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Effect of Cultivars and Sowing Dates on Nutrient Uptake and Yield of Chickpea under Aberrant Climatic Conditions in Black Soils of Central India

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Authors' contributions

This work was carried out in collaboration between all authors. Author SN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KR and SR managed the analyses of the study. Author JS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Field experiments were carried out in Indian Institute of Soil Science, Bhopal, India to identify the most suitable variety, appropriate sowing time and their subsequent interaction on nutrient uptake and yield performance in chickpea under rainfed conditions in black soils. There were two dates of sowing viz., first and second fortnight of November and four varieties of chickpea like, JG 16, JG 11, JG 315 and JG 218. The results shown that the nutrient uptake and yield were depending on the time of sowing. The nutrient uptake patterns showed that the first sowing date plants recorded greater nutrient uptake compared to the second date of sowing in both experiments. Among the varieties JG 315 recorded the highest nutrient uptake followed by JG 11. The yield obtained in both sowing dates shown that sowing at first fortnight of November was better and would give 14-29% more yield in chickpea. This study concluded that late sowing will reduce the nutrient uptake, dry matter production and yield irrespective of the varieties.

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Among the varieties the highest yield was recorded by the variety JG 11 irrespective of the date of sowing. and hence under late sowing conditions the variety JG 11 is preferred over other varieties.

Keywords: Chickpea; cultivars; sowing date; nutrient uptake; weather.

1. INTRODUCTION

Climate change impact is a major concern for winter crops like chickpea in central India where irrigation facility is very much limited. Chickpea (*Cicer arietinum* L.) is the most important pulse crop of *rabi* season cultivated mainly in semiarid and warm temperate regions of the world. It produces 126 kg protein from one hectare and is probably the highest protein yielding grain legume except, groundnut and soybean [1]. In India, chickpea cultivation being restricted mainly to rainfed areas or cultivated under residual moisture, lack of nutrient management, instability of yield, low harvest index, inadequate management practices, higher incidence of pests and diseases and faulty management of pest and diseases. Chickpea meets 80% of its nitrogen requirement from symbiotic nitrogen fixation and can fix up to 140 kg N from air [2]. The fixed N not only can meet the requirements of the legume for maximum grain formation, but can also be available for use by subsequent crops, after mineralization of chickpea crop residues. But the P and K nutrition is mainly met through applied fertilizers.

The performance of the crop mainly depended on the cultivar performance and the environmental area where it is growing. As far as a variety is considered its optimum time of sowing has a crucial role in fully utilizing the genetic potentiality as it provides the best possible growing conditions such as light, temperature, rainfall, humidity. It was reported that the main causes of yield component variability are genotypic [3], genotype by environment interactions [4] and climatic variability in terms of temperature regime and moisture availability [5,6]. Unlike other winter growing legumes, chickpea is very susceptible to low temperatures, especially at flowering [7,8].

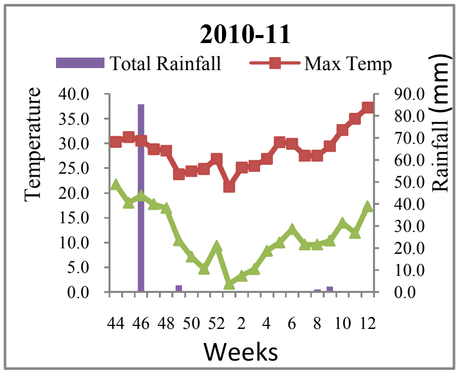
In chickpea sowing date is one of the most important agronomic factors affecting chickpea productivity [9]. The environmental factors which determine optimum sowing date are the pattern of moisture availability during plant growth, temperature and photoperiod. In a given region, the optimum sowing date depends mainly upon the timing of rainfall [10]. Chickpea cultivation is absolutely dependent on soil moisture reserve where planting is made late during the recession of the main rainy season to escape the water-logging condition. Proper agronomic management practices also need to be identified to help the crop adjust to the changing environment. The uptake of nutrients and yield of varieties in the changing weather factors helps to select the most promising varieties in terms of yield and nutrient use efficiency. With this view two field experiments were conducted to identify the most suitable variety, appropriate sowing time and their subsequent interaction on nutrient uptake and yield performance in chickpea under varying environment.

