.27	85.35	24.55

Key: *, **, ns indicate significance at 0.05 and 0.01 probability levels, and non-significant, respectively. ¥=figures in parenthesis refers to degrees of freedom, CV= coefficient of variation. DFF=Days to first flowering, DFFF=Days to fifty percent flowering, DFFP=Days to fifty percent podding, DEP=Days to end of podding, DM=Days to maturity, FPH=First pod height, PPP=Number of pods per plant, SPP=Number of seeds per plant, HSW=Hundred seed weight, YLD=Yield, BMY=Biomass yield, HI=Harvest index

Similarly, yield and yield related traits such as grain yield, biomass yield, number of pods plant^{-1}, hundred seed weight and harvest index showed highly significant variation ($p \leq 0.001$) among the tested genotypes, whereas, difference in number of seeds plant^{-1} among chickpea genotypes remained statistically insignificant (Table 4), though the Cv was high due possibly uneven surface irrigation management. The present result is in agreement with report by Singh *et al.* (1990), who observed variations for grain yield, biomass weight, harvest index, and other traits such as number of pods plant-1 and hundred seed weight in chickpeas. Generally, out of the 12 traits studied, most traits exhibited highly significant differences under heat stress, indicating the presence of variability in responses of chickpea genotypes to high temperature that underlines the utility of the materials for applied breeding programme and these sources of heat tolerance can be used for physiological and genetic studies in heat tolerance breeding

Highly significant difference ($p \leq 0.01$) was the case due to planting date influence days to first flowering (DFF), days to 50% flowering (DFFF), days to first podding (DFP) , days to maturity (DM) and first pod height (FPH) (Table 4). Number of pods plant^{-1}(NPP), number of seeds plant^{-1}(SPP), hundred seeds weight(HSW), grain yield(YLD), biomass yield(BMY) and harvest index (HI) varied highly significantly as planting delayed from Jan 23 to Feb 24, implying the impact of heat stress on late sown crops (Table 4). With regard to interaction between planting dates and tested genotypes, significant interaction effect was recorded on number of fifty percent flowering. This is an evidence for the influence of planting date (increased temperature) on flowering and pod setting potential of chickpea genotypes under heat stressed condition. (Table 2 & 4).

Performance of Chickpea Genotypes

Crop phenology and growth parameters

Significant difference in crop phenology was observed among the chickpea genotypes for both planting dates (p1 and p2). The ANOVA showed that there were highly significant differences in flowering times (days to 1st flowering and days to 50% flowering) and days to 1st podding among germplasms for both p1 and p2 (Table 5 & 6). However all genotypes tended to mature more or less close to each other irrespective of their differences in pre-maturity phenology (Table 5 & 6).

Over all mean values of germplasms revealed that all of the test genotypes took lesser mean number of days ranging between 28-36 and 37-47 days for 1st flowering and 50% flowering compared to the standard checks Arerti, DZ 10-4 and DZ 10-11 (40-47 days). There were about 3 weeks gap between the earliest DZ-2012-CK-0034 (28 days) followed by ICCV 10307 (29 days) and the latest (Arerti) germplasms which took 48 days to show the first flower. On the other hand, the standard check Arert (57 days) and DZ 10-4 (53 days) were among the latest genotype to produce the first pod and 50% podding, while ICCV 09301 (43days) and ICCV 10307 (44days) were the earliest (43-44 days) to produce the first pod and 50% podding (Table 6). Though there was no statistically marked difference among the genotypes in their number of days to attain maturity, almost all the tested genotypes matured little earlier (76-81 days) than the standard checks Arerti (82-84 days) (Table 6,8,9).

Table 6. Mean values of phenological traits and growth parameters of chickpea genotypes under heat stress at Werer, 2015.

