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Supriya Debnath
Jawaharlal Nehru Krishi Vishwavidyalaya

R Shiv Ramakrishnan
Indian Agricultural Research Institute

Ashish Kumar
Jawaharlal Nehru Krishi Vishwavidyalaya

Radheshyam Sharma
Jawaharlal Nehru Krishi Vishwavidyalaya

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Supriya Debnath[1], R. Shiv Ramakrishnan[2]*, Rohit K. Kumawat[1], Mrunal Ghogare[1], Parikha P. Singh[1], Ashish Kumar[3], Stuti Sharma[4], Radheshyam Sharma[5], Preeti S. Nayak[6], Gyanendra Tiwari[7] and R.K. Samaiya[8]

[1]Ph.D. Research Scholar, Department of Plant Physiology, JNKVV, Jabalpur (Madhya Pradesh), India.
[2]Scientist, (Plant Physiology), Department of Plant Breeding and Genetics, JNKVV, Jabalpur (Madhya Pradesh), India.
[3]Scientist, (Plant Pathology), Department of Plant Breeding and Genetics, JNKVV, Jabalpur (Madhya Pradesh), India.
[4]Scientist, (Plant Breeding and Genetics), Department of Plant Breeding and Genetics, JNKVV, Jabalpur (Madhya Pradesh), India.
[5]Assistant Professor, Biotechnology Centre, JNKVV Jabalpur (Madhya Pradesh), India.
[6]Guest Faculty, Department of Plant Physiology, JNKVV, Jabalpur (Madhya Pradesh), India.
[7]Professor, Department of Plant Physiology, JNKVV, Jabalpur (Madhya Pradesh), India.
[8]Professor & Head, Department of Plant Physiology, JNKVV Jabalpur (Madhya Pradesh), India.

(Corresponding author: R. Shiv Ramakrishnan)*
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ABSTRACT: Heat stress is one of the most important constraints for crop production. Temperature beyond the optimum level leads to heat stress and causes irreversible damage to the growth and development of chickpea. Biomass partitioning is highly responsive to environmental stimuli affecting seed yield under sub-optimal conditions. Plant growth regulator application is a viable option to alter biomass partitioning, optimizing seed yield under heat stress conditions. Therefore, an experiment was conducted to identify effective plant growth regulators for biomass partitioning in chickpeas under high-temperature stress conditions. The investigation comprises two chickpea genotypes *viz*., JG 14 (heat tolerant cultivar) and JG 36 with two dates of sowing *viz*., timely sown (18th November) and late (20th December) sown for exposing the crop to high temperature and nine sub-sub treatments *viz*., control (no spray), water spray, foliar spray of plant growth regulator *viz*., thiourea (100ppm, 200 ppm, 400 ppm and 600 ppm) and salicylic acid (200 ppm, 400 ppm am 600 ppm) at anthesis stage. Delayed sown high-temperature stress condition reduces biomass partitioning in leaves, main stem, and secondary branches, with an increase in pods. Heal tolerant variety JG 14 exhibited enhanced biomass partitioning in leaves, main stems, secondary branches, and pods compared to JG 36. Under timely sown conditions at the physiological maturity stage (90 DAS), salicylic acid @ 200 ppm and 400 ppm efficiently increased biomass partitioning in pods and main stem, respectively. Pulse, a source-limited crop, is desired to enhance source activity under heat-stress conditions. In the present study, under high-temperature stress conditions, source activity or biomass partitioning in source tissue (leaves) was enhanced by foliar application of salicylic acid @ 400 ppm, while thiourea @ 600 ppm enhances biomass partitioning in the main stem and secondary branches.

Keywords: Biomass partitioning, plant growth regulator, heat stress, late sowing, heat tolerance, salicylic acid, thiourea.