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil

Field experiments were carried out at Indian Institute of Soil Science, Bhopal (Between 23°18'14" and 23°18'48" N latitude and 77°24'17" and 77°24'58" E longitude on Vindhyan plateau of western Madhya Pradesh) to study the effect of sowing dates on yield and nutrient uptake of 4 varieties of chickpea in Vertisol during the *rabi* seasons of 2010-11 and 2011-12. The weather data during the experimental periods are presented in Fig. 1.

The initial analysis revealed that the experimental soil contained 0.50 % organic carbon, 250 kg ha^{-1} nitrogen, 15.7 kg ha^{-1} available phosphorus and 450 kg ha^{-1} available K with pH 8.3. The initial soil moisture content measured gravimetrically during 2010-11 season was 22 per cent and that of 2011-12 was 18 per cent. Experiment was laid out in factorial RBD with three replications and net plot size of 3.0 X 5.0 m^2. Seedbed was prepared by 2-3 times ploughing followed by leveling. The treatments were consisted of four varieties of chickpea (JG 16, JG 11, JG 315 and JG 218) and two sowing dates, first and second fortnight of November. The breeder seeds of these different varieties were collected from the respective research stations. The sowing was done manually with seed rate of 80 kg ha^{-1} at a row to row distance of 45 cm.



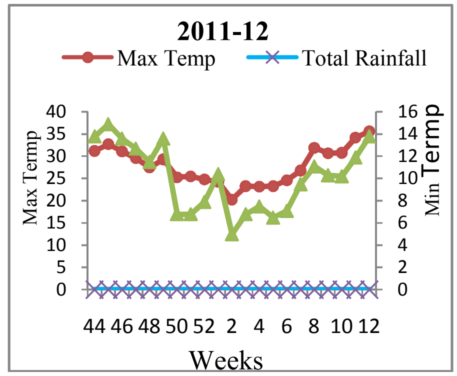


Fig. 1. Weather parameters during 2010-11 and 2011-12

2.2 Fertilizer Application and Other Cultural Practices

A starter dose of N @ 20 kg ha^{-1}, P_2O_5 @ 60 kg ha^{-1} and K_2O @ 20 kg ha^{-1} was applied at the time of sowing in the form of Urea, Single Super phosphate and Muriate of Potash respectively. Zinc in the form of Zinc Sulphate (21% Zn and 18% S) @ 20 kg ha^{-1} to supply 5 kg Zinc was also applied. Thinning was done at 15 days after germination to maintain a plant to plant distance of 10 cm and optimum plant population. Hoeing was done thrice to keep the crop weed free. No irrigation was given as the crop was raised as rainfed crop. Different varieties were harvested on different dates according to their maturity (Table 1).

2.3 Data Recording and Analysis

Five plants were selected at random from each net plot for recording observation. For recording dry matter production plant samples from field were dried in shade and then dried in hot air oven at 70°C. Dry weights were recorded and mean values worked out and expressed as g $plant^{-1}$. Morphological characters of the varieties which may change with changing climatic factors like seed yield, seed weight, seed index etc were studied. Seed yield was recorded by taking the total yield ha^{-1}, seed index by weighing the 100 seeds from each treatment. For plant nutrient analysis the oven dried samples were powdered stored in butter paper cover. The total N content of the plant sample was estimated by modified micro-kjeldahl method as given by Jackson [11]. The total P content of the plant samples was estimated by vanadomolybdophosphoric yellow colour method [11] and read in a spectrophotometer (Spectronic Instruments, Leeds, UK). The total K content of the samples were estimated by using a flame photometer as suggested by Jackson [11]. The uptake of nutrients was calculated by multiplying the plant/ seed dry weight by nutrient concentration in the respective plant part. Soil moisture content during sowing, reproductive stage and at harvest was measured gravimetrically.

2.4 Statistical Analysis

Statistical analysis and interpretation of results were done by calculating values of C.D. (critical difference) at 5% level of probability through analysis of variance technique as described by Gomez and Gomez [12].

