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Plant Growth Regulator Mediated Improved Leaf Area Development and Dry Matter Production under Late Sown High Temperature Stress condition in Chickpea

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ABSTRACT: Agriculture is a climate-driven process highly affected by an increase in the global mean surface temperature due to global warming. Temperature beyond the optimum level leads to heat stress and causes irreversible damage to the growth and development of chickpea. Plant growth regulator application is a viable option to induce heat tolerance and achieve a stable yield. Therefore, an experiment was conducted to identify effective plant growth regulators for improving dry matter production and leaf area development in chickpea under high-temperature stress conditions. The investigation comprises two chickpea genotypes *viz*., JG14 (heat tolerant cultivar) and JG 36 with two different dates of sowing *viz.*, normal sown and late sown over two years for exposing the crop to high temperature and nine sub-sub treatments *viz*., control (no spray), water spray, foliar spray of plant growth regulators *viz*., thiourea (100ppm, 200 ppm, 400 ppm and 600 ppm) and salicylic acid (200 ppm, 400 ppm and 600 ppm) at anthesis stage. Due to high-delayed sown temperature stress conditions, reduction in leaf area, dry matter production of primary branches, secondary branches, pods, and total dry matter production was recorded. Heat tolerant genotype JG14 exhibited enhanced dry matter production and leaf area development at all stages over genotype JG36. Foliar application of salicylic acid @200 ppm induces heat stress tolerance in chickpea by augmenting leaf area development, dry matter production of leaf, primary & secondary branches, pods, and total dry matter production as compared to other treatments under delayed sown conditions. Under normal sown condition, foliar application of thiourea @ 600 ppm effectively enhanced leaf area, dry matter of leaf, primary and secondary branches. Salicylic acid @ 400 ppm enhanced pod dry matter and total dry matter production under normal sown condition.

Keywords: Dry matter production, leaf area, plant growth regulators, late sowing, heat stress, heat tolerance, salicylic acid, thiourea.

INTRODUCTION

Chickpea is an important crop and is an important source of protein, dietary fibers, vitamins and minerals for good health (Wood and Grusak 2007). Chickpea also enhance soil fertility by fixing biological nitrogen fixation. Chickpea is grown in an adverse range of climate worldwide ranging from subtropical regions of the Indian sub-continent and North-Eastern Australia to the Mediterranean region of West Asia, North Africa, South and South-west Europe (Ganjeali *et al*., 2011). India is the largest chickpea producing country with 75% of the global production (Garg *et al*., 2006). However, with present productivity level of chickpea, it is not sufficient to fulfill the protein requirement of the ever-increasing population. Chickpea production faces many challenges due to abiotic stresses such as drought, low and high temperature owing to ever changing climate (Garg *et al*., 2015). Unpredictable climate change is a major constraint limiting chickpea production particularly high comparison extremes *i.e.*, high (> 30°C) and low (< 15°C) temperature which reduces grain yield considerably (Kadiyala *et al*., 2016). In India, the area under late sown chickpea is increasing in Northern and Central India due to the growing of short-duration crops after the late harvesting of preceding kharif crops. Due to which chickpea crop is constantly facing high temperature stress at the later stage of pod- formation and pod filling (Kumar *et al*., 2020). At late-stage, heat stress damages the thylakoid membrane, impairing PS I and PS II, reducing photosynthetic rate which affects drymatter accumulation (Prasad *et al*., 2008). The dry matter accumulation in primary and secondary branches and leaves determines the source activity which consequently determines the yield as well. The availability of carbohydrates to floral development and pod formation is an important factor determining sink activity (Liu *et al*., 2004). High temperature speeds the seed filling rate and transfer of assimilates from leaf to pod but reduces the seed filling duration (Farooq *et al*., 2017). Heat stress reduces the photo assimilate transport from current assimilation; under this condition, remobilization of reserve assimilates of stem and branches plays a very important role in determining plant growth and development. Heat stress also hastens senescence of photosynthetic leaf tissue and hydrolysis of macro molecules such as protein lipids etc. Heat stress also causes degradation of chlorophyll leading to reduction in leaf area affecting dry matter assimilation and yield (Jespersen *et al.,* 2016). Plant growth regulator is a viable option to mitigate the effect of high temperature stress in plants. Naturally, plant growth regulators are the endogenous signaling molecule that play an important role in every aspect of plant development, growth and defense responses (Emnecker and Strader 2020; Kupers *et al*., 2020). These PGRs helps in the sessile plants in sensing the stress conditions, transducing the signals for expression of genes for stress tolerance. Cytokinin application alleviate adverse impact of heat stress on panicle differentiation and spikelet formation (Li *et al*., 2021). Protective role of salicylic acid against heat stress was repeatedly reported. Salicylic acid application leads to improve plant growth by increasing plant height, biomass and photosynthetic efficiency (Wassie *et al*., 2020). Therefore, it was hypothesized that plant growth regulator application mitigates heat stress effect by enhancing dry matter production and improving leaf area in chickpea.

MATERIAL AND METHODS

The experiment was conducted at experimental farm of Seed Technology Research Unit, JNKVV, Jabalpur. For the present study, a field experiment was conducted in split-split plot design with three replications using two chickpea genotypes, *i.e*., V1-JG36 and V2-JG14 (heat tolerant cultivar) and high temperature treatment was imposed by delaying the sowing dates *i.e.* D 1-Normal sown (23rd November and 26th November) and D2-Late sown (9th January and 5th January) in 2020-21 and in 2021-22, respectively. In both conditions, different plant growth regulators were applied at flowering stage *viz.,* T1-control (no spray), T2- foliar spray of water, T3-thiourea@100 ppm, T4-thiourea@200 ppm, T5-thiourea@400 ppm, T6-thiourea@600 ppm, T7-salicylic acid@200 ppm, T8-salicylic acid@400 ppm and T9-salicylic acid@600 ppm. Heat stress was experienced by chickpea crop at the time of foliar application (*i.e*. before flowering) to its maturity under the late sown condition. Under well-timed sown condition, (Fig. 1A) at the time of foliar application to chickpea maturity, maximum and minimum temperature was existing between 17.2°C-32.0°C and 3°C-17.6°C in 2020-21 and 19°C-31.5°C and 3°C-17.6°C in 2021-22. Under delayed condition, maximum and minimum temperature was ranging from 27.8°C to 41.2°C and 9°C-20.5°C, respectively in 2020-21 and 28°C to 41.2°C and 9°C to 22°C, in 2021-22, respectively at the time of foliar application to its maturity.

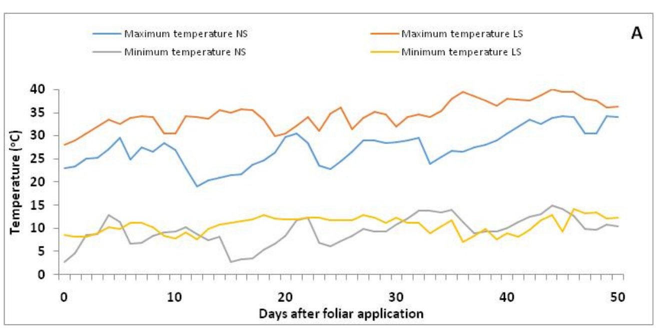

Fig. 1. Maximum, mean and minimum temperature recorded from flowering stage to crop maturity under both normal and late sown conditions in 2020-21.

