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EFFECT OF HIGH TEMPERATURE STRESS ON YIELD AND YIELD ATTRIBUTES OF DIFFERENT CHICKPEA GENOTYPES

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The planting of chickpea is usually delayed in north-western parts of India due to popularization of rice-wheat cropping system. Due to this it experienceshigh temperature at the end of the cropping season.In the present study, an effort was made to study the effect of high temperature stress on yield and its attributesin twenty different chickpea *(Cicer arietinum* L.) genotypes. These genotypes were sown under three different planting dates (23rd Oct., 21st Nov., 18th Dec.). Results revealed that genotypessown during 21st Nov. have more chlorophyll content at 50% flowering and 50%podding stage as compare to 23rd Oct. and 18th Dec. sown genotypes. Besides this total chlorophyll content was found to be more during flowering stage as compare to vegetative and poddlingstage in all three planting dates.The yield and its component, *viz.* number of pod plant^{-1}, number of seed per pod, biological yield, seed yield per plant and harvest index washigher in 21st Nov. sown genotypes as compare to 23rd Oct. and 18th Dec. sown genotypes, respectively. Correlation studies showed significant positive association of seed yield with number of seed per pod (r=0.419), 100 seed weight (r=0.815) and Biological yield per plant (r=0.763). It is inferred that Pusa-1103, BGD-72, KWR-108 and Pant-G 186 genotypes is efficient in terms of yield components and produced the higher seed yield under late planting conditions. These genotypes could be used as good breeding material for developing temperature tolerant genotypes.

Keywords : *Cicer arietinum* L.; High temperature stress; Harvest index; Total chlorophyll content.

Introduction

Chickpea *(Cicer arietinum* L.) is one of the most important cool-season legumes grown extensively throughout the world, particularly in West and South Asia and North African countries. It has been grown in semiarid regions of the world for hundreds of years. The major chickpea producers India, Pakistan and Turkey contribute 67.0, 9.5 and 6.7 %, respectively to the world harvest. India predominates in chickpea supply and it has the distinction of being the largest producer and consumer in the world. The important chickpea growing states of India are Madhya Pradesh, Punjab, Haryana, Rajasthan, Uttar Pradesh, Bihar, Gujarat, Maharashtra, Karnataka and Andhra Pradesh. Latest estimate for 2007-08 indicate that the production of pulses in the country is 16.64 million tonnes from an area of 26.15 million hectares. Chickpea is the most important pulse recorded production of 6.43 million tonnes during 2007-8. Inspite of having largest area under chickpea in the world India's position in average productivity is yet to see major breakthrough to meet the per capita availability of 50 g pulses/day to alleviate proteins energy malnutrition.

Chickpea has a strong indeterminate growth habit. When growing conditions are favorable the plant continues vegetative growth without setting pods or filling fewer pods. Heat or drought stresses during the later part of the life cycle are required to hasten the termination of reproductive growth for a timely maturity. However,

Table 1. Percent soil moisture during various stages of chickpea (2009-10).

Soil depth (cm)	Crop growth stages				
	At sowing time	Vegetative stage	Flowering stage	Pod formation stage	harvest
0 - 30	15.45	20.36	16.83	13.81	10.75
30 - 60	17.89	21.28	18.64	14.63	11.52
60 - 90	18.89	22.05	19.92	16.81	12.26

severestress during reproductive development, particularly after the commencement of pod set, can cause significant pod abortion and decreased seed filling. The major constraints for low productivity are abiotic stresses, *viz.* temperature,moisture, nutrients and salt stress. Among them temperature stress are the most important abiotic stress for productivity. It has been reported by many researchers that in northern India, late planting of chickpea is done after harvest of rice, early potato or cotton. Under such situations the crop has to be sown up to the end of November to mid-December. Such late sown chickpea crop experiences low temperature during seedling establishment time and high temperature at the end of the cropping season. Low temperature at initial stage of crop growth results in poor and slow vegetative growth, whereas high temperature at the end of cropping season lead to problem of poor biomass and forced maturity[1].