Table 1. Varietal characters used in the study

Character	Varieties			
	JG 16 (V1)	**JG 11 (V2)**	**JG 315 (V3)**	**JG 218 (V4)**
Duration	113	95-100	110-130	115-120
Av. Yield (q ha^{-1})	19-20	15-17	20-25	18-20
Growth habit	Semi spreading plant with profuse branching and dark green foliage	Semi spreading	Erect with dark green foliage	Semi erect, branching from main stem
Flower Colour	Dark pink	Dark pink	Light pink	Medium sized pink colour
1000 seed weight	220	225-240	160-200	180

3. RESULTS AND DISCUSSION

3.1 Effect of Sowing Date on Nutrient Uptake

Perusal of data in Table 2 clearly revealed that sowing date significantly influenced the total nitrogen uptake in both years. The first date of sowing resulted in a significantly high nitrogen uptake compared to second sowing. There was a drastic reduction in the nitrogen uptake in the second sowing compared to the first in both years. The delay in sowing might result the seeds to face a more dry soil environment in the later growing periods and hence affected the growth and biomass production, led to low nitrogen uptake. Also it was noticed that irrespective of the date of sowing the nitrogen uptake was high in the year 2010-11 (126.33 kg ha^{-1}) compared to 2011-12. The decrease in uptake of nitrogen during 2011-12 might be due to the absence of rainfall during the crop growing period (Fig. 1). The low soil moisture (15 per cent) and the initial high temperature might caused the low growth and nodulation, this might expressed in the low nitrogen fixation and hence the uptake also. These findings are in conformity with the findings of Gan et al. [13] and Beck et al. [14].

During the year 2010-11 phosphorus uptake (Table 2) not showed a significant difference between first and second sowing but it was significant in 2011-12. In the year 2010-11 the phosphorus uptake was the highest in the first date of sowing but it was on par with second sowing. Phosphorus is mainly contributed for the early root development and initial vigour of the plant. Generally chickpea tend not to respond to phosphorous fertilizer even in soils with low available phosphorous status compared to other food legumes and cereals, suggests that the crop is extremely efficient at taking up phosphorous from the soil [15,16]. The more distributed rainfall during the year 2010-11 (Fig. 1) might supply more soil moisture during the early development of the crop both in first and second sowing. This might be the reason for similar uptake of phosphorus in both sowing dates in 2010-11. But in the next year there was a significantly high phosphorus uptake in the first sowing compared to the second. This might be due to the availability of comparatively the more residual moisture (18 per cent) along with the left over phosphorus (28 kg ha^{-1}) from the previous crop during the first sowing and root establishment compared to second (15 per cent soil moisture). If there is adequate moisture in the soil the availability of phosphorus can be enhanced due to the strong association of VAM (vesicular-arbuscular mycorrhizal fungi) and plant roots [17] and the acid exudates from the roots allow the plant to take up more phosphorus from the alkaline soils [18]. It was reported that low soil temperature depressed the growth of corn seedlings and the total phosphorus was lower at low temperature [19].

Total potassium uptake was found significantly different in first and second sowing dates. The first sowing recorded a significantly high K uptake than the second sowing in both 2010-11 and 2011-12. There was a high potassium uptake in both sowing dates during 2010-11 than 2011-12. The high uptake might be attributed to the better weather and environmental conditions existing during the crop growth period. Wang et al. [20] reported that there was a positive correlation between K uptake and water acquisition in plants. Hence the reduction in soil moisture affects the uptake of K and the total biomass production. This might be the reason for low K uptake in 2011-12, when there was low rainfall during the crop growing period (Fig. 1).

3.2 Effect of Varieties on Nutrient Uptake

Nitrogen uptake was significantly differed due to the varieties irrespective of the years (Table 2). The highest nitrogen uptake (128.27 kg ha^{-1}) in the year 2010-11 was recorded by the variety V2 (JS 11) but it was on par with the variety V3 (JS 315) with a nitrogen uptake of 126.2 kg ha^{-1}. At the same time the total nitrogen uptake recorded by the variety V3 (JS 315) (92.24 kg ha^{-1}) in 2011-12 was significantly high compared to all other varieties. Nitrogen uptake in 2010-11 was significantly high compared to 2011-12 irrespective of the varieties. Due to short of rain (Fig. 1) there was a drastic reduction of moisture during the sowing time in 2011-12 and the plant might derived a small proportion of crop N nitrogen requirement from symbiotic N_2 fixation. These findings are agreement with that of Marcellos et al. [21].

