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Effect of sowing dates and micronutrient on physiological changes in chickpea varieties (*Cicer arietinum* L.) under changing climatic conditions

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Abstract
The field experiments were conducted at Student Instructional Farm, Department of Agronomy CSAUAT Kanpur, during *rabi* seasons in the year 2017-18 and 2018-19. The objective of investigation was to study the effect of basal application of boron (3.0 kg ha^{-1}) and molybdenum (2.5 kg ha^{-1}) on plant traits (morphological, physiological, phenological, biochemical, yield and its components) of three chickpea varieties under early, timely and late sown condition. It was designed in double split plot design with three replications. The three dates of sowing i.e., Early (D_1), timely (D_2) and late sown (D_3) conditions were allocated in the main plots and three chickpea varieties *i.e.*, V_1 (KWR-108), V_2 (Awarodhi) and V_3 (Radhey) in sub plot and for each plot both chemical treatments were applied as basal at sowing time.
Results revealed that physiological growth in terms of growth parameters, physiological characters, phenological development yield and its components varied significantly all the treatments during both year of cropping seasons. The results indicated application of boron (@ 3.0 kg ha^{-1}) with three condition of sowing i.e., early (D_1) timely (D_2) and late (D_3) of chickpea crop. Among cultivars, maximum responsive was V_3 (Radhey) in most of traits and gave significantly higher higher value of leaf area Leaf area (cm^2), Relative Growth Rate (RGR), Crop Growth Rate (CGR), Net Assimilation Rate (NAR) of 50% flowering and 75% flowering as compared to all other corresponding tested treatments. Among cultivars, maximum responsive was Radhey (V_3) in most of traits and gave significantly higher grain yield (19.24 & 20.17 q ha^{-1}) and followed by KWR-108 (V_1) *i.e*, 17.93 & 18.76 q ha^{-1}, and minimum in Awarodhi (V_2) *i.e*.. 15.96 & 16.76 q ha^{-1} with both is concerning experimental years.

Keywords: Investigation, physiological characters, *rabi* seasons, treatments, varieties

Introduction
Pulses are gaining importance globally for being the cheap source of vegetable protein. Their demand for protein is increasing by about 3% annually and also the awareness as human food, animal feed and soil health. Pulse crops play an important role in Indian agriculture. They form an integral part of diet as source of protein. Pulses are the unique crops they have capability to fix atmospheric nitrogen in symbiotic association with root nodule bacterium (Rhizobium). Pulses are versatile crops to fit in diverse cropping systems and grown both during Rabi and Kharif season. Chickpea is used as vegetables, pulses and some are processed as pickle canning, frozen or dehydrated to increase the availability during off season.
Chickpea (*Cicer arietinum* L.) is also known as gram, Bengal gram or Spanish pea and is considered to be the third most important pulse crop of the world. In India, it is an important source of protein in human diet. It plays a significant role in sustaining production of the subsistence farming system. Major production of chickpea comes from Central and Northern India. However, its area production is increasing in Southern states.
Chickpea is a cool season herbaceous annual food legume and grown as a winter crop in the tropics. It is the largest produced food legume in South Asia and the third largest produced food legume globally after common bean (*Phaseolus vulgaris*) and field pea (*Pisum sativum*).
Apart from the human diet, pulses form an important fraction of cattle feed and fodder as hay, green fodder and concentrates. Due to their short duration habit they can be grown as main, intercrop and green manure crop. Pulses are known to improve soil fertility as they fix atmospheric nitrogen through symbiotic nitrogen fixation with the help of bacterium called Rhizobia. Thus, every pulse plant is a mini-fertilizer factory itself.

Experimental details

The technical programme and features of the varieties used are being described here as under:

The experiment was laid out in double split plot design having twenty one treatments combinations which were replicated thrice. The treatments and layout plan have been given in Table (1) respectively.