S/No	Treatment /Entry	DFF	DFFF	DFP	DEP	DM	PLHT	FPH
1	ICCV-10409 (K)	30.3hij	40.2def	44.8gh	62.3e-j	79.8abcd	27.9cde	15.2b-f
2	ICCV-09315 (K)	30.8ghi	39.3ef	44.5gh	61.0e-j	78.2bcde	28.0cde	13.6hi
3	DZ-CK-0034 (D)	28.0k	38.8fg	48.3def	60.0hij	77.8cde	31.9abc	14.0e-h
4	ICCV-09309 (D)	31.2fgh	39.3ef	48.0def	63.2d-i	80.0abcd	28.6cde	15.2a-e
5	ICCV-10107 (D)	29.7ij	38.8fg	46.7efg	62.0e-j	79.2a-e	28.1cde	13.0i
6	ICCV-10404 (K)	31.3efgh	39.8ef	44.3gh	62.5e-j	79.2a-e	28.7cde	13.6hi
7	ICCV-10108 (D)	32.3e	38.7fg	50.8c	65.5cde	81.7abcd	29.6bcde	14.0d-h
8	ICCV-07313 (K)	31.7efgh	39.0fg	46.5efg	58.8ij	76.7cde	27.5e	14.3c-h
9	ICCV-09311 (K)	31.0fghi	40.2def	44.8gh	60.0hij	79.3a-e	28.1cde	13.7fghi
10	ICCV-10102 (K)	32.7e	40.8cde	45.2gh	60.2ghij	80.5abcd	28.2cde	15.1b-g
11	ARERTI (K)	47.5a	55.2a	57.0a	72.7a	84.7a	27.7de	15.8ab
12	DZ-10-4 (K)	42.3b	46.8b	53.2b	71.2ab	82.3abc	32.9ab	13.7ghi
13	ICCV-09301 (K)	31.2fgh	39.2ef	43.2h	64.0d-h	78.8a-e	28.9bcde	13.8e-h
14	ICCV-10103 (D)	31.5efgh	39.2ef	51.2bc	64.8def	81.0abcd	34.6a	14.7b-h
15	ICCV-10307 (K)	29.0jk	37.3g	44.3gh	58.5j	73.8e	26.7e	13.5hi
16	DZ-10-11 (D)	40.0c	47.7b	49.8cd	69.5abc	77.3cde	29.8bcde	13.1i
17	ICCV-09304 (K)	32.7e	41.7cd	46.3fg	61.3e-j	76.0de	31.8abcd	15.5abc
18	DZ-CK-0044 (D)	30.5hi	39.0fg	49.3cd	64.7defg	78.0bcde	28.9bcde	15.5abcd
19	ICCV-10311 (K)	30.7ghi	39.3ef	44.3gh	60.3f-j	77.8cde	30.1bcde	14.6b-h
20	ICCV-09307 (K)	32.0efg	46.8b	48.3cde	67.5bcd	83.8ab	26.8e	16.7a
21	DZ-CK-0041(D)	35.7d	42.2c	50.3cd	63.3d-i	77.0cde	30.3bcde	14.3c-h
Grand mean		33	41.4	47.7	63.5	79.2	29.3	14.4
	LSD (0.05)	1.4	1.8	2.5	4.5	5.9	4.1	1.5
	CV (%)	3.6	3.7	4.5	6.2	6.5	12.2	9

Key: DFF=Days to first flowering, DFFF=Days to fifty percent flowering, DFP=Days to first podding, DEP=Days to end of podding, DM=Days to maturity, PLHT=Plant height, FPH=First pod height

The result of the study probably illustrate plasticity response of the crop, whereby plants grown under high temperature and low rain fall condition make adjustment of the environment through alteration of their normal physiological growth and development process. The decline in number of days to flower and maturity in the tested genotypes shorten their vegetative period so that their transformation in to reproductive phase assures their seed production under the existing high temperature. It has been reported that early phenology (time to flowering, podding and maturity) plays critical role in adaptation of chickpea cultivars to different environments (Berger et al.2004, 2006) and Early phenology is a key trait for adaptation of chickpea to short season environments as it helps crop to escape from end season stresses (drought, temperature extremities). Hence the tested chickpea genotypes identified with early phenological traits in this study can make progress in genetic studies and breeding for early phenology in targeted high temperature areas. Highly significant variation among chickpea genotypes was observed in their plant height and 1st pod height. The highest plant height (34.6cm) and 1st pod height (16.7) measure was taken from ICCV 10103 and ICCV 099307, respectively. ICCV 10307 (26cm) and ICCV 10107 (13cm) were found to be the shortest of all in their height and 1st pod height (Table 6).

Yield and yield components

Highly significant inherent variation among the chickpea genotypes was observed for number of podsplant^{-1}, hundred seeds weight, grain yield, biomass yield and harvest index for both planting dates whereas, number of seeds plant^{-1} exhibited non-significant differences (Table 7). The highest number of pods per plant (93) and seeds per plant (106) was found for desi types ICCV- 10103**,** followed by ICCV 10108 (92), while the lowest number of pods per plant (19) and seeds per plant (22) was observed in the kabuli type ICCV 09304 (Table 7).