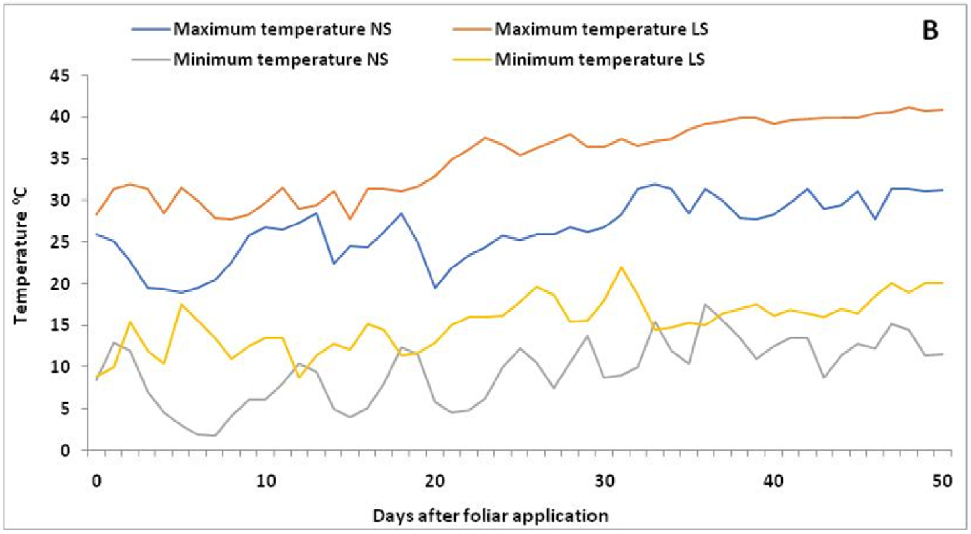

Fig. 2. Maximum and minimum temperature recorded from flowering stage to crop maturity under both normal and late sown conditions in 2021-22.

The data on maximum and minimum temperature at the time of foliar application to maturity under normal sown (NS) and late sown (LS) condition in 2020-21 and 2021-22 has been shown in Fig. 1 and 2. Three plant samples were collected from each treatment and observations on dry matter of leaf, primary branches, secondary branches, pods and total dry matter were recorded at 45, 60, 75 and 90 DAS. Leaf area was measured at 45, 60, 75 and 90 DAS with the help of leaf area meter supplied by LI-COR Biosciences.

RESULT AND DISCUSSION

A. Influence of sowing dates on leaf area, dry matter accumulation of leaf, primary and secondary branches, pods and total dry biomass at 45, 60, 75 and 90 DAS

Analysis of variance of pooled data over two years (2020-21 and 2021-22) revealed significant difference for dry matter of leaves, primary branches, secondary branches, pods, total dry matter and leaf area. Under normal sowing, dry matter of leaf increased from 45 DAS (1.67g) to 60 DAS (2.07g) and thereafter it decreases at 75 DAS (1.37 g) to 90 DAS (1.18 g). Under late sown condition, dry matter of leaves increases from 45 DAS (1.33g) to 60 DAS (1.79g) and thereafter it decreases at 75 DAS (1.37g) to 90DAS (1.17g) (Table 2). Delayed sown high temperature stress condition leads to reduction in dry matter of leaves by 20.36%, 11.11%, 18.45% and 11.36% over normal sowing at 45 DAS, 60 DAS, 75 DAS and 90DAS, respectively. This is in consistent with Ahamed *et al.* (2010) who reported that high temperature leads to reduction in leaf lamina and leaf sheath dry weights in wheat as compared to normal environment. Dry weight of the intact plant vegetative organs (stems + leaves) decreased during high temperature, probably due to export of non-structural carbohydrates to the developing kernels (Plaut *et al.*, 2004). Long-term effects of high temperature on leaf photosynthesis are associated with leaf senescence and protein degradation which causes reduction in leaf dry weight (Khatib *et al.*, 1984).

Dry matter studies on secondary branches revealed that under normal sown condition it increases from 45 DAS (2.02 g) to 75 DAS (2.43 g) and it decreases further at 90 DAS (2.35 g). Under late sown condition, it increases from 45DAS (1.87g) to 60DAS (1.99 g) and thereafter it decreases at 75 DAS (1.92 g) to 90 DAS (1.85 g) (Table 3). High temperature prevailing under late sown condition leads to reduction in dry matter of secondary branches by 8.02%, 15.38%, 20.98% and 21.27% over normal sowing at 45 DAS, 60 DAS, 75 DAS and 90 DAS, respectively. It is in conformity with Wang *et al.* (2010) who reported that high temperature stress, leads to production of 8% fewer branches in the desi and 15% fewer (P, 0.05) in Kabuli. Similarly, high temperature caused significant declines in shoot dry mass, relative growth rate and net assimilation rate in maize, pearl millet and sugarcane (Ashraf *et al.*, 2004, Wahid *et al.*, 2007). Dry matter studies on primary branches revealed that under normal sown condition, it increases from 45 DAS (0.43 g) to 90 DAS (0.70g). Under late sown condition, it increases from 45 DAS (0.33 g) to 75 DAS (0.54 g) and it decreases to 90 DAS (0.74 g). Under late sown condition, it increases from 45 DAS (0.36 g) to 75 DAS (0.53 g) and it decreases to 90 DAS (0.50 g) (Table 4). Delayed sown high temperature stress condition leads to reduction in dry matter of primary branches by 15.84%, 7.95%, 16.60% and 32.93% over normal sowing at 45DAS, 60DAS, 75 DAS and 90 DAS, respectively. Similar results are reported by Ashraf *et al.* (2002); Wahid *et al.* (2007). Dry matter studies of pods revealed that under normal sown condition it increases from 45 DAS (2.74 g) to 90 DAS (14.24 g). Under late sown condition, dry matter of pods increases from 45 DAS (2.56 g) to 90 DAS (18.40g) (Table 5). High temperature at late sown condition leads to increase in dry weight of pods by 9.63%, 80%, 67% and 72.12% over normal sowing at 45 DAS, 60 DAS, 75 DAS and 90 DAS, respectively. Heat stress decreases photosynthetic efficiency that shifts the dynamics between sources and sinks (Ferguson *et al*., 2021). This shift in source-sink dynamics lead to enhanced translocation of photo-assimilates towards reproductive parts (pods) in chickpea. Total dry matter studies revealed that under normal sown condition it increases from 45 DAS (6.85 g) to 90 DAS (18.65g). Under late sown condition, it increases from 45DAS (5.95 g) to 90DAS (21.34g) (Table 6). Late sown condition leads to increase in total dry matter by 15.48%, 32.53%, 31.19% and 40.35% over normal sowing at 45 DAS, 60 DAS, 75 DAS and 90 DAS, respectively. This is in consistent with Baidya *et al*. (2018) who reported maximum total dry weight at second sowing (late sown, 6 December) in lentil. The increase in dry weight is attributed to higher partitioning of assimilates towards pods as compared to primary branches, secondary branches and leaves.