Treatments

A. Varieties - 3 (main-plots)

V_1 - KWR- 108

V_2 - Awarodhi

V_3 - Radhey

B. Micronutrients -2 (sub-plots)

M_1- Molybdenum

M_2-Boron

C. Different date of sowing

D_1- First date of sowing

D_2- Second date of sowing

D_3- Third date of sowing

Table 1: Treatments combinations

S. No.	Treatment	Treatment Combination
1	T_1	$D_1V_1M_1$
2	T_2	$D_1V_1M_2$
3	T_3	$D_1V_2M_1$
4	T_4	$D_1V_2M_2$
5	T_5	$D_1V_3M_1$
6	T_6	$D_1V_3M_2$
7	T_7	$D_2V_1M_1$
8	T_8	$D_2V_1M_2$
9	T_9	$D_2V_2M_1$
10	T_{10}	$D_2V_2M_2$
11	T_{11}	$D_2V_3M_1$
12	T_{12}	$D_2V_3M_2$
13	T_{13}	$D_3V_1M_1$
14	T_{14}	$D_3V_1M_2$
15	T_{15}	$D_3V_2M_1$
16	T_{16}	$D_3V_2M_2$
17	T_{17}	$D_3V_3M_1$
18	T_8	$D_3V_3M_2$

Field preparation

The experimental field was prepared after pre-sowing irrigation for chickpea; the field was prepared following pre-sowing irrigation. At proper moisture condition, first ploughing was done with tractor drawn soil turning plough, followed by two cross harrowing with tractor drawn harrow for both the crops. Planking was done after each ploughing to make the field friable, well levelled and to conserve the moisture for proper germination of the seeds.

Weeding and Intercultural Operations

To maintain the plots weed-free for good crop growth, immediately after sowing pre-emergence herbicide, Pendimethalin @ 1.0 to 1.5 L/acre was sprayed. After that, three manual weeding were carried out in the experimental field. The first weeding was done at the time of thinning *i.e.* a week after emergence. Subsequent weeding was done at 35 and 55 DAS. Other intercultural operations were done as and when necessary.

Seed and sowing

The Chickpea (*Cicer arietinum* L.) was sown on November 01, 2017 and November 10, 2018 with maintaining row to row spacing of 30 cm and plant to plant spacing of 10 cm. The optimum plant population of maize was maintained during both the years by thinning extra plants during seedling emergence. The recommended seed rate @ 75-100 kg ha^{-1} was used for sowing purpose.

Application of fertilizer:

The Urea, Di-ammonium phosphate, Muriate of potash and micronutrients (Molybdenum and Boron) fertilizers *i.e.*, were used as a source of N, P, K, Mo and B, respectively. Full dose of P and K was applied as a basal dose amounting 60 and 40 kg per hectare after field preparation. It is well known fact that all the crops belonging to family leguminoseae in general and Fabaceae in particular requiring less amount of fertilizer N due to their biologically active N fixation mechanism. So, less amount of N was supplemented through inorganic sources, it was calculated 40 kg per hectare. In which half of N doses were applied as basal and remaining amount of nitrogen was top dressed at grain filling stage. However, the micronutrients namely Molybdenum and Boron were applied @ 2.5 kg $^{-1}$ and 3.0 kg $^{-1}$, respectively. The N, P_2O_5 and K_2O were given @ 20, 60 and 60 kg ha^{-1}, respectively.

Leaf area (cm^2)

Leaf area of three selected plants were measured with the help of automatic leaf area meter and average leaf area was calculated and recorded at pre flowering, flowering and post flowering stage.

Crop Growth Rate (CGR)

The CGR is the rate of dry matter production per unit ground area per unit time. It was calculated adopting the formula as suggested by Watson *et al.* (1952).

$$CGR = \frac{W2 - W1}{t2 - t1} \text{ g m}^{-2} \text{ day}^{-1}$$

Where

W_1 = Dry weight (g) of the plants at time t_1

W_2 = Dry weight (g) of plants at time t_2

Relative Growth Rate (RGR)

The RGR is the rate of increase in dry matter per unit of dry matter present. The RGR was determined by adopting the formula suggested by Blackman (1969).

$$RGR = \frac{\text{LogW2} - \text{LogW1}}{\text{t2} - \text{t1}} \text{ mg g}^{-1} \text{ day}^{-1}$$

Where

W_1 and W_2 represent the dry matter in g at time interval t_1 and t_2 respectively, while log_e is natural logarithms.

