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Assessment of Chickpea (*Cicer arietinum* L.) Genotypes under Normal and Late Sown Environments using Stress Indices

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ABSTRACT

Background: Heat stress is a major restrain in chickpea (*Cicer arietinum* L.) productivity. Developing tolerant chickpea genotypes contributes breeding materials for hybridization programme. Stress indices related to abiotic stresses are found effective in screening of genotypes for high temperature tolerance in chickpea.

Methods: An experiment with 24 genotypes under two different environments *i.e.,* timely and late sown conditions was planned to identify the chickpea genotypes tolerant to heat stress, using thirteen stress indices. Stress Susceptibility Index (SSI) is the cardinal index to group genotypes based on their tolerance level. Stress indices Mean Productivity (MP), Geometric Mean Productivity (GMP), Harmonic Mean (HM) Index, Heat Resistant Index (HRI) and Modified Heat Tolerance Index (MHTI) are very effective in identifying stress tolerant genotypes.

Result: The result indicated that genotypes H 04-75, H 08-75, H 12-26, H 09-96, ICCV 92944, DCP 92-3 and GNG 2226 are tolerant to heat stress. The identified genotypes can be used as parents in hybridization programme for breeding chickpea cultivars tolerant to high temperature environments.

Key words: Chickpea, Genotypes, High temperature, Stress indices, Tolerant.

INTRODUCTION

Raising temperature and continuous climate change are disadvantageous for normal plant growth and development, leading to adverse loss of chickpea productivity. Chickpea production reduced up to 15% for rise in per degree optimum temperature (Devasirvatham and Tan, 2018). Chickpea yields well at cool conditions with substantial protein content. the annual production of chickpea had huge fluctuations over the years due to climate change. Yield loss of 53 kg ha^{-1} was recorded with 1°C rise in seasonal temperature (Basu *et al.,* 2009; Devasirvatham and Tan, 2018). Chickpea is sown in mid of October in dryland area and first week of November in semi-arid regions. The critical period of heat stress in chickpea is reproductive stage. High temperatures (≥35°C) during this stage adversely affect pollen fertility and grain yield (Devasirvatham *et al.,* 2013; Sita *et al.,* 2017).

Growing conditions and the inherent capacity of the genotypes decides the performance of chickpea under high temperature conditions. Late sowing causes exposure of reproduction phase to heat stress, resulting in a catastrophic reduction in the potential yield of the crop. The chickpea germplasm displays substantial variation and varied sensitivity under heat stress. Screening of chickpea germplasm for heat tolerance identifies genotypes for extended cultivation of the crop to previously unsuitable regions and withstand the change in the climatic scenario. Stress indices help to evaluate the level of tolerance in genotypes via various parameters and identify varieties/ genotypes with greater tolerance to stresses (Thiry *et al*., 2016). Using heat stress indices, the crop genotypes can be classified based on their response to temperature stress. Thus, the selected genotypes are used as parents in hybridization programmes with an objective of heat tolerance in chickpea.

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MATERIALS AND METHODS

The present investigation was carried out at the Research Farm of Haryana Agricultural University, Pulses Section, Hisar. The research material constituted 24 chickpea genotypes including four checks (HC 1, ICCV 4958, ICCV 92944, HC 5). The field experiment was conducted in the year 2018 - 2019 under normal and late sown conditions in randomized block design (RBD) with three replications. The normal sowing was carried out in the second week of November 2018 and the late sown crop in the second week of December 2018. Recommended agronomic practices were followed uniformly under both timely sown (non-heat stress) and late sown (heat stress) conditions. Single plant yield was recorded from 10 randomly selected plants in each replication for individual genotypes under stressed and non-stressed conditions.

Based on the yield data, thirteen heat tolerance indices were calculated by the following formulae (Table 1).

RESULTS AND DISCUSSION

The results obtained from calculating heat stress indices indicated that the performance of chickpea genotypes are highly influenced by sowing environments (Table 2a and 2b).