INTRODUCTION

High temperature stress is one of the most important constraints for crop production. Temperature is a major factor determining seed yield and quality in chickpea (Christophe *et al*., 2011). 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). Chickpea is an important crop and is an important source of protein, dietary fibers, energy vitamins and minerals for good health (Wood and Grusak 2007). The productivity of chickpea is not sufficient to fulfill the protein requirement for the increasing human population (Henchion *et al*., 2017). Chickpea production faces many challenges due to various abiotic stresses such as drought, and low and high temperatures (Garg *et al.*, 2015; Jha *et al*., 2018). A temperature of 14-16°C, usually 15°C, is considered a threshold for reproduction in chickpea. Despite being a cool-season crop, chickpea also faces high-temperature (HT) stress during reproductive development in warmer regions and in late-sown environments. High temperature aborts floral buds, flowers and pods, loss of pollen viability and fertility ultimately leading to reduced seed set, size and yield (Devasirvatham *et al*., 2015). 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 dry matter accumulation (Prasad *et al*., 2008). High temperature negatively affects flower initiation, pollen viability (germination and tube growth), stigma receptivity, ovuleviability, ovule size, fertilization, seed/fruit set, seed composition, grain filling, and seed quality (Barnabás *et al*., 2008). Plants photosynthesize to create carbon compounds for growth and energy storage. Sugars created through photosynthesis are then transported by phloem using the pressure flow system and are used for growth or stored for later use. Biomass partitioning causes this sugar to be divided in a way that maximizes growth, provides the most fitness, and allows for successful reproduction After responding to environmental stimuli, plants partition biomass accordingly, utilizing resources from the environment and maximizing growth. 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). Plant hormones play a large part in biomass partitioning since they affect differentiation and growth of cells and tissues by changing the expression of genes and altering morphology (Toungous *et al*., 2018). 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). These PGRs helps in the sessile plants in sensing the stress conditions, transducing the signals for expression of genes for stress tolerance. Therefore, it was hypothesized that plant growth regulator application ameliorates heat stress effect by affecting biomass partitioning 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*. D1-Timely sown (23^{rd} November and 26^{th} November) and D2-Late sown (9^{th} January and 5^{th} January) in 2020-21 and in 2021-22, respectively. In both conditions, different plant growth regulators were applied at flowering stage *viz.* T_1-control (no spray), T_2- foliar spray of water, T_3-thiourea@100 ppm, T_4-thiourea@200 ppm, T_5-thiourea@400 ppm, T_6-thiourea@600 ppm, T_7-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 timely 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 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. The data on maximum and minimum temperature at the time of foliar application to maturity under timely sown (NS) and late sown (LS) condition in 2020-21 and 2021-22 has been showed in Fig. 1 and 2. Three plant samples were collected from each treatment and observations on dry matter of leaves, secondary branches, main stem and pods were recorded at 60, 75 and 90 DAS. Biomass partitioning on leaves, secondary branches, main stem and pods were determined from the dry mass of individual plant parts as a percentage of total plant dry mass.

RESULT AND DISCUSSION

A. Influence of sowing dates on biomass partitioning of leaf, secondary branches, main stem and pods at 60, 75 and 90 DAS

Delayed sown high-temperature stress condition reduces leaves' biomass partitioning by 28.59%, 30.69%, and 20.89% over timely sowing at 60 DAS, 75 DAS, and 90 DAS, respectively. Under timely sowing, biomass partitioning of leaves decreased from 60 DAS (18.99%) to 75 DAS (11.38%) and 90 DAS (7.34%) (Table 1). Under late sown conditions, biomass partitioning of leaves decreased from 60 DAS (13.56%) to 75 DAS (7.89%) and at 90DAS (5.80%) (Table 1). This result is similar to Ahamed *et al*. (2010), who reported that high temperatures in wheat caused reduced biomass partitioning of leaf lamina and leaf sheath compared to a timely environment. Biomass partitioning in plant vegetative organs decreased during high temperatures, probably due to export of non-structural carbohydrates to the developing kernels (Plaut *et al*., 2004).

Biomass partitioning studies on secondary branches revealed that under timely sown conditions, it decreased from 60 DAS (21.52%) to 75 DAS (16.47%) and 90 DAS (13.00%) (Table 2). Under late sown conditions, it decreased from 60 DAS (15.18%) to 75 DAS (11.04%) and 90 DAS (9.14%) (Table 2). High temperature prevailing under late sown condition leads to a reduction in biomass partitioning of secondary branches by 29.44%, 32.99%, and 29.67% over timely sowing at 60 DAS,75 DAS, and 90 DAS, respectively. It is consistent with Wang *et al.* (2010), who reported that high-temperature stress produced 8% fewer branches in the desi and 15% fewer (P, 0.05) in Kabuli. Similarly, high temperature caused significant declines in biomass partitioning in the shoot, relative growth rate, and net assimilation rate in maize, pearl millet, and sugarcane (Ashraf *et al*., 2004; Wahid *et al*., 2007). Biomass partitioning studies on the main stem revealed that under timely sown condition, it decreased from 60 DAS (4.85%) to 75 DAS (4.34%) and 90 DAS (4.08%). Under late sown conditions, it decreased from 60 DAS (15.18%) to 75 DAS (11.04%) and 90 DAS (9.14%) (Table 3). High temperature prevailing under late sown condition leads to a reduction in biomass partitioning of the main stem by 24.09%, 26.79%, and 39.29% over timely sowing at 60 DAS, 75 DAS, and 90 DAS, respectively. Similar results are reported by (Ashraf *et al.*, 2002; Wahid *et al*., 2007; Kushwaha *et al*., 2011; Kaushal *et al.,* 2013). Biomass partitioning studies of pods revealed that under timely sown condition, it increased from 60 DAS (54.64%) to 75 DAS (67.80%) and 90 DAS (75.58%) (Table 4). Heat stress decreases photosynthetic efficiency, which shifts the dynamics between sources and sinks (Ferguson *et al*., 2021; Nagar *et al*., 2021). This shift in source-sink dynamics leads to enhanced translocation of photo-assimilates towards reproductive parts (pods) in chickpea. Under late sown condition, it increased from 60 DAS (67.57%) to 75 DAS (77.89%) and 90 DAS (82.58%) (Table 4). High-temperature stress leads to increased biomass partitioning of pods by 23.67%, 14.88%, and 9.26% over timely sowing at 60 DAS, 75 DAS, and 90 DAS, respectively. This result is consistent with Rai *et al*. (2016), who observed that under high temperature, dry matter partitioning towards pods increased as compared to vegetative plant parts.

