

Dynamics of Vegetative and Reproductive Growth Pattern in Chickpea (*Cicer arietinum* L.) with their Correlations to Seed Yield under Different Sowing Dates in North India

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ABSTRACT

Aims: To observe the effect of sowing dates on vegetative and reproductive growth rate of chickpea genotypes at different intervals i.e. 30, 60, 90, and 120 DAS with their correlations to seed yield.

Study design: Randomized block design (RBD)

Place and Duration of Study: At fields of Pulses section, department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar during Rabi season of 2017-18 and 2018-19.

Methodology: The experiment was conducted with ten genotypes of chickpea (*Cicer arietinum* L.) viz ICCV 88503, ICCV 92944, HC- 1, HC-3, HC-5, H12-64, H13-01, H13-02, H14-01 and H14-04 for three dates of sowing i.e. 15th October, 15th November and 15th December under different environmental conditions.

Results: The dry weight of leaves, stem, pods, plant height, crop growth rate, relative growth rate and pollen viability were minimum in 15th December sowing and maximum in 15th October sowing at all intervals. Among genotypes, maximum dry matter and growth rate were observed in H12-64 and H13-01 while minimum were found in H14-04. Seed yield exhibited significant positive correlation with all traits in 15th October and 15th November sowing while non-significant was on 15th December sowing.

Conclusion: Among sowing dates, 15th October and 15th November sowing were suitable for all traits and with delay in sowing from 15th November to 15th December, adverse effects were observed on all the traits due to environmental factors. Chickpea genotypes H12-64 and H13-01 were found to be promising in all the sowing dates and can be used in further breeding programme of chickpea for temperature tolerance.

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Keywords: Sowing dates, Growth rate, Genotypes, Dry weight, Chickpea

INTRODUCTION

Chickpea is cool season crop cultivated throughout the world. In India, Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Andhra Pradesh, Karnataka, Chhattisgarh, Bihar and

Jharkhand are major chickpea cultivating and producing states contributing more than 95% to the total chickpea area and production. (Anonymous, 2018-19). With the intensification of wheat cultivation during *rabi* season, the pulse area reduced in the northern states, especially where irrigation facilities were available. This has forced, chickpea to shift towards comparative warmer and harsher growing environment of the southern states (Dixit *et al.*, 2019).

In northern part of India, it is normally sown during second fortnight of October. Sometime its sowing is delayed depending upon the withdrawal of monsoon and late harvest of preceding *kharif* crop like rice and sugarcane which ultimately results in poor yield (Wang *et al.*, 2006).

Growth analysis is being used as an important tool for assessing crop productivity in various crops. Analysis of crop growth and development gives an insight not only on the performance of a particular genotype but also impact on crop at particular stages that ultimately leads to low production. Therefore optimum sowing time plays an important role to fully exploit the production potential of a cultivars as it provides optimum growth conditions such as temperature, light, humidity and rainfall (Iraddi, 2008).

Sowing time play a vital role in influencing the growth of chickpea particularly through prevailing temperature during germination and reproductive phases as pulses are sensitive to change in temperature and the late-sown crop is exposed to high temperatures (>35°C) at its reproductive stage in the months of February and March and low temperature (>5°C) at vegetative stages in the months of December and January (Berger *et al.*, 2011; Kumar *e tal.*, 2012). The high temperature at late sown condition may adversely affect the growth and productivity of crops as both duration and grain filling stages are sensitive to alteration in temperature (Moradshahiet *al.*, 2004). However, during early sown conditions, temperature below 10 °C is also causes drastic changes in physiological processes ranging from plant water status, photosynthesis to reactive oxygen species (ROS) and crop growth rate, dry matter production, flowering or pollen viability and has adverse effect on chickpea production and results in losses from 15-20 % (Ali and Kumar, 2005; Bakht *et al.*, 2006; Chaturvedi *et al.*, 2009).