Between the varieties there was a significant difference in phosphorus uptake was observed in both 2010-11 and 2011-12 (Table 2). The highest phosphorus uptake was recorded by the variety V3 (JS 315) (18.12 kg ha^{-1}) followed by V1 (JS 16) (16.91 kg ha^{-1}) in 2010-11. The same variety V3 (JS 315), showed the highest phosphorus uptake (18.07 kg ha^{-1}) followed by V2 (JS 11)

(17.01 kg ha^{-1}) in 2011-12. The high uptake may be attributed to the high content of phosphorus in the plant parts and the increase in dry matter production in these varieties. The difference in phosphorus uptake by the same varieties in different years mainly attributed to the environmental conditions prevailing in the area. The efficient varieties will absorb nutrients continuously even in the adverse environmental conditions and perform better than the inefficient varieties. Here it was found that JG 315 recorded the highest phosphorus uptake in both the years irrespective of the weather variables and proved that it is a phosphorus use efficient variety. Genetic variability in phosphorus efficiency was reported by Marcante et al. [22].

Among the varieties V3 (JS 315) recorded significantly high potassium uptake compared to other varieties followed by V4 (JS 218) which was on par with the variety V2 (JS 11) in the year 2010-11 (Table 2). But during 2011-12, the total K uptake values were not significant between varieties. The highest K uptake was recorded by the variety V3 (JS 315) followed by V2 (JS 11). There was a drastic reduction of K uptake by the varieties was observed in the year 2011-12. The factors like soil temperature and moisture content are important in the uptake of K by crops. The low soil moisture and high temperature during the crop growth period might cause this reduction of nutrient uptake. There are reports that K uptake by the plant is more sensitive than the uptake of other nutrient elements with change in temperature, moisture content, aeration and compaction [23].

3.3 Effect of Interaction of Sowing Date and Varieties on Nutrient Uptake

Table 3 clearly showed the interaction effect of varieties and sowing date on nitrogen uptake. The interaction showed significant difference between nitrogen uptakes in both the years. The highest nitrogen uptake was observed by the variety V2 (JS 11) followed by V3 (JS 315) on first sowing date in 2010-11. This explains the best combination of this variety with suitable sowing time. The least value of nitrogen uptake in 2010-11 and 2011-12 were observed in the variety V1 (JS 16) followed by V2 (JS 11) on second sowing date and these clearly describe

Table 2. Effect of sowing dates and varieties on total NPK uptake (kg ha^{-1})

Sowing Date	Total N uptake		Total P uptake		Total K uptake	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
D1	126.33	100.91	16.93	18.02	76.72	59.75
D2	107.96	70.39	16.54	16.01	55.63	41.53
C.D	4.81	2.73	N/A	0.63	3.55	2.47
SE(d)	2.22	1.26	0.45	0.29	1.64	1.14
Variety						
V1 (JS 16)	104.24	82.92	16.91	16.14	59.34	48.89
V2 (JS 11)	128.27	84.84	15.25	17.01	65.17	50.90
V3 (JS 315)	126.20	92.24	18.12	18.07	74.43	52.21
V4 (JS 218)	109.87	82.60	16.66	16.83	65.76	50.58
C.D	6.80	3.86	1.38	0.90	5.02	N/A
SE(d)	3.14	1.78	0.64	0.41	2.32	1.61

Table 3. Interaction effect of sowing dates and varieties on total NPK uptake (kg ha^{-1})