B. Influence of contrasting set of chickpea varieties on biomass partitioning *at 60, 75 and 90 DAS*

JG14 chickpea variety has been released as a heat tolerant variety in India (Gaur *et al*., 2014). JG 14 exhibited maximum biomass partitioning of leaves at 60 DAS (17.81%), 75 DAS (10.11%), and 90 DAS (6.70%) (Table 1). JG14 exhibited increased biomass partitioning of leaves over JG36 by 20.76%, 10.48%, and 3.87% decrease at 60 DAS, 75 DAS, and 90DAS, respectively. This result is consistent with Kumar *et al.* (2020), who carried out research having four contrasting genotypes, namely BG 240 and JG 14 (relatively heat tolerant), SBD 377 (moderately tolerant), and ICC 1882 (relatively heat sensitive) and concluded that under heat stress condition, heat tolerant genotypes BG 240 and JG 14 maintained a higher level of dry matter partitioning on leaves. Biomass partitioning of secondary branches studies revealed that in heat tolerant variety JG14, it decreased from 60 DAS (19.54%) to 75 DAS (14.40%) and at 90DAS (11.61%) (Table 2). Heat tolerant variety JG14 exhibited an increase in biomass partitioning on secondary branches over JG36 by 13.90%, 9.77%, and 10.22% at 60 DAS, 75 DAS and 90 DAS, respectively. Biomass partitioning of main stem studies revealed that in variety JG14, it decreased from 60DAS (4.60%) to 75DAS (3.92%) and at 90DAS (3.55%) (Table 3). Heat tolerant variety JG14 exhibited increased biomass partitioning on the main stem over JG36 by 16.65%, 8.58%, and 18.01% at 60DAS, 75DAS, and 90DAS, respectively. Delayed sown heat stress condition caused a maximum reduction in biomass partitioning in the main stem and secondary branches in heat susceptible variety ICC 1882 (Kumar *et al*., 2020). Seed yield per plant was positively and significantly correlated with the number of primary and secondary branches, and its value was maximum in the heat-tolerant genotype (Kuldeep *et al*., 2014). Biomass partitioning of pods studies revealed that in variety JG14, it increased from 60DAS (58.05%) to 75DAS (71.57%) and at 90DAS (78.14%) (Table 4). Heat tolerant variety JG14 decreased biomass partitioning on pods over JG36 by 9.51%, 3.44%, and 2.33% at 60DAS, 75DAS, and 90DAS, respectively. Source strength enhancement was well elucidated by JG14. Similarly, Kim *et al.* (2011) reported that consistently high-temperature stress increased the rates of grain filling and a fraction of dry matter partitioning to panicle and leaf senescence while reducing their durations under the temperature regime of 24.4 and 21.9°C in temperate variety of *Oryza sativa*.

C. Effect of Plant growth regulator treatment on biomass partitioning in leaf, secondary branches, main stem and pods in chickpea varieties under timely and late sown conditions