Maximum hundred seed weight was observed in the kabuli types ICCV-10404 (45g) and ICCV 09311 (43g)**,** while the lowest hundred seed weight was recorded from the standard checks DZ 10-4 (10g), DZ 10-11 (11g) and Arerti (20g).The result of this study also showed there were highly significant differences ($P \leq 0.01$) in biomass yield and grain yield and harvest index among chickpea genotypes for both planting dates (P1 and P2) (Table 7). The highest grain yield was obtained from ICCV 09309 (1187 kg/ha), ICCV 10307 (1035 kg/ha) and ICCV 10108 (1014 kg/ha), while the lowest grain yield was obtained from the standard check Arerti (308 kg/ha) followed by ICCV 09307 (328 kg/ha) and DZ – 10-11 (338 kg/ha). The possible explanation for this is that the standard check has been developed under high potential ecology and miss more of stress response genes to respond or adapt. 13 lines achieved significantly higher yield level than the best yielding standard check DZ 10-4 (399 kg/ha) with marked yield advantage. Results further revealed that the high yielding genotypes produced high biomass yield as compared to low yielding ones. The highest biomass yield was obtained from ICCV-09309 (2352 kg/ha) followed by ICCV-10108 (2224 kg/ha), which were also the highest seed yielder (Table 7). According to the report by Asnake, (2014), released cultivars gave average grain yield up to 3350 kg ha^{-1} based on on-farm evaluation and 2600-5000kg ha^{-1} on research stations all under potential chickpea agroecology. Reduction of yield due to increased temperature has been reported by Karla et al., 2008, who observed chickpea grain yield decreased by 53-301kg ha^{-1} in 1^0C increase of temperature. In this study we roughly calculated the reduction in seed size and yield for Arerti, and it was like exposed to $10C^0$ more temperature than its normal adaptation, and reduced yield 10 fold, and seed size by 1/3rd.

Table 7. Mean values of yield and yield components of chickpea genotypes under heat stress at Werer, 2015.

S/NO	Treatment	PPP	SPP	HSW	BMY	YLD	HI
1	ICCV-10409 (K)	29.5fghi	32.8fghi	39.2bc	1625.2cde	585.5defg	33.2def
2	ICCV-09315 (K)	36.7d-i	44.0d-h	39.6bc	1765.8bcde	810.2bcd	46.0ab
3	DZ-CK-0034 (D)	50.7cde	55.7cde	29.3e	1929.8abcd	963.0abc	49.8a
4	ICCV-09309 (D)	77.0ab	87.7ab	22.0fgh	2351.7a	1188.8a	50.8a
5	ICCV-10107 (D)	50.5cde	60.7cd	25.4f	1085.7h	520.7efgh	43.0abcd
6	ICCV-10404 (K)	33.5d-i	36.3e-i	45.9a	1585.0c-g	615.7def	36.6bcde
7	ICCV-10108 (D)	78.2a	89.3ab	21.0gh	2224.0ab	1013.5ab	44.8abc
8	ICCV-07313 (K)	34.5d-i	41.8d-i	39.9bc	1921.5abcd	912.0bc	48.4a
9	ICCV-09311 (K)	27.7ghi	31.2ghi	42.7ab	1360.3efgh	589.7defg	42.8abcd
10	ICCV-10102 (K)	43.0c-g	54.5cdef	38.6cd	1785.8bcde	799.0bcd	42.5abcd
11	ARERTI (K)	31.3e-i	39.0d-i	20.1gh	1946.2abc	308.0h	16.1g
12	DZ-10-4 (K)	57.2bc	92.5a	10.4i	1509.2c-h	398.5fgh	26.0fg
13	ICCV-09301 (K)	22.2hi	19.7i	35.7d	1609.0cdef	480.3efgh	24.7fg
14	ICCV-10103 (D)	93.0a	106.0a	20.3gh	2115.2ab	1034.8ab	48.3a
15	ICCV-10307 (K)	22.3hi	26.7ghi	38.5cd	1087.7h	480.3efgh	40.2abcd
16	DZ-10-11 (D)	48.2cdef	67.2bc	10.9i	1077.8h	337.7gh	26.8ef
17	ICCV-09304 (K)	19.0i	22.8hi	41.5bc	1141.3h	382.2fgh	27.7ef
18	DZ-CK-0044 (D)	51.5cd	58.3cde	19.1h	1346.5efgh	639.0def	45.1abc
19	ICCV-10311 (K)	38.8c-i	45.0c-h	38.3cd	1475.5d-h	711.0cde	46.1ab
20	ICCV-09307 (K)	27.0hi	29.8ghi	31.2e	1769.8bcde	326.8gh	15.9g
21	DZ-CK-0041(D)	39.5c-h	49.0c-g	23.1fg	1154.2fgh	458.3efgh	35.2cdef
Grand mean		43.4	51.9	30.1	1612.7	645.5	37.6
LSD (0.05)		19.9	22.6	3.4	459.9	271.2	10.6
CV (%)		40	37.9	9.9	24.8	36.6	24.6

