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Identification of chickpea (*Cicer arietinum*) breeding lines tolerant to high temperature

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Chickpea (*Cicer arietinum* L.) is a self-pollinated, cool season loving annual legume crop. Heat stress is posing a serious threat to agricultural production and food safety in light of the changing environment. The IPCC projected between 2030 and 2052 that, global warming will accelerate to 1.5°C from the current rate of 0.2°C per decade. More than 15% of the land area worldwide is exposed to high temperature (Sun *et al.* 2019). The optimum temperature for the growth of chickpea is wide ranging between 10–30°C, beyond that it feels the heat stress. The effect of high temperature depends on the strength, continuity of exposure and level of risen temperature (Janni *et al.* 2020). India's central and southern regions in which chickpea cultivation has significantly risen are mainly subject to heat stress. Temperature more than 32°C at the time of flowering, pod formation and grain filling stage cause several abnormalities like, sterility of pollens, flower drop and pod abortion which ultimately caused seed yield loss (Gaur *et al.* 2019, Pareek *et al.* 2019, Jha *et al.* 2021). In this investigation we used simple, effective and efficient screening method for identifying heat tolerant genotypes under late sown conditions.

Forty two advanced breeding lines of *desi* chickpea were screened for high temperature tolerance in timely planting (25 November, E I), late planting (25 December E II) and very late planting (25 January E III) heat stress during winter (*rabi)* season 2020–21 in randomized complete block design (RCBD) with 3 replications at seed breeding farm Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, Madhya Pradesh. The research plot consisted of one row of 4.0 m length and irrigation was given before flowering stage in timely, late and very late planting to avoid moisture stress.

Data were collected for yield and its attributing traits like, days to 50% flowering (DTF), days to maturity (DM), plant height (PH-cm), number of primary branches per plant (NPBPP), number of secondary branches per plant (NSBPP), total number of effective pods per plant (NEPPP), 100-seed weight (100 SW-g), harvest index (HI-%) and seed yield per plant (SYPP-g). The average weather data are depicted in Fig 1. Correlation and path analysis was calculated using Window-Stat 9.1 software. Heat tolerance indices including Yield index, Mean productivity, Geometric mean productivity and Yield reduction per cent were estimated as:

Yield Index (YI), Ys/Yms (Gavuzzi *et al.* 1977)

Mean productivity (MP), (Yp + Ys)/2 (Hossain *et al.* 1990);

Geometric mean productivity (GMP), Yp × Ys (Ramirez and Kelley 1998)

$$\text{Yield reduction (YR\%)} = \frac{Ys - Yp}{Yp} \times 100$$

where Yp, mean yield of genotype in normal planting condition; Ys, mean yield of genotype in high temperature stress condition; Ymp, mean yield of all the genotypes in normal planting condition; Yms, mean yield of all the genotype in high temperature stress condition.

The high GCV (%) and PCV (%) was reported for NEPPP (30.2%, 48.1% respectively), followed by TNPPP (26.0%, 40.2%), SYPP (24.1%, 32.7%), BYPP (22.5%, 29.8%) and 100 SW (21.7%, 25.7%). High heritability coupled with high genetic advance as % of mean was recorded for 100 SW (71.4%, 37.8%). Selection criteria based on these traits can help to isolate more promising lines for chickpea improvement (Table 1). These results are similar with the findings of Hailu (2020) and Katkani *et al.* (2022).

The traits BYPP, HI, 100 SW, TNPPP showed significant positive correlation and direct effect on SYPP. These traits may be included in selection criteria for simultaneously increased for seed yield per plant in chickpea. Based on pooled analysis, TNPPP, BYPP and 100 SW had high GCV (%), high heritability coupled with high GA as percentage of mean, significant positive and direct effect on SYPP in E II (late sown) and NEPPP and BYPP in E III (high