Therefore, to increasing the productivity of chickpea under late planting condition it is important to understand the various physiological and biochemical processes, which impart tolerance and allow the pace of process at relatively elevated levels. Also an effort was made to analyze the causes of differences in biomass production of a tolerant and susceptible genotype. Better understanding of morpho-physiological aspects for high temperature stress in relation to yield potential will be helpful in breeding programme for crop improvement.

Material and Method

Twenty chickpea genotypes (*Cicer arietinum* L.) collected from major regional station of the country in consultation with chickpea project coordinators were taken and grown during year 2009-10 in three different dates *i.e.* 23rd Oct., 21st Nov., 18th Dec.at experimental farm of Division of Plant Physiology, Indian Agriculture Research Institute, New Delhi. The experiment was conducted in plot size of 3×1.8 m for each genotype in a randomized block design. Row to row and plant to plant distance was maintained at 30 cm and 10 cm, respectively. The geographical location of Delhi is 28^0 - 24' N Latitude and 72^0 - 12' E longitudein northern hemisphere at an altitude of 228.61 meters above mean sea level. Climatologically Delhi attains a semi dry sub-tropical climate with extremes for dry summer and cold winter. The mean annual evaporation is 850 mm, with mean daily evaporation ranging from as low as 2.2 mm in the month of January to as high as 16.0 mm in the month of June. Normal agronomic practices were adopted to raise the crop. The plot was fertilized @ 20kg N and 40 kg P_2O_5 ha^{-1}as basal dose just before sowing.One pre-sowing irrigation was given and made the soil conductive for proper germination and growth.

For sampling, five plants were pulled out at each sample time.Leaf area (cm^2 $palnt^{-1}$) was measured by leaf area meter (Model LI-3100, LICOR Inc, Nebraska, USA). Chlorophyll was estimated according to the method of Hiscox and Israelstam[2] using dimethyl sulfoxide (DMSO) and expressed as mg g^{-1}fw. Soil moisture content was monitored periodically from different soil depth *viz.* 0-30, 30-60, and 60-90 cm at sowing time, vegetative stages, flowering stages, pod formation stage and at the time of harvesting by gravimetric method. The meteorological data collected from the Division of Agriculture Physics, I.A.R.I., New Delhi indicated that the maximum average temperature during three different sowing dates were 32.8°C, 25.3°C and 23.3°C whereas minimum temperature were 15.8°C, 15°C, 9.6°C, respectively. Harvest indices (HI) were calculated by the following equations.

Harvest Index (HI) = 100 × [(grain yield)/ (shoot biomass)]

Result and Discussion

Pattern of soil moisture content (%)- The soil moisture content was initially sufficient for germination in three dates of sowing (15.45%, 20.27% and 18.05%).In general the soil moisture content increased with the increase in soil depth. During vegetative stage maximum moisture content was observed, which gradually decline till the harvest.At the harvest time, the gap in moisture content at different depth was narrowed down, being 10.75, 11.52 and 12.26 percent at 0-30, 30-60, 60-90 cm, respectively during the year 2009-10.

Crop Phenology- Phenology has a powerful effect on plant growth response and productivity under high temperature stress. For most crop species, breeding for shorter duration is a major objective, not only to match phenology to season length, but also for other reasons such as to fit crop/ genotypes into more intensive crop rotation.The impact of temperature stress was clearly seen on 50% flowering, 50% podding and on duration of maturity in I, II and III planting dates, respectively. The variability was seen in all the phases; however significantly more number of days were required for 50% flowering in second planting (76.60 days) followed by first (51.85 days) and third planting (63.50 days). Among the genotypes RSG-991 (74.33 days), C-235 (71.33 days) and GNG-459 (70.33 days) showed significantly higher number of days for 50% flowering than national check Pusa-256 (65.67 days). Significantly higher numbers of days were required for 50% pod formation in first planting (95 days) followed by second (46.75 days) and third planting (42.70 days). While among the genotypes maximum number of days were required by RSG 143-1 (74.67 days) and minimum