Under the timely sown condition, at the post-flowering stage (60 DAS), salicylic acid @ 600 ppm, 200 ppm, and thiourea @ 200 ppm enhanced dry matter partitioning towards leaves, main stem and secondary branches. In the seed filling stage (75 DAS), water spray enhanced dry matter partitioning towards leaves, secondary branches and main stem. In contrast, salicylic acid@400ppm enhanced dry matter partitioning towards pods in timely sown condition. Under the timely sown condition, during physiological maturity (90 DAS), salicylic acid @ 200 ppm and 400 ppm efficiently increased dry matter partitioning towards pods and main stem, respectively (Fig. 4). This result is inconsistent with the findings of Bekheta *et al.* (2009); Khan *et al.* (2003); Debnath *et al*. (2022). This salicylic acid dry matter enhancing effect under high-temperature stress is also evidenced in hybrid maize (Ahmad *et al.*, 2014); Mustard (Hayat *et al*., 2009). This might be because salicylic acid application enhanced the activity of antioxidative enzymes protecting the plants from direct and indirect effects of temperature stress, thereby improving the photosynthetic efficiency, metabolism, and growth (Hayat *et al*., 2009). Pulse being a source-limited crop, seed yield is drastically affected due to a reduction in source size and strength. Therefore, pulse yield under high-temperature stress can be increased by enhancing source strength. Under the late sown high-temperature stress condition, at the post-flowering stage (60 DAS), thiourea @ 400 ppm, salicylic acid @ 200 ppm, enhanced dry matter partitioning towards leaves (15.28%) and main stem (4.06%), respectively. In the seed-filling stage (75 DAS), Salicylic acid @ 200 ppm enhances dry matter partitioning towards leaves (8.85%) and main stem (3.67%), whereas salicylic acid @ 400ppm enhances dry matter partitioning towards secondary branches (11.62%). During the physiological maturity stage (90 DAS), thiourea @ 600 ppm increased dry matter partitioning towards the main stem (2.88%) and secondary branches (9.99%), respectively while, salicylic acid @ 400 ppm enhances biomass partitioning in leaf (Fig. 3). The result is inconsistent with the findings of Bekheta *et al.* (2009); Khan *et al.* (2003); Nagar *et al*. (2015). This salicylic acid dry matter enhancing effect under high-temperature stress is also evidenced in hybrid maize (Ahmad *et al*., 2014), Mustard (Hayat *et al.*, 2009) and in coriander (Sharma *et al*., 2022). This might be because salicylic acid application enhanced the activity of antioxidative enzymes protecting the plants from direct and indirect effects of temperature stress, thereby improving the photosynthetic efficiency, metabolism, and growth (Hayat *et al.*, 2009).

Table 1: Effect of Plant growth regulator on biomass partitioning in leaf at 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	60 DAS			75 DAS			90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T_1	16.64	17.63	17.14	10.20	12.14	11.17	7.10	6.50	6.80
	T_2	19.25	22.17	20.71	11.79	15.23	13.51	8.88	10.16	9.52
	T_3	15.33	20.30	17.82	9.16	13.88	11.52	6.05	9.52	7.79
	T_4	13.91	19.10	16.51	8.56	11.87	10.22	6.18	8.54	7.36
	T_5	12.11	24.17	18.14	10.43	14.35	12.39	6.13	8.77	7.45
	T_6	19.64	23.20	21.42	13.22	9.59	11.41	8.11	6.40	7.26
	T_7	14.69	23.33	19.01	9.58	10.72	10.15	7.08	7.49	7.29
	T_8	16.40	20.59	18.50	8.78	12.68	10.73	4.39	6.54	5.47
	T_9	20.22	23.18	21.70	11.67	10.98	11.33	6.96	7.27	7.12
	Mean	16.47	21.52	18.99	10.38	12.38	11.38	6.76	7.91	7.34
Late sown	T_1	13.05	12.53	12.79	6.82	6.84	6.83	5.80	4.48	5.14
	T_2	9.68	16.65	13.17	7.34	7.93	7.64	6.06	5.67	5.87
	T_3	15.00	14.30	14.65	6.48	7.47	6.98	5.20	4.61	4.91
	T_4	13.06	13.25	13.16	7.53	7.52	7.53	6.13	5.66	5.90
	T_5	16.47	14.09	15.28	8.28	8.58	8.43	6.14	6.17	6.16
	T_6	14.10	13.20	13.65	8.55	8.14	8.35	6.86	5.63	6.25
	T_7	11.27	14.10	12.69	9.45	8.24	8.85	7.36	6.04	6.70
	T_8	13.15	14.04	13.60	8.73	8.85	8.79	3.98	6.05	5.02
	T_9	11.47	14.71	13.09	8.19	7.02	7.61	7.62	5.02	6.32
	Mean	13.03	14.10	13.56	7.93	7.84	7.89	6.13	5.48	5.80
	Varieties	14.75	17.81	16.28	9.15	10.11	9.63	6.45	6.70	6.57
Statistics		CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	2.01			1.21			1.23		
	PGR (T)	1.54			1.35			1.21		
	Varieties (V)	2.59			1.25			1.12		
	S × V × T	3.54			2.99			1.85		