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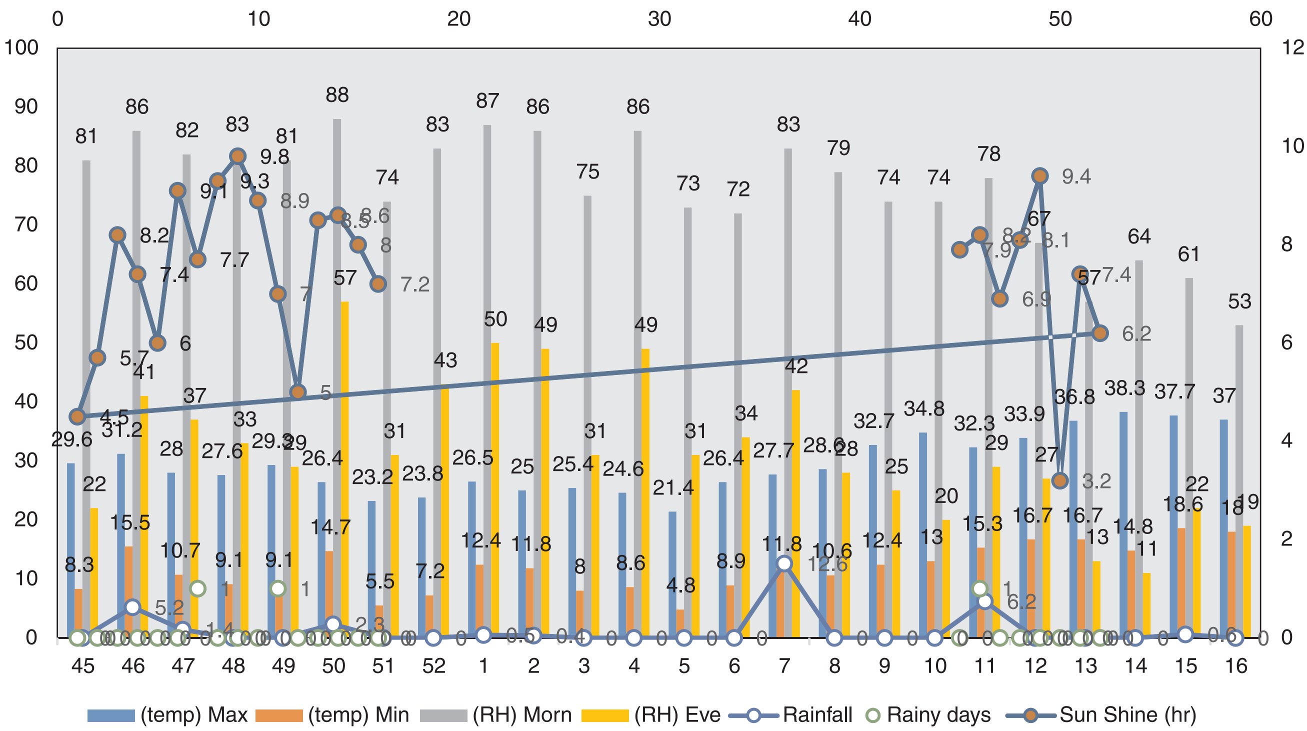

Fig 1 Weekly meteorological data observed during the crop season from November 2020 to April 2021.

temperature stress). These traits are main yield attributing elements; in future selection of these traits will be more effective for fashioning plant type of chickpea for rice-wheat cropping system and high temperature stress conditions to obtain more seed yield.

The promising lines having high seed yield per plant were JG 2020-26 (28.06 g), JG 2020-27 (27.08 g) and JG 2020-31 (26.51) in late planting and indicated their suitability for rice fallows with high TNPPP, BYPP, 100 SW and HI, whereas the breeding lines JG 2020-1 (13.68 g), JG 2020-26 (13.06 g) and JG 2020-31 (12.73 g) recorded high NEPPP, BYPP and SYPP and performed superior in high temperature stressed condition. Crop growth is negatively affected by high temperature by damaging morpho-physiological traits and ultimately decreasing yield (Jameel *et al.* 2021). High temperature shrink seed size and yield, mainly beyond 32°C (Devasirvatham *et al.* 2015). The mean minimum and maximum temperatures at grain filling stage under late and very late sown condition were higher than timely sown by 4.1°C and 5.3°C during 2020–21. Rising of temperature in late and very late sown condition responsible for early anthesis, increasing senescence, forced maturity and reduce grain filling duration by 10–15 days. The effect of climate change and high temperature on seed yield is estimated by

Table 1 Genetic parameters of variability for yield and its attributing traits (pooled analysis)

