Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; SP1: 2889-2894

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Phenophases and sink activity on grain yield of chickpea genotypes under normal and elevated temperature conditions

SK Pandey, S Pandey, AS Gontia, S Ramakrishnan and A Rani

Abstract
A field study was conducted to examine the effect of increasing temperature on chickpea phenology, crop growth rate (CGR), sink activity (Assimilate remobilization) and grain yield under normal and late sown condition with thirty one (31) prominent chickpea genotypes. The observations were recorded on phenological and growth analysis traits affecting grain yield of chickpea. The duration of phenological traits *viz.*Firstflower Initiation (FFI), First Pod Initiation (FPI), Flower End (FE) and Physiological Maturity were found shorter under late sown conditions as compared to normal. Maximum assimilate remobilization rate and was found in Vaibhav under normal sown and RSG 888, Vijay and Vaibhav under late sown condition.Maximum crop growth rate (CGR) was found in L 550, JG 11, GNG469 under normal and PG 96006, ICC4958, JG 218 and L 550 under late planting situation. Under late sown conditions grain yield was reduced and low heat susceptibility index (HSI) < 0.50 was found in Vijay, JGK2 and JG74. The minimum grain yield reduction (%) was observed in JG 14 and Annegiri genotype under elevated temperature conditions, therefore these genotypes can be utilized as a donor parent in crop improvement programme..

Keywords: Phenophases, grain yield, chickpea genotypes, temperature conditions

1. Introduction
Chickpea (*Cicerarietinum*L.) is a cool season legume crop and is grown in several countries worldwide as a food source. In India 2015-16 cultivated area about 8.39 million ha with a production about 7.06 million tone and 840 kg ha^{-1} productivity.
In Madhya Pradesh it was cultivated in an area of 3017 thousand ha and production 3364 thousand tones and Productivity 1115 kg ha^{-1}(Anonymous2017).
It incurs heavy yield losses when exposed to high temperatures (≥35°C) at reproductive stage. Daily or seasonal temperatures above optimum become a limiting factor for crop production when they coincide with critical stages of development (Thuzar, 2010). Intergovernmental Panel on Climate Change (IPCC) has projected 1.6 to 3.8oC increase in global average air temperature at the critical stage may cause considerable yield losses (Anonymous 2007). In chickpea days to flower initiation, 50 per cent flowering, pod initiation, physiological maturity, indicated that from first date of sowing and it decreased continuously up to eighth date of sowing and Fourth dates of sowing took significantly maximum number of days for all phenological stages reported by Kulkarni and Chimmad (2014). A quantitative understanding of the response of phenological development to environmental factors helps predict crop yield. The phenological stages of chickpea *(Cicerarietinum*L.) growth may be broadly classified as emergence, flowering, pod set, and physiological maturity. Being indeterminate, the last three stages occur simultaneously in different parts of the plant along with vegetative growth (Summerfield & Wien 1980).Mild temperature stress(MTS) showed significant impact on reproductive dynamics followed by reduced yield. Thus, predicted moderate increase in air temperature under future climate change scenario might be critical for the cool-season chickpea crop (Bahuguna, *et al.,* 2012). Anonymous (2014) reported the prominent effect of high temperature with day length shift is to advancement of flower initiation by 15-20 days while reproductive phase duration was shortened by about 15 days. Due to short reproductive phase, pod filling process is either faster or grains are incompletely filled resulting in reduced seed size. Hastening physiological maturity at high temperature limits the grain filling of chickpea.The advantage of high rate of sink activity for seed yield under drought environments was clearly highlighted in chickpea (Krishnamurthy *et al.,* 1999). Other physiological associated traits also ameliorate the effect effect of abiotic stresses reported by Verma*et al.* (2018).

effect of abiotic stresses reported by Vermaet *al.* (2018).

Thus, more highly mobile stored assimilates in the plant organs could remediate the potential disadvantage from more biomass. Hence, the present investigation was formulated to know the effect of elevated temperature on phenology and yield of chickpea genotypes.