Interaction between V and D	Total N Uptake		Total P uptake		Total K uptake	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
D1V1	113.09	101.87	16.03	16.83	65.92	58.27
D1V2	155.67	104.42	15.46	18.29	79.95	61.92
D1V3	127.43	105.71	17.54	19.67	79.03	59.81
D1V4	109.15	91.65	18.70	17.28	81.97	59.00
D2V1	95.39	63.98	17.79	15.45	52.76	39.50
D2V2	100.87	65.26	15.04	15.73	50.39	39.87
D2V3	124.97	78.77	18.70	16.48	69.83	44.61
D2V4	110.59	73.55	14.61	16.37	49.55	42.15
C.D.	9.61	5.46	1.96	N/A	7.09	N/A
SE(d)	4.44	2.52	0.64	0.58	3.28	2.28

that the varieties V1 (JS 16) and V2 (JS 11) are not at all suitable for a late sowing purpose in terms of nitrogen uptake and use efficiency. During 2011-12 the nitrogen uptake by all the varieties in both first and second sowing were declined due to the prevailing weather factors like low rainfall and high temperature during the crop growth periods.

The interaction effect of sowing dates and varieties on phosphorus uptake was significant in 2010-11 (Table 3). The highest phosphorus uptake was recorded by the combination of first sowing with the variety V4 (JS 218) and the second sowing with the variety V3 (JS 315). This clearly explains that if the sowing is delayed the best variety suitable is V3 (JS 315) for better yield and nutrient uptake. But the second year experiment showed that the phosphorus uptake was not significantly different in the interaction effect. The highest phosphorus uptake was recorded by the combination D1V4 followed by D1V2 in the first sowing. The second sowing resulted in low phosphorus uptake with all varieties in both years compared to the first sowing. The late sowing might result the plants to face the low soil moisture conditions and hence affected the mycorrhizal association ultimately resulted the low uptake of phosphorus in the second sowing.

A significantly high K uptake was observed in the year 2010-11 due to the interaction effect of sowing dates and varieties (Table 3). The highest K uptake was recorded by the combination D1V4 which was on par with D1V2, D1V1 and D1V3. But the K uptake in the second sowing showed a drastic reduction in all varieties. But during 2011-12 there was no significant difference between the K uptake by any combination of varieties and sowing dates. The K uptake values showed a drastic drop in this year in all interaction treatments. This might be due to the low and less distributed rainfall during the crop growing period and the sudden raise in temperature in the end of season. The highest value was observed with the combination D1V2 in first sowing and D2V3 in the second sowing.

3.4 Effect of Sowing Date on Dry Matter Production (DMP), Yield and Seed Index

The dry matter production was significantly high in D1 compared to D2 in both the years (Table 4). During 2010-11 high dry matter production was recorded for both D1 and D2 than the corresponding sowing dates in 2011-12. The increased TDM production from early sowings was strongly related to the amount of radiation which the crop absorbed [24].

The dry matter accumulation in D2 was significantly low in both years. The drop in biomass production and its distribution to different plant parts under late sowing could have been caused due to sudden drop in temperature during the grand growth phase and then a sharp rise in temperature during the maturity resulting in higher respiration losses and reduced growth rate. During the year 2011-12 the dry matter production was very low in both sowing compared to 2010-11. The comparatively high minimum and maximum temperature and absence of rainfall (Fig 1) during the crop growing period in second year resulted in low biomass production and yield.

Table 4 showed that seed yield was significantly different due to sowing date in both years. The highest seed yield was recorded by D1 in both years compared to D2. In the year 2010-11, D1 recorded 22.7% more yield compared to D2 and the corresponding increase was 31% in 2011-12. In chickpea, yield is the final outcome of the total dry matter produced during the growing season being partitioned into seed [25]. The more dry matter production in the first sowing resulted the efficient partitioning of the photosynthates and hence contributed to more yield. In the year 2011-12 the total rainfall received was very low and hence the residual moisture also. Hence the seed yield in 2011-12 was low compared to 2010-11. The effect of seeding date on grain yield was partly through the increase of 100-seed weight and branch number reported by Mengistu [26]. In the later period of growth late sown crop faced increasing day length and temperature resulted in low yield. These results are in conformity with Munirathnam and Sangita [27] and Mansoor et al. [28]. Early seeding would be a key to optimized water use, increased biomass, and hence, more assimilate to the grain. Many researchers reported that, early planting dates have higher yields in chickpea [29,30].