Leaf area dynamics revealed that under normal sown condition leaf area at 45 DAS (980.68cm^2) decreases to 60 DAS (639.62 cm^2), 75 DAS (314.50 cm^2) and 90 DAS (309.11cm^2). Under late sown condition, leaf area dynamics revealed maximum leaf area of 686.77 cm^2 at 45 DAS and thereafter it decreases at 60 DAS (590.83cm^2), 75 DAS (240.56 cm^2) and 90 DAS (235.89cm^2) (Table 1). Late sown condition leads to reduction in leaf area by 30.42%, 13.48%, 23.59% and 23.70% over normal sowing at 45 DAS, 60 DAS, 75 DAS and 90 DAS, respectively. Leaf area is a function of development of new leaves, area expansion of leaves and the senescence of old leaves. Late sowing condition induced high temperature stress reduces the development of new laves, reduces leaf area expansion, and enhances senescence of leaves (Jumrani *et al*., 2014: Chakrabarti *et al*., 2013; Soltani *et al*., 2006; Devasirvatham *et al*., 2018).

B. Influence of contrasting set of genotypes on dry matter production and leaf area development at 45, 60, 75 and 90 DAS

JG14 chickpea variety has been released as heat tolerant variety in India (Gaur *et al*., 2014). This trait is very well exemplified in dry matter dynamics of leaves where high temperature tolerant variety JG14 exhibited maximum dry matter of leaves at 45 DAS (1.66g), 60DAS (2.02g), 75 DAS (1.57g) but however at 90 DAS variety JG36 exhibited maximum (1.28g) (Table 2). JG14 exhibited increase in dry matter of leaves over JG36 by 23.88%, 6.87%, 16.32% and 4.68% decrease at 45 DAS, 60 DAS, 75 DAS and 90DAS, respectively. Heat tolerant genotypes had higher allocation of dry matter to leaves as compared to heat sensitive one for better photosynthetic tissues for improved source allocation towards economic sink. This result is in consistent with the findings of Kumar *et al*., (2020) who reported maximum reduction in leaf dry weight in heat sensitive cultivar ICC 1882.

Dry matter dynamics of secondary branches revealed that in sensitive variety JG36, it increases from 45 DAS (1.91g) to 75 DAS (2.13g) and thereafter it decreases to 90 DAS (2.10 g) with increase of 9.42% in dry matter at 90 DAS over 45 DAS. However, in tolerant variety JG14, it increases from 45 DAS (1.98g) to 75DAS (2.83g) and thereafter it decreases to 90 DAS (2.11g) (Table 3). Heat tolerant variety JG14 exhibited increase in dry matter of secondary branches over JG36 by 3.66%, 4.24%, 4.69% and 1.00% at 45 DAS, 60 DAS, 75 DAS and 90 DAS, respectively. Dry matter dynamics of primary branches revealed that in variety V1 (JG36) it increases from 45 DAS (0.370g) to 90 DAS (0.599g) with increase of 61.90% at 90 DAS over 45 DAS. However, in variety V2 (JG14), dry matter of primary branches increases from 45 DAS (0.421g) to 90 DAS (0.642g) with increase of 52.49% at 90 DAS over 45 DAS (Table 4). Variety V2 exhibited increase in dry matter of primary branches over variety V1 by 7.17% at 90 DAS. Delayed sown heat stress condition causes maximum reduction in main and secondary branches in heat susceptible variety ICC 1882 (Kumar *et al*., 2020). Seed yield per plant was positively and significantly correlated with number of primary branches, number of secondary branches and its value was maximum in heat tolerant genotype (Kuldeep *et al*., 2014). Dry matter dynamics of pods revealed that in variety JG36 it increases from 45DAS (2.66g) to 90DAS (16.25g). However, in variety JG14, dry matter of pods increases from 45 DAS (2.64g) to 90 DAS (14.82g) (Table 5). JG 36 exhibited increase in dry matter of pods over JG14 by 9.64% at 90 DAS. Chickpea being a source limited crops, yield improvement will be realized only through enhancement in source activity. Source strength enhancement was well elucidated by JG14. In contrast, JG36 allocates photo-assimilate towards strengthening of sink tissue as reflected by its maximum increase in pod dry weight. Total dry matter dynamics revealed that variety JG36 exhibited increases of total dry matter over variety JG14 by 7.61% at 90 DAS. The marginal increase in total dry matter in heat sensitive variety JG36 might be attributed to increased pod dry weight.

High-temperature stress hastens leaf senescence leading to a reduction in leaf area. This reduction in leaf area decreases photosynthetic assimilation and growth rate in chickpea. Heat tolerant variety JG14 exhibited maximum leaf area at 45 DAS (838.56 cm^2), 60 DAS (553.14 cm^2), 75 DAS (281.39cm^2), and 90 DAS (276.69cm^2) (Table 1). High-temperature tolerance in chickpea can be induced by enhancing the leaf area through breeding or agronomic intervention.

C. Influence of Plant Growth Regulator on dynamics of leaf area development and dry matter accumulation of leaf, primary and secondary branches, pods and total biomass

Stress-induced changes in reactive oxygen species and hormone levels are thought to play a role in yield reduction during stress combination (Sinha *et al*., 2021). Phytohormones are the endogenous signal molecules that play an important role in almost every aspect of plant development, growth, and defense processes (Emenecker and Strader 2020; Jang *et al*., 2020; Küpers *et al*., 2020). Exogenous application of phytohormones significantly ameliorated heat-induced damage and improved plant heat tolerance, which indicates that phytohormones actively participate in plant response to heat stress (Li *et al*., 2021). Heat stress reduced dry matter of leaf, main stem and secondary branches as reported earlier by Kumar *et al.* (2017). The foliar application of salicylic acid at 100 ppm at the flower initiation and pod filling stage resulted the highest dry matter accumulation and yield (Tomar *et al.*, 2022). Foliar application of Plant growth regulator increased the dry matter accumulation under both normal and delayed sown condition. Salicylic acid @ 200 ppm were found very effective for increasing dry matter of leaves at 45 DAS (1.72g) and 90 DAS (1.37g) with increase of 29.32% and 24.77% over no spray (1.33g) (Table 2). Thiourea @ 400 and 600ppm were found to be effective in increasing dry matter of leaves @ 75 DAS (1.71g) and 60 DAS (2.21g) with 30.53% and 30.00% increase over no spray, respectively (Table 2). Dry matter studies of main stem and secondary branches revealed significant difference at all the different stages of observation. Salicylic acid @ 200ppm were found to be effective in increasing dry matter of main stem (0.48g, 0.60g, & 0.69g) with respective increase of 35.56%, 45.87% and 36.83% over control-no spray (0.36g, 0.42g and 0.51g) at 45, 60 and 75 DAS, respectively (Table 4). Similarly, Salicylic acid @ 200 ppm enhances dry matter of secondary branches at 45, 60 and 75 DAS (2.08g, 2.28g and 2.28g) with respective increase of 11.22%, 9.80% and 9.80% over without spray (Table 4). Stress alleviation effect on dry matter of leaves, stem was also reported in chickpea (Patel *et al*., 2012). Salicylic acid enhances dry matter production under stress and non-stress condition in chickpea (Kumar *et al*., 2020). Salicylic acid @ 200ppm were found to be effective in enhancing pod dry matter at 45 DAS (2.80 g), 60 DAS (7.91 g), 75 DAS (12.28g) except at 90 DAS where salicylic acid @ 400 ppm was found to be effective (19.49g) (Table 5).