Materials and Methods

Thirty one promising chickpea genotypes viz., PG 96006, GNG 663, RSG 888, Pusa 2440, PBG 5, K 850,Vijay, Avrodhi, GCP 101, ICCV 92944, Annegiri, CSJD 884, JGK 2,ICC 4958, RSG 991, JG 74, Pusa 240, PG5, JG 218, BGD 103, JG 11, JGG 1, L550, Dohadyellow, RSG 945, Vaibhav, GG 2, Pusa Green 112, RSG 143-1, GNG 469, JG 14 were grown under two regimes viz., normal (Third week of November) and late sown (third week of January). The experiment was laid out in a randomized complete block design with three replications under All India Coordinated Research Project on Chickpea (Physiology), in the experimental field of Seed Breeding Farm, Department of Plant Breeding and genetics, JNKVV Jabalpur. Size of each plot was kept 3.6 m^2, with 4 row of 3 m length. Row to row distance was 30 cm and plant to plant was 7-8 cm. The recommended packages of practices were followed to raise a healthy crop. Data were recorded on traits first flower initiation (FFI), first pod initiation (FPI), flower end (FE), physiological maturity, crop growth rate, days partition Coefficient (p) or rate of partitioning (assimilate remobilization rate/ sink activity) and grain yield per plot. Data were subjected to statistical analysis using Windostat version 9.1 analytical software at the 5% probability level.The main traits recorded were as follows:

Heat Susceptibility Index (HSI): Heat susceptibility index (HSI) and percent reduction due to moisture stress were estimated by the
formula suggested by Fischer and Maurer (1978).

HSI=(1-Yd/Yp)/D

Where, Yd = Grain yield of the genotype in late sown conditions. Yp = Grain yield of the genotypes in normal sown conditions.

$$\text{Heat Index (D)} = 1 - \frac{Meangrainyieldofchickpeagenotypesunderlatesowncondition}{meangrainyieldofchickpeagenotypesundernormalsowncondition}$$

Growth analysis: The hot-air oven dried shoot weights were used for the estimation of crop growth rate (CGR) as:

CGR = total shoot dry weight at final harvest /Growth Period (days) (g m-2 day-1)

And partition Coefficient (p) or rate of partitioning to estimate the assimilate remobilization rate (sink activity) was calculated by a formula presented by Krishnamurthy *et al.* (1999).

$$PartitionCoefficient(p) = \frac{Seedyield\ /reproductiveperiodsin\ 0\ cday}{CGR}$$

Where the reproductive period = ◦ C day for final harvest − ◦ C day to reach 50% flowering.

Grain Reduction (%) = (Normal Grain yield – Late grain yield/ Normal Grain yield) x 100.

Grain Yield (kg ha-1): The grain yieldwas recorded after threshing, cleaning and drying the grains. It is also known as economical yield.

Results and discussion

(a) Phenologicaltraits: The phenology ofchickpeagenotypes grown under late sown condition was observed to be shorter and reproductive phase was also shorterwith respect toFirst Flower Initiation (FFI), First Pod Initiation (FPI), Flower End (FE) and Physiological Maturity days **(Fig. 1)** as also reported by Srinivasan *et al.* (1998). According to Wery *et al.* (l993) critical temperature during the reproductive phase including flowering and pod filling plays an important role in productivity. Kumari *et al.,*(2017) observed that chickpea is susceptible to high-temperature stress at reproductive stages as various metabolic processes and adversely impact reduces crop yield.

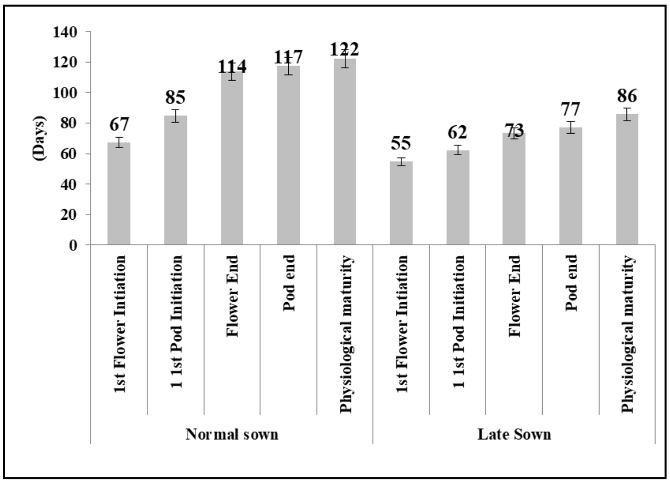

Fig 1: Performance of chickpea genotypes under normal and late sown condition for phenology