Stress susceptibility index (SSI)

Y_{ns} and Y_s are the mean yield of genotypes under timely and late sown conditions. Genotypes with SSI < 1 are more tolerant to heat stress conditions. Experimental results showed that the chickpea genotype H 04-87 had the lowest SSI (0.36) followed by DCP 92-3 (0.46), GNG 2226 (0.53), H 04-75(0.63), H 08-75 (0.64) and GNG 2144 (0.64), considered tolerant to heat stress. The genotype H 13-01 indicated high susceptibility with SSI value of 1.33 followed by H 13-02 (1.32), GNG 663 (1.28), H 12-17 (1.27) and H 14-21 (1.23). Other genotypes exhibited an intermediate response to heat stress. Grouping of genotypes based on SSI help out breeders in selection of suitable genetic material for stress tolerance programme (Zdravkovic *et al.,* 2013).

Mean productivity (MP) index

A high value for mean productivity indicates that the genotype is suitable for late sown conditions. In context of it, high variability was exhibited by the breeding materials for MPI. The genotype GNG 1958 displayed high mean productivity followed by H 12-26, H 13-02, H 12-17 and H 04-75, while, H 04-87, GNG 2144, H 12-22, ICCV 4958 and GNG 2226 exhibited low mean productivity.

Geometric mean productivity (GMP) index

Genotypes with high values for geometric mean productivity are considered to be tolerant for heat stress. In that case, GNG 1958, H 12-26, H 04-75, H 08-75, H 09-96 and ICCV 92944 are the top genotypes with high GMP index and genotype H 04-87, H 12-22, GNG 2144, H 13-01 and ICCV 4958 had the lowest values for geometric mean productivity.

Harmonic mean (HM) index

The genotypes with high harmonic mean are suitable for timely sown and late sown conditions. Genotypes H 04-75, GNG 1958, H 08-75, H 12-26, H 09-96 and ICCV 92944 had higher values for harmonic mean. These genotypes are considered to be stable in different environmental conditions. Whereas, H 13-01, H 12-22, GNG 663, H 13-02 and HC 5 are genotypes not suitable for late sown conditions. Other genotypes exhibited average performance in different environments. Scientific reports by Darvishzadeh *et al.* (2010) recommend that stress indices MP, GMP and HM are effective in screening breeding lines under stress and non-stress conditions.

Heat tolerance index (HTI)

Variability for heat tolerance index among the chickpea genotypes were found significant and lines with high HTI values are desirable for high temperature tolerance. HTI values are high for genotypes GNG 1958, H 12-26, H 04-75 and H 08-75 indicating tolerance nature to withstand heat conditions. Genotypes H 04-87, H 12-22, GNG 2144, H 13-01 and ICCV 4958 are not preferred for heat environments as they exhibited lower HTI values. Drikvand *et al.* (2012) reported that MP, GMP and STI are the most suitable indices for evaluating genotypes under stress conditions.

Yield index (YI)

Breeding lines with higher yield index have greater stability to withstand high temperature environments. Genotypes with <1 YI values are considered to be susceptible while YI value >1 indicates tolerant nature. Concerning it, genotype H 04-75 is more tolerant to heat stress with highest YI followed by H 08-75, GNG 1958, ICCV 92944, H 09-96, H 12-26, H 13-36, DCP 92-3 and GNG 2226. Susceptible genotypes

Table 1: List of heat stress indices.