Table 2: Effect of Plant growth regulator on biomass partitioning in secondary branches at 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	60 DAS			75 DAS			90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T_1	19.19	24.60	21.90	15.93	20.38	18.16	12.74	14.05	13.40
	T_2	18.65	23.27	20.96	16.90	22.82	19.86	13.96	16.25	15.11
	T_3	19.85	23.91	21.88	15.60	17.74	16.67	10.99	16.44	13.72
	T_4	20.14	23.91	22.03	13.40	17.31	15.36	10.43	16.30	13.37
	T_5	20.71	22.02	21.37	14.53	15.87	15.20	10.63	14.17	12.40
	T_6	19.14	22.08	20.61	16.01	15.72	15.87	12.70	12.11	12.41
	T_7	20.80	23.18	21.99	16.22	16.43	16.33	13.15	13.91	13.53
	T_8	20.28	22.40	21.34	14.04	15.65	14.85	7.84	11.41	9.63
	T_9	19.26	23.91	21.59	15.35	16.63	15.99	11.87	15.09	13.48
	Mean	19.78	23.25	21.52	15.33	17.62	16.47	11.59	14.41	13.00
Late sown	T_1	15.97	18.11	17.04	10.43	10.42	10.43	9.88	7.81	8.85
	T_2	15.95	17.82	16.89	10.68	10.27	10.48	9.42	8.62	9.02
	T_3	13.98	16.10	15.04	10.84	11.29	11.07	9.14	8.32	8.73
	T_4	14.20	16.50	15.35	11.07	11.39	11.23	9.70	9.81	9.76
	T_5	13.81	14.78	14.30	11.02	11.59	11.31	8.31	9.05	8.68
	T_6	14.07	15.19	14.63	11.04	11.52	11.28	10.49	9.48	9.99
	T_7	14.52	14.65	14.59	11.12	11.36	11.24	9.43	8.61	9.02
	T_8	14.01	14.56	14.29	11.01	12.23	11.62	8.26	9.37	8.82
	T_9	14.29	14.77	14.53	10.89	10.52	10.71	10.69	8.21	9.45
	Mean	14.53	15.83	15.18	10.90	11.18	11.04	9.48	8.81	9.14
	Varieties	17.16	19.54	18.35	13.12	14.40	13.76	10.54	11.61	11.07
Statistics		CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	4.56			2.36			1.5		
	PGR (T)	1.56			1.45			1.65		
	Varieties (V)	1.65			1.85			1.51		
	S × V × T	4.52			2.85			3.95		

Table 3: Effect of plant growth regulators on biomass partitioning in main stem at 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	60 DAS			75 DAS			90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T_1	3.88	4.93	4.41	4.00	4.38	4.19	3.37	3.37	3.37
	T_2	3.95	4.94	4.45	4.04	5.60	4.82	3.67	3.31	3.49
	T_3	4.95	5.24	5.10	4.49	4.32	4.41	3.24	4.86	4.05
	T_4	4.58	5.66	5.12	3.44	4.94	4.19	2.87	5.75	4.31
	T_5	5.09	5.00	5.05	3.91	4.23	4.07	3.00	5.99	4.50
	T_6	4.32	5.30	4.81	4.38	4.42	4.40	4.04	5.35	4.70
	T_7	4.90	6.16	5.53	4.58	4.66	4.62	4.11	4.67	4.39
	T_8	4.48	4.56	4.52	3.70	4.42	4.06	2.33	3.72	3.03
	T_9	3.99	5.43	4.71	4.17	4.51	4.34	3.49	6.29	4.89
	Mean	4.46	5.25	4.85	4.08	4.61	4.34	3.35	4.81	4.08
Late sown	T_1	3.26	3.64	3.45	2.60	2.81	2.71	2.58	1.96	2.27
	T_2	3.33	4.27	3.80	2.80	2.82	2.81	2.40	2.20	2.30
	T_3	3.32	3.47	3.40	3.16	3.01	3.09	2.66	2.07	2.37
	T_4	3.62	3.39	3.51	3.39	2.97	3.18	2.68	2.75	2.72
	T_5	3.39	3.84	3.62	3.44	3.22	3.33	2.34	2.15	2.25
	T_6	3.64	4.38	4.01	3.19	3.97	3.58	3.04	2.73	2.89
	T_7	3.63	4.48	4.06	3.49	3.84	3.67	2.85	2.32	2.59
	T_8	3.27	4.14	3.71	3.13	3.47	3.30	2.28	2.41	2.35
	T_9	3.33	3.91	3.62	3.02	2.91	2.97	3.18	1.98	2.58
	Mean	3.42	3.95	3.68	3.14	3.22	3.18	2.67	2.29	2.48
	Varieties	3.94	4.60	4.27	3.61	3.92	3.76	3.01	3.55	3.28
Statistics		CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	1.54			1.2			1.25		
	PGR (T)	1.52			1.96			1.52		
	Varieties (V)	1.25			1.21			0.95		
	S × V × T	1.95			1.55			1.98		