(b) Heat Susceptibility Index (HSI): Heat susceptibility Index developed by Fischer and Maurer (1978) can be used to assess the stress tolerance of crops in yield and yield components. Genotypes with stress susceptibility Index value <0.5,>0.5- <1.0 and >1.0 can be classified as highly tolerant, moderately tolerant and susceptible respectively. Under elevated temperature condition chickpea genotypes Vijay, JGK2 and JG 74 were found highly tolerant **(Fig. 2(a),** whileminimum grain yield reduction (%) was found in JG14 and Annegiri genotypes.**(Fig.2 (b**).Same observations on reduction of seed yield under water stress condition were found by Rahangdale *et al*., (1994) and it was upto15.2%.

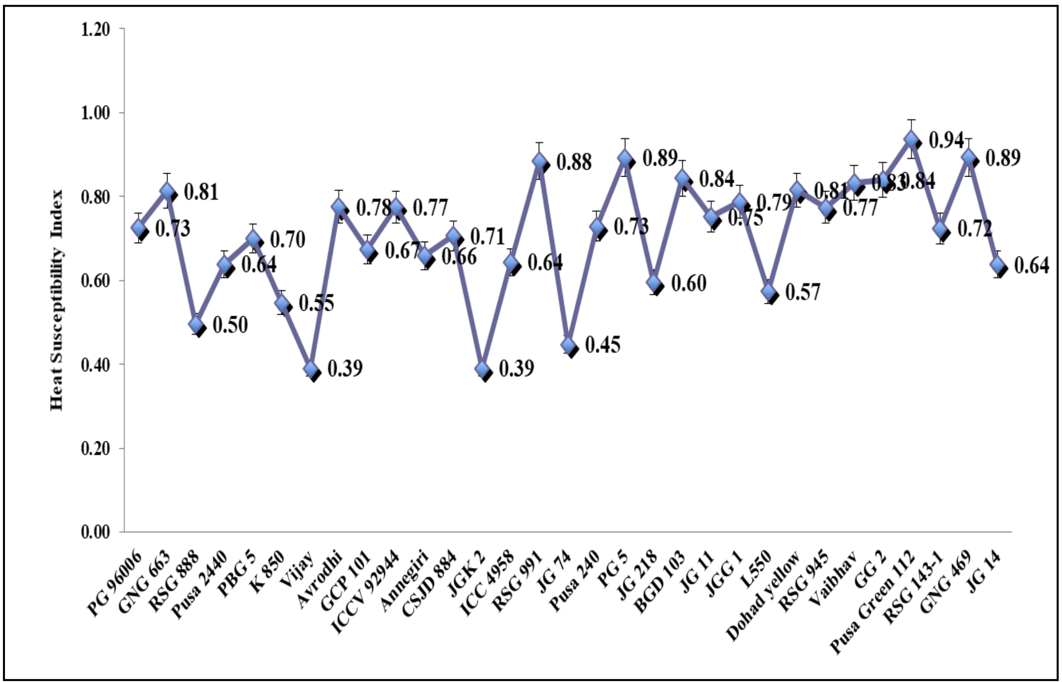

Fig 2(a): Effect of elevated temperature on chickpea genotypes using heat susceptibility index