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MATERIALS AND METHODS

The experimental site (Hisar) is located in North-West of India. The values of weather parameters were taken from observatory located in the research farm of Agro meteorology department in Hisar Agricultural University (Figure 1 and 2). All the parameters were measured at different growth stages *i.e* 30, 60, 90 and 120 DAS (days after sowing). The five randomly

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2. Add Location Map

selected plants from each plot were uprooted and sun dried. The dry weight of stem, leaves and pods were taken and average was recorded. For plant height, the perpendicular distance from the ground level to the tip of the plant was measured in centimetre. CGR was measured by using the following formula (Reddy and Reddy, 2009): $CGR = (W_2 - W_1) / P (T_2 - T_1)$ Where, P is the land area and W1 and W2 are dry weights at T₁ and T₂ time, respectively. RGR was measured by the following formula (Reddy and Reddy, 2009): $RGR = (\text{Loge}W_2 - \text{Loge}W_1) / (T_2 - T_1)$ Where, W1 and W2 are dry weights at T₁ and T₂ time, respectively. Viability of freshly released pollen grains was assessed by 2,3,5 triphenyl tetrazolium chloride (TTC) test (Hauser and Morrison, 1964).

All the collected data were statistically analyzed by pooled analysis of both year (2017-18 and 2018-19) through OPSTAT software at the Computer Centre, Department of Statistics, CCS HAU, Hisar.

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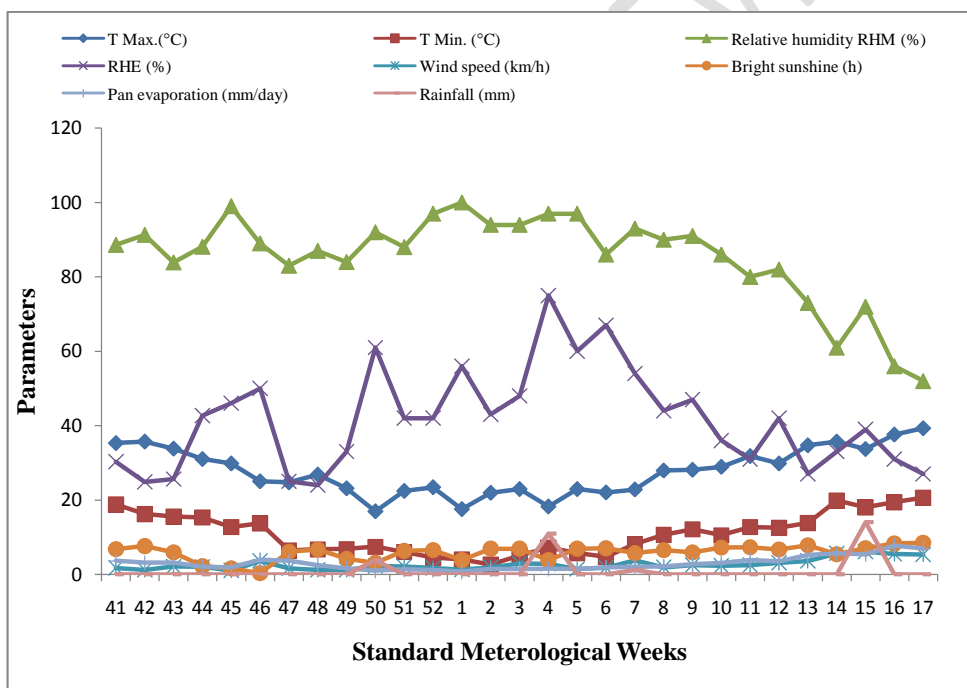


Fig. 1: Values of weather parameters during cropping season of 2017-18.