Table 4: Effect of plant growth regulators on biomass partitioning in pods at 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	60 DAS			75 DAS			90 DAS		
		JG 36	JG 14	Mean	JG 36	JG 14	Mean	JG 36	JG 14	Mean
Normal sown	T_1	60.29	52.84	56.57	69.87	63.10	66.49	76.79	76.07	76.43
	T_2	58.15	49.63	53.89	67.27	56.35	61.81	73.48	70.28	71.88
	T_3	59.86	50.56	55.21	70.75	64.06	67.41	79.72	69.18	74.45
	T_4	61.37	51.33	56.35	74.60	65.88	70.24	80.52	69.41	74.97
	T_5	62.09	48.81	55.45	71.13	65.55	68.34	80.24	71.06	75.65
	T_6	56.89	49.42	53.16	66.39	70.27	68.33	75.15	76.15	75.65
	T_7	59.62	47.33	53.48	69.63	68.19	68.91	75.66	73.93	74.80
	T_8	58.85	52.46	55.66	73.48	67.25	70.37	85.44	78.33	81.89
	T_9	56.53	47.48	52.01	68.81	67.89	68.35	77.68	71.35	74.52
	Mean	59.29	49.98	54.64	70.21	65.39	67.80	78.30	72.86	75.58
Late sown	T_1	67.71	65.72	66.72	80.15	79.93	80.04	81.74	85.75	83.75
	T_2	71.04	61.25	66.15	79.19	78.98	79.09	82.13	83.51	82.82
	T_3	67.71	66.12	66.92	79.53	78.23	78.88	83.00	85.00	84.00
	T_4	69.12	66.86	67.99	78.01	78.12	78.07	81.49	81.78	81.64
	T_5	66.33	67.29	66.81	77.26	76.60	76.93	83.21	82.64	82.93
	T_6	68.19	67.24	67.72	77.22	76.37	76.80	79.62	82.16	80.89
	T_7	70.58	66.76	68.67	75.93	76.55	76.24	80.36	83.04	81.70
	T_8	69.57	67.25	68.41	77.13	75.45	76.29	85.47	82.18	83.83
	T_9	70.92	66.61	68.77	77.89	79.55	78.72	78.52	84.78	81.65
	Mean	69.02	66.12	67.57	78.03	77.75	77.89	81.73	83.43	82.58
	Varieties	64.16	58.05	61.11	74.12	71.57	72.85	80.01	78.14	79.08
Statistics		CD at 5%			CD at 5%			CD at 5%		
	Sowing (S)	1.57			1.67			1.54		
	PGR (T)	1.78			1.96			1.87		
	Varieties (V)	1.99			122			0.78		
	S × V × T	3.89			2.55			1.87		

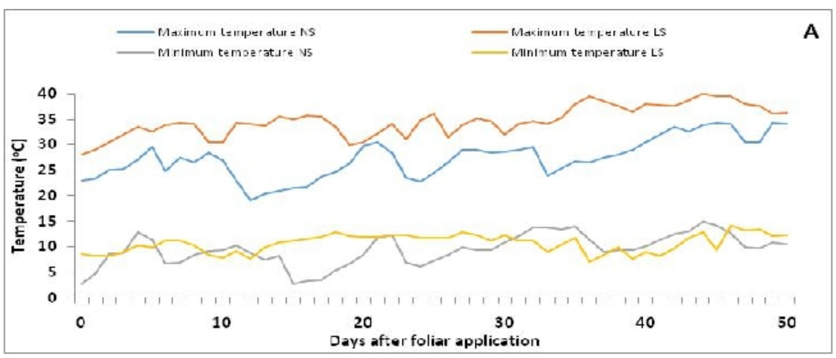

Fig. 1. Maximum, mean and minimum temperature recorded from flowering stage to crop maturity under both normal and late sown conditions in 2020-21.