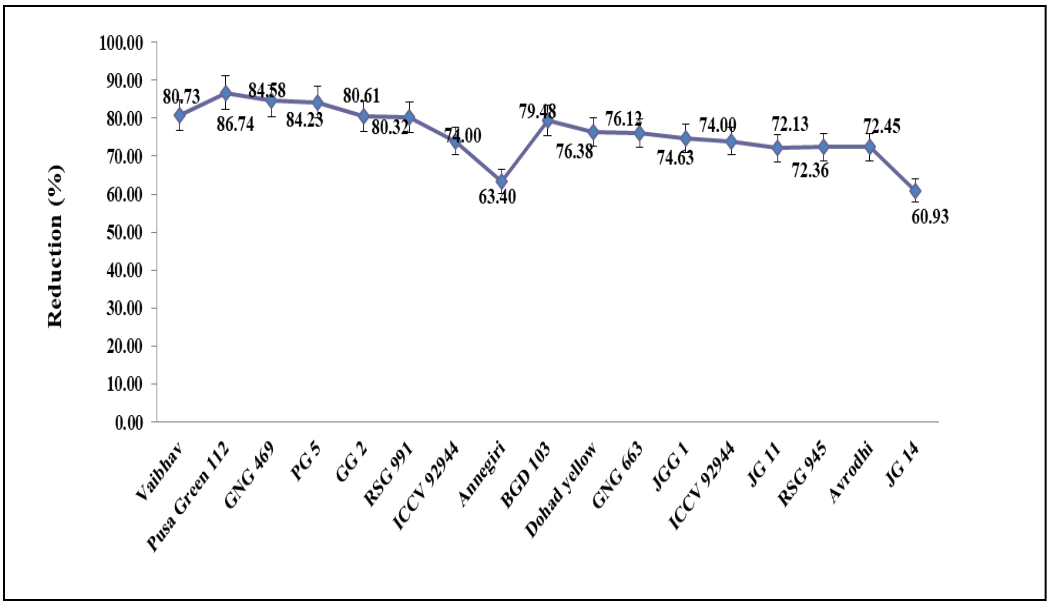

Fig 2(b): Percentage reduction in grain yield under high temperature condition

(c) Growth analysis

The increase in air temperaturesat flowering time was higher under late sown than under normal sown conditions. This means that though the differences in time to flowering and yield potential explained large part of the increasing temperature on yield variation under late sown conditions, the mean of crop growth rate (CGR) under normal sown conditions was slightly higher than late sownconditions (Fig. 3 a&b). On the other hand, the mean assimilate remobilization (Sink activity)(p) under normal sown conditions was higher as compared to the sink activity under late sown conditions (Fig. 3 (a &b). High CGR was reported in Vaibhav under normal sown; and RSG 888 and Vaibhav genotypes under late sown condition. Similar finding reported by Chakrabarti *et al.*, (2013) elevated temperature stress throughout the growth period reduced crop growth duration and accelerated maturity of chickpea genotypes.

Maximum assimilate remobilization rate was observed in Vaibhav, while maximum crop growth rate (CGR) was found in chickpea genotypes L550, JG11, GNG469 and JG14 under normal sown conditions. Under late planting, maximum sink activity was observed in RSG 888, Vijay and Vaibhav and maximum crop growth rate was found in PG 96006, ICC4958, JG218 and L550 chickpea genotypes. This would be the influence of the elevated temperature pattern altered by late sowing. The severe increasing temperature intensity after flowering under late sown conditions might have forced the plants to remobilize the shoot dry matter to seeds rapidly compared to normal sown conditions. A similar finding of the rate of partitioning explaining more variation in yield was reported earlier (Krishnamurthy *et al.*, 1999).