Net Assimilation Rate (NAR)

Net assimilation rate (NAR) is the rate by which dry weight increased per unit leaf area per unit time. It was calculated by using the following formula (Watson, 1952) and expressed as g m^{-2} day^{-1}.

$$NAR = \frac{(\text{W2} - \text{W1})}{(\text{t2} - \text{t1})} \frac{(\text{loge A2} - \text{loge A1})}{(A2 - A1)}$$

Where'

W_2 &W_1 = Total dry weight of the plant

A_2 &A_1 = Leaf area of plant

t_2 & t_1 = Times of intervals

Result and discussion

Leaf area (cm^2)

The leaf area per plant of chickpea recorded at 30, 60 and 90 DAS has been given in Table 2.

A critical examination of data showed that different variety, date of sowing and micronutrient treatments had significant effect on leaf area per plant. At initial stage of growth i.e.; (30 DAS), leaf area was low, then increased gradually and reached its peak at 90 DAS during in the year 2017-18 and 2018-19.

The significant effect of leaf area (cm^2) observed in variety V_3 (Radhey) with 129.24 and 132.27 cm^2 (30 DAS), 497.06 and 508.09 cm^2 (60 DAS), 543.69 and 556.38 cm^2 (90 DAS) followed by variety V_1 (KWR-108) with 120.39 and 1123.71 cm^2 (30 DAS), 462.41 and 473.66 cm^2 (60 DAS), 506.37 and 518.68 cm^2 (90 DAS). The lowest leaf area (cm^2) was observed in variety V_2 (Awarodhi) with 107.19 and 109.67 cm^2 (30 DAS), 411.79 and 421.81 cm^2 (60 DAS), 450.92 and 884.43 cm^2 (90 DAS) during 1st year and 2nd year experiment.

The data pertaining of higher leaf area (cm^2) was recorded date of sowing (D_1) with 133.05 and 1136.65 cm^2 (30 DAS), followed by date of sowing (D_2) 118.43 and 121.21 cm^2 and lowest leaf area (cm^2) recorded in late sowing (D_3) with 105.33 and 107.80 cm^2 (30 DAS), Similar trend was also recorded at 60 DAS and 90 DAS during both cropping seasons, respectively.

Application of boron recorded enhancement of leaf area (cm^2) at all the growth stages (30, 60 and 90 DAS) for both the year of experimentation. The highest mean value of leaf area with treatment (M_2) boron @ 3.0 kg ha^{-1} 122.93 and 125.81 cm^2 (30 DAS), 472.59 and 483.39 cm^2 (60 DAS), 517.09, and 529.35 cm^2 (90 DAS) followed by treatment (M_1) molybdenum @ 2.5 kg ha^{-1} 114.95 and 117.97 cm^2 (30 DAS), 441.59 and 452.29 cm^2 (60 DAS), 483.56 and 495.59 cm^2 (90 DAS) during both experimental seasons, respectively.

Interaction effect of leaf area cm^2 was found non-significant during both years of experimentation.

Table 2: Effect of varieties, dates of sowing and micronutrients on leaf area (cm^2) $plant^{-1}$ of chickpea at 30, 60 and 90 DAS