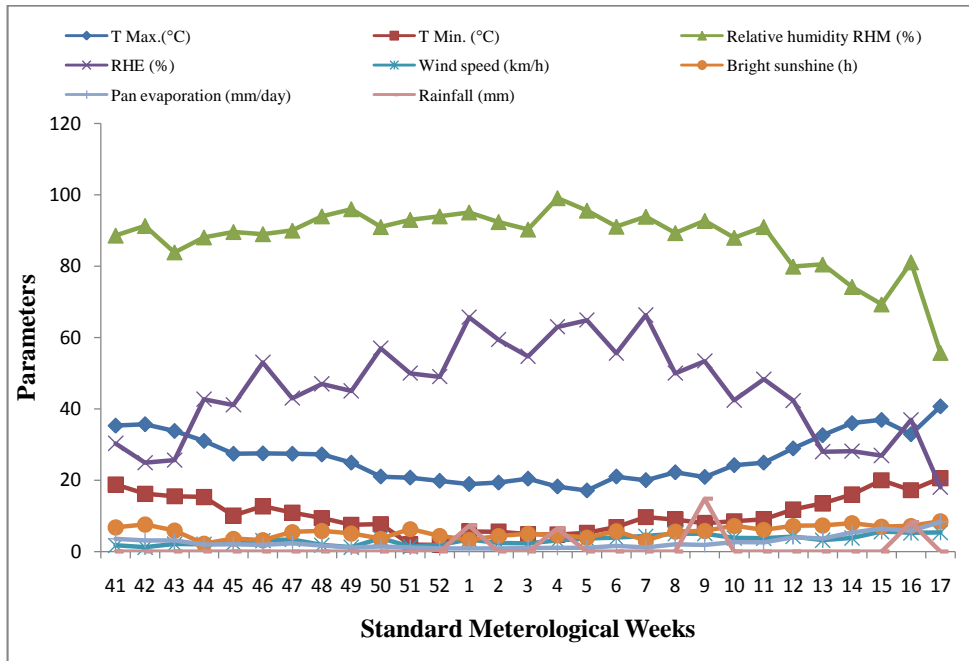


Fig. 2: Values of weather parameters during cropping season of 2018-19.

RESULTS AND DISCUSSION

In the present investigation the decreasing trend was observed for dry matter production and its distribution in component parts with delayed sowing from 15th October. The rate of dry matter accumulation in stem and leaves at different sowing dates was increased with the advancing age of the crop but dry weight of leaf declined towards maturity in all genotypes due to the translocation of stored photosynthates from source towards the sink. The highest dry matter was observed in genotypes sown on 15th October and declined with delayed sowing (Table 1). Among the genotypes maximum dry weight of leaf and stem were observed in H12-64 and H13-01 and minimum were recorded in H14-04 at all the growth stages (30, 60, 90, 120 DAS). This might be due to differential growth potential of the genotypes. The reduction in dry matter of leaf and stem beyond 15th October sowing date was due to curtailment of the growth period by 30 days in 15th November and 60 days in 15th December sowing. The later a crop is planted the shorter the potential season for growth and development. Similar results due to different sowing dates on dry matter accumulation in chickpea also observed by (Onyari *et al.*, 2010; Sekhar *et al.*, 2015; Pawar, 2015; Ray *et al.*, 2017).

Table.1: Effects of sowing dates on dry weight of leaves and stem (gm)

Sowing dates	Dry weight of leaves (gm)				Dry weight of Stem (gm)			
	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
15 th Oct	0.46	1.47	3.86	4.81	0.23	2.68	3.95	6.46
15 th Nov	0.38	1.42	3.81	4.66	0.20	2.57	3.92	5.80
15 th Dec	0.30	0.95	2.61	3.31	0.14	1.87	2.70	4.18
CD at 5%	0.05	0.01	0.04	0.05	0.03	0.04	0.05	0.08
Genotypes								
H12-64	0.41	1.31	3.46	4.29	0.20	2.39	3.54	5.53
H13-01	0.41	1.31	3.46	4.29	0.20	2.39	3.54	5.52
H13-02	0.40	1.30	3.45	4.28	0.20	2.38	3.53	5.51
H14-01	0.38	1.28	3.44	4.28	0.20	2.39	3.53	5.51
H14-04	0.36	1.24	3.39	4.23	0.17	2.33	3.49	5.46
HC 1	0.37	1.27	3.42	4.25	0.19	2.35	3.52	5.47
HC 3	0.37	1.27	3.42	4.25	0.18	2.35	3.51	5.49
HC 5	0.37	1.27	3.42	4.25	0.18	2.35	3.51	5.49
ICCV88503	0.38	1.27	3.42	4.26	0.19	2.37	3.53	5.51
ICCV92944	0.38	1.27	3.42	4.25	0.18	2.36	3.52	5.50
CD at 5%	0.09	0.03	0.08	0.10	0.06	0.07	0.09	0.14