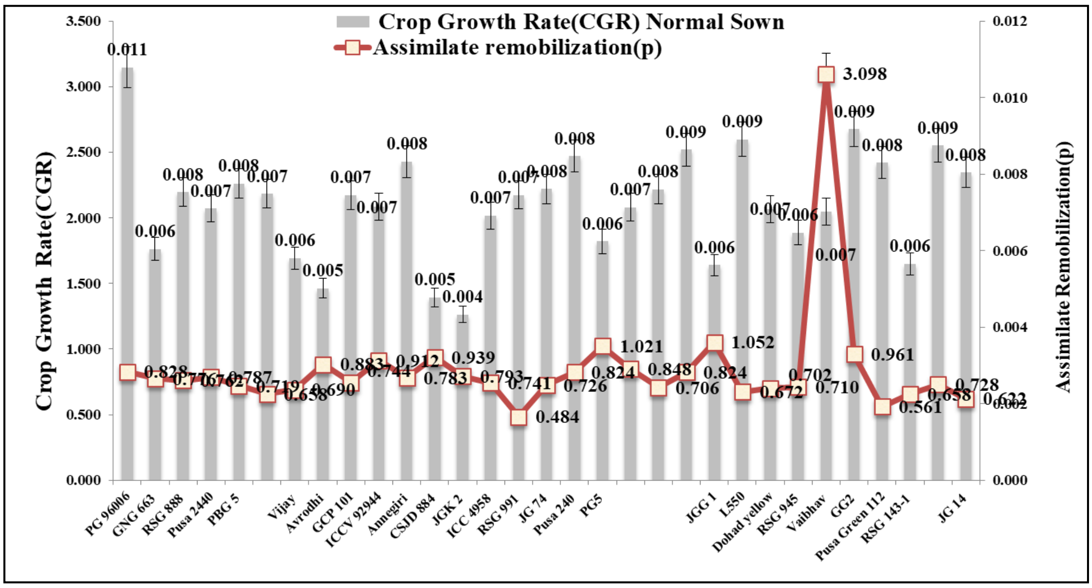

Fig 3(a): Effect of Crop Growth Rate ($gm^{-2}day^{-1}$) and Assimilate Remobilization (Sink Activity) on chickpea genotypes under normal sown conditions

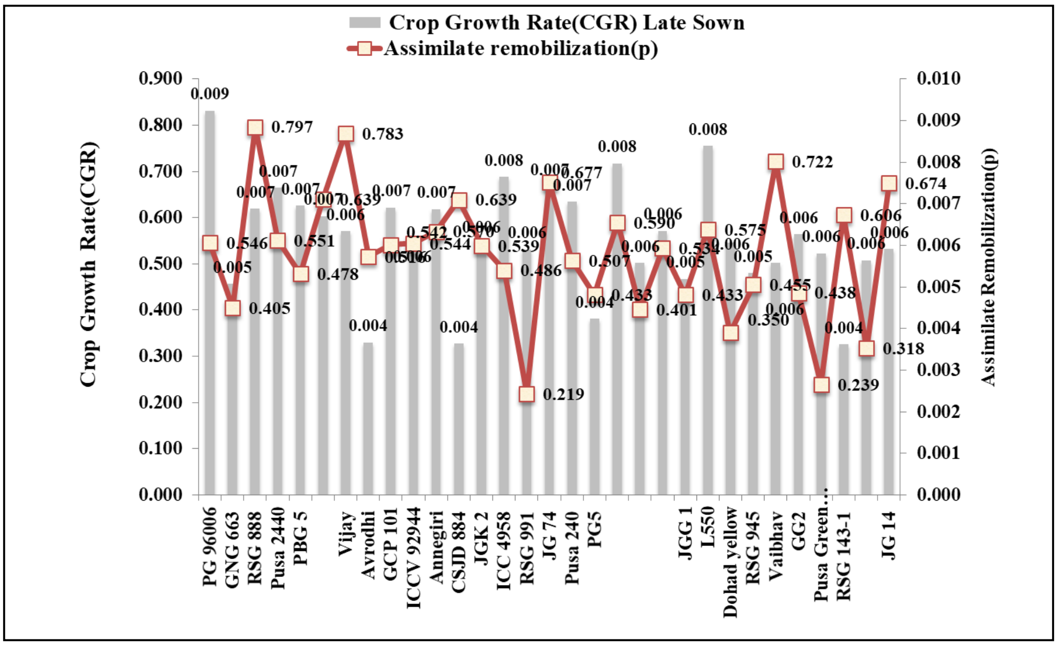

Fig 3(b): Effect of Crop Growth Rate ($gm^{-2}day^{-1}$) and Assimilate Remobilization (Sink Activity) on chickpea genotypes under late sown conditions

(d). **Grain Yield (kgha-1):**

Highest grain yield was recorded for Vaibhav, followed by GG2 and JG 11undernormal sown conditions, whereas, high grain yield and minimum yield reduction under late sown conditions was reported for Annegiri, JG14 and Vaibhav. (Fig.4). Similar results reported by Bahuguna, *et al.* (2012) mild temperature stress (MTS) decreased seed number, seed size and seed weight $plant^{-1}$.Chickpea yield declined with the increase in temperature during the 2008–2009 year and the decline per degree temperature rise was 6.8(%) reported by Chakrabarti *et al.* (2013).Elevated temperature stress during reproduction show flower abortion and reduced seed filling, foremost to smaller seeds and poor yields by Kumari *et al.*,(2017).