Treatment	30 DAS 2017-18	60 DAS 2017-18	90 DAS 2017-18	30 DAS 2018-19	60 DAS 2018-19	90 DAS 2018-19
Varieties						
KWR-108	120.39	462.41	506.37	123.71	473.66	518.68
AWARODHI	107.19	411.79	450.92	109.67	421.81	461.89
RADHEY	129.24	497.06	543.69	132.27	508.09	556.38
SE(d)	1.48	5.52	6.79	1.66	5.83	7.27
CD (0.05)	3.22	12.03	14.78	3.59	1269	15.83
Date of sowing						
1 November	133.05	511.66	559.67	136.65	523.41	573.17
10 November	118.43	455.01	498.27	121.21	466.02	510.32
20 November	105.33	404.59	443.05	107.80	414.12	453.48
SE(d)	1.93	8.32	9.20	2.23	5.83	9.89
CD (0.05)	5.35	23.08	25.54	6.17	16.17	26.39
Micronutrient						
Molybdenum	114.95	441.59	483.56	117.97	452.29	495.29
Boron	122.93	472.59	517.09	125.81	483.39	529.35
SE(d)	1.95	7.74	9.01	2.19	7.73	9.65
CD (0.05)	4.08	16.25	18.92	4.59	16.23	20.26

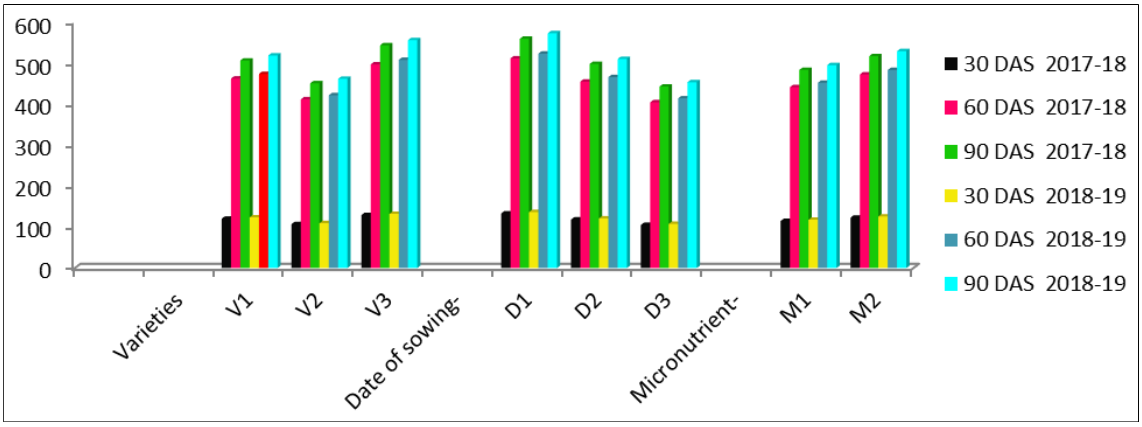

Fig 1: Effect of varieties, dates of sowing and micronutrients on leaf area (cm^2) plant^{-1} of chickpea at 30, 60 and 90 DAS

Crop growth rate (CGR) in g m^{-2} day^{-1}

The crop growth rate (CGR) increased with the advancement of crop age up to 90 DAS and thereafter it showed a declining trend Table 3. This parameter reflects the efficiency of plant to accumulate biomass per unit time. Maximum crop growth rate was observed at 60-90 DAS followed by 30-60, and lowest 0-30 DAS under different varieties, dates of sowing and micronutrient treatments during 2017-18 and 2018-19.

A close examination of the data shows that varieties caused significant difference in crop growth rate during both the cropping season. Highest CGR (0.065 and 0.067) was observed with variety V_3 (Radhey) than V_1 (KWR-108) but was at par with V_2 (Awarodhi) at 0-30 DAS during both year of experimentation. A similar trend was observed at 30-60, 60-90, DAS and 90 DAS to at maturity stage during 1st year and 2nd year.

Different dates of sowing also exerted significant variation on crop growth rate at all growth stages during both the years. At 0-30 DAS, significantly higher crop growth rate (0.066 and 0.101) was observed with date of sowing (D_1) which was statistically at par with date of sowing (D_2) and superior over rest of the treatments during both the experimental years. While, least crop growth rate was noted under date of sowing (D_3). Almost a similar trend was observed at 30-60, 60-90, DAS and 90 DAS to at maturity stage in both years.