In the present investigation, the dry weight of pods and plant height reduced with delayed sowing due to change in climatic variables especially rise in temperature. The dry weight of pods and plant height increased gradually from flowering to pod maturation and remained almost constant thereafter till maturity. Significantly the highest and lowest dry weight of pods and plant height were observed at 15th October and 15th December sowing date, respectively at 30, 60, 90 and 120 DAS (Table 2). This might be due to congenial environmental conditions *i.e.* optimum temperature and sunshine hours that prevailed during 15th October sowing date. The genotype H13-01 recorded highest dry weight of pods and plant height at all critical growth stages (30, 60, 90 and 120 DAS) and lowest in H14-04. This variations might be due to different growth potential of the genotypes. Similar results due to different sowing dates on plant height in chickpea also observed by (Mrudula *et al.*, 2013; Rehman *et al.*, 2015; Sekhar *et al.*, 2015; Pawar, 2015; Patil *et al.*, 2017).

Table.2: Effects of sowing dates on dry weight of pods, plant height and pollen viability

Sowing dates	Dry w.t of pods (gm/plant)		Plant Height (cm)			Pollen Viability (%)	
	100 DAS	120DAS	30 DAS	60 DAS	90 DAS	120 DAS	80-90DAS
15 th Oct	5.15	8.19	10.5	25.1	55.3	72.2	69.14
15 th Nov	5.09	8.15	9.9	23.6	53.1	69.5	69.01
15 th Dec	4.07	6.09	9.1	19.5	43.5	59.7	57.50
CD at 5%	0.06	0.10	0.5	0.04	0.4	0.4	2.05
Genotypes							
H12-64	4.81	7.53	10.9	23.7	53.3	70.8	73.05
H13-01	4.80	7.52	10.9	23.6	53.1	70.6	73.01
H13-02	4.78	7.49	10.6	23.4	52.3	69.3	69.79
H14-01	4.79	7.51	10.2	23.3	50.4	67.6	68.31
H14-04	4.72	7.43	8.1	20.3	43.8	62.0	60.47
HC 1	4.76	7.46	9.8	22.7	49.4	65.4	64.71
HC 3	4.76	7.47	9.4	22.6	47.9	65.6	66.44
HC 5	4.75	7.46	9.3	22.5	47.4	65.1	65.71
ICCV88503	4.77	7.47	9.5	22.9	49.7	66.2	66.85
ICCV92944	4.77	7.47	9.4	22.8	48.7	65.9	66.54
CD at 5%	0.11	0.18	0.9	0.08	0.7	0.7	2.10

In current study, the pollen viability in chickpea differed significantly at 50 % flowering stage (80-90 DAS). Among three dates of sowings lowest pollen viability was recorded in crop sown on 15th December and highest in 15th October and 15th November sowing. This might be due to comparatively high temperature (28.9°C) prevailing at 50% flowering in 15th December sowing than 15th October and 15th November sowing (22.2°C). The data in table 2 showed that highest pollen viability in genotypes was recorded in genotypes H12-64 and H13-01 whereas, minimum pollen viability was in H14-04 this might be due to their different tolerance behavior of genotypes against temperature stress. Similar results due to temperature variation also observed by Krishnamurthy *et al.* 2011; Upadhyaya *et al.* 2011 and Nayyar *et al.* 2005 in chickpea, Pressman *et al.* 2006 in tomato and Snider *et al.* 2011 in cotton.