Key: PPP=Number of pods per plant, SPP=Number of seeds per plant, HSW=Hundred seed weight, YLD=Yield, BMY=Biomass yield, HI=Harvest index

The result of this study showed, 13 lines out of 18, achieved significantly higher yield level than the best yielding standard check DZ 10-4 (399 kg/ha). This significant grain yield increment among the test genotypes is due to their comparatively higher heat tolerance and therefore we can use them as source of heat tolerance in further breeding activities. It was also indicated the top 3 high yielding chickpea genotypes are desi types which achieved significantly higher yield level than kabuli type's chickpea genotypes (Table 7). Study by Tibebu (2011), confirmed that desi chickpea types were high yielder, better in biomass rate and harvest index over kabuli types of chickpeas, which could come from inherent variability in the two types.

Effect of planting date on chickpea growth

Planting date caused significant difference in crop phenology (DFF, D50%F, DFP, DEP and DM) and among the studied genotypes (Table 8). Mean values of Number of days to 1st flowering, number of days for 50% flowering, number of days for 50% podding and number of days to reach maturity decreased significantly as planting date delayed from Jan 23 to Feb 24 (Table 2). There were 2-4 days difference in flowering times among genotypes and variation in crop maturity was 14 days during P1 and 11 days during P2 (Table 8).The result indicated the overall crop cycle further shortened under late sowing condition and this was associated with high temperature during the second planting. The result further revealed that chickpea phenology had negatively significant association with maximum temperature. Plant height and 1st pod height reduced from 31cm to 28cm and 18cm to 11cm, as planting date delayed from Jan 23 to Feb 24. The relatively taller chickpea plants may be attributed to the longer growing period and vigorous growth associated with earlier planting. In contrast, there was no statistically significant difference among germplasms in their number of primary branches (Table 8).

Table 8. Mean performances for phenological traits and growth parameter of chickpea genotypes grown under heat stress at Werer, 2015

S.N	Treatment /Entry	PD	DFF	DFFF	DFP	DEP	DM	PLHT	FPH
1	ICCV-10409 (K)	1	30.33hij	43.33c	48.33g	62.67def	82.67a-d	18.60b-f	18.60b-f
		2	30.33f-i	37.00de	49.33fgh	62.00c-f	77.00abc	16.60cde	16.60cde
2	ICCV-09315 (K)	1	31.00f-i	42.67cde	48.67fg	62.67def	81.33a-d	17.60b-h	17.60b-h
		2	30.67e-i	36.00de	48.33gh	59.33def	75.00abc	15.40d-g	15.40d-g
3	DZ-2012-CK-0034 (D)	1	29.00ij	41.67c-f	53.67bc	64.00cde	83.66abc	16.87e-h	16.87e-h
		2	27.00j	36.00de	51.67e-h	56.00f	72.00bc	19.87bc	19.87bc
4	ICCV-09309 (D)	1	32.66efg	41.67cdef	54.33bc	64.67cde	86.33ab	19.33a-d	19.33a-d
		2	29.67hi	37.00de	53.33d-g	61.67c-f	73.67abc	16.00c-f	16.00c-f
5	ICCV-10107 (D)	1	29.67ij	42.00c-f	52.67bcd	63.00def	83.66abc	16.27fgh	16.27fgh
		2	29.67hi	35.67de	48.67gh	61.00c-f	74.67abc	12.00g	12.00g
6	ICCV-10404 (K)	1	31.00f-i	42.33c_f	49.33efg	63.67de	82.67a-d	17.20c-h	17.20c-h
		2	31.67efg	37.33de	48.67gh	61.33c-f	75.67abc	16.13cde	16.13cde
7	ICCV-10108 (D)	1	33.67e	40.33ef	52.67bcd	64.33cde	84.33abc	17.67b-h	17.67b-h
		2	31.00e-i	37.00de	56.33a-e	66.67a-d	79.00ab	14.27d-g	14.27d-g
8	ICCV-07313 (K)	1	32.00e-h	42.33c-f	52.00cde	61.67def	80.67bcd	18.27b-f	18.27b-f
		2	31.33e-h	35.67de	48.67gh	56.00f	72.67abc	16.00c-f	16.00c-f
9	ICCV-09311 (K)	1	32.00e-h	42.67cde	48.67fg	58.00f	82.67a-d	17.93b-g	17.93b-g
		2	30.00ghi	37.67d	49.00fgh	62.00c-f	76.00abc	14.60d-g	14.60d-g
10	ICCV-10102 (K)	1	33.67e	43.67c	49.67d-g	61.67def	83.66abc	19.60abc	19.60abc
		2	31.67efg	38.00d	48.67gh	58.67ef	77.33abc	17.20cde	17.20cde
11	ARERTI (K)	1	48.33a	56.67a	62.00a	74.33a	89.33a	18.27b-f	18.27b-f
		2	46.67a	53.67a	59.67ab	71.00a	80.00ab	22.40b	22.40b
12	DZ-10-4 (K)	1	42.67b	47.67b	55.33b	70.33ab	83.66abc	16.20fgh	16.20fgh
		2	42.00b	46.00b	61.00a	72.00a	81.00a	18.00cd	18.00cd
13	ICCV-09301 (K)	1	32.00e-h	41.33c-f	48.00g	65.00b-e	82.00a-d	17.47c-h	17.47c-h
		2	30.33f-i	37.00de	48.00h	63.00b-f	75.67abc	16.80cde	16.80cde
14	ICCV-10103 (D)	1	32.66efg	40.67def	53.33bc	66.33b-e	84.67abc	18.87a-e	18.87a-e
		2	30.33f-i	37.67d	56.00a-e	63.33b-f	77.33abc	15.13d-g	15.13d-g
15	ICCV-10307 (K)	1	28.66j	40.0f	48.67fg	61.00ef	75.00d	15.33h	15.33h
		2	29.33i	34.67e	48.00h	68.00abc	72.67abc	16.60cde	16.60cde
16	DZ-10-11 (D)	1	40.33c	48.33b	54.66bc	69.33abc	84.67abc	15.73gh	15.73gh