Character	Range			GCV (%)	PCV (%)	h^2 (bs) (%)	GA as % of mean
	Min.	Max.	Av.				
DTF	54.1	68.0	60.4	5.6	6.8	67.4	9.4
DM	94.0	105.1	99.0	2.8	3.9	49.8	4.0
PH	43.4	63.8	51.9	9.7	12.7	58.0	15.2
NPBPP	2.1	3.2	2.7	6.9	15.2	20.5	6.4
NSBPP	7.3	13.5	11.3	9.2	19.9	21.6	8.9
TNPPP	25.4	80.7	44.6	26.1	40.2	42.0	34.8
NEPPP	20.1	77.2	41.0	30.3	48.2	39.4	39.1
100 SW	13.1	31.3	21.5	21.8	25.8	71.4	37.9
BY	21.0	50.3	30.9	22.6	29.9	57.1	35.2
HI	41.9	63.7	48.8	9.1	15.2	35.7	11.2
SYPP	8.8	22.8	14.6	24.2	32.7	54.7	36.9

Refer to methodology for characters details.

Table 2 Heat tolerance indices between E I and EII and E I and EIII

Genotype	YI EI and EII	YI E I and E III	MP EI and EII	MP E I and E III	GMP EI and EII	GMP E I and E III	YR (%) EI and EII	YR (%) E I and E III
JG 2020-1	1.32	1.50	21.3	18.6	449.5	321.6	-18.67	-41.81
JG 2020-2	0.92	1.13	14.1	12.5	197.5	152.0	-9.74	-30.49
JG 2020-3	0.74	0.91	10.9	9.7	118.7	91.5	-2.98	-25.23
JG 2020-4	0.83	0.85	13.4	11.2	176.4	113.8	-19.04	-47.76
JG 2020-5	0.89	1.16	12.9	11.8	167.2	137.2	-1.38	-19.05
JG 2020-6	0.78	0.74	11.6	9.4	135.0	81.3	-6.41	-43.63
JG 2020-7	0.79	1.18	13.5	13.2	178.5	167.6	-26.29	-30.78
JG 2020-8	0.59	1.19	10.5	11.7	107.1	135.8	-31.71	-13.34
JG 2020-9	0.94	0.78	14.5	11.3	210.4	109.6	-12.87	-54.63
JG 2020-10	1.51	1.30	24.1	19.1	573.7	311.8	-17.00	-54.89
JG 2020-11	0.86	0.85	15.3	13.0	227.1	140.7	-31.30	-57.43
JG 2020-12	0.99	0.81	14.9	11.4	220.8	114.3	-7.76	-52.23
JG 2020-13	0.76	1.20	11.0	11.0	121.7	120.9	-1.62	-2.25
JG 2020-14	1.33	0.76	19.8	13.7	390.3	141.4	-5.75	-65.85
JG 2020-15	1.00	0.66	15.2	10.9	229.3	94.4	-7.92	-62.10
JG 2020-16	1.06	0.63	15.7	10.9	247.1	91.9	-5.02	-64.66
JG 2020-17	0.74	1.02	10.9	10.2	119.0	103.3	-3.78	-16.46
JG 2020-18	0.78	1.23	11.6	11.5	133.6	131.8	-3.74	-5.01
JG 2020-19	0.75	0.89	11.0	9.6	121.0	89.5	-1.80	-27.39
JG 2020-20	1.23	0.60	21.4	15.2	443.3	135.9	-28.21	-77.99
JG 2020-21	0.60	0.67	10.1	8.8	100.0	70.1	-24.13	-46.78
JG 2020-22	0.80	0.95	12.7	11.2	158.8	118.4	-16.27	-37.55
JG 2020-23	1.09	1.14	16.6	13.9	274.7	181.3	-9.80	-40.46
JG 2020-24	1.28	0.75	19.0	13.2	361.8	133.1	-5.62	-65.27
JG 2020-25	1.14	0.75	18.4	13.6	336.1	137.7	-18.51	-66.62
JG 2020-26	1.18	1.44	17.6	15.6	309.5	236.9	-5.95	-28.00
JG 2020-27	1.87	1.18	28.9	20.7	829.2	328.9	-11.56	-64.92
JG 2020-28	1.06	1.17	16.1	13.8	259.2	180.5	-9.79	-37.17
JG 2020-29	1.34	1.15	19.9	15.5	396.7	213.9	-5.13	-48.85
JG 2020-30	1.41	1.00	22.7	17.0	508.2	226.3	-18.75	-63.81
JG 2020-31	1.14	1.40	17.6	15.8	309.9	238.9	-12.04	-32.18
JG 2020-32	1.65	0.92	28.3	20.5	781.2	273.1	-26.94	-74.46
JG 2020-33	1.02	0.92	16.1	13.0	258.5	147.1	-16.28	-52.36
JG 2020-34	1.07	1.10	16.4	13.6	267.8	172.5	-10.74	-42.49
JG 2020-35	1.61	1.09	23.5	16.9	553.1	235.7	-2.60	-58.50
JG 2020-36	1.00	0.61	15.1	10.7	228.6	88.1	-8.30	-64.66
JG 2020-37	1.63	1.09	23.9	17.0	568.7	238.9	-2.89	-59.21
JG 2020-38	0.87	0.91	12.8	10.7	164.4	108.5	-4.79	-37.14
JG 2020-39	0.92	0.48	13.5	9.0	181.9	59.2	-3.21	-68.49
JG 2020-40	1.49	1.27	22.5	17.4	502.9	269.1	-7.83	-50.68
Check-1	1.20	1.19	23.0	19.7	495.4	310.8	-39.52	-62.05
Check-2	1.41	1.62	20.9	18.1	435.1	314.5	-5.09	-31.39