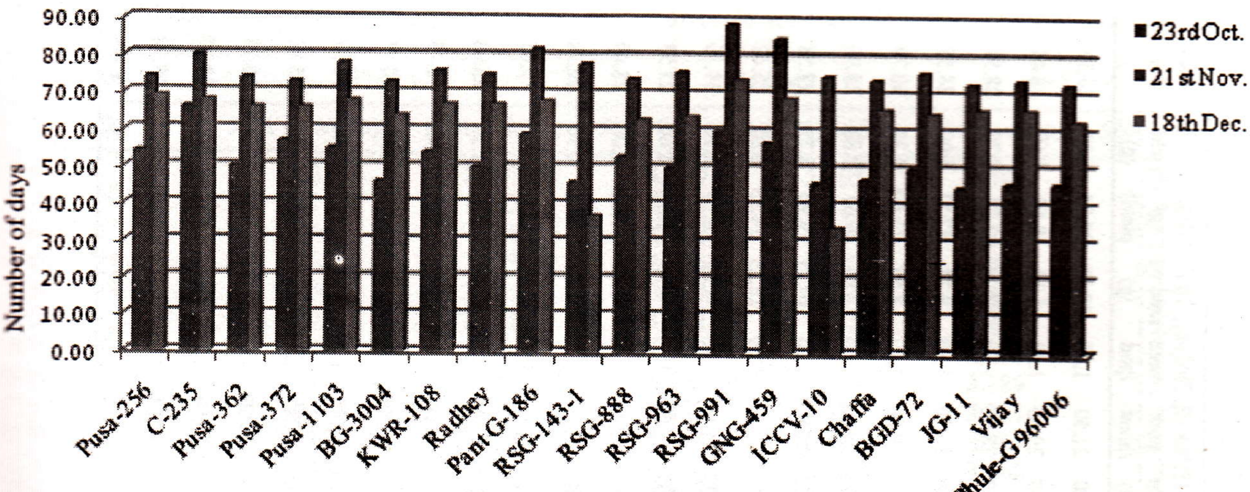

Fig. 1. Days to 50% flowering

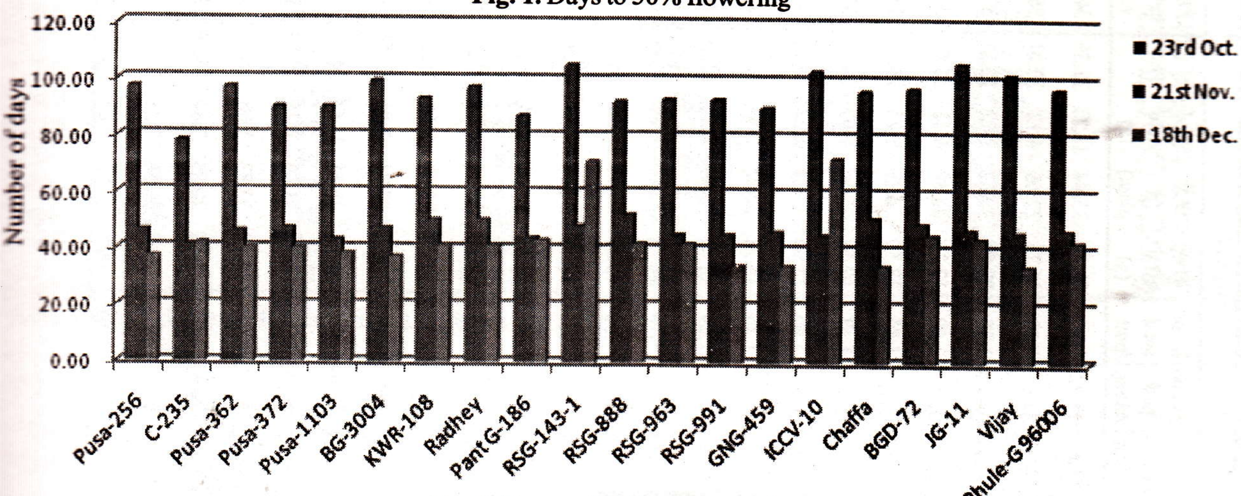

Fig. 2. Days to 50% Pod Formation

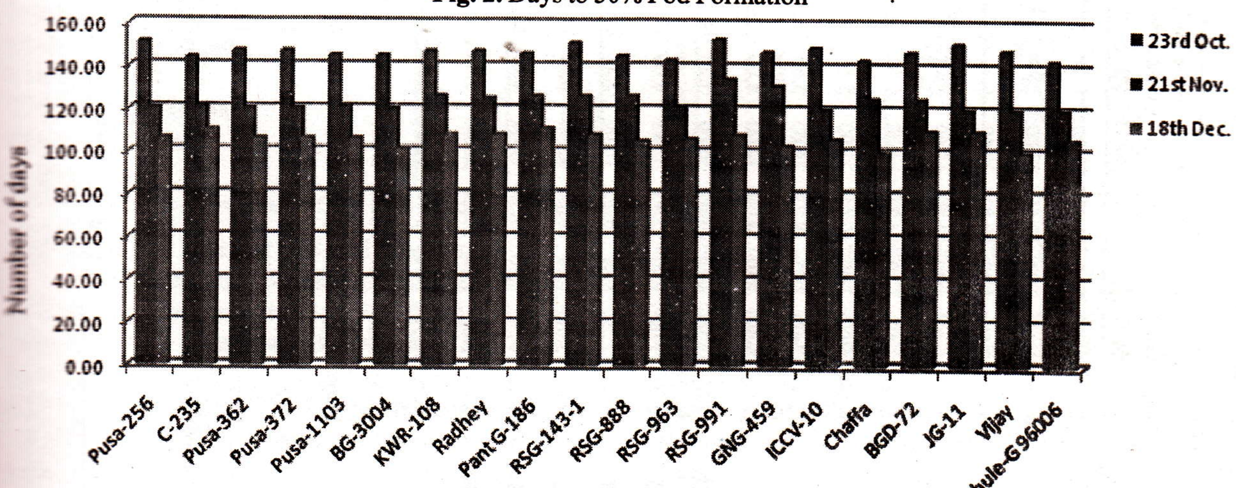

Fig. 3. Physiological maturity

Fig. 1, 2& 3. Showing Phenological traits of chickpea genotypes.

Table 2. Seed yield and its attributes in chickpea genotypes during different sowing dates.