Heat stress indices	Formulae	Desirable value	References
Stress susceptibility index (SSI)	$[1 - (y_s/y_{ns})] / [(1 - Y_s/Y_{ns})]$	<1	Fischer and Maurer, 1978
Mean productivity (MP)	$(y_{ns} + y_s) / 2$	High	Hossian *et al.,* 1990
Geometric mean productivity (GMP)	$\sqrt{y_{ns} \times y_s}$	High	Ramirez-Vallejo and Kelly, 1998
Harmonic mean index (HM)	$[2 (y_{ns}) (y_s)] / (y_{ns} + y_s)$	High	Raman *et al.,* 2012
Heat tolerance index (HTI)	$y_{ns} \times y_s / (Y_{ns})^2$	High	Fernandez, 1992
Yield index (YI)	y_s / Y_s	High	Gavuzzi *et al.,* 1997
Yield stability index (YSI)	y_s / y_{ns}	High	Bouslama and Schapaugh, 1984
Tolerance index (TOL)	$y_{ns} - y_s$	Low	Rosielle and Hamblin, 1981
Relative heat index (RHI)	$(y_s / y_{ns}) / (Y_s / Y_{ns})$	High	Fischer *et al.,* 2003
Heat resistance index (HRI)	$[y_s \times (y_s / y_{ns})] / Y_s$	High	Lan, 1998
Stress susceptibility percentage index (SSPI)	$[y_{ns} - y_s / (2Y_{ns})] \times 100$	Low	Moosavi *et al.*, 2008
Stress non-stress production index (SNPI)	$[(y_{ns} + y_s) / (y_{ns} - y_s)]^{1/3} \times [y_{ns} \times y_s \times y_s]^{1/3}$	High	Moosavi *et al.,* 2008
Modified heat tolerance index (MHTI)	$NS = (y_{ns})^2 / (Y_{ns})^2 \times HTI$ $S = (y_s)^2 / (Y_s)^2 \times HTI$	High	Farshadfar and Sutka, 2002

were H 13-01, GNG 663, H 13-02, HC 5 and H 12-63. The remaining genotypes showed intermediate nature. Jha *et al.* (2018) suggested MP, GMP, YI and SSI as efficient selection indices for recognizing heat tolerant cultivars in chickpea.

Yield stability index (YSI)

The performance of genotypes in late sown conditions can be identified by yield stability index. Genotypes with high YSI values are desirable for late sown conditions. H 04-87 displayed the highest YSI value followed by DCP 92-3, GNG 2226, H 04-75, GNG 2144 and H 08-75. YSI values were low for H 13-01, H 13-02, GNG 663, H 12-17 and H 14-21 indicating poor performance in late sown conditions.

Tolerance index (TOL)

Tolerance index is recommended for evaluating genotypes suitable for high temperature stress. The lines exhibiting low values for TOL are more stable in different growing conditions (timely and late sown). Variability for tolerance index was found significant among the breeding materials and genotypes H 04-87, DCP 92-3, GNG 2226, H 04-75 and ICCV 4958 and displayed lower tolerance values indicating suitability for high temperature conditions. H 13-02, H 12-17, GNG 663, H 14-21, GNG 1958 and H 13-01 were genotypes having higher values for TOL index which will not be suitable for growing in high temperature conditions. A study by Khan and Dhurve (2016) concluded that the stress indices SSI, TOL and YSI are effectual in screening genotypes for drought resistance in rice under two variable growing conditions.

Relative heat index (RHI)

RHI is a positive index for investigating the nature of stress tolerance in crop plants. Genotypes with high RHI are suitable for growing in stress environments. On basis of RHI values, genotypes H 04-87, DCP 92-3, GNG 2226, H 04-75, GNG 2144 and H 08-75 are most desirable for growing in stress conditions. Genotypes H 13-01, H 13-02, GNG 663, H 12-17, H 14-21 and HC 5 were revealing lowest values for relative heat index.

Heat resistance index (HRI)

Breeders are most interested in heat resistance index as it identifies the breeding materials producing potential yield under both timely (non-stress) and late (stress) sown conditions. Genotypes H 04-75, H 08-75, DCP 92-3, ICCV 92944, H 09-96 and H 04-87 had HRI values >1 indicating tolerance to heat stress. Genotypes H 13-01, H 13-02, GNG 663, H 12-17, H 14-21, HC 5 and H 12-63 are more vulnerable to heat stress. Papathansiou *et al.* (2015) proposed that grouping of genotypes on basis of various stress indices is effective for the selection of genotypes showing stable performance with high potential yield under different environmental conditions.

Table 2a: Variability of heat stress indices of chickpea genotypes based on seed yield under timely and late sown conditions.

