Effect of Different Irrigation Regimes and Row Spacings on Growth and Yield of Isabgol (*Plantago ovata*) during Rabi Season

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Abstract

A field investigation entitled Effect of different irrigation regimes and spacings on isabgol (*Plantago ovata*) during rabi season was carried out on black soil of Nagarjun Medicinal plants Garden, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during the summer season of 2014-2015. The experiment was laid out in factorial Randomized block design with nine treatments and three replications in order to study the effect of irrigation regimes and spacings and their integration effect on growth, yield attributes and productivity for isabgol. The main plot consisted three irrigation levels viz., 0.6 IW/CPE, 0.8 IW/CPE and 1.0 IW/CPE while the sub-plot treatments consisted of spacings viz., 30 cm, 22.5 cm and 15 cm. Experimental results revealed that growth characters were significantly higher with irrigation scheduled at 1.0 IW/CPE followed by 0.8 IW/CPE and 0.6 IW/CPE. Yield attributes and seed yield were significantly higher with irrigation scheduling 1.0 IW/CPE. Water Use Efficiency was higher with irrigation scheduling 0.6 IW/CPE. The economic analysis viz. GMR and NMR was higher with irrigation scheduled at 1.0 IW/CPE, but B:C ratio was higher in irrigation scheduled at 0.6 IW/CPE. Uptake of nutrient was increase marginally with irrigation scheduled at 1.0 IW/CPE. Spacing of 30 cm recorded increased growth characters compared to 15 cm and 22.5 cm. Seed yield were increased due to spacing of 15 cm. Nutrient uptake of crop was notable higher with spacing of 30 cm followed by 22.5 cm and 15 cm. Spacing of 30 cm also produce higher GMR, NMR and 15 cm spacing recorded highest B:C ratio.

Keywords: water use efficiency, plant density, IW/CPE, nutrient uptake, swelling.

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Introduction

Isabgol (*Plantago ovata*) is known as Psyllium, Isabgol, Ispaghula. Isabgol is 30-35 cm tall short-stemmed annual herb. The seed husk is the commercial part and is separated by physical process. It contains colloidal mucilage (30%), mainly consisting xylose, arabinose, galacturonic acid with rhamnose and galactose etc. The husk (epicarp) has the property of absorbing and retaining water. The husk is used against constipation, irritation of digestive tract etc. In addition, these are also used in food industries for preparation of ice cream, candy etc.

Isabgol is an irrigated *rabi* season crop which grows well on light to medium soils with good drainage. It is traditionally grown in light sandy to sandy loam soils. However, recently it has been cultivated successfully on clay loam, medium black, black cotton and also on heavy black soils. It is sown in the month of November-December and harvested in the month of March-April. It requires cool and dry weather for its growth and maturity. For getting higher yield of Isabgol proper spacing and optimum irrigation level needs to be identified for the Vidarbha region.The medicinal crops are grown by the marginal farmers on relatively poor lands in variable stress condition. The present research was undertaken to find out irrigation requirement for Isabgol and to find out suitable spacing for Isabgol. The present investigation is very effective for assessing the growth and yield of isabgol under different irrigation regimes and spacing treatments.

Materials and Methods

A field experiment entitled "Effect of irrigation regime and spacing on growth and yield of isabgol (*Plantago ovata*) during rabi season" was conducted during 2014-15.

The experiment was laid out in factorial randomized block design with two factor (Irrigation: I, Spacing: S) and nine treatments each replicated three times. The treatments were allotted randomly in each replication. The plot size was 4.00 x 3.60 m. Details of the treatments along with symbols used in plan of layout are as follows.

Factor A: Irrigation level

Irrigation was given as per the schedule of irrigation treatments. A common irrigation was given before planting for good emergence. Later irrigation was given as per the treatment. The discharge of water through pipe in the plot was measured by the volume method.

Treatment	Number of irrigations	Dates of irrigation
I1 0.6 IW/CPE	6	22-12-2014, 11-01-2015, 28-01-2015, 11-02-2015, 28-02-2015, 16-03-2015.
I2 0.8 IW/CPE	8	17-12-2014, 30-12-2014, 16-01-2015, 28-01-2015, 08-02-2015, 20-02-2015, 04-03-2015, 16-03-2015.
I3 1.0 IW/CPE	10	14-12-2014, 25-12-2014, 06-01-2015, 19-01-2015, 28-01-2015, 06-02-2015, 15-02-2015, 24-02-2015, 15-03-2015.

Factor B: Spacing between rows

S1 - 15.0 cm

S2 - 22.5 cm

S3 - 30.0 cm

Absolute growth rate (AGR) of height and total dry matter weight was calculated by following formula and expressed as g day^{-1} plant^{1}.

$$AGR = \frac{H_2 - H_1}{T_2 - T_1}$$

$$AGR = \frac{W_2 - W1}{T2 - T1}$$

Where,

H_2 and H_1 and W_2 and W_1 refer to height and total dry matter of plant at T_2 and T_1 time, respectively.