		2	39.67c	47.00b	53.00d-h	69.67ab	70.00c	14.00efg	14.00efg
17	ICCV-09304 (K)	1	33.00ef	42.33c-f	48.67fg	61.67def	77.33cd	19.00a-e	19.00a-e
		2	32.33de	41.00c	54.00c-e	61.00c-f	74.67abc	16.30cde	16.30cde
18	DZ-2012-CK-0044 (D)	1	31.00f-i	40.33ef	51.67c-f	64.33cde	81.00bcd	20.00ab	20.00ab
		2	30.00ghi	37.67d	55.00b-e	65.00a-e	75.00abc	12.13fg	12.13fg
19	ICCV-10311 (K)	1	30.67f-j	42.00c-f	48.00g	61.00ef	80.00bcd	16.73e-h	16.73e-h
		2	30.67e-i	36.67de	48.67gh	59.67def	75.67abc	17.10cde	17.10cde
20	ICCV-09307 (K)	1	32.00e-h	47.67b	55.67b	67.00bcd	86.67ab	21.10a	21.10a
		2	32.00def	46.00b	59.00abc	56.00f	81.00a	27.20a	27.20a
21	DZ-2012-CK-0041(D)	1	37.67d	43.00cd	54.66bc	63.67de	77.33cd		17.07d-h
		2	33.67d	41.33c-f	57.33a-d	63.00b-f	76.67abc		15.20d-g
	Grand mean	1	33.52	43.46	51.94	64.30	82.54		17.86
		2	32.38	39.33	52.49	62.68	75.84		16.62
	LSD	1	2.01	2.36	3.29	5.40	8.19		2.43
		2	1.94	2.71	5.17	7.42	8.80		3.98

Key: DFF=Days to first flowering, DFFF=Days to fifty percent flowering, DFP=Days to first podding, DEP=Days to end of podding, DM=Days to maturity, PLHT=Plant height, FPH=First pod height

Planting date also caused significantly affected number of pods plant^{-1}, number of seeds plant^{-1}, hundred seeds weight, grain yield, biomass yield and harvest index (Table 9). However the interaction effect between genotypes and planting date remained statistically insignificant. Average number of pods per plant and seeds per plant were decreased from 50 to 37 and from 60 to 43 as planting date was delayed from Jan 23 to Feb 24 (Table 9). This might be due to increased temperature during late planting which associated with loss of stigma receptivity, poor pollen germination and failure of pollen fertilization and pollen formation and it might lead to embryo abortion of small endosperms as reported earlier (Egli 2005). Delayed planting significantly reduced average hundred seed weight from 31g to 29g (Table 9).

This might be due to prevalence of higher temperature in delayed planting (Fig 1 and 2) at the reproductive stage which caused reduced remobilization of photosynthate to grain yield. Planting date also negatively affected in grain yield of chickpea genotypes to reduce by half during the second planting (430 kg/ha) as compared to first planting (860 kg/ha)(Table 9). This might be linked with reduced pollen viability and stigma receptivity through oxidative stress in the leaves which causes failure of fertilization (Kumar, 2012).