Seed index was found significantly different due to sowing date in the year 2010-11 (Table 4). The highest seed index recorded in D1 was 19.03 g in the year 2010-11. The late sowing decreased the seed index due to insufficient partitioning of photosynthates towards the seed. Kumar et al. [31] reported that in an experiment at Hisar the 100 seed weight (seed index) decreased in all the cultivars of chickpea with delay in sowing. Ozdemir and Karadavut [32]

Table 4. Effect of sowing dates and varieties on DMP, Seed yield and Seed Index

Sowing Date	Dry matter production (g plant^{-1})		Seed Yield (g plant^{-1})		Seed Index (g)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
D1	16.41	11.95	9.18	6.62	19.03	16.37
D2	13.46	9.24	7.81	4.68	16.47	16.75
C.D	0.80	0.49	0.43	0.38	0.59	N/A
SE(d)	0.37	0.22	0.20	0.18	0.27	0.32
Variety						
V1 (JS 16)	14.45	11.08	7.79	5.31	16.89	14.49
V2 (JS 11)	17.83	10.56	11.60	6.44	20.42	18.52
V3 (JS 315)	16.16	10.77	8.66	6.13	14.59	15.20
V4 (JS 218)	11.31	9.96	5.92	4.74	19.10	18.04
C.D	1.13	0.69	0.61	0.54	0.84	0.99
SE(d)	0.52	0.32	0.28	0.25	0.39	0.46

found that autumn sowing increased 100-seeds weight of chickpea by an average of 10% over spring sowing and shown that this result was owing to the moderate temperature regime during the seed filling stage. The seed index in 2011-12 showed no significant difference between the two dates of sowing. Similar results were reported by Nawaz et al. [33], Chaitanya and Chandrika [34] and Ahmed et al. [35]. The higher value was recorded by D2 which was on par with D1.The partitioning of photosynthates towards seed was more or less same for both sowing dates in the year 2011-12. In a study Chaitanya and Chandrika [34] reported that date of sowing has no significant influence on seed index.

3.5 Effect of Cultivars on Dry Matter Production (DMP), Yield and Seed Index

The dry matter production showed significant difference between varieties in both years (Table 4). The highest DMP was recorded by the variety V2 (JS 11) (17.83 g plant^{-1}) which was significantly high compared to all other varieties during the year 2010-11. Here the lowest DMP was recorded by the variety V4 (JS 218) with a value 11.31 g plant^{-1} which was higher than the DMP values obtained by all the varieties. The highest DMP of 11.08 g plant^{-1} was recorded by the variety V1 (JS 16) which was on par with V2 (JS 11) and V3 (JS 315) in the year 2011-12. Similarly here also the lowest value was recorded by the variety V4 (JS 218). Bahadur et al. [36] and Kumar et al. [37] were reported the genotypic variations in dry matter production in chickpea genotypes. Dry matter redistribution is an extreme variable in different chickpea genotypes [38].

Different varieties had significant effect on yield in 2010-11 and 2011-12 (Table 4). The highest yield was recorded by the variety V2 (JS 11) (11.60 g plant^{-1}) which was significantly high compared to all other varieties in the year 2010-11. During 2011-12 also the highest yield was recorded by the variety V2 (JS 11) (6.44 g plant^{-1}) which was on par with V3 (JS 315) (6.13g plant^{-1}). Saxena et al. [39] (1990) reported that a prerequisite for high chickpea yields is high DM production. The lowest yield was recorded by the variety V4 (JS 218) in both years. The variety V2 (JS 11) recorded 47.5% more yield compared to V4 (JS 218) in 2010-11 where as it was 26.4% in 2011-12. Overall poor yield of the chickpea varieties in the year 2011-12 might be resulted from the higher evaporation rate, depletion of soil moisture over time as there was no rainfall during the growing season.