Total dry matter studies revealed that salicylic acid @ 200 ppm was found to be effective in increasing total dry matter at 45 DAS (7.26g) and 75 DAS (16.83g) with respective increase of 18.82% and 11.23% over without spray-control. Salicylic acid @400 ppm enhances total dry matter at 90 DAS (23.44g) exhibiting superiority of 26.29% increase over T1 control (18.56g) (Table 6). Salicylic acid alleviates stress effect by enhancing pod dry weight in Peanut (Maamoun *et al*., 2013), common bean (Sadeghipour *et al*., 2012). Leaf is the important photosynthetic parts of plants determining yield under optimal and sub-optimal condition. High-temperature stress detrimentally affects the growth of green leaf areas by retarding the development of new leaves and fastening the senescence of mature leaves. Photosynthetic green laminar growth is detrimentally affected due to high temperature stress as development of new leaf retards along with hastening of mature leaf. Salicylic acid @ 200 ppm expressed its superiority over other treatments by enhancing leaf area at 45DAS (935.11cm^2) 75DAS (332.75cm^2) and 90 DAS (327.72cm^2) with respect to 35.55%, 51.87% and 53.09% increase over control (Table 1). Salicylic acid mediated enhancement of leaf area under abiotic stresses was also reported in wheat (Munir *et al*., 2018; Jatana *et al.*, 2022; Singh *et al*., 2021), mustard (Godara *et al*., 2016), Cluster bean (Meena *et al*., 2017). Exogenous SA enhances tomato heat tolerance through improving photosynthesis efficiency and scavenging of reactive oxygen species by induction of antioxidants (Shah Jahan, 2019). SA pretreatment alleviates the decrease of the net photosynthesis rate by protecting photosystem II function and maintaining higher Rubisco activities under heat stress (Wang *et al*., 2010).

D. Effect of Plant growth regulator treatment on dry matter assimilation in leaf, primary branches, secondary branches, pods and leaf area development in chickpea varieties under normal and late sown condition

Concerning the interaction effect of sowing dates, varieties and plant growth regulator, analysis of variance revealed significant effect on dry matter of leaves, primary branches, secondary branches, pods, total dry matter and leaf area at all different stages of growth. Thiourea @ 600 ppm were found to be effective in enhancing leaf dry weight under normal sown condition at 60 DAS (2.48 gm), 75 DAS (1.77 g) and 90 DAS (1.91 g). Thiourea modulate stress tolerance at molecular level, irrespective of the stress applied (Wahid *et al*., 2017). The present finding of thiourea promoting effect on increasing leaf dry weight is well evidenced in other crops like cluster bean (Garg *et al*., 2006; Burman *et al*., 2004), maize (Amin *et al*., 2013). In contrast, under delayed sown condition, Salicylic acid @ 200 ppm was highly effective in enhancing leaf dry weight at 45 DAS (1.71 g), 75 DAS (1.63 g) and 90 DAS (1.44 g) (Table 2). Salicylic acid @ 200 ppm enhances dry weight of secondary branches and primary branches under booth normal and late sown condition in chickpea (Table 3 & 4). Ganesh *et al.*

(2017) reported that salicylic acid increases number of secondary branches in mustard under heat stress. Similarly, Abbaszadeh *et al*. (2020) reported improving in number of secondary branches using salicylic acid under drought stress in *Rosmarinus officinalis*. Dry mass accumulation in pods is increased by salicylic acid @ 400 ppm under normal condition at 60 DAS (6. 20 g), 75 DAS (11.65 g) and 90 DAS (20.98 g). However, Salicylic acid @ 200 ppm effectively increases dry weight of pods under late sown condition at 45 DAS (2.67 g) and 60 DAS (4.74g), while salicylic acid @ 400 ppm increases pod dry weight @ 90 DAS (18.02g) (Table 5). Total dry matter accumulation studies revealed that Salicylic acid @ studies revealed that SA @ 400 ppm was highly efficient in enhancing total dry matter at 75 DAS (16.91 g) and 90 DAS (25.43 g) under normal sown condition. However, SA @ 200 ppm & 400 ppm was equally effective under late sown condition at all the different stage of growth in increasing total dry matter (Table 6). This salicylic acid dry matter enhancing effect under high temperature stress is also evidenced in hybrid maize (Ahmad *et al*., 2014) and Mustard (Hayat *et al.,* 2009). This might be due to the fact that salicylic acid application enhanced activity of antioxidative enzymes protecting the plants from direct as well as indirect effects of temperature stress thereby, improving the photosynthetic efficiency, metabolism and growth (Hayat *et al*., 2009).

Leaf area dynamics at different stages under normal conditions revealed that thiourea @ 400 ppm enhances expression of leaf area at 45 DAS (1100.75 cm^2) and 60 DAS (721.21 cm^2), while SA @ 200 ppm showed enhanced expression at 75 DAS (365.75 cm^2) and 90 DAS (360.38 cm^2). Under delayed sown high temperature stress condition, thiourea @ 200 ppm and 400 ppm enhanced leaf area @45 DAS (843.99 cm^2) and 60 DAS (697.41 cm^2), while Salicylic acid @ 200 ppm enhances leaf area @ 75 DAS (299.73 cm^2) and 90 DAS (295.06 cm^2) (Table 1). The devastating effect of delayed sown high temperature stress condition in Leaf area was ameliorated by thiourea. This is in consistent with Anjum *et al*. (2011) who reported stress ameliorating effect of thiourea in leaf area by foliar spray of thiourea at seedling and pre-anthesis stages in bread wheat.