Various micronutrients application caused significant variation in CGR at all growth stages. Significantly higher CGR (0.061 and 0.103) at 0-30 DAS was observed with application of M_2 boron @ 3.0 kg ha^{-1} However, least CGR was observed under M_1 molybdenum @ 2.5 kg ha^{-1} at all growth stages during both the year of investigations. Similar trend was also found at 30-60, 60-90 and 90 DAS to at maturity stage during both the experimentation years.

Though, value of interaction effect of varieties, dates of sowing and micronutrients was not significant at all the stages

Table 3: Effect of varieties, dates of sowing and micronutrients on crop growth rate (g m^{-2} day^{1}) of chickpea at 0-30, 30-60, 60-90 DAS and 90 DAS- maturity stage

Treatment	0-30 DAS 2017-18	30-60 DAS 2017-18	60-90 DAS 2017-18	90-Harvest time 2017-18	0-30 DAS 2018-19	30-60 DAS 2018-19	60-90 DAS 2018-19	90-Harvest time 2018-19
Varieties								
KWR-108	0.060	0.096	0.245	0.089	0.062	0.100	0.255	0.091
AWARODHI	0.053	0.085	0.217	0.078	0.056	0.090	0.228	0.080
RADHEY	0.065	0.104	0.264	0.097	0.067	0.107	0.273	0.098
SE(d)	0.002	0.005	0.006	0.002	0.002	0.006	0.007	0.001
CD (0.05)	0.003	0.010	0.013	0.003	0.003	0.012	0.014	0.002
Date of sowing								
1 November	0.066	0.107	0.272	0.099	0.069	0.111	0.283	0.101
10 November	0.059	0.095	0.241	0.087	0.061	0.099	0.251	0.089
20 November	0.052	0.084	0.213	0.77	0.055	0.087	0.221	0.079
SE(d)	0.002	0.005	0.007	0.004	0.002	0.006	0.007	0.001
CD (0.05)	0.004	0.014	0.018	0.011	0.004	0.015	0.019	0.003
Micronutrient								
Molybdenum	0.057	0.091	0.232	0.084	0.059	0.095	0.242	0.086
Boron	0.061	0.099	0.252	0.092	0.064	0.103	0.261	0.094
SE(d)	0.002	0.005	0.006	0.002	0.002	0.006	0.006	0.001
CD (0.05)	0.003	0.009	0.012	0.003	0.003	0.011	0.013	0.002

