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RESEARCH ARTICLE

Radiation interception and light use efficiency by different sowing environments in chickpea

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SUMMARY : Experiment was laid out in a Split Plot Design with three replications and twelve treatment combinations formed due to (A) three sowing dates *viz.*, (i) 49th MSW(D_1),(ii) 50th MSW(D_2),(iii) 51th MSW (D_3), (B) four potash levels (i) 0 kg K_2O ha^{-1} (K_1), (ii) 25 kg K_2O ha^{-1}(K_2) , (iii) 50 kg K_2O ha^{-1} (K_3) and (iv) 75 kg K_2O ha^{-1} (K_4). Chickpea sown on 10th December produced significantly higher grain and straw yield over rest of the treatments. The minimum dry matter accumulation per plant was recorded in late sown crop (51st MSW). The cause of reduction in accumulation of dry matter might be happened due to rise in temperature as well as depletion of soil moisture. The mean APAR was higher in early sown crop (49th MSW) throughout the growing period of chickpea which was significantly superior over rest of the treatments. The lowest APAR was recorded in late sown crop (51th MSW). This might be explained as favourable climatic conditions available during the early sown crop which might have resulted into profuse growth, that consequently reflected into more accumulation of dry matter and APAR. The light use efficiency was significantly superior in 49th MSW throughout the growing period of crop while, it was recorded the lowest under late sown crop (51th MSW). This might be attributed due to early sown crop to get benefit of better light and moisture conditions, which might have resulted into higher vegetative growth and development consequently resulting into higher light use efficiency. On other hand, late sown crop faced increasing day length and temperature.

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Key Words :
Radiation interception, Light use efficiency, Sowing environments, Chickpea

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Pulses play significant role in sustainable agriculture and provide natural security to predominant vegetarian population of the country. However, due to increase in national population, pulses consumption has gone down from 60 g/day/capita in the year 1951 to 31 g/day/capita during the year 2012 (Anonymous, 2012 a and b). Pulses are important not only for their value as human food but also the important source of high protein content for livestock. It has been important component of Indian agriculture enabling the land to restore fertility by fixing the atmospheric nitrogen. It helps in producing reasonable yield of succeeding crops by restoring the fertility of soil. It also meets the demand of human dietary requirement *viz.*, proteins, carbohydrates, fat and other nutrient sources. The non adoption of improved agro-techniques in a climate change scenario as irrigation scheduling, variable planting dates and use of mulch are the limiting factors for low productivity and poor in creation of favourable microclimatic conditions. Globally this climate change should also be addressed in eco-friendly manner. With this back ground in view, the present investigation was undertaken to know the radiation interception and light use efficiency as influenced by sowing windows in chickpea.

EXPERIMENTAL METHODOLOGY

An experiment on studies on sowing dates and potash levels on growth, yield and quality of chickpea cv. 'Digvijay' was conducted at Post Graduate Institute Research farm of Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar during the year 2009-10 in *Rabi* season.The soil of experimental field was clayey in texture, low in available nitrogen (148.25 kg ha^{-1}), medium in available phosphorus (16.32 kg ha^{-1}) and very high in potassium (432.58 kg ha^{-1}) with slightly alkaline reaction (pH 8.1). The experiment was laid out in a Split Plot Design with three replications and twelve treatment combinations formed due to three sowing dates *viz.*, D_1- 49th MSW; D_2- 50th MSW and D_3- 51st MSW relegated into main plot as main plot treatments and four potash levels *viz.*, K_1-0 kg K_2O ha^{-1}; K_2-25 kg K_2O ha^{-1}; K_3-50 kg K_2O ha^{-1} and K_4-75kg K_2O ha^{-1} relegated into sub plot as sub plot treatments. The chickpea crop was sown on various sowing dates *viz.*, 49th, 50th, 51st MSW in December, 2009 by dibbling the seeds on both side of ridges (ridges and furrows opened at 90 cm width) at 45 x 10 cm spacing. All the doses of fertilizer were applied as a basal dose before sowing. The seeds were inoculated with rhizobium culture @25 g per kg seeds and again seeds were treated with PSB culture @25 g per kg seeds at the time of sowing.

Measurement of absorbed photosynthetically radiation :

The various components of PAR *viz.*, incident radiation, transmitted radiation, reflected radiation, were measured at an interval of 28 days around local solar noon, with the help of line quantum sensor between 12.30 and 14.30 hours. To eliminate the effect of solar elevation, the measurements were made simultaneously at mid-day.