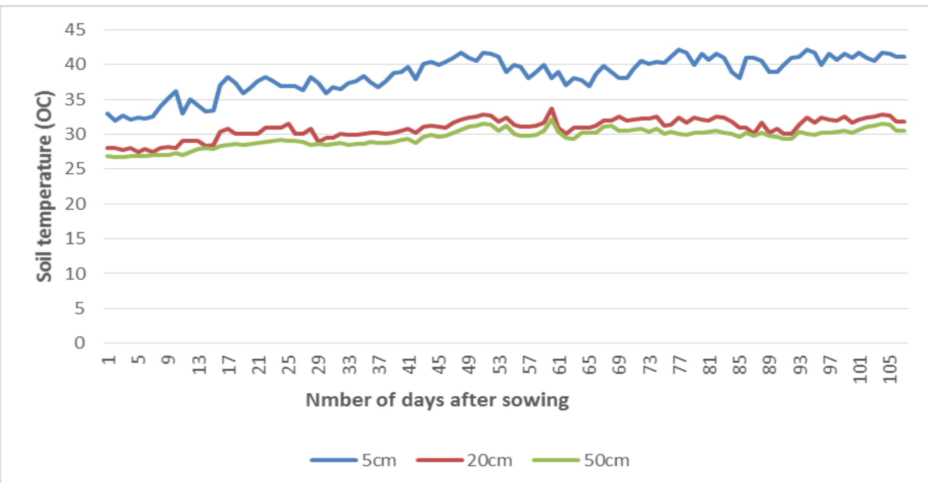

Fig 2. Maximum and minimum soil temperatures at WARC during the chickpea growing season for considered soil depths

Table 9. Mean performances for yield and yield components of chickpea genotypes grown under heat stress at Werer, 2015.

S.N	Treatment /Entry	PD	PPP	SPP	HSW	YLD	BMY	HI
1	ICCV-10409 (K)	1	36.00de	40.67ef	41.97bcd	852.7b-f	2164.7a-e	39.66b-e
		2	23.00e-h	25.00fgh	36.47cde	318.3f-i	1085.7c-f	26.74fgh
2	ICCV-09315 (K)	1	40.33de	49.00def	40.10bcd	1003.0a-e	2132.0a-e	48.14a-d
		2	33.00c-h	39.00d-h	39.07a-d	617.3b-e	1399.7bcd	43.89a-d
3	DZ-2012-CK-0034(D)	1	55.33cde	58.33def	30.43fg	1186.0abc	2378.7abc	49.89abc
		2	46.00b-e	53.00b-e	28.17f	740.0abc	1481.0bcd	49.81ab
4	ICCV-09309 (D)	1	87.00abc	99.67abc	23.10hi	1416.7a	2836.3a	49.89abc
		2	67.00ab	75.67ab	20.90gh	961.0a	1867.0ab	51.81a
5	ICCV-10107 (D)	1	51.33de	56.67def	26.73gh	822.3b-f	1616.7def	49.45abc
		2	49.67bc	64.67a-d	23.97g	219.0hi	554.7f	36.58b-f
6	ICCV-10404 (K)	1	36.67de	40.67ef	48.97a	867.3b-f	2153.7a-e	39.93b-e
		2	30.33c-h	32.00e-h	42.73a	364e-i	1016.3def	33.30c-f
7	ICCV-10108 (D)	1	92.00ab	104.67ab	22.50hi	1340.0a	2818.0a	47.54a-d
		2	64.33ab	74.00ab	19.53h	687.0a-d	1630.0abc	42.06a-e
8	ICCV-07313 (K)	1	32.00e	41.67ef	38.23cde	1051.0a-d	1935.0b-f	56.31a
		2	37.00c-g	42.00d-g	41.57ab	773.0abc	1908.0ab	40.44a-f
9	ICCV-09311 (K)	1	33.67e	37.67ef	43.50abc	797.7c-f	1758.0c-f	45.85a-e
		2	21.67fgh	24.67gh	41.80ab	381.7d-i	962.7def	39.83e-f
10	ICCV-10102 (K)	1	50.67de	64.33cde	41.00bcd	1059.3a-d	2215.0a-d	47.88a-d
		2	35.33c-g	44.67c-g	36.10de	538.7b-g	1356.7b-e	37.08a-f
11	ARERTI (K)	1	37.00de	44.33def	20.43i	489.3f	1821.3c-f	26.02f
		2	25.67e-h	33.67e-h	19.77h	126.7i	2071.0a	6.12i
12	DZ-10-4 (K)	1	67.67bcd	113.00ab	10.77j	508.0f	1591.3def	31.60ef
		2	46.67bcd	72.00abc	10.00i	289.0ghi	1427.0bcd	20.30ghi
13	ICCV-09301 (K)	1	24.33e	25.67f	36.43de	725.7def	2129.0a-e	32.05ef
		2	20.00fgh	13.67h	34.87e	235.0ghi	1089.0c-f	17.38hi
14	ICCV-10103 (D)	1	111.33a	128.33a	21.17hi	1259.0ab	2597.0ab	48.47a-d
		2	74.67a	83.67a	19.47h	810.7ab	1633.3abc	48.11abc
15	ICCV-10307 (K)	1	30.00e	34.67ef	36.90de	719.0def	1370.7f	50.64abc
		2	14.67gh	18.67gh	40.07abc	241.7ghi	804.7ef	29.84e-h
16	DZ-10-11 (D)	1	56.3cde3	78.67bcd	12.43j	521.7f	1459.0ef	33.91def
		2	40.00c-f	55.67a-e	9.40i	153.7i	696.7f	19.61ghi
17	ICCV-09304 (K)	1	28.00e	33.67ef	44.87ab	636.0def	1679.0c-f	35.54c-e
		2	10.00h	12.00h	38.13b-e	128.3i	603.7f	19.96ghi
18	DZ-2012-CK-0044(D)	1	55.33cde	62.67de	19.27i	805.0b-f	1623.0def	52.28ab