The data presented in table 3 indicated that the minimum CGR and RGR were observed in 15th December and maximum CGR and RGR were observed on 15th October sowing at all the growth stages (0-30, 31-60, 61-90 and 91-120 DAS) of crop. This might be due to that the high temperature at initial stages in 15th October sowing resulted into accelerated plant growth that produces more dry matter which resulting into increased plant growth rate (CGR and RGR) while in 15th December sowing, low temperature at vegetative phase and high temperature at reproductive phase could be accounted by low

dry matter production that resulted into decreased plant growth rate (CGR and RGR) at all the growth stages.

Table.3: Effects of sowing dates on crop growth rate and relative growth rate

Crop Growth Rate (g m ⁻² day ⁻¹)					Relative Growth Rate (g g ⁻¹ day ⁻¹)			
Sowing dates	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
15 th Oct	0.027	0.128	0.310	0.217	0.0087	0.0362	0.0362	0.0055
15 th Nov	0.025	0.122	0.301	0.191	0.0080	0.0358	0.0358	0.0052
15 th Dec	0.018	0.081	0.237	0.133	0.0063	0.0177	0.0177	0.0048
CD at 5%	0.001	0.002	0.006	0.003	0.001	0.0001	0.0001	0.0001
Genotypes								
H12-64	0.027	0.120	0.295	0.191	0.0082	0.0126	0.0302	0.0053
H13-01	0.026	0.119	0.295	0.191	0.0082	0.0126	0.0302	0.0053
H13-02	0.025	0.119	0.285	0.191	0.0078	0.0125	0.0300	0.0052
H14-01	0.024	0.105	0.288	0.183	0.0077	0.0118	0.0299	0.0052
H14-04	0.021	0.104	0.274	0.169	0.0071	0.0116	0.0296	0.0049
HC 1	0.022	0.104	0.276	0.173	0.0072	0.0119	0.0296	0.0052
HC 3	0.023	0.104	0.287	0.173	0.0075	0.0117	0.0300	0.0051
HC 5	0.023	0.104	0.276	0.172	0.0072	0.0118	0.0296	0.0052
ICCV88503	0.024	0.119	0.282	0.185	0.0083	0.0125	0.0305	0.0052
ICCV92944	0.022	0.104	0.276	0.173	0.0071	0.0119	0.0296	0.0051
CD at 5%	0.001	0.004	0.009	0.006	0.001	0.0002	0.0002	0.0001

Among the genotypes maximum CGR and RGR were observed in H12-64 and H13-01 and minimum were recorded in H14-04 at all the growth stages (0-30, 31-60, 61-90 and 91-120 DAS). The variation in these genotypes might be due to their genetic makeup. Similar results due to different sowing dates has also been reported earlier in the literature by (Kabir *et al.*, 2009 in chickpea, Alam *et al.*, 2014; Solanki and Mundra, 2015; Khayat *et al.*, 2016 in *Brassica juncea*).

Table.4: Correlations of different parameters with seed yield

Traits	Growth stages (DAS)	15 th October	15 th November	15 th December
Plant Height	30	0.810**	0.767**	0.545 ^{NS}
	60	0.860**	0.901**	0.445 ^{NS}

	90	0.810**	0.872**	0.565 ^{NS}
	120	0.810**	0.824**	0.421 ^{NS}
	SY	1.000	1.000	1.000
DW	30	0.766**	0.814**	0.436 ^{NS}
	60	0.777**	0.854**	0.478 ^{NS}
	90	0.750*	0.809**	0.375 ^{NS}
	120	0.807**	0.817**	0.308 ^{NS}
	SY	1.000	1.000	1.000
CGR	0-30	0.747*	0.780**	0.457 ^{NS}
	31-60	0.678*	0.669*	0.730*
	61-90	0.662*	0.965**	0.437 ^{NS}
	91-120	0.759*	0.743*	0.623 ^{NS}
	SY	1.000	1.000	1.000
RGR	0-30	0.685*	0.772**	0.111 ^{NS}
	31-60	0.681*	0.583 ^{NS}	0.116 ^{NS}
	61-90	0.694*	0.644*	0.251 ^{NS}
	91-120	0.377 ^{NS}	0.170 ^{NS}	0.621 ^{NS}
	SY	1.000	1.000	1.000
PV	80-90	0.821*	0.815*	0.611 ^{NS}
	SY	1.000	1.000	1.000