Determination of absorbed radiation:

Absorbed PAR was worked out by adopting the equation given by Gallo and Daughtry (1986).

$$Ra = (Ri + Rs) - (Rt + Rr)$$

where,
Ra = Absorbed radiation
Ri = Incident radiation
Rr = Plant canopy reflected radiation
Rt= Transmitted radiation
Rs= Soil surface reflected radiation

To calculate light use efficiency, cumulated absorbed radiation was converted from $\mu molm^{-2}s^{-1}$ to MJm^{-2} by multiplication of factor 0.0188.

$$x = \frac{\text{Amount of dry matter produced } (g^{-2})}{\text{Amount of cumulative light absorbed } (MJ\ m^{-2})}$$

where,
x=Estimation of light use efficiency (LUE)

Experimental Findings and Discussion

The experimental findings regarding the response of chickpea cv. 'Digvijay' to various sowing dates and potassium levels in respect of growth, yield and their attributes, protein content in seed under *Rabi* conditions are presented and discussed in this paper.

Mean total weight of dry matter per plant (g):

Data on mean total weight of dry matter per plant as influenced periodically by different treatments are presented in Table 1. The rate of dry matter accumulation per plant increased from 1.87 g at 28 DAS to 30.93 g per plant at harvest. However, the maximum rate of accumulation of dry matter per plant was higher during 56 DAS to harvest.

Effect of sowing dates:

The mean dry matter accumulation per plant was significantly influenced by different sowing dates at later crop growth stages 56 DAS onwards. The dry matter accumulation per plant in early sown crop (49th MSW) was found significantly superior over rest of the treatments. The minimum dry matter accumulation per plant was recorded in late sown crop(51st MSW). The cause of reduction in accumulation of dry matter might be happened due to rise in temperature as well as depletion of soil moisture (Siddique *et al*., 1999). Similar results were recorded by Park *et al.* (1987) and Fallah (2008).

Effect of potassium levels:

The mean dry matter accumulation per plant was significantly influenced by different potassium levels at 56 DAS onwards. There was gradual increase in mean dry matter accumulation per plant with increasing potassium levels up to 50 kg K_2O ha^{-1}. The mean dry matter accumulation per plant was significantly higher with application of 50 kg K_2O ha^{-1} over rest of the treatments. The lowest dry matter per plant was recorded in control. This might be due to influence of potassium on crop growth through its effects on water uptake, root growth, maintenance of turgor, transpiration and stomatal regulation (Li *et al.*,1989).

Effect of interaction:

The interaction effects between sowing dates and potassium levels on mean total weight of dry matter per plant were found to be non-significant.

Mean leaf area per plant (dm^2):

Data on mean leaf area per plant as influenced periodically by different treatments are presented in Table 2. The data in table revealed that the leaf area per plant increased with advancement in the age of the crop but there was slightly reduction in leaf area at harvest.

Effect of sowing dates:

The data presented in Table 2 revealed that the leaf area of plant was influenced significantly due to sowing dates at

Table 1: Mean dry matter (g) per plant as influenced periodically by various treatments

Treatments	28 DAS	42 DAS	56 DAS	70 DAS	84 DAS	At harvest
Sowing dates						
D_1:49th MSW	1.93	5.56	9.61	18.17	29.25	34.83
D_2:50th MSW	1.93	5.51	10.23	16.37	25.40	30.72
D_3: 51thMSW	1.75	5.17	11.54	14.68	21.60	27.24
S.E.±	0.10	0.33	0.32	0.35	0.68	0.75
C.D. (P=0.05)	NS	NS	0.96	1.04	2.03	2.23
CV %	7.32	9.12	7.60	6.09	8.24	6.79
Potash levels kg ha^{-1}						
K_1:(0)	1.71	5.20	9.15	14.54	23.67	27.86
K_2: (25)	1.86	5.24	10.33	16.38	25.46	30.83
K_3: (50)	2.04	5.99	11.89	18.21	27.23	34.01
K_4: (75)	1.86	5.23	10.47	16.48	25.68	31.02
S.E.±	0.19	0.24	0.46	0.40	0.35	0.11
C.D. (P=0.05)	NS	NS	1.36	1.19	1.05	0.34
Interaction (D x K)						
S.E.±	0.34	0.48	0.31	0.74	0.58	1.14
C.D. (P=0.05)	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.
General mean	1.87	5.41	10.46	16.40	25.51	30.93
CV %	8.18	8.47	6.76	7.34	9.24	7.87