Genotypes	23rd Oct.							21st Nov.							18th Dec.						
	Plant height (cm)	No. of pod /plant	No. of seed /pod	100 seed wt. (g)	B.Y. (g/ plant)	Seed yield (g)	H.I. (%)	Plant height (cm)	No. of pod /plant	No. of seed /pod	100 seed wt. (g)	B.Y. (g/ plant)	Seed yield (g)	H.I. (%)	Plant height (cm)	No. of pod /plant	No. of seed /pod	100 seed wt. (g)	B.Y. (g/ plant)	Seed yield (g)	H.I. (%)
Pusa-256	59.00	18.90	1.30	21.50	22.00	5.00	22.73	44.67	23.52	1.30	22.11	35.84	11.25	31.39	36.00	21.50	1.00	18.75	22.75	6.00	26.37
C-235	46.00	26.00	1.20	10.56	23.00	3.80	16.52	38.50	31.00	1.40	11.23	22.66	6.12	27.01	36.67	29.00	1.00	5.12	8.60	1.60	18.64
Pusa-362	51.00	23.50	1.20	20.83	29.00	6.75	23.28	42.50	30.00	1.20	22.92	30.62	8.22	26.85	39.33	28.50	1.00	11.15	7.72	2.20	28.51
Pusa-372	51.00	28.50	1.40	12.02	41.00	5.40	13.17	47.33	35.50	1.60	12.31	23.87	6.12	25.64	36.00	16.50	1.10	9.78	17.51	5.00	28.55
Pusa-1103	65.00	26.50	1.70	21.35	31.00	6.80	21.94	37.67	36.50	1.80	23.50	36.29	9.75	26.87	28.33	10.00	1.10	8.65	13.64	4.20	30.79
BG-3004	55.00	24.00	1.30	19.14	31.00	5.14	16.58	42.33	27.50	1.42	19.54	28.66	6.07	21.19	37.00	26.50	1.00	8.07	9.67	2.80	28.96
KWR-108	60.00	27.60	1.35	18.73	25.00	5.60	22.40	55.83	31.00	1.40	22.99	34.11	8.32	24.39	47.33	20.00	1.10	10.75	9.90	2.73	27.58
Radhey	61.00	28.00	1.40	14.10	30.00	4.00	13.33	47.50	29.00	1.30	18.72	26.05	5.84	22.42	28.67	20.00	1.00	15.23	14.95	3.80	25.42
Pant G-186	59.00	33.50	1.30	13.34	36.00	5.20	14.44	39.67	36.00	1.60	13.52	18.69	6.22	33.28	36.33	16.50	1.00	4.95	6.73	2.10	31.16
RSG-143-1	56.00	27.00	1.70	15.65	30.45	4.00	13.14	39.83	33.00	1.10	16.43	34.50	8.24	23.88	32.00	13.00	1.00	6.76	6.80	1.60	23.53
RSG-888	59.00	27.50	1.20	13.36	16.00	3.21	20.06	43.67	31.60	1.50	15.01	19.60	6.14	31.33	38.00	12.00	1.00	6.84	7.02	2.00	28.49
RSG-963	57.00	33.00	1.40	16.19	43.00	6.52	15.16	55.33	38.00	1.40	18.61	31.52	9.44	29.95	48.67	15.00	1.10	4.61	4.42	0.90	20.38
RSG-991	67.00	11.50	1.10	10.75	18.00	2.20	12.22	48.00	18.60	1.30	13.92	39.68	4.24	10.69	36.17	12.00	1.00	4.93	11.73	2.00	17.05
GNG-459	63.00	36.00	1.20	11.48	28.00	5.40	19.29	45.33	43.60	1.50	17.94	26.71	6.74	25.23	37.00	11.00	1.10	3.94	9.32	2.20	23.60
ICCV-10	53.00	25.50	1.10	13.85	30.00	3.60	12.00	37.00	34.00	1.70	14.25	31.08	6.14	19.76	32.33	14.00	1.10	2.11	3.27	0.42	12.83
Chaffa	41.00	15.60	1.10	10.80	34.00	3.42	10.06	41.00	18.00	1.50	11.52	25.74	3.49	13.56	39.00	26.50	1.00	6.77	11.57	2.40	20.75
BGD-72	62.00	31.00	1.50	23.42	31.00	7.20	23.23	41.17	41.00	1.60	24.41	46.61	11.64	24.97	33.67	12.00	1.20	17.74	8.70	5.40	62.07
JG-11	52.00	23.00	1.10	23.96	24.00	3.00	12.50	44.67	29.00	1.10	24.25	31.08	7.76	24.97	38.00	5.50	1.10	7.09	8.52	2.20	25.82
Vijay	65.00	22.00	1.40	14.65	36.00	4.40	12.22	44.50	27.00	1.30	15.20	33.83	5.66	16.73	39.67	18.00	1.00	4.26	7.17	1.20	16.74
Phule-G 96006	53.00	24.00	1.70	14.74	26.00	5.78	22.23	36.67	29.00	1.80	14.87	32.85	7.64	23.26	30.30	29.50	1.20	3.75	7.62	1.40	18.37
Mean	56.75	25.63	1.33	16.02	29.22	4.82	16.82	43.66	31.14	1.44	17.66	30.50	7.25	24.17	36.52	17.85	1.06	8.06	9.88	2.61	25.78
CD at 5%	3.52	2.64	1.68	2.09	3.40	0.94	3.64	2.64	2.85	1.03	3.97	1.21	2.42	2.74	1.44	2.75	0.04	3.17	3.65	2.96	1.72

Table 3. Total chlorophyll content (mg g[-1] fw) in chickpea genotypes sown during 23[rd] Oct., 21[st] Nov. and 18th Dec.