YI, Yield index; MP, Mean productivity; GMP, Geometric mean productivity; YR, Yield reduction per cent.

calculating various heat tolerance indices (Table 2). The lines JG 2020-27 (1.87), JG 2020-32 (1.65), JG 2020-37 (1.63) in E I and E II and JG 24 (1.62), JG 2020-1 (1.50), JG 2020-26 (1.44) in E I and E III recorded highest YI. Highest MP and recording lines are JG 2020-27 (28.8), JG 2020-32 (28.3), JG 2020-10 (24.0) in E I and E II and JG 2020-27(20.6), JG 2020-32 (20.5), JG 36 (19.7) in E I and E III. Likewise, in E I and E II, maximum GMP noted by JG 2020-27 (829.1), JG 2020-32 (781.2), JG 2020-10 (573.6) and JG 2020-27 (328.8), JG 24 (314.5), JG 36 (310.8) in E I and E III. Therefore the advance lines depicting higher YI, MP and GMP can be proficiently utilizes in selecting promising genotypes under high temperature stress conditions (Jha *et al.* 2017).

The lowest yield reduction (YR %) was reported in JG 36 (in E I and E II) and JG 2020-20 (in E I and E III). The lines, viz. JG 2020-27, JG 2020-32 recorded higher YI, MP and GMP in E I and E II, whereas the genotypes JG 24, JG 2020-1, JG 2020-27 revealed higher YI, MP and GMP under E I and E III. Promising breeding lines recognized on the basis of heat indices would be utilized for chickpea improvement in context of climate change.

The main target of a plant breeder is to enhance the genetic potential of the crop for higher economic returns. The traits TNPPP, BYPP and 100 SW in late sown and NEPPP and BYPP in high temperature stress must be selected to obtain more seed yield. The statistics obtained on these aspects will be highly valuable to formulate the suitable selection conditions to be proficient for genetic improvement of seed yield in chickpea. This research articulate simple and effective screening manner for identifying high temperature (heat stress) tolerant chickpea genotypes in field condition, also recognized a group of most favorable chickpea genotypes according to their suitability towards pooled and specific environment based on different quantitative traits that can be easily utilized in any breeding program to identify heat tolerant genotypes for improving yield ability of chickpea under the scenario of global climate change.

SUMMARY

In context of climate change, yield potential of chickpea is hampered by heat stress. Increasing area of rice fallows, shifting in cropping system and global warming, needs to identify the chickpea genotypes tolerant to high temperature. With this objective an experiment was conducted during winter (*rabi)* season of 2020–21 at the seed breeding farm of Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, Madhya Pradesh in randomized complete block design (RCBD) with 3 replications. Forty two genotypes of chickpea were grown under timely (E I), late (E II) and very late planting (heat stress condition-E III). Selection of chickpea genotypes based on BYPP, HI and 100 SW will be more effective for constructing plant type suited to late sown conditions. On the basis of different heat indices, genotype JG 2020-27, JG 2020-32 in E I and E II and genotype JG 24, JG 2020-1, JG 2020-27 in E I and E III recorded higher YI, MP and GMP, respectively. Promising breeding lines recognized on the basis of various heat indices would be utilized in different chickpea improvement breeding programme in current changing climatic conditions.

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