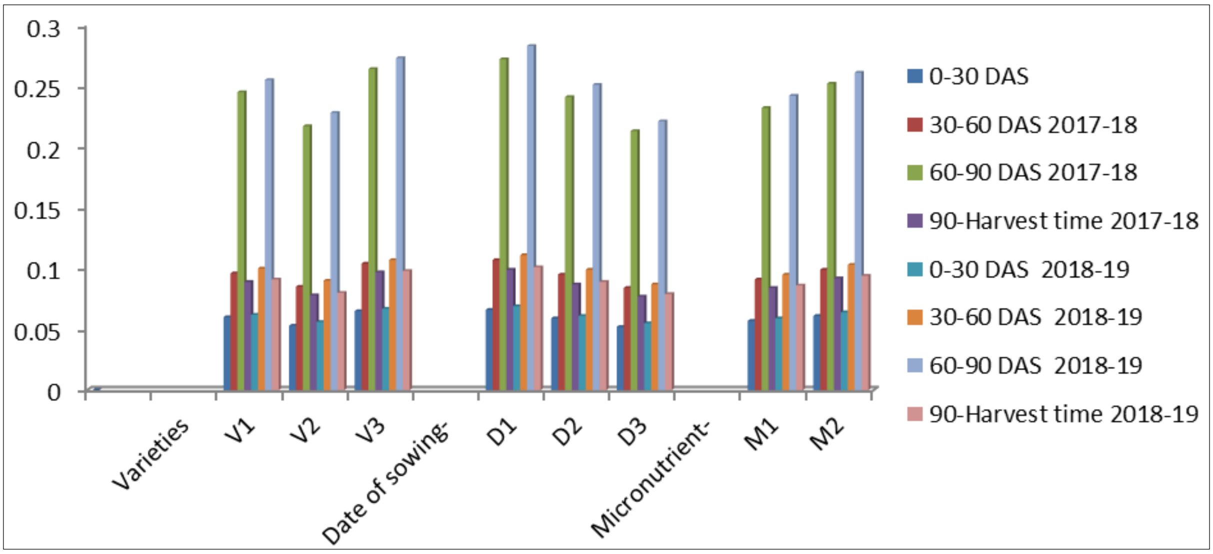

Fig 2: Effect of varieties, dates of sowing and micronutrients on crop growth rate (g m^{-2} day^{1}) of chickpea at 0-30, 30-60, 60-90 DAS and 90 DAS- maturity stage

Relative growth rate (g g^{-1} day^{-1})

It is apparent from the perusal of the results Table 4 that relative growth rate (RGR) was recorded at 30-60, 60-90 DAS and 90 DAS to maturity stage. Different variety, dates of sowing and micronutrients during both the years of investigation. RGR was decreased with advancement of crop growth and recorded maximum at 30-60 DAS during both the years.

Different varieties of chickpea significantly higher RGR (5.37 and 5.54) at 30-60 DAS was observed by variety V_3 (Radhey) which was statistically followed by variety V_1 (KWR-108) 4.99 and 5.18. However, least RGR was observed with variety V_2 (Awarodhi) 4.42 and 4.65 at 30-60 DAS. Similar trend was also recorded at all growth stages during 2017-18 and 2018-19.

Different dates of sowing also exerted significant variation on relative growth rate at all growth stages during both the years. At 30-60 DAS, higher relative growth rate (5.54 and 5.71) was observed with date of sowing (D_1) which was statistically relative growth rate (4.89 and 5.10) followed by date of sowing (D_2). The least relative growth rate was noted under date of sowing (D_3) with (4.35 and 4.56). Almost a similar trend was observed at 60-90, DAS and 90 DAS to at maturity stage in both years of investigation.

Application of different micronutrient significant variation in RGR at all growth stages. Significantly higher RGR (5.12 and 5.35) at 30-60 DAS was observed with application of M_2 (Boron @ 3.0 kg ha^{-1}) However, minimum RGR (4.73 and 4.90) was observed under M_1 (molybdenum @ 3.0 kg ha^{-1}) at all growth stages during both the year of investigations. Similar trend was also recorded at 60-90, DAS and 90 DAS to at maturity stage during both cropping season.

Interactions among variables could not reach to the level of significance.

Table 4: Effect of varieties, dates of sowing and micronutrients on relative growth rate (g g^{-1} day^{-1}) of chickpea at 30-60, 60-90 DAS and 90 DAS- maturity stage

Treatment	30-60 DAS 2017-18	60-90 DAS 2017-18	90 DAS -Maturity 2017-18	30-60 DAS 2018-19	60-90 DAS 2018-19	90 DAS -Maturity 2018-19
Varieties						
KWR-108	4.99	1.44	0.82	5.18	1.49	0.85
AWARODHI	4.42	1.27	0.73	4.65	1.34	0.76
RADHEY	5.37	1.54	0.87	5.54	1.61	0.92
SE(d)	0.05	0.03	0.02	0.06	0.05	0.2
CD (0.05)	0.09	0.06	0.04	0.13	0.09	0.4
Date of sowing						
1 November	5.54	1.59	0.91	5.71	1.66	0.94
10 November	4.89	1.40	0.79	5.10	1.46	0.83
20 November	4.35	1.25	0.71	4.56	1.31	0.75
SE(d)	0.09	0.03	0.02	0.12	0.06	0.03
CD (0.05)	0.25	0.09	0.06	0.32	0.16	0.6
Micronutrient						
Molybdenum	4.73	1.36	0.78	4.90	1.42	0.81
Boron	5.12	1.47	0.84	5.35	1.54	0.87
SE(d)	0.07	0.04	0.02	0.09	0.06	0.03
CD (0.05)	0.15	0.08	0.05	0.19	0.12	0.05