Abbreviations: DW= Dry weight, CGR= Crop growth rate, RGR= Relative growth rate, PV= Pollen

Viability

Correlations with seed yield: Seed yield exhibited significant positive correlation with all traits in 15th October and 15th November sowing while non-significant was on 15th December sowing (Table 4).

Comment [U6]: Recommendations and Suggestions

CONCLUSION

Dry matter production, growth rate and pollen viability of chickpea genotypes varied due to sowing dates. With delay in sowing from 15th October to 15th December, there were decrease in growth rate, dry matter production and pollen viability of chickpea. Average over sowing dates the values of growth rate, dry matter production and pollen viability was highest in genotypes H12-64 and H13-01 whereas lowest values was in H14-04. So it is concluded that chickpea genotypes H12-64 and H13-01 were found to be promising in all the sowing dates and can be used in further breeding programme of chickpea for early (cold tolerance) and late

(heat tolerance) sown conditions.

REFERENCES

Alam MJ, Ahmed KS, Mollah MRA, Tareq MZ, Alam J. Effect of planting dates on the yield of mustard seed. *International Journal of Applied Science and Biotechnology*. 2014; 3(4): 651-654.

Ali M, Kumar S. Chickpea (*Cicer arietinum* L.) research in India: Accomplishments and future strategies. *Indian Journal of Agricultural Sciences*. 2005;75: 125-133.

Anonymous. Progress report 2018-19. All India Coordinated Chickpea Improvement Project

Bakht J, Asghari B, Dominy P. The role of abscisic acid and low temperature in chickpea (*Cicer arietinum*) cold tolerance and effects on plasma membrane structure and function. *Journal of Experimental Botany*. 2006; 57: 3707-3715.

Berger JD, Milroy SP, Turner NC, Siddique KHM, Imtiaz M, Malhotra R. Chickpea evolution has selected for contrasting phenological mechanisms among different habitats. *Euphytica*. 2011;180: 1-15.

Chaturvedi SK, Mishra DK, Vyas P, Mishra N. Breeding for cold tolerance in chickpea. *Trends in Biosciences*. 2009;2:1-6.

Dixit GP, Srivastava AK, Singh NP. Marching towards self-sufficiency in chickpea. *Current Science*. 2019;116(2) : 239-245.

Hauser EJP, Morrison JH. The cytochemical reduction of nitro blue tetrazolium as an index of pollen viability. *American Journal of Botany*. 1964;51: 748-752

Iraddi VS. Response of mustard (*Brassica juncea* L. Czernj and Cosson) varieties to date of sowing and row spacing in Northern transition zone of Karnataka. Thesis Submitted to the University of Agricultural Sciences, Dharwad, In partial fulfillment of the requirements for the Degree of Master of science (Agriculture) In Agronomy. 2008;55-81.

Kabir AHMF, Bari MN, Karim A, Khaliq QA, Ahmed JU. Effect of sowing time and cultivars on the growth and yield of chickpea under rainfed condition. *Bangladesh Journal of Agricultural Research*. 2009;34 (2): 335-342.

Khayat M, Rahnama A, Lorzadeh S. Physiological indices, phenological characteristics and trait evaluation of canola genotypes response to different planting dates. *Proceeding : National Academy of Science, Section B, Biological Science, India*. 2016;235-243.

Krishnamurthy L, Gaur PM, Basu PS, Chaturvedi SK, Tripathi S, Vadez V, Rathore A, Varshaney RK, Gowda CLL. Large genetic variation for heat tolerance in the reference collection of chickpea (*Cicer arietinum* L.) germplasm. *Plant Genetic Resources*. 2011; (9): 59-61.