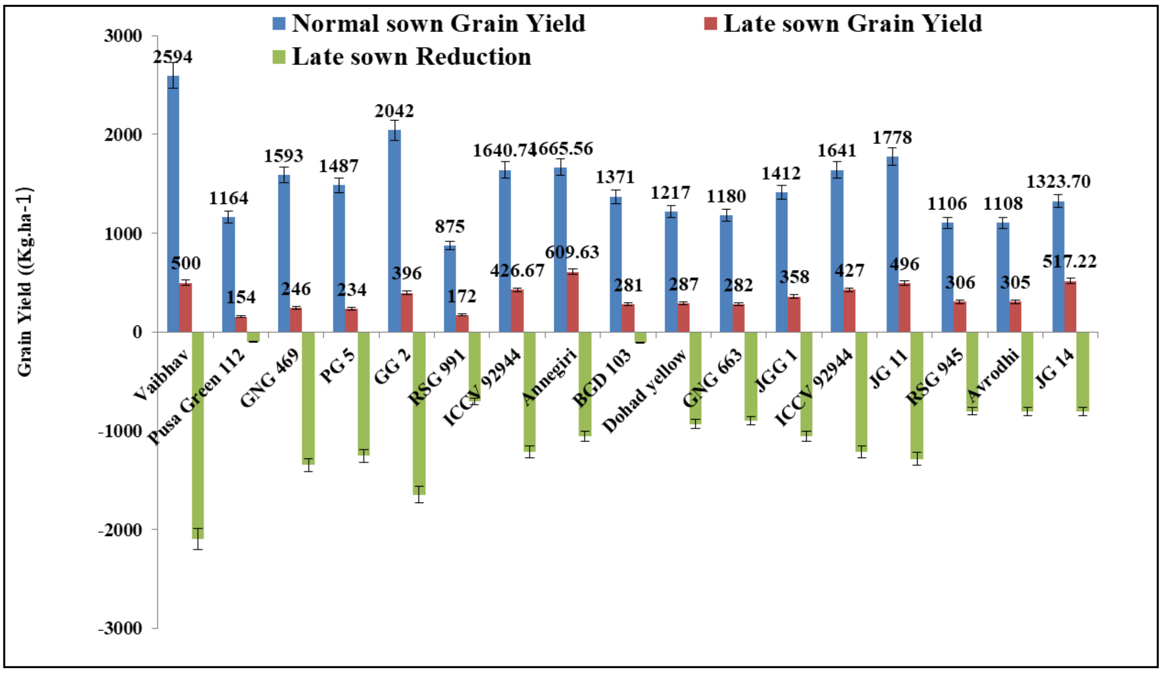

Fig 4: Comparisonof chickpea genotypeson grain yieldsand grain reduction under normal and late sown conditions

Conclusion

It is significant to select the right combination of traits in chickpea phenology,CGR and assimilation remobilization for increasing temperature tolerance are the main objectives of chickpea breeding. Efforts can lead to better success for selection of donor parents. The CGR could be considered as a trait for water harvesting since the total water use, viz. total transpiration might be correlated with the plant growth. Ensuring relatively large sink (pods) quantity could also contribute to improved yield under increasing temperature.Genotypes Vaibhav and RSG88 might be having better assimilation remobilization capacity with increased grain yield under increasing temperature. On the basis of yieldperformance Annegiri, JG14 and Vaibhav maybe used as a tolerant genotype and may be helpful as a donor parent in breeding programmesunder late sown conditions.

Acknowledgements

Authors are grateful to P.I. (Plant Physiology), AICRP on chickpea, IIPR, Kanpur and financial support received through ICAR AICRP on Chickpea is duly acknowledged.

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