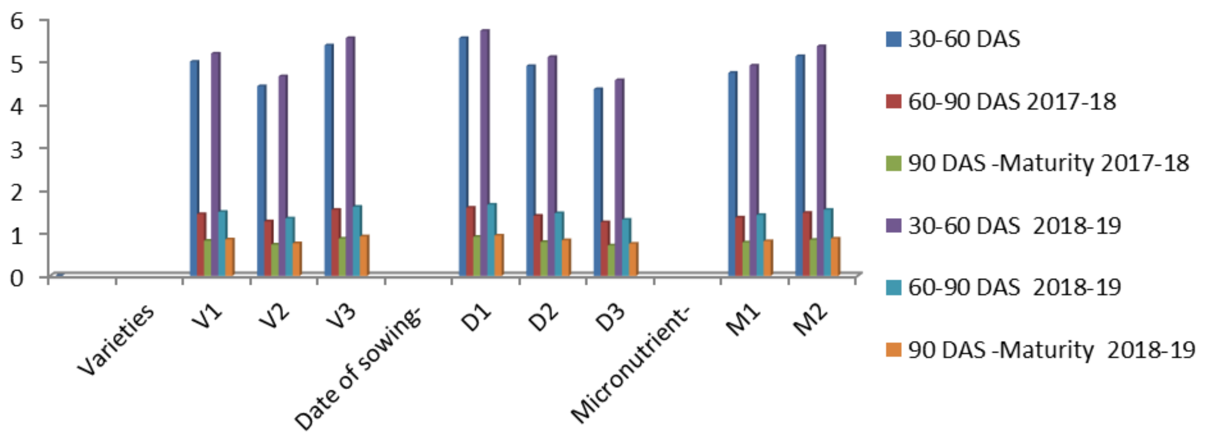

Fig 3: Effect of varieties, dates of sowing and micronutrients on relative growth rate (g g^{-1} day^{-1}) of chickpea at 30-60, 60-90 DAS and 90 DAS-maturity stage

Net assimilation rate (g cm^{-2} day^{-1})

Data pertaining to net assimilation rate (NAR) are presented in Table 5. The results revealed that net assimilation rate decreased with advancement of crop age during both the years.

It is evident from the data that different varieties caused significant variation on net assimilation rate at all stages during both the years. At 30-60 DAS, significantly higher NAR was observed with variety V_3 (Radhey) which was statistically at par with variety V_1 (KWR-108). However, least NAR was observed with variety V_2 (Awarodhi) at all growth stages during both the year of experimentation. Similar trend was also recorded at 60-90, 90 DAS to at maturity stage during both the years of study.

Different dates of sowing also significant variation on net assimilation rate at all growth stages during both the years. At 30-60 DAS, higher net assimilation rate (0.312 and 0.315) was observed with date of sowing (D_1) which was statistically net assimilation rate (0.298 and 0.300) followed by date of sowing (D_2). The lowest net assimilation rate was noted under date of sowing (D_3) with (0.283 and 0.285). Almost a similar trend was observed at 60-90, and 90 DAS to at maturity stage in both years of experimentation.

Net assimilation rate also reach the level of significance with application of micronutrients at all stages. Application of different micronutrient significant variation in NAR at all growth stages. Significantly higher NAR (5.12 and 5.35) at 30-60 DAS was observed with application of M_2 (Boron @ 3.0 kg ha^{-1}) However, minimum NAR (4.73 and 4.90) was observed under M_1 (molybdenum @ 3.0 kg ha^{-1}) at all growth stages during both the year of investigations. Almost similar trend was also recorded at 60-90, DAS and 90 DAS to at maturity stage during both cropping season.

The interaction effect as a result of imposition of different varieties, dates of sowing and micronutrients was found to be non-significant.