The seed index was found significant difference between varieties in both years. The highest seed index was recorded by the variety V2 (JS 11) followed by V4 (JS 218) in both years. The bold nature of the seeds of variety V2 (JS 11) might be the reason for high seed index of this variety. This character is attributed to variety's genetic makeup and highly heritable in nature and hence the environment has less effect in seed index. A high demand for assimilate from filling seeds when the supply of current assimilate is decreasing often results in an assimilate shortfall [40,41]. As a result, other sources of assimilates are required to keep up seed filling and seed size, otherwise seeds are smaller or they take much longer to fill. The lowest seed index was recorded by V3 (JS 315) in 2010-11 while it was by V1 (JS 16) in 2011-12. Kabir et al. [42] reported that there was no significant

Table 5. Interaction effect of sowing dates and varieties on DMP, Seed yield and Seed Index

Interaction between V and D	Dry matter production (g plant^{-1})		Seed Yield (g plant^{-1})		Seed Index (g)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
D1V1	16.39	12.16	8.64	5.61	18.19	16.43
D1V2	20.44	11.68	12.94	7.48	21.92	18.03
D1V3	17.51	12.70	9.16	7.76	15.72	14.06
D1V4	11.30	11.25	5.96	5.65	20.28	18.29
D2V1	12.51	10.00	6.94	5.00	15.59	14.92
D2V2	15.23	9.44	10.26	5.40	18.59	17.67
D2V3	14.81	8.83	8.16	4.50	13.46	14.96
D2V4	10.64	8.67	5.88	3.83	18.26	17.46
C.D.	1.60	N/A	0.88	0.54	N/A	0.82
SE(d)	0.74	0.45	0.40	0.25	0.44	0.38

difference between varieties in terms of seed index.

3.6 Effect of Interaction of Sowing Date and Varieties on Dry Matter Production, Yield and Seed Index

The dry matter production showed significant difference due to interaction of sowing date and varieties in 2010-11 (above Table 5). The highest dry matter production was observed in D1V2 followed by D1V3 which was on par with D1V1. In the second sowing- variety combinations the highest dry matter production was recorded by D2V2 which was on par with D1V3. The lowest value was recorded by D1V4 which was on par with D2V4 and D2V1. The above average temperatures helped to ensure high growth rates, and adequate moisture anticipated the crop had a long growing season. This helped to accumulate more dry matter during the year 2010-11. The interaction between variety and sowing date was not showed significant dry matter production in 2011-12.

Analysis of grain yield demonstrated significant differences among cultivars and the sowing dates in both years (Table 5). The highest seed yield was recorded by D1V2 (12.94 g plant^{-1}) followed by D2V2 (10.26 g plant^{-1}) in 2010-11. In the second year there was drastic reduction of seed yield in all interaction treatments compared to first year. The highest seed yield was recorded by D1V3 (7.76 g plant^{-1}) which was on par with D1V2 (7.48 g plant^{-1}). The lowest yield was recorded by D2V4 in both the years. This indicates that the variety V4 (JS 218) is very much sensitive to environment and not at all suitable for the late sowing. Bahal et al. [43] reported that dates and genotypes interaction was highly significant for seed yield.

Table 5 clearly showed that there was no significant difference in seed indexes at any interaction treatments in year 2010-11. The highest seed index was recorded by the interaction treatment D1V2 followed by D1V4 and the lowest seed index was recorded by D2V3 in 2010-11. During 2011-12 the highest seed index was reported by D1V4 which was on par with D1V2. The lowest seed index (14.96 g) was recorded by D2V3. In a study Kabir *et al.* [42] reported that there was no difference in 100-seed weight of chickpea with respect to cultivars. It was also reported that the seed index was a stable character and variation mainly depends on the genotype [44].

4. CONCLUSION

The optimal time of sowing in chickpea depends on the interaction between the environment and the available varietal germplasm. Choosing an optimum sowing time can be a compromise between maximizing yield potential and minimizing disease levels. But due to irregular weather conditions, like lack of rainfall or excess rainfall, change in temperature pattern etc. and rainfed farming, sowing at optimum time is sometimes not practical in black soils of central India. From the present investigation it is concluded that sowing at first fortnight of November was better and would give 14-29% more yield in chickpea. Also it was convinced that late sowing would reduce the nutrient uptake, dry matter production and yield irrespective of the varieties. Among the varieties the highest yield was recorded by the variety JG 11 irrespective of the date of sowing. Hence it is suggested that the variety V2 (JS 11) could be preferred over other varieties to get high yield in the adverse conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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