Genotypes	23[rd] Oct.		21[st] Nov.		18[th] Dec.	
	50% flowering	50%podding	50% flowering	50%podding	50% flowering	50%podding
Pusa-256	3.221	1.447	4.079	2.305	3.580	1.806
C-235	3.327	1.553	2.129	0.355	3.267	1.493
Pusa-362	2.462	0.688	4.578	2.804	3.288	1.514
Pusa-372	3.967	2.193	4.256	2.482	2.728	0.954
Pusa-1103	4.630	2.856	3.849	2.075	3.446	1.672
BG-3004	4.095	2.321	3.092	1.318	3.459	1.685
KWR-108	3.128	1.354	3.683	1.909	3.661	1.887
Radhey	3.712	1.938	3.557	1.783	3.289	1.515
Pant G-186	3.823	2.049	3.330	1.556	3.251	1.477
RSG-143-1	4.051	2.277	3.163	1.389	2.961	1.187
RSG-888	2.765	0.991	3.170	1.396	3.148	1.374
RSG-963	3.328	1.554	2.541	0.767	3.348	1.574
RSG-991	2.649	0.875	3.330	1.556	2.959	1.185
GNG-459	3.475	1.701	3.134	1.360	3.183	1.409
ICCV-10	2.942	1.168	2.964	1.190	3.526	1.752
Chaffa	2.578	0.804	2.581	0.807	4.240	2.466
BGD-72	4.472	2.698	3.580	1.806	2.981	1.207
JG-11	3.367	1.593	3.086	1.312	3.151	1.377
Vijay	3.595	1.821	2.446	0.672	3.446	1.672
Phule G 96006	3.787	2.013	3.617	1.843	3.355	1.581
Mean	3.469	1.695	3.308	1.534	3.313	1.539
CD 5%	0.215	0.195	0.283	0.247	0.112	0.064

Table 4. Correlation coefficient among different traits at maturity in chickpea genotypes.

Traits.	1	2	3	4	5	6	7	8	9	10
1. Plant height	1.000	.812**	-.370**	.752**	.263*	.271*	.417**	.487**	0.203	-.389**
2 Days to 50% flowering			1.000	-.784**	.306*	0.237	0.102	0.092	.379**	.366**
3. Days to 50% pod formation				1.000	0.046	0.166	.287*	.392**	-0.006	-.495**
4. Number of pod per plant					1.000	.374**	.493**	.565**	.637**	-0.013
5. Number of seed per pod						1.000	.293*	.566**	.419**	-0.17
6.100-seed weight							1.000	.716**	.815**	0.146
7. Biological yield (g/pant).								1.000	.763**	-.302*
8. Seed yield per plant									1.000	.283*
9. Harvest index.										1.000

**Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

by C-235 (53.67 days) for 50% pod formation.

First planting recorded significantly more number of days to attain maturity (146.959 days) followed by second (123.35 days) and third planting (106.20 days). Among the genotypes maximum number of days was required by Pusa-261 (131.67 days) and minimum by BG-3004 (122 days). The unusual rise in temperature during Feb./ March both in minimum and maximum caused drastic reduction in duration of phenophages in all the genotypes however, in Pusa-1103 and BGD-72 duration of phenophages could not be reduced in planting III depict that these are relatively tolerant types. It is inferred that equal distribution of phenophages Ist, IInd and IIIrd particularly under late planting conditions so as to keep proper balance between source and sink development is a trait of a temperature tolerant genotypes.

Height - Significant difference for plant height was observed among genotypes sown during three different dates. At maturity it ranged from 41 cm (Chaffa) to 67 cm (RSG-991) in planting I, from 36.17cm (RSG-991) to 55.83 (KWR-108) in planting II and from 28.33 cm (Pusa-1103) to 48.67 cm (RSG-963) in planting III (Table 2). In general higher seed yielding genotypes like KWR-108, RSG-963, Pusa-1103 and BGD-72 have attained good height in all the planting condition (Table 2).