Table 5: Effect of varieties, dates of sowing and micronutrients on Net assimilation rate (g g^{-1} day^{-1}) of chickpea at 30-60, 60-90 DAS and 90 DAS- maturity stage

Treatment	30-60 DAS 2017-18	60-90 DAS 2017-18	90 –Maturity DAS 2017-18	30-60 DAS 2018-19	60-90 DAS 2018-19	90-Maturity DAS 2018-19
Varieties						
KWR-108	0.297	0.197	0.114	0.299	0.198	0.116
AWARODHI	0.274	0.181	0.106	0.276	0.183	0.108
RADHEY	0.322	0.213	0.123	0.325	0.215	0.125
SE(d)	0.003	0.004	0.002	0.004	0.003	0.003
CD (0.05)	0.007	0.007	0.004	0.009	0.007	0.006
Date of sowing						
1 November	0.312	0.207	0.120	0.315	0.208	0.122
10 November	0.298	0.197	0.115	0.300	0.199	0.117
20 November	0.283	0.187	0.109	0.285	0.189	0.110
SE(d)	0.006	0.006	0.003	0.006	0.006	0.003
CD (0.05)	0.015	0.016	0.005	0.017	0.017	0.008
Micronutrient						
Molybdenum	0.291	0.193	0.112	0.293	0.194	0.114
Boron	0.305	0.201	0.118	0.307	0.203	0.120
SE(d)	0.004	0.003	0.003	0.004	0.005	0.003
CD (0.05)	0.008	0.005	0.005	0.009	0.009	0.006

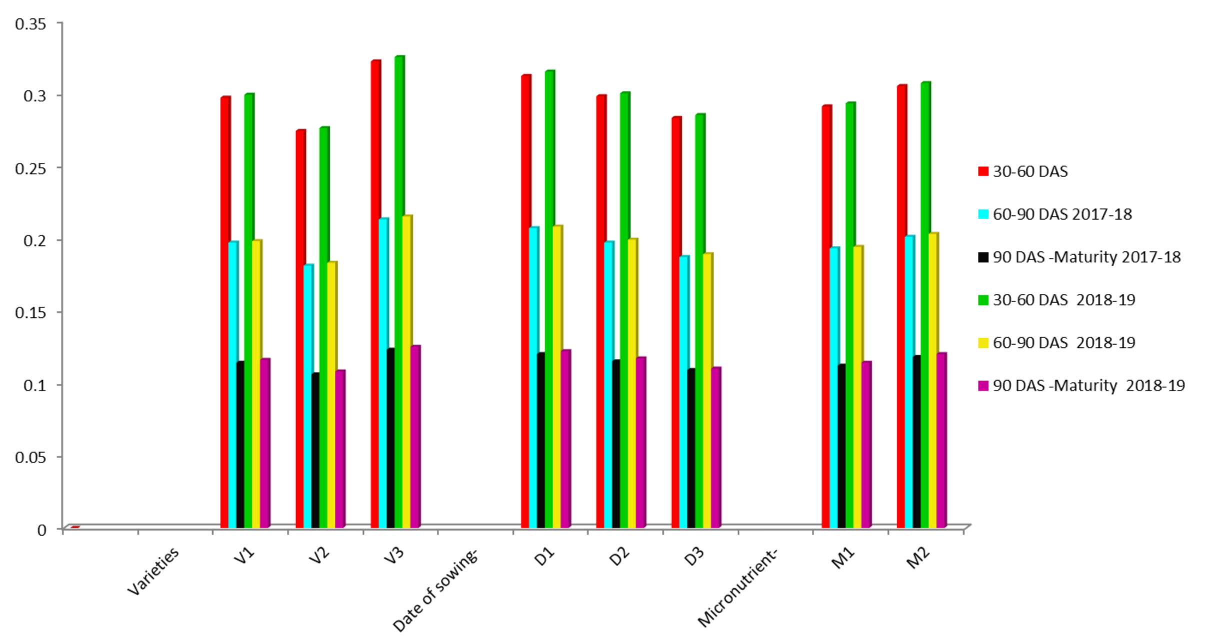

Fig 4: Effect of varieties, dates of sowing and micronutrients on Net assimilation rate (g g^{-1} day^{-1}) of chickpea at 30-60, 60-90 DAS and 90 DAS

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