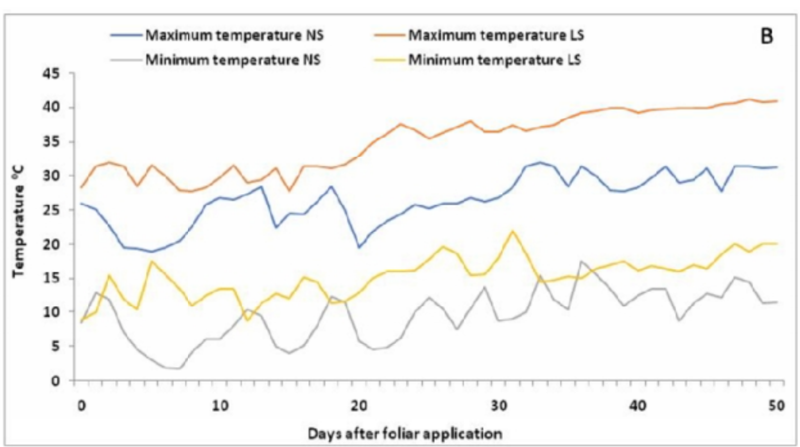

Fig. 2. Maximum and minimum temperature recorded from flowering stage to crop maturity under both normal and late sown conditions in 2021-22.

Heat Stress

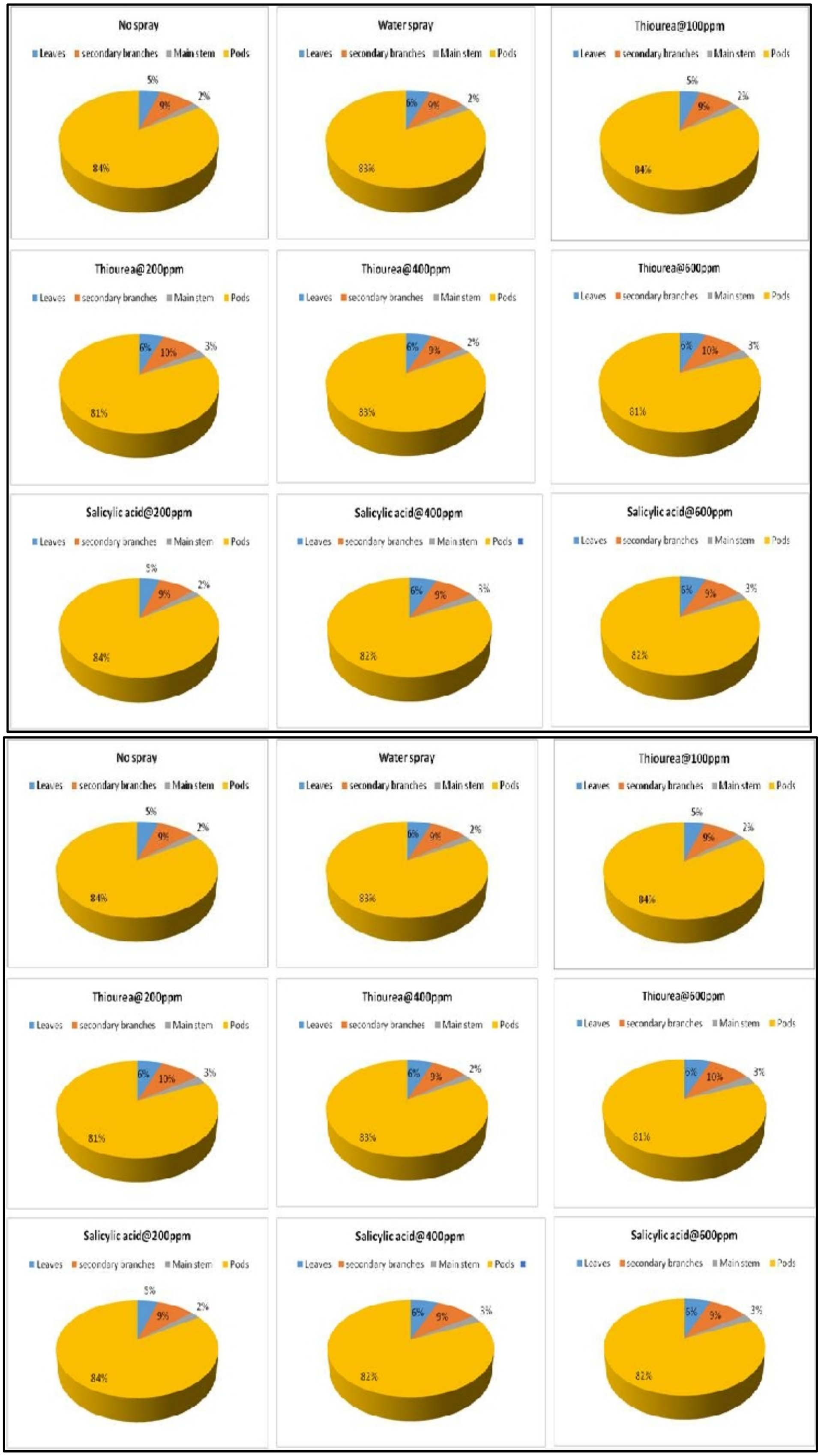

Fig. 3. Dry Matter partitioning in Leaf, main stem, secondary branches and pods in Chickpea under heat stress condition.