Genotypes	y_{ns}	y_s	SSI	MP	GMP	HM	HTI	YI
GNG 1958	84.32	27.89	1.03	56.11	48.49	41.92	0.79	1.46
HC 1*	43.06	17.62	0.91	30.34	27.55	25.01	0.25	0.93
H 12-22	35.11	13.49	0.94	24.30	21.76	19.49	0.16	0.71
GNG 663	72.77	11.84	1.28	42.31	29.36	20.37	0.29	0.62
H 12-17	80.03	13.68	1.27	46.86	33.09	23.37	0.37	0.72
ICCV 4958*	34.39	16.49	0.80	25.44	23.81	22.29	0.19	0.87
ICCV 92944*	49.40	27.26	0.69	38.33	36.70	35.14	0.45	1.43
H 12-55	52.50	14.71	1.10	33.61	27.79	22.98	0.26	0.77
H 13-36	51.05	25.15	0.78	38.10	35.83	33.70	0.43	1.32
PUSA 547	44.26	14.61	1.03	29.44	25.43	21.97	0.22	0.77
H 12-63	58.54	13.39	1.18	35.97	28.00	21.80	0.26	0.70
DCP 92-3	32.07	22.44	0.46	27.25	26.82	26.40	0.24	1.18
H 13-01	64.04	8.48	1.33	36.26	23.30	14.97	0.18	0.45
H 04-75	57.03	33.55	0.63	45.29	43.74	42.25	0.64	1.76
H 13-02	86.83	11.93	1.32	49.38	32.19	20.98	0.35	0.63
H 04-87	24.49	18.75	0.36	21.62	21.43	21.24	0.15	0.98
GNG 2144	29.77	17.31	0.64	23.54	22.70	21.89	0.17	0.91
H 08-75	53.21	30.92	0.64	42.06	40.56	39.11	0.55	1.62
H 14-11	71.09	17.36	1.16	44.23	35.13	27.91	0.41	0.91
H 09-96	50.13	27.15	0.70	38.64	36.89	35.22	0.46	1.43
H 12-26	74.79	26.32	0.99	50.56	44.37	38.94	0.66	1.38
H 14-21	70.37	13.82	1.23	42.09	31.18	23.10	0.33	0.73
GNG 2226	30.88	20.14	0.53	25.51	24.94	24.38	0.21	1.06
HC 5**	61.55	12.66	1.22	37.10	27.91	21.00	0.26	0.66

*Check variety as well as parents in crosses. **Check variety.

Table 2b: Variability of heat stress indices of chickpea genotypes based on seed yield under timely and late sown conditions.

Genotypes	YSI	TOL	RHI	HRI	SSPI	SNPI	MHTI (NS)	MHTI (S)
GNG 1958	0.33	56.43	0.95	0.48	51.63	50.71	1.87	1.69
HC 1*	0.41	25.44	1.17	0.38	23.28	31.72	0.16	0.22
H 12-22	0.38	21.62	1.10	0.27	19.78	24.31	0.07	0.08
GNG 663	0.16	60.93	0.47	0.10	55.74	24.20	0.51	0.11
H 12-17	0.17	66.35	0.49	0.12	60.70	27.66	0.79	0.19
ICCV 4958*	0.48	17.90	1.38	0.42	16.38	29.84	0.08	0.14
ICCV 92944*	0.55	22.14	1.58	0.79	20.25	50.29	0.37	0.92
H 12-55	0.28	37.78	0.80	0.22	34.57	27.24	0.24	0.15
H 13-36	0.49	25.90	1.41	0.65	23.70	45.62	0.38	0.75
PUSA 547	0.33	29.65	0.95	0.25	27.13	26.57	0.14	0.13
H 12-63	0.23	45.15	0.66	0.16	41.31	25.58	0.30	0.13
DCP 92-3	0.70	9.63	2.01	0.82	8.81	45.05	0.08	0.33
H 13-01	0.13	55.56	0.38	0.06	50.84	18.18	0.25	0.04
H 04-75	0.59	23.49	1.69	1.04	21.49	62.79	0.70	1.99
H 13-02	0.14	74.89	0.39	0.09	68.52	25.36	0.88	0.14
H 04-87	0.77	5.74	2.20	0.75	5.25	40.18	0.03	0.15
GNG 2144	0.58	12.46	1.67	0.53	11.40	32.30	0.05	0.14
H 08-75	0.58	22.29	1.67	0.94	20.39	57.68	0.52	1.45
H 14-11	0.24	53.73	0.70	0.22	49.16	32.80	0.70	0.34
H 09-96	0.54	22.98	1.55	0.77	21.03	49.89	0.38	0.93
H 12-26	0.35	48.47	1.01	0.49	44.35	47.63	1.23	1.26
H 14-21	0.20	56.55	0.56	0.14	51.74	27.14	0.54	0.17
GNG 2226	0.65	10.74	1.87	0.69	9.82	39.05	0.07	0.23
HC 5**	0.21	48.89	0.59	0.14	44.73	24.65	0.33	0.12