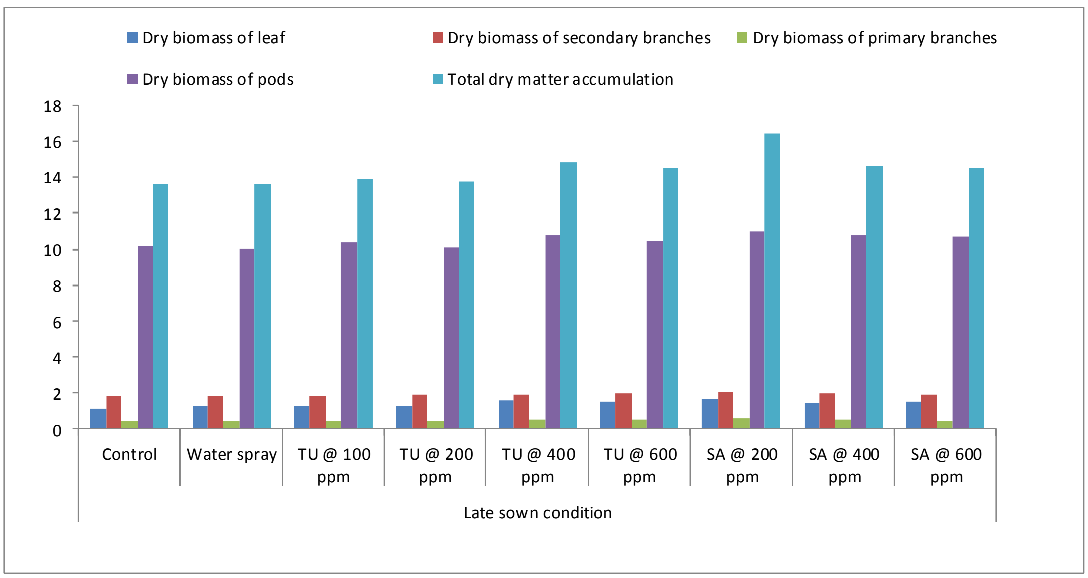

Fig. 3. Effect of Plant growth regulators on the dry biomass of leaf, primary branches, secondary branches, pods and total dry matter accumulation over the varieties under late sown condition (data is average value of 45, 60, 75 and 90 DAS pooled over two years).

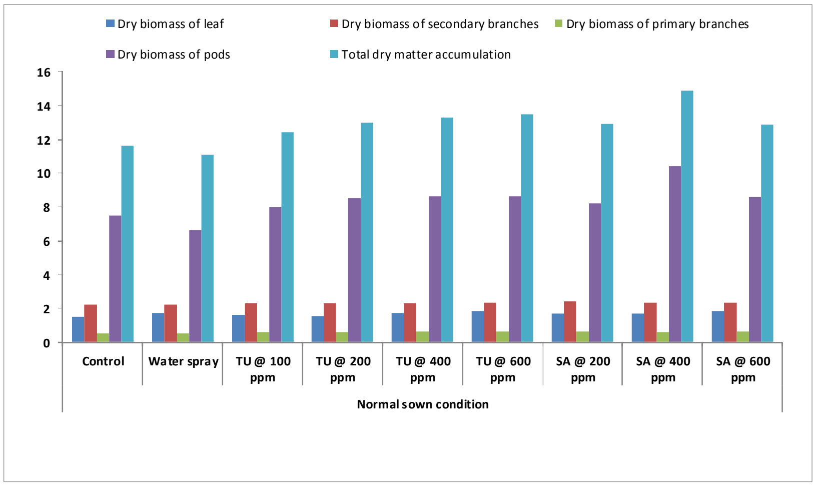

Fig. 4. Effect of Plant growth regulators on the dry biomass of leaf, primary branches, secondary branches, pods and total dry matter accumulation over the varieties under normal sown condition (data is average value of 45, 60, 75 and 90 DAS pooled over two years).

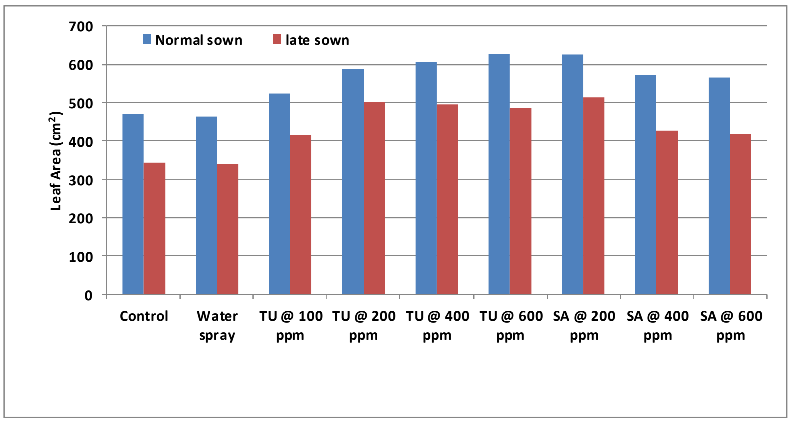

Fig. 5. Effect of Plant growth regulators on the Leaf area over the varieties under normal sown condition (data is average value of 45, 60, 75 and 90 DAS pooled over two years).

Table 1: Effect of Plant growth regulator on Leaf area at 45, 60, 75 and 90 DAS in chickpea varieties JG 36 and JG 14 under normal and late sown condition (pooled data over two years).

Sowing	Plant growth regulator application	Leaf area@45 DAS			Leaf area@60 DAS			Leaf area@75 DAS			Leaf area@90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T1	802.83	879.83	**841.33**	563.32	379.3	**471.29**	240.04	263.00	**251.50**	234.35	257.86	**246.11**
	T2	783.78	885.03	**834.41**	559.85	404.9	**482.39**	241.04	267.00	**254.02**	234.35	261.91	**248.13**
	T3	912.14	939.34	**925.74**	654.45	556.1	**605.29**	292.46	263.00	**277.71**	286.77	257.86	**272.32**
	T4	925.1	1038.2	**981.64**	663.5	554.6	**609.04**	382.06	324.70	**353.37**	376.37	319.58	**347.98**
	T5	1009.69	1093.3	**1051.47**	693.8	674.7	**684.25**	392.74	298.40	**345.59**	387.05	293.35	**340.20**
	T6	1090.76	1110.7	**1100.75**	719.28	624.2	**671.73**	304.22	399.20	**351.73**	298.53	394.14	**346.34**
	T7	1081.2	1050.6	**1065.92**	733.26	671.9	**702.58**	374.37	357.20	**365.77**	368.68	352.07	**360.38**
	T8	1078.34	984.51	**1031.43**	644.03	538.8	**591.42**	311.66	326.40	**319.02**	305.97	321.27	**313.62**
	T9	994.04	996.12	**995.08**	660.25	538.6	**599.41**	239.88	384.80	**312.33**	234.19	379.67	**306.93**
	Mean	**964.21**	**997.51**	**980.86**	**654.64**	**549.22**	**601.93**	**308.72**	**320.40**	**314.56**	**302.92**	**315.30**	**309.11**
Late sown	T1	545.34	531.44	**538.39**	530.62	404.2	**467.43**	170.07	203.30	**186.70**	165.03	199.01	**182.02**
	T2	538.92	543.13	**541.03**	494.22	435.3	**464.77**	171.07	191.70	**181.39**	165.04	187.4	**176.22**
	T3	697.4	647.97	**672.69**	579.26	540.3	**559.76**	222.62	210.90	**216.78**	217.58	206.63	**212.11**
	T4	811.81	876.17	**843.99**	680.46	534.1	**607.26**	311.79	242.90	**277.33**	306.75	238.55	**272.65**
	T5	738.68	726.31	**732.50**	678.34	716.5	**697.41**	322.52	236.20	**279.36**	317.49	231.89	**274.69**
	T6	755.84	740.861	**755.84**	723.14	606	**664.55**	233.95	306.00	**269.96**	228.92	301.65	**265.29**
	T7	789.42	819.17	**804.30**	681.22	642.5	**661.87**	304.88	294.60	**299.73**	299.85	290.27	**295.06**
	T8	640.4	630.77	**635.59**	620.42	570.7	**595.55**	242.22	243.80	**242.99**	237.19	239.44	**238.32**
	T9	651.31	661.87	**656.59**	633.82	563.9	**598.87**	170.44	252.20	**211.32**	165.41	247.88	**206.65**
	Mean	**685.46**	**679.60**	**686.77**	**624.61**	**557.05**	**590.83**	**238.84**	**242.39**	**240.62**	**233.70**	**238.08**	**235.89**
Statistics		CD at 5%			CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	7.57			1.20			1.64			1.64		
	PGR (T)	11.70			7.88			3.79			3.79		
	Varieties (V)	10.58			4.78			1.83			1.83		
	S × V × T =	23.40			15.76			7.57			7.59		

Table 2: Effect of Plant growth regulator on Leaf dry matter at 45, 60, 75 and 90 DAS in chickpea varieties JG 36 and JG 14 under normal and late sown condition (pooled data over two years).