Kumar N, Nandwal AS, Yadav R, Bhasker P, Kumar S, Devi S, Singh S, Lather VS. Assessment of chickpea genotypes for high temperature tolerance. *Indian Journal of Plant Physiology*. 2012;17(3 and 4): 224-232.

Moradshahi A, Eskandari BS, Kholdebarin B. Some physiological responses of canola (*Brassica napus* L.). *Iranian Journal of Science and Technology*. 2004;(28): 43-50.

Mrudula G, Rani YA, Madhan M, Mohan and Reddy MVS. Influence of plant physiological characters on yield of chick pea (*Cicer arietinum* L.) genotypes. *Progressive Research*. 2013;8(1): 133-134.

Nayyar H, Bains T, Kumar S. Low temperature induced floral abortion in chickpea: relationship to abscisic acid and cryoprotectants in reproductive organs. *Environmental and Experimental Botany*. 2005;(53): 39-47.

Onyari CAN, Ouma JP, Kibe AM. Effect of tillage method and sowing time on phenology, yield and yield components of chickpea (*Cicer arietinum* L.) under semi-arid conditions in Kenya. *Journal of Applied Biosciences*. 2010; (34): 2156 – 2165.

Patil DD, Nayak MK, Patel HR. Effect of dates of sowing and irrigation levels on yield and yield attributing characters of chickpea. *International Journal of Agriculture Sciences*. 2017;(20): 4220-4221.

Pawar Nandu B. Effect of extended sowing dates on growth and yield of chickpea. *International Journal of Recent Scientific Research*. 2015;(10): 6884-6887.

Pressman E, Harel D, Zamski E, Shaked R, Althan L, Rosenfeld K, Firon N. The effect of high temperatures on the expression and activity of sucrose cleaving enzymes during tomato (*Lycopersicon esculentum*) anther development. *Journal of Horticultural Science and Biotechnology*. 2006;(81): 341-348.

Ray K, Singh D, Jat AL. Effect of sowing time and seed rate on growth and yield of chickpea cultivars. *Advance Research Journal of Improvement and Sustainability*. 2017; (4):2231-2640.

Reddy T.Y, Reddy GHS. *Principles of Agronomy*, Kalyani publishers, Ludhiana, pp. 2009; 91-93.

Rehman IH, Qamar R, Rehman A, Ahmad F, Qamar J, Saqib M, Nawaz S. Effect of different sowing dates on growth and grain yield of chickpea (*Cicer arietinum* L.) cultivars under agro-environment of Taluka Dokri Sindh, Pakistan. *American Journal of Experimental Agriculture*. 2015; (1):46-53.

Sekhar D, Kumar P, Rao KT. Performance of chickpea varieties under different dates of sowing in high altitude zone of Andhra Pradesh, India. *International Journal of Current Microbiology and Applied Sciences*. 2015; (8): 222-229.

Snider JL, Oosterhuis DM, Loka DA, Kawakami EM. High temperature limits *in vivo* pollen tube growth rates by altering diurnal carbohydrate balance in field-grown *Gossypium hirsutum* pistils. *Journal of Plant Physiology*. 2011; (6): 1168-1175.

Solanki NS, Mundra SL. Phenology and productivity of mustard (*Brassica juncea* L.) under varying sowing environment and irrigation levels. *Annals of Agriculture Research*. 2015; (3): 312-317.

Upadhyaya HD, Dronavalli N, Gowda CLL, Singh S. Identification and evaluation of chickpea Nayar, H., Bains, T. and Kumar, S. (2005). Low temperature induced floral abortion in chickpea: relationship to abscisic acid and cryoprotectants in reproductive organs. *Environmental and Experimental Botany*. 2011;(53): 39-47.

Wang J, Gan YT, Clarke F, Mc-Donald CL. Response of chickpea yield to high temperature stress during reproductive development. *Crop Science*. 2006; (46): 2171-2178.

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