*Check variety as well as parents in crosses. **Check variety.

Stress susceptibility percentage index (SSPI)

Lower the values of SSPI greater the potential of genotypes to withstand the stress conditions. H 04-87, DCP 92-3, GNG 2226, GNG 2144, ICCV 4958 and H 12-22 were the genotypes identified that can withstand the heat stress conditions. Genotypes H 13-02, H 12-17, GNG 663, H 14-21 and GNG 1958 are not suitable for stress environments. Farshadfar *et al.* (2018) indicated that SSPI, RSI and SRI are appropriate indicators for evaluating stress tolerant genotypes.

Stress non-stress production index (SNPI)

SNPI identifies the genotypes with high yield and potential performance in both stress and non-stress conditions. Genotypes H 04-75, H 08-75, GNG 1958, ICCV 92944 and H 09-96 exhibited stable performance in both growing conditions. The potential performance of genotypes H 13-01, GNG 663, H 12-22, HC 5, H 13-02 and H 12-63 was reduced due to the stress environment. The stress index, SNPI is appropriate for the selection of breeding materials for the economical purpose under both stress and non-stress environments in chickpea (Farshadfar and Geravandi, 2013).

Modified heat tolerance index (MHTI)

HTI serves the purpose of screening breeding materials for the selection of genotypes with high yield under heat stress conditions. To increase the efficiency of HTI, Modified Heat Tolerance Index (MHTI) under stress and non-stress conditions were recommended by Farshadfar and Sutka (2002). Genotypes with high MHTI values are desirable. Accordingly, genotypes H 04-75, GNG 1958 and H 12-26 are found suitable for both stress and non-stress conditions. Genotypes H 13-02, H 12-17 and H 14-11 in non-stress conditions and genotype H 12-26 in stress condition exhibited higher values of MHTI, respectively, indicating the suitability of particular growing conditions. The potential yield of genotypes H 13-01, H 12-22, GNG 663, HC 5, PUSA 547, H 12-63, ICCV 4958 H 13-02 and GNG 2144 was reduced to a greater extent due to high temperature stress. Stress indices MP, GMP, HM, STI, SNPI and MSTI are suggested by Gholienzhad *et al.* (2014) for selecting genotypes in severe stress conditions.

CONCLUSION

Conventional screening of chickpea germplasm for heat stress tolerance is simple and cost-effective. A combination of heat stress indices helps in grouping of genotypes based on their tolerance ratio. The study identified ten chickpea genotypes (H 04-75, H 04-87, H 08-75, H 09-96, H 12-26, ICCV 92944, DCP 92-3, GNG 1958, GNG 2144 and GNG 2226) showing resistance in heat stress condition. Genotypes H 13-01, GNG 663, H 13-02, H 14-21, H 12-22, HC 5 and ICCV 4958 were vulnerable to heat stress. Further, stress indices SSI, GMP, HTI, YSI, RHI, TOL, SSPI

and MHTI are recommended for screening genotypes for abiotic stress tolerance in chickpea.

Conflict of interest

All authors declared that there is no conflict of interest.

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