		2	47.67bcd	54.00b-d	19.00h	473.0c-g	1070.0def	38.01a-f
19	ICCV-10311 (K)	1	43.00de	53.33def	39.20bcd	756.3c-f	1572.0def	43.61a-e
		2	34.67c-g	36.67d-h	37.47cde	665.7a-e	1379.0bcd	48.59ab
20	ICCV-09307 (K)	1	31.00e	36.67ef	33.43ef	565.7ef	2182.7a-e	25.33f
		2	23.00e-h	23.00gh	29.00f	88.0i	1357.0b-e	6.49i
21	DZ-2012-CK-0041(D)	1	53.00de	67.67cde	24.67hi	679.0def	1591.3def	41.74a-e
		2	26.00d-h	30.33e-h	21.60gh	237.7ghi	717.0f	28.69e-f
	Grand mean	1	50.10	60.57	31.24	860.03	1982.11	42.65
		2	36.68	43.24	29.00	430.92	1243.33	32.60
	LSD	1	33.34	36.25	5.77	458.10	751.85	15.45
		2	23.00	28.16	3.89	2.028	554.39	15.07

Key: DFF=Days to first flowering, DFFF=Days to fifty percent flowering, DFP=Days to first podding, DEP=Days to end of podding, DM=Days to maturity, PLHT=Plant height, FPH=First pod height

Estimation of Heat Tolerance indices

For better evaluation the genotypes for heat tolerance, some selection indices, including STI, TOL, SSI, MP and GMP were used. Tolerance indices were calculated on the basis of grain yield. The greater the TOL value, the larger yield reduction under heat stress conditions and the higher heat sensitivity. A selection based on minimum yield reduction under stress conditions in comparison with no stress conditions (TOL) failed to identify the most tolerant genotypes (Farshadfar *et al.*, 2014). Rosielle and Hamblin (1981) reported that selection based on the tolerance index often leads to selecting cultivars which have low yields under no stress conditions. The greater SSI and TOL values, the greater sensitivity to stress, thus a smaller value of these indices is favored.

Therefore, according to the result obtained from this study (Table 10), the genotypes showed the greater TOL values were ARERTI, ICCV-10404 and ICCV-09311. In contrast, the genotypes ICCV-10102, ICCV-09309, DZ-2012-CK-0034 and DZ-2012-CK-0041 showed lower TOL and higher STI values, and that means these materials were found heat tolerant genotypes relative to others, but may be with poor yield potential. Hence, the heat tolerant materials can be used in the breeding program either for direct advancement based on their agronomic merits or could be used in the crossing program for further manipulation.

Table 10. Grain yield (Kg/ha) and heat tolerance related characters influenced by different genotypes.