Timely sown condition

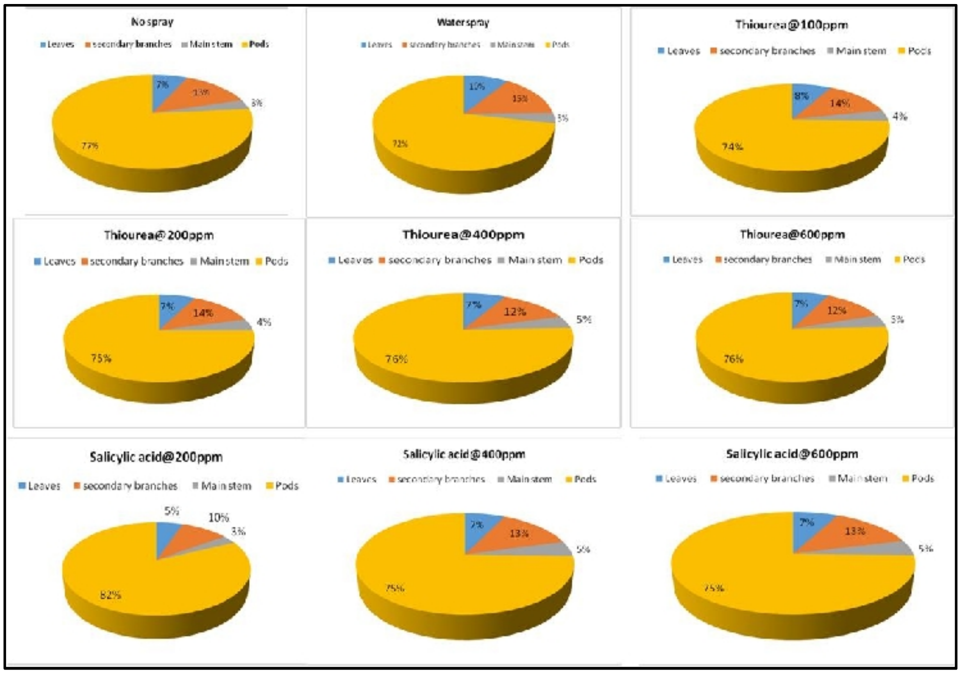

Fig. 4. Dry Matter partitioning in Leaf, main stem, secondary branches and pods in Chickpea under normal sown condition.

CONCLUSION

The dry matter partitioning towards leaves, secondary branches, and main stem decreases as the phenology progresses from flowering to maturity under timely and high-temperature stress conditions. In contrast, dry matter partitioning towards pods increases with the progression of growth duration under both timely and high-temperature stress conditions. Late sown high-temperature stress reduces dry matter partitioning of leaves, secondary branches, and main stem, whereas an increase in dry matter partitioning towards pods was observed. Heat tolerant chickpea variety, JG 14, reflected an increase in biomass partitioning towards leaves, secondary branches, and main stem compared to the JG 36 chickpea variety. Under the timely sown condition, at the post-flowering stage, salicylic acid @ 600 ppm, 200 ppm, and thiourea @ 200 ppm enhanced dry matter partitioning towards leaves, secondary branches and main stem. In the seed filling stage, at 75 DAS, water spray enhances dry matter partitioning towards leaves, secondary branches and main stem. In contrast, salicylic acid@400ppm enhances dry matter partitioning towards pods in timely sown condition. Under the timely sown condition, during physiological maturity at 90 DAS, salicylic acid @ 200 ppm and 400 ppm efficiently increased dry matter partitioning towards pods and main stem, respectively (Fig. 4). Pulse being a source-limited crop, seed yield is drastically affected due to a reduction in source size and strength. Therefore, pulse yield under high-temperature stress can be increased by enhancing source strength. In the present study, Plant growth regulator salicylic acid @ 400 ppm proves its potential by enhancing biomass partitioning towards source tissues (leaf), main stem, and secondary branches (Fig. 3). Plant growth regulator salicylic acid @ 400 ppm can mitigate high-temperature stress effect on yield through enhancing biomass partitioning towards source tissue (leaf), main stem, and secondary branches.

FUTURE SCOPE

Salicylic acid@200ppm helps achieve maximum dry matter partitioning towards pods in chickpea under timely sown conditions. Plant growth regulators, particularly salicylic acid @ 400 ppm, will be recommended to farmers to enhance dry matter partitioning towards leaves, main stem, and secondary branches under heat stress condition.

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