Relative growth rate (RGR) was worked out as per formula and expressed in g day^{-1} plant^{-1}. Net assimilation rate (NAR) is defined as the rate of increase in plant dry matter per unit of assimilatory surface per unit time.

Important yield attributing characters were studied at 45. 60, 90 days after sowing (DAS) and at harvest. Number of spikes plant^{-1} from randomly selected five plants were measured. Spikes were selected from the randomly selected five plants and length of spike was measured with scale in cm. All the spikes of the selected plants were threshed separately and the swelling factor measured separately. Swelling of seeds was recorded by treatment by adopting the procedure described in Biannual Report (1978-80) on medicinal and Aromatic plants by taking 1 g seed in 25 ml graduated stopper cylinder. Twelty mililitre distilled water was added and seeds were agitated for thorough wetting. The mixture was allowed to stand for 20 minutes and again agitated for uniform distribution. Then it was allowed to stand for 6 hrs. Volume of swelling capacity of seed was recorded in cc g^{-1}.

The plants harvested from net plot were threshed, cleaned and seed weight plot^{-1} was recorded separately. The seed yield was then converted into hectare yield (kg ha^{-1}).

Moisture tubes were used for moisture studies. Water use efficiency for various treatments was calculated on the basis of grain yield and consumptive use of water in a given irrigation treatment. It indicates that amount of grain yield produced per unit of water consumed per unit of land.

$$WUE = \frac{Y}{ET}$$

where,

WUE = Water use efficiency (kg ha^{-1} mm^{-1})

Y = Economic yield (kg ha^{-1}) in a particular treatment

ET = Total evapotranspiration (mm) i.e. CU in the concerned treatment

Consumptive use of water under each irrigation treatment was calculated by considering following components.

1. The potential evapo-transpiration during the period of 72 hours after irrigation.
2. Soil moisture depletion by the crop from a con cerned profile.
3. Effective rainfall during the period of two con-

secutive sampling, at the time of irrigation.

$$Cu = \sum_{k=1}^{N} E_k \times K + \sum \frac{n\,(Ma_i - Mb_i)}{100} \times As_i \times D_i + ER$$

Where,

Cu = Consumptive use of water in mm, for the period between two Consecutive irrigation

E_k = Actual evaporation from USWB open pan, for the period of 72 hours (After irrigation to the time till sampling in wet soil become possible)

K = A constant for potential evapotranspiration, for Dec., Jan (0.6) and Feb., March (0.7) and in Akola region.

Ma_i = Soil moisture (%) after irrigation

Mb_i = Soil moisture (%) just before irrigation

n = Number of soil layer

As_i = Bulk density of the i^{th} layer (g cm^{-3})

D_i = Soil depth of the i^{th} layer two consecutive sampling period

Thus consumptive use during the given irrigation interval was worked out by adding all the above component together and all such consumptive use figures were added together to get the total consumptive use during the season of the crop.

The nutrient uptake by seed and straw after harvest were calculated in kg ha^{-1} and g ha^{-1}

Results And Discussion

Pre-harvest Plant height

Data on plant height at various growth stages as influenced by different treatments are presented in Table 1. Mean plant height increased progressively and reached to its maximum at harvest. The rate of increase in height was rapid in between 45 to 90 DAS and it was hastened between 90 to harvest may be due to Spike formation. The plant attained mean height of 32.16 cm at harvest. The effect of different irrigation levels and spacings was observed to be significant at 45, 60, 90 DAS and at harvest.

The plant height was significantly influenced due to the scheduling of irrigation at 45 and 60 DAS significantly higher plant height was observed at 1.0 IW/CPE irrigation scheduling recorded significantly superior over 0.6 IW/CPE, However it was at par with irrigation scheduled at 0.8 IW/CPE.

At 90 DAS and at harvest maximum plant height was observed at 1.0 IW/CPE over 0.6 IW/CPE and 0.8 IW/CPE irrigation regimes. The treatment 0.6 IW/CPE and 0.8 IW/CPE were statistically at par with each other. treatment 0.6 IW/CPE and 0.8 IW/CPE were statistically at par with each other.

Increase in plant height might be due to optimum soil moisture availability favouring the nutrient uptake, resulting in better growth as against scheduling irrigation through 0.6 IW/CPE and 0.8 IW/CPE. The irrigation scheduling at 50 CPE of 1.0 IW/CPE provides higher soil moisture availability due to which plant absorbed more water and resulted in higher plant height as compared to other levels.

The effect of spacing on plant height was observed significantly at 45, 60 While non significant 90 DAS and at harvest. At 45 & 60, maximum plant height were observed with spacing of S_3 which was significantly superior over S_1 and S_2. While S_1 and S_2 were statistically at par with each other.