Sowing	Plant growth regulator application	Leaf dry matter @ 45 DAS			Leaf dry matter@ 60 DAS			Leaf dry matter @ 75 DAS			Leaf dry matter @ 90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T1	1.85	1.4	**1.63**	1.87	1.65	**1.76**	1.481	1.4	**1.40**	1.24	1.06	**1.15**
	T2	2.00	1.53	**1.76**	2.25	2.22	**2.24**	1.59	1.63	**1.61**	1.42	1.37	**1.40**
	T3	1.51	1.67	**1.59**	1.77	2	**1.89**	1.43	1.92	**1.68**	1.28	1.39	**1.34**
	T4	1.56	1.5	**1.53**	1.55	1.91	**1.73**	1.5	1.74	**1.62**	1.35	1.3	**1.33**
	T5	1.52	1.62	**1.57**	1.35	2.59	**1.97**	1.72	2.24	**1.98**	1.32	1.49	**1.41**
	T6	2.13	1.48	**1.80**	2.37	2.59	**2.48**	1.99	1.54	**1.77**	1.51	1.31	**1.41**
	T7	1.41	2.04	**1.72**	1.7	2.59	**2.15**	1.44	1.67	**1.56**	1.28	1.33	**1.31**
	T8	1.5	1.64	**1.57**	1.91	2.18	**2.05**	1.49	2.05	**1.77**	1.3	1.39	**1.35**
	T9	2.06	1.73	**1.89**	2.43	2.37	**2.40**	1.83	1.66	**1.75**	1.36	1.19	**1.28**
	Mean	**1.73**	**1.62**	**1.68**	**1.91**	**2.23**	**2.07**	**1.62**	**1.76**	**1.68**	**1.34**	**1.31**	**1.33**
Late sown	T1	0.76	1.31	**1.03**	1.52	1.29	**1.41**	1.14	1.22	**1.18**	1.05	1.05	**1.05**
	T2	0.87	1.7	**1.28**	1.14	1.83	**1.49**	1.22	1.43	**1.33**	1.14	1.16	**1.15**
	T3	0.34	1.79	**1.06**	2.08	1.69	**1.89**	1.11	1.22	**1.17**	1.06	0.97	**1.02**
	T4	0.77	1.53	**1.15**	1.84	1.56	**1.70**	1.3	1.26	**1.28**	1.2	1.05	**1.13**
	T5	1.25	1.69	**1.47**	2.36	1.98	**2.17**	1.45	1.44	**1.45**	1.42	1.22	**1.32**
	T6	1.38	1.64	**1.51**	2.02	1.89	**1.96**	1.48	1.52	**1.50**	1.27	1.15	**1.21**
	T7	1.43	1.99	**1.71**	1.55	2.06	**1.81**	1.68	1.57	**1.63**	1.55	1.32	**1.44**
	T8	0.6	1.89	**1.24**	1.83	2	**1.92**	1.5	1.46	**1.48**	0.93	1.19	**1.06**
	T9	1.2	1.85	**1.52**	1.57	2.01	**1.79**	1.41	1.32	**1.37**	1.38	1.11	**1.25**
	Mean	**0.96**	**1.71**	**1.33**	**1.77**	**1.81**	**1.79**	**1.37**	**1.38**	**1.37**	**1.22**	**1.14**	**1.18**
Statistics		CD at 5%			CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	0.0118			0.0553			0.021			0.0148		
	PGR (T)	0.0319			0.0287			0.0248			0.0221		
	Varieties (V)	0.0142			0.0148			0.008			0.0110		
	S × V × T=	0.0465			0.0574			0.0496			0.0442		

Table 3: Effect of Plant growth regulator on dry matter of secondary branches at 45, 60, 75 and 90 DAS in chickpea varieties JG 36 and JG 14 under normal and late sown condition (pooled data over two years).

Sowing	Plant growth regulator application	Dry matter of secondary branches @45 DAS			Dry matter of secondary branches @60 DAS			Dry matter of secondary branches @75 DAS			Dry matter of secondary branches @90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T1	1.95	1.98	**1.97**	2.15	2.3	**2.23**	2.3	2.35	**2.33**	2.23	2.29	**2.26**
	T2	1.94	1.98	**1.96**	2.18	2.33	**2.26**	2.28	2.45	**2.37**	2.23	2.19	**2.21**
	T3	1.99	1.97	**1.98**	2.29	2.35	**2.32**	2.44	2.45	**2.45**	2.33	2.4	**2.37**
	T4	1.78	2.13	**1.96**	2.25	2.39	**2.32**	2.36	2.54	**2.45**	2.27	2.48	**2.38**
	T5	1.97	2.02	**2.00**	2.3	2.36	**2.33**	2.4	2.48	**2.44**	2.29	2.4	**2.35**
	T6	1.88	2.12	**2.00**	2.31	2.46	**2.39**	2.41	2.53	**2.47**	2.36	2.48	**2.42**
	T7	2.16	2.17	**2.17**	2.4	2.57	**2.49**	2.44	2.56	**2.50**	2.37	2.46	**2.42**
	T8	2.1	2.13	**2.12**	2.36	2.37	**2.37**	2.38	2.53	**2.46**	2.32	2.43	**2.38**
	T9	2.03	2.05	**2.04**	2.32	2.45	**2.39**	2.4	2.51	**2.46**	2.31	2.46	**2.39**
	Mean	**1.98**	**2.06**	**2.02**	**2.28**	**2.40**	**2.34**	**2.38**	**2.49**	**2.43**	**2.30**	**2.40**	**2.35**
Late sown	T1	1.75	1.81	**1.78**	1.86	1.87	**1.87**	1.75	1.85	**1.80**	1.78	1.75	**1.77**
	T2	1.78	1.83	**1.81**	1.87	1.96	**1.92**	1.78	1.86	**1.82**	1.77	1.76	**1.77**
	T3	1.79	1.81	**1.80**	1.94	1.9	**1.92**	1.85	1.84	**1.85**	1.86	1.74	**1.80**
	T4	1.77	1.89	**1.83**	2	1.95	**1.98**	1.91	1.9	**1.91**	1.9	1.82	**1.86**
	T5	1.86	1.96	**1.91**	1.98	2.08	**2.03**	1.93	1.95	**1.94**	1.92	1.79	**1.86**
	T6	1.87	1.95	**1.91**	2.01	2.17	**2.09**	1.9	2.15	**2.03**	1.94	1.95	**1.95**
	T7	1.96	2.04	**2.00**	2	2.14	**2.07**	1.98	2.16	**2.07**	1.99	1.88	**1.94**
	T8	1.92	1.94	**1.93**	1.95	2.08	**2.02**	1.89	2.01	**1.95**	1.92	1.84	**1.88**
	T9	1.9	1.91	**1.91**	1.95	2.02	**1.99**	1.88	1.99	**1.94**	1.94	1.81	**1.88**
	Mean	**1.84**	**1.90**	**1.87**	**1.95**	**2.02**	**1.99**	**1.87**	**1.97**	**1.92**	**1.89**	**1.82**	**1.85**
Statistics		CD at 5%			CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	0.0144			0.0013			0.0064			0.0127		
	PGR (T)	0.0097			0.0085			0.0099			0.0103		
	Varieties (V)	0.0142			0.0058			0.0031			0.0029		
	S × V × T=	0.0195			0.0171			0.0199			0.0207		