N.S. = Non-significant

Table 2: Mean leaf area (dm^2) per plant as influenced periodically by various treatments

Treatments	28 DAS	42 DAS	56 DAS	70 DAS	84 DAS	At harvest
Sowing dates						
D_1:49th MSW	0.94	1.48	2.49	3.64	4.42	3.34
D_2:50th MSW	0.72	1.30	2.25	3.32	4.10	3.08
D_3: 51thMSW	0.65	1.17	1.83	2.80	3.67	2.59
S.E.±	0.003	0.06	0.07	0.006	0.04	0.009
C.D. (P=0.05)	0.011	0.20	0.27	0.023	0.15	0.034
CV %	6.45	8.27	9.14	7.34	8.43	7.65
Potash levels kg ha^{-1}						
K_1:(0)	0.65	1.24	2.16	3.09	3.93	2.83
K_2: (25)	0.76	1.22	2.21	3.27	4.12	3.02
K_3: (50)	0.91	1.43	2.34	3.41	4.16	3.15
K_4: (75)	0.76	1.38	2.00	3.24	4.04	3.00
S.E.±	0.002	0.05	0.13	0.01	0.07	0.017
C.D. (P=0.05)	0.008	0.15	0.39	0.03	0.21	0.053
Interaction (D x K)						
S.E.±	0.004	0.09	0.22	0.01	0.13	0.03
C.D. (P=0.05)	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.
General mean	0.77	1.32	2.19	3.25	4.06	3.00
CV %	7.34	9.17	8.34	6.37	9.12	8.62

N.S. = Non-significant

all the crop growth stages of observation. The leaf area was higher under sowing on 49th MSW which was significantly superior over other sowing dates. The minimum leaf area was recorded in late sown crop (51st MSW). This might be attributed to long day length and increase in temperature in late sown crop. The present results are in conformity with Mansur *et al.* (2010) and Chaitanya and Chandrika (2006).

Effect of potassium levels:

The leaf area was influenced significantly due to different potassium levels at all growth stages of observation. The leaf area increased with increase in potassium levels up to 50 kg K_2O ha^{-1} and declined thereafter which was significantly higher than other potassium levels. The minimum leaf area was recorded under control. This might be due to high water uptake, osmo-regulation and root growth of the plant.The results are in conformity with Saxena *et al*. (1996) and Vairavan (1996).

Meteorological studies:

Effect of absorbed photosynthetically active radiations (APAR):

Data on absorbed photosynthetically active radiations as influenced periodically by different treatments are presented in Table 3.

Effect of sowing dates:

Perusal of data in Table 3 revealed that there was significantly superior effect of sowing dates on absorbed photosynthetically active radiations. The mean APAR was higher in early sown crop (49th MSW) throughout the growing period of chickpea which was significantly superior over rest of the treatments. The lowest APAR was recorded in late sown crop (51st MSW). This might be explained as favourable climatic conditions available during the early sown crop might have resulted into profuse growth, which consequently reflected into more accumulation of dry matter and APAR.

Effect of interaction:

Interaction effect between sowing dates and potassium levels in respect of absorbed photosynthetically active radiations was found to be non-significant.

Studies on light use efficiency (LUE):

Data on light use efficiency as influenced periodically by different treatments are presented in Table 4. The light use efficiency of chickpea increased with the advancement of age of the crop but there was slight reduction in rate at 84 DAS. The light use efficiency was maximum at 74 days after sowing.

Effect of sowing dates:

The periodical light use efficiency on chickpea differed significantly throughout the growing period under various sowing dates. The light use efficiency was significantly superior in 49th MSW throughout growing period of crop while, it was recorded the lowest under late sown crop (51st MSW).