	Grain Yield							
Treatment /Entry	Potential	Stress	% yield reduction	SSI (%)	MP	TOL	STI	GMP
ICCV-10409 (K)	2450.79	585.50	76.11	1.08	1518.15	1865.29	0.24	1197.89
ICCV-09315 (K)	2548.12	810.17	68.21	0.97	1679.14	1737.96	0.32	1436.80
DZ-2012-CK-0034 (D)	1847.03	963.00	47.86	0.68	1405.01	884.03	0.52	1333.67
ICCV-09309 (D)	2029.55	1188.83	41.42	0.59	1609.19	840.71	0.59	1553.32
ICCV-10107 (D)	1556.69	520.67	66.55	0.95	1038.68	1036.02	0.33	900.29
ICCV-10404 (K)	3369.64	615.67	81.73	1.17	1992.65	2753.98	0.18	1440.34
ICCV-10108 (D)	2104.31	1013.50	51.84	0.74	1558.90	1090.81	0.48	1460.38
ICCV-07313 (K)	2461.23	912.00	62.95	0.90	1686.62	1549.23	0.37	1498.21
ICCV-09311 (K)	2820.48	589.67	79.09	1.13	1705.07	2230.82	0.21	1289.63
ICCV-10102 (K)	1417.89	799.00	43.65	0.62	1108.44	618.89	0.56	1064.37
ARERTI (K)	3519.45	308.00	91.25	1.30	1913.73	3211.45	0.09	1041.15
DZ-10-4 (K)	1633.55	398.50	75.61	1.08	1016.03	1235.05	0.24	806.83
ICCV-09301 (K)	1860.23	480.33	74.18	1.06	1170.28	1379.89	0.26	945.27
ICCV-10103 (D)	2540.62	1034.83	59.27	0.85	1787.73	1505.79	0.41	1621.46
ICCV-10307 (K)	2004.17	480.33	76.03	1.09	1242.25	1523.83	0.24	981.16
DZ-10-11 (D)	1702.43	337.67	80.17	1.15	1020.05	1364.77	0.20	758.19
ICCV-09304 (K)	1849.54	382.17	79.34	1.13	1115.85	1467.37	0.21	840.73
DZ-2012-CK-0044 (D)	1666.67	639.00	61.66	0.88	1152.83	1027.67	0.38	1031.99
ICCV-10311 (K)	2250.00	711.00	68.40	0.98	1480.50	1539.00	0.32	1264.81
ICCV-09307 (K)	2509.81	326.83	86.98	1.24	1418.32	2182.98	0.13	905.70
DZ-2012-CK-0041 (D)	1384.27	458.33	66.89	0.96	921.30	925.94	0.33	796.53

K=Kabuli, D=Desi. €=indicating standard check chickpea varieties

Conclusion

The Combined analysis of variance showed there were highly significant differences among the tested genotypes for most of the traits considered, except for DM, FPH and SPP, indicating the existence of variability among tested genotypes and the potential for selection under heat stress environments. The overall mean values of germplasms revealed that all of the test genotypes took lesser mean number of days ranging between 28-36 and 37-47 days to show 1st flowering and 50% flowering than the standard checks Arerti, DZ 10-4 and DZ 10-11 (40-47 days). Though there was no statistically marked difference among the genotypes in their number of days to attain maturity, almost all the tested genotypes matured earlier (76-81 days). Since, ICRISAT had classified chickpea varieties matured in < 85 days as extra early, 85- 115 as early and > 115 days as late maturing varieties, all of the test genotypes used in this study can be regrouped as extra early maturing and can make progress in breeding for early phenology in targeted high temperature areas. Highly significant variation among the chickpea genotypes was observed for number of podsplant^{-1}, hundred seeds weight, grain yield, and biomass yield and harvest index for both planting dates. Based on the observation on yield performance, most of the test genotypes gave significantly higher biomass yield and grain yield than all of the standard checks under heat stress condition of ≥35C^0. The top 3 best responding genotypes under heat stressed environment were ICCV 09309 (1187 kg/ha), ICCV 10103 (1035 kg/ha) and ICCV 10108 (1014 kg/ha). These heat tolerant chickpea materials can further be taken to breeding advance as source parents It was also indicated the top 3 high yielding chickpea genotypes are desi types which achieved significantly higher yield level than kabuli types chickpea .This might suggest that, desi types constituency of heat combating genes better compared to kabuli types.

Planting date between last week of January and February significantly affected plant parameters as the thermal condition was increasingly differed. The result indicated that high temperature stress significantly reduced the mean values of DFF, D50%F, DFP, DEP, DM, VP, FP, GFP, MP, PLHT, FPH, NBR, PPP, HSW, YLD and BMY with delayed sowing. It may therefore be concluded that the heat screening planting protocol can be conducted somewhere between mid-January to beginning of February, with the analogy that in mutagenesis treatment about 50% deformation is assumed right dose to likely impose the expected change.

For better decision making heat indices including STI, TOL, SSI, MP and GMP could be calculated on the basis of grain yield. Accordingly, the tested chickpea genotypes showed the greater TOL values were ARERTI, ICCV-10404 and ICCV-09311, indicating their poor tolerance whereas genotypes ICCV-10102, ICCV-09309, DZ-2012-CK-0034 and DZ-2012-CK-0041 showed lower TOL and higher STI values, and they are found relatively better heat tolerant genotypes. This study is in its early state of emergence, and further optimization of protocols, facilities and analytical approaches should be coming down the course.

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