Table 4 : Effect of plant growth regulators on dry matter of primary branches at 45, 60, 75 and 90 DAS in chickpea varieties JG 14 and JG 36 under normal and late sown condition (pooled data over two years).

Sowing	Plant growth regulator application	Dry matter of primary branches @45 DAS			Dry matter of primary branches @60 DAS			Dry matter of primary branches @75 DAS			@90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T1	0.36	0.41	**0.39**	0.44	0.46	**0.45**	0.58	0.51	**0.55**	0.59	0.55	**0.57**
	T2	0.34	0.42	**0.38**	0.46	0.5	**0.48**	0.55	0.6	**0.58**	0.59	0.45	**0.52**
	T3	0.39	0.4	**0.40**	0.57	0.52	**0.55**	0.7	0.6	**0.65**	0.69	0.71	**0.70**
	T4	0.31	0.53	**0.42**	0.51	0.57	**0.54**	0.61	0.73	**0.67**	0.63	0.88	**0.76**
	T5	0.5	0.43	**0.47**	0.57	0.54	**0.56**	0.65	0.66	**0.66**	0.65	1.02	**0.84**
	T6	0.41	0.52	**0.47**	0.52	0.59	**0.56**	0.66	0.71	**0.69**	0.75	1.1	**0.93**
	T7	0.47	0.53	**0.50**	0.57	0.68	**0.63**	0.69	0.73	**0.71**	0.74	0.83	**0.79**
	T8	0.41	0.49	**0.45**	0.52	0.48	**0.50**	0.63	0.72	**0.68**	0.69	0.79	**0.74**
	T9	0.34	0.41	**0.38**	0.48	0.56	**0.52**	0.65	0.68	**0.67**	0.68	1.03	**0.86**
	Mean	**0.39**	**0.46**	**0.43**	**0.52**	**0.54**	**0.53**	**0.64**	**0.66**	**0.65**	**0.67**	**0.82**	**0.74**
Late sown	T1	0.3	0.35	**0.33**	0.38	0.38	**0.38**	0.44	0.5	**0.47**	0.47	0.44	**0.46**
	T2	0.32	0.36	**0.34**	0.39	0.47	**0.43**	0.47	0.51	**0.49**	0.45	0.45	**0.45**
	T3	0.32	0.35	**0.34**	0.46	0.41	**0.44**	0.54	0.49	**0.52**	0.54	0.43	**0.49**
	T4	0.29	0.36	**0.33**	0.51	0.4	**0.46**	0.59	0.5	**0.55**	0.53	0.51	**0.52**
	T5	0.38	0.41	**0.40**	0.49	0.54	**0.52**	0.6	0.54	**0.57**	0.54	0.42	**0.48**
	T6	0.38	0.41	**0.40**	0.52	0.63	**0.58**	0.55	0.74	**0.65**	0.56	0.56	**0.56**
	T7	0.43	0.48	**0.46**	0.5	0.66	**0.58**	0.62	0.73	**0.68**	0.6	0.51	**0.56**
	T8	0.39	0.39	**0.39**	0.46	0.59	**0.53**	0.54	0.57	**0.56**	0.53	0.47	**0.50**
	T9	0.37	0.36	**0.37**	0.46	0.54	**0.50**	0.52	0.55	**0.54**	0.58	0.44	**0.51**
	Mean	**0.35**	**0.39**	**0.37**	**0.46**	**0.51**	**0.49**	**0.54**	**0.57**	**0.56**	**0.53**	**0.47**	**0.50**
Statistics		CD at 5%			CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	0.0053			0.0024			0.008			0.0127		
	PGR (T)	0.0075			0.008			0.0095			0.0103		
	Varieties (V)	0.0008			0.0057			0.0025			0.0029		
	S x V x T=	0.0151			0.0001			0.0191			0.0207		

Table 5: Effect of plant growth regulators on dry matter of pods at 45, 60, 75 and 90 DAS in chickpea varieties JG 14 and JG 36 under normal and late sown condition (pooled data over two years).

Sowing	Plant growth regulator application	Dry matter of pods @45 DAS			Dry matter of pods @60 DAS			Dry matter of pods @75 DAS			Dry matter of pods @90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T1	2.63	2.47	**2.55**	6.76	4.93	**5.85**	10.14	7.28	**8.71**	13.44	12.4	**12.92**
	T2	2.61	2.48	**2.55**	6.78	4.97	**5.88**	9.07	6.04	**7.56**	11.71	9.45	**10.58**
	T3	2.66	2.46	**2.56**	6.89	4.97	**5.93**	11.05	8.86	**9.96**	16.86	10.1	**13.48**
	T4	2.58	2.82	**2.70**	6.84	5.12	**5.98**	13.11	9.67	**11.39**	17.53	10.56	**14.05**
	T5	2.97	2.71	**2.84**	6.9	5.22	**6.06**	11.73	10.23	**10.98**	17.28	12.03	**14.66**
	T6	2.89	2.81	**2.85**	6.85	5.51	**6.18**	10	11.29	**10.65**	13.94	15.6	**14.77**
	T7	2.9	2.94	**2.92**	6.88	5.26	**6.07**	10.47	10.6	**10.54**	13.63	13.07	**13.35**
	T8	2.84	2.9	**2.87**	6.84	5.56	**6.20**	12.43	10.87	**11.65**	25.3	16.65	**20.98**
	T9	2.77	2.82	**2.80**	6.8	4.86t	**6.80**	10.76	10.25	**10.51**	15.12	11.63	**13.38**
	Mean	**2.76**	**2.71**	**2.74**	**6.84**	**5.19**	**6.02**	**10.97**	**9.45**	**10.21**	**16.09**	**12.39**	**14.24**
Late sown	T1	2.46	2.41	**2.44**	7.89	6.77	**7.33**	13.41	14.2	**13.81**	14.73	19.22	**16.98**
	T2	2.48	2.42	**2.45**	8.33	6.74	**7.54**	13.17	14.27	**13.72**	15.39	17.02	**16.21**
	T3	2.48	2.41	**2.45**	9.39	7.8	**8.60**	13.57	12.72	**13.15**	16.84	17.79	**17.32**
	T4	2.51	2.64	**2.58**	9.74	7.88	**8.81**	13.47	13.03	**13.25**	15.96	15.18	**15.57**
	T5	2.6	2.69	**2.65**	9.49	9.46	**9.48**	13.49	12.85	**13.17**	19.18	16.35	**17.77**
	T6	2.61	2.69	**2.65**	9.75	9.61	**9.68**	13.32	14.22	**13.77**	14.69	16.86	**15.78**
	T7	2.64	2.7	**2.67**	9.73	9.75	**9.74**	13.49	14.54	**14.02**	16.92	18.09	**17.51**
	T8	2.59	2.61	**2.60**	9.68	9.58	**9.63**	13.25	12.4	**12.83**	19.86	16.18	**18.02**
	T9	2.57	2.58	**2.58**	9.68	9.11	**9.40**	13.41	15.01	**14.21**	14.22	18.65	**16.44**
	Mean	**2.55**	**2.57**	**2.56**	**9.30**	**8.52**	**8.91**	**13.40**	**13.69**	**13.55**	**16.42**	**17.26**	**16.84**
Stati		CD at 5%			CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	0.011			0.0400			0.9202			0.941		
	PGR (T)	0.017			0.2265			0.2556			1.261		
	Varieties (V)	0.010			0.0191			0.3632			1.361		
	S × V × T=	0.034			0.045			0.511			2.523		