Table 3: Mean absorbed photosynthetically active radiations (µmoles m^{-2} s^{-1})as influenced periodically by various treatments

Treatments	28 DAS	42 DAS	56 DAS	70 DAS	84 DAS	At harvest
Sowing dates						
D_1:49th MSW	112.08	184.33	302.75	384.17	447.00	106.54
D_2:50th MSW	104.08	172.17	284.33	342.08	423.07	99.13
D_3: 51thMSW	98.17	147.08	269.33	322.08	403.42	94.25
S.E.±	0.03	0.48	0.04	0.10	0.27	0.04
C.D. (P=0.05)	0.13	1.65	0.13	0.36	0.78	0.13
CV %	9.46	6.92	7.37	8.24	7.43	9.67
Potash levels kg ha^{-1}						
K_1:(0)	101.78	165.49	283.10	347.08	421.89	97.21
K_2: (25)	103.67	166.67	284.15	348.11	422.16	99.67
K_3: (50)	108.10	170.68	288.72	352.56	427.78	104.16
K_4: (75)	105.67	168.12	286.22	356.33	425.13	99.11
S.E.±	0.32	0.32	0.13	0.14	0.20	0.18
C.D. (P=0.05)	0.97	0.98	0.38	0.48	0.60	0.53
Interaction (D x K)						
S.E.±	0.62	0.38	0.27	0.19	0.38	0.23
C.D. (P=0.05)	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.
General mean	104.78	167.86	285.47	349.44	424.47	101.39
CV %	6.65	7.39	9.24	9.16	8.68	8.12

N.S. = Non-significant

Table 4: Mean light use efficiency (g MJ^{-1}) as influenced periodically by various treatments

Treatments	28 DAS	42 DAS	56 DAS	70 DAS	84 DAS	At harvest
Sowing dates						
D_1:49th MSW	1.46	1.62	1.71	1.83	1.56	1.31
D_2:50th MSW	1.27	1.47	1.52	1.64	1.40	1.21
D_3: 51thMSW	1.16	1.35	1.43	1.54	1.31	1.12
S.E.±	0.02	0.001	0.02	0.03	0.03	0.02
C.D. (P=0.05)	0.07	0.003	0.06	0.09	0.09	0.06
CV %	5.68	6.34	5.95	6.61	5.64	7.12
Potash levels kg ha^{-1}						
K_1:(0)	1.24	1.38	1.44	1.58	1.31	1.12
K_2: (25)	1.27	1.48	1.55	1.67	1.42	1.21
K_3: (50)	1.39	1.58	1.67	1.78	1.53	1.31
K_4: (75)	1.29	1.47	1.56	1.65	1.42	1.22
S.E.±	0.03	0.03	0.03	0.02	0.07	0.04
C.D. (P=0.05)	0.09	0.09	0.10	0.08	0.21	0.12
Interaction (D x K)						
S.E.±	0.05	0.002	1.03	0.83	1.02	1.05
C.D. (P=0.05)	N. S.	N. S.	N. S.	N. S.	N. S.	N. S.
General mean	1.30	1.48	1.55	1.67	1.42	1.21
CV %	6.70	7.45	6.35	8.27	6.18	6.71

N.S. = Non-significant

This might be attributed due to early sown crop to get benefit of better light and moisture conditions, which might have resulted into higher vegetative growth and development consequently resulting into higher light use efficiency. On other hand, late sown crop faced increasing day length and temperature. Similar results are in conformity with Lin *et al.* (2007) and Singh *et al.* (2008).

Effect of potassium levels:

The light use efficiency of chickpea was significantly influenced due to various potassium levels. The light use efficiency was significantly highest with application of 50 kg K_2O ha^{-1} while it was recorded the lowest in control. This might have caused due to activation of various enzymes, water relation and stomatal movement by potassium, resulting into higher accumulation of dry matter reflecting into higher light use efficiency.

Effect of interaction:

The interaction effect between sowing dates and potassium levels on light use efficiency was found to be non-significant.

Conclusion:

The mean APAR was higher in early sown crop (49th MSW) throughout the growing period of chickpea which was significantly superior over rest of the treatments. The lowest APAR was recorded in late sown crop (51st MSW). This might be explained as favourable climatic conditions available during the early sown crop which might have resulted into profuse growth, that consequently reflected into more accumulation of dry matter and APAR. The light use efficiency was significantly superior in 49th MSW throughout the growing period of crop while, it was recorded the lowest under late sown crop (51st MSW). This might be attributed due to early sown crop that get benefit of better light and moisture conditions, which might have resulted into higher vegetative growth and development consequently resulting into higher light use efficiency. On other hand, late sown crop faced increasing day length and temperature.

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