Leaf character - Significant differences were noted amongst genotypes sown during different period in leaf area (cm² plant⁻¹) at 50% flowering and 50% podding stage. Leaf area gradually increased to maximum at 50 % podding and then decline to maturity. Amongst the genotypes sown during 23rd Oct., highest leaf area was noticed in Vijay while it was lowest in BG-3004 at both 50% flowering and 50% podding stage. Whereas, in planting II and III both maximum leaf area was observed in Radhey and minimum in BG -3004 at 50% flowering stage. However during 50% podding stage JG-11 (376.48 $cm^2 plant^{-1}$) showed maximum and Vijay showed minimum leaf area in II planting stage and in III planting stage KWR-108 (258.20 cm^2 $plant^{-1}$) showed maximum while RSG-963 (210.80 cm^2 $plant^{-1}$) showed least leaf area.

Total chlorophyll content at 50% and 50% podding showed significant differences among genotypes in sowing dates (Table 3). Chlorophyll content increases gradually and varied from 2.578 to 4.630 at 50% flowering stage and from 0.688 to 2.698 at 50% podding during Ist sowing date. However, in IInd planting Pusa-362 have maximum and in IIIrd planting ICCV-10 showed maximum chlorophll content in both 50% flowering and 50% podding stage. It was also noted that the genotypes like Pusa-256, Pusa-1103, BG-3004, BGD-72 have highest chlorophyll content also have higher seed yield and genotypes like Pusa-26, C-235 have the minimum chlorophyll contents have least seed yield in all the stages. Better performance of these superior genotypes under different planting conditions was attributed to its maintenance of higher chlorophyll contents.

Seed yield and its attributes - Seed yield had shown significant and positive association with total dry matter, chlorophyll content, number of seeds per pod, biological yield per plant and harvest index.Number of seed per pod varied from 1.10 in RSG-991, ICCV-10, Chaffa and JG-11 to 1.70 in Pusa-1103, RSG-143-1, Phule-G-96006 in 23rd Oct. planting condition. Whereas, in 21st Nov. and 18th Dec. planting it varied from 1.10 to 1.80 and 1.00 to 1.20 respectively. Seed yield per plant varied from 2.20 to 7.20 in Planting Ist, 3.49 to 11.63 in IInd planting and 0.90 to 6.00 in IIIrd planting conditions. Seed yield per plant is significantly and positively correlated with number of pod per plant (r=0.374).

Biological yield per plant showed significant and positive correlation with number ofpod per plant (r=0.565), number of seed per pod (r=0.566) and 100-seed weight (r=0.716). Hundred seed weight differed significantly among the genotypes sown during different periods and it shows positive correlation with total dry weight (r=0.462), number of pod per plant (r=0.493) and number of seed per pod (r=0.293). The variation in yield component and seed yield among the chickpea genotypes were also reported by Chandra and Yadav[3].

The harvest index ranged from 10.06% in Chaffa to 23.28% in Pusa-362 in Ist planting, 10.69% (RSG-991) to 31.39% (Pusa-256) and 12.83% (ICCV-10) to 31.16% (Pant G-186) in IIIrd planting. HI was significantly and positively correlated with the seedyield (r=0.283). Improved harvest index represents increased physiological capacity to mobilize photosynthates from source to sink. Kumar *et al.*[4] reported that harvest index is an important criterion for improvement in yield which is strongly influenced by environment. The positive relationship obtained between seed yield and harvest index is an indication of better dry matter partitioning towards the reproductive parts.

On the basis of results obtained, it is concluded genotypes like Pusa-1103, BGD-72, KWR-108 and Pant-G 186 were superior for several physiological traits under late sown condition. These genotypes performed better than other due to higher number of pod, seed yield/plant, higher total dry matter production and harvest index (H.I.) in 21st Nov. sown conditions. These genotypes maintain proportionate balance between vegetative and reproductive growth. They may be used in breeding programme effectively for increasing productivity level further under stress environment. Also yield potential of chickpea crop can be increased further by increasing tolerance at cellular, physiological and morphological levels. The simple traits like percent membrane injury and chlorophyll content may be used in screening of large number of genotypes for stress tolerance.

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