Table 6: Effect of plant growth regulators on total dry matter at 45, 60, 75 and 90 DAS in chickpea varieties JG 14 and JG 36 under normal and late sown condition (pooled data over two years).

Sowing	Plant growth regulator application	Total dry matter @45 DAS			Total dry matter @60 DAS			Total dry matter @75 DAS			Total dry matter @90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T1	6.41	6.25	**6.33**	11.21	9.33	**10.27**	14.51	11.53	**13.02**	17.5	16.3	**16.90**
	T2	6.88	6.41	**6.65**	11.66	10.02	**10.84**	13.49	10.71	**12.10**	15.93	13.45	**14.69**
	T3	6.54	6.5	**6.52**	11.51	9.83	**10.67**	15.62	13.82	**14.72**	21.15	14.6	**17.88**
	T4	6.63	6.97	**6.80**	11.15	9.98	**10.57**	17.58	14.67	**16.13**	21.77	15.22	**18.50**
	T5	6.95	6.79	**6.87**	11.11	10.7	**10.91**	16.49	15.6	**16.05**	21.53	16.93	**19.23**
	T6	7.3	6.92	**7.11**	12.04	11.14	**11.59**	15.06	16.07	**15.57**	18.55	20.48	**19.52**
	T7	6.94	7.67	**7.31**	11.54	11.1	**11.32**	15.04	15.55	**15.30**	18.02	17.68	**17.85**
	T8	6.85	7.15	**7.00**	11.62	10.59	**11.11**	16.91	16.17l	**16.91**	29.61	21.25	**25.43**
	T9	7.19	7	**7.10**	12.02	10.23	**11.13**	15.64	15.09	**15.37**	19.47	16.3	**17.89**
	Mean	**6.85**	**6.85**	**6.85**	**11.54**	**10.32**	**10.93**	**15.59**	**14.13**	**14.86**	**20.39**	**16.91**	**18.65**
Late sown	T1	5.26	5.88	**5.57**	12.12	10.3	**11.21**	16.73	17.77	**17.25**	18.02	22.42	**20.22**
	T2	5.44	6.3	**5.87**	12.26	11	**11.63**	16.63	18.07	**17.35**	18.74	20.38	**19.56**
	T3	4.92	6.35	**5.64**	13.87	11.8	**12.84**	17.06	16.26	**16.66**	20.29	20.93	**20.61**
	T4	5.33	6.41	**5.87**	14.09	11.79	**12.94**	17.27	16.68	**16.98**	19.58	18.57	**19.08**
	T5	6.09	6.74	**6.42**	14.3	14.06	**14.18**	17.46	16.78	**17.12**	23.05	19.78	**21.42**
	T6	6.23	6.68	**6.46**	14.29	14.29	**14.29**	17.24	18.57	**17.91**	18.45	20.52	**19.49**
	T7	6.45l	7.21	**7.21**	13.78	14.61	**14.20**	17.77	18.97	**18.37**	21.05	21.78	**21.42**
	T8	5.48	6.82	**6.15**	13.92	14.25	**14.09**	17.18	16.44	**16.81**	23.23	19.68	**21.46**
	T9	6.03	6.71	**6.37**	13.65	13.68	**13.67**	17.22	18.87	**18.05**	18.11	21.99	**20.05**
	Mean	**5.60**	**6.57**	**6.08**	**13.59**	**12.86**	**13.23**	**17.17**	**17.60**	**17.39**	**20.06**	**20.67**	**20.37**
Statistics		CD at 5%			CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	0.027			0.065			0.945			0.948		
	PGR (T)	0.040			0.036			0.252			1.262		
	Varieties (V)	0.021			0.021			0.370			1.360		
	` S ×V × T=	0.080			0.072			0.504			2.530		

CONCLUSION

Delayed sown high-temperature stress causes a devastating effect on dry matter production of leaf, primary branches, secondary branches, and leaf area development. Heat tolerant genotypes JG 14 exhibited maximum increase in dry matter of leaf, primary and secondary branches. In contrast, JG 36 exhibited enhanced pod dry matter and total dry matter. JG 14 reveals a maximum increase in leaf area at all stages of growth over normal and late-sown conditions. Under the normal sown condition, over the varieties and averaging over different stages of growth, thiourea @ 600 ppm was found to be effective in enhancing leaf area (630.00 cm^2) (Fig. 5), leaf dry weight (1.865g), and primary branches dry weight (0.658 g) (Fig. 4). Salicylic acid @ 200 ppm expressed maximum dry matter production of secondary branches (2.39g). In comparison, salicylic acid @ 400 ppm was found to be effective in enhancing pod dry matter (10.42g) and total dry matter (14.85g) (Fig. 4). Under delayed sown high-temperature stress condition, salicylic acid @ 200 ppm proves its stress mitigating potential by exhibiting superiority in enhancing leaf area (514.07 cm^2) (Fig. 5), dry weight of leaf (1.644 gm), dry weight of primary branches (0.566 g) and secondary branches (2.01 g), dry matter of pods (10.98 g) and total dry matter production (16.45 g) (Fig. 3).

FUTURE SCOPE

The Plant growth regulator mitigates the high-temperature stress effect on plant growth and development. This plant growth regulator can be recommended to farmers for stable yield in chickpea under changing climatic conditions. The identified PGR will be tested for its efficacy under challenging abiotic stress conditions such as drought, salinity, and cold stress in different crops for yield stability under changing climatic conditions.

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Conflict of Interest. None.

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