The spacing of S_1 produced higher growth parameters

Table 1. Plant height (cm) $plant^{-1}$ as influenced by different irrigation levels and spacings

Treatments	45 DAS	60 DAS	90 DAS	At harvest
Irrigation levels				
I1 (0.6 IW/CPE)	16.97	20.64	29.84	31.38
I2 (0.8 IW/CPE)	17.87	22.25	29.99	31.73
I3 (1.0 IW/CPE)	18.01	22.93	30.95	33.38
SE (m) ±	0.27	0.28	0.29	0.21
CD (P = 0.05)	0.82	0.83	0.88	0.62
Spacing				
S1 (15 cm)	18.54	22.93	30.38	31.88
S2 (22.5 cm)	17.28	21.56	30.28	32.04
S3 (30 cm)	17.03	21.34	30.12	32.58
SE (m) ±	0.27	0.28	0.29	0.21
CD (P = 0.05)	0.82	0.83	NS	NS
Interaction Irrigation x Spacing				
SE (m) ±	0.47	0.48	0.51	0.36
CD (P = 0.05)	NS	NS	NS	NS
General Mean	17.62	21.94	30.26	32.16

plant^{-1} which was mainly due to better resource availability and reduction in interplant competition in plant community.

The above results are in conformity with the findings reported by Patel *et al*. (2011), Hussain Akhtar *et al*. (2012) and Siddaraju *et al*. (2010).

Interaction effect was found to be non significant in respect of plant height at all the crop growth stages.

Number of leaves plant^{-1}

The data on number of leaves plant^{-1} as influenced by various treatments at different plant growth stages are presented in Table 2.

The number of leaves plant^{-1} increased from 60 DAS and maximum was at 90 DAS after which leaf number declined at harvest, due to dropping of older leaves by senescence. Maximum rate of leaf production was observed between 60 to 90 DAS.

The irrigation scheduling significantly influenced the number of leaves plant^{-1} at all the stages of crop growth except at harvest. At 45 DAS, maximum number of leaves plant^{-1} was observed with irrigation scheduling at 1.0 IW/CPE and recorded significantly superior over 0.6 IW/CPE and 0.8 IW/CPE. While 0.8 IW/CPE and 0.6 IW/CPE were at par with each other.

Table 2 . Number of leaves plant^{-1} as influenced by different irrigation levels and spacings.

Treatments	45 DAS	60 DAS	90 DAS	At harvest
Irrigation levels				
I1 (0.6 IW/CPE)	17.07	23.40	38.61	33.72
I2 (0.8 IW/CPE)	17.69	23.52	38.97	34.77
I3 (1.0 IW/CPE)	18.42	24.67	40.61	35.05
SE (m)±	0.25	0.23	0.21	0.98
CD (P = 0.05)	0.75	0.68	0.63	NS
Spacing				
S1 (15 cm)	17.39	23.62	39.10	34.34
S2 (22.5 cm)	17.48	23.53	39.18	34.55
S3 (30 cm)	18.30	24.43	39.91	34.65
SE (m) ±	0.25	0.23	0.21	0.98
CD (P = 0.05)	0.75	0.68	0.63	NS
Interaction Irrigation x Spacing				
SE (m) ±	0.43	0.40	0.37	1.69
CD (P = 0.05)	NS	NS	NS	NS
General Mean	17.72	23.86	39.40	34.51

At 60 DAS, maximum number of leaves plant^{-1} was observed in irrigation scheduling at 1.0 IW/CPE which was significantly higher over other levels. Irrigation scheduling at 0.6 IW/CPE and 0.8 IW/CPE were at par.

The frequent irrigation provided in the treatments recorded higher vegetative growth resulted into more number of leaves plant^{-1}.

At 90 DAS, maximum number of leaves plant^{-1} was observed with irrigation scheduling at 1.0 IW/CPE which was significantly higher over other levels. While 0.8 IW/CPE and 0.6 IW/CPE were at par with each other.

Irrigation level at 1.0 IW/CPE recorded highest number of leaves plant^{-1} at all the crop growth stages. Similar results were obtained by Trivedi *et al*. (2004), Singh *et al*. (2014), Yadav *et al*. (2012) and Pawar *et al*. (2013).

The effect of spacing on number of functional leaves plant^{-1} was found significant at all stages of crop growth except at harvest. The crop sown with 30 cm spacing produced significantly higher number of leaves than spacing 15 cm and 22.5 cm at all stages of crop growth except at harvest.

At 60 and 90 DAS, maximum number of leaves plant^{-1} were recorded with spacing of 30 cm which was significantly superior over 15 cm and 22.5 cm. While number of leaves plant^{-1} at 15 cm and 22.5 cm spacings were at par with each other.

At 45 DAS maximum number of leaves plant^{-1} was observed at 30 cm spacing which was at par with 22.5 cm spacing treatments but significantly superior to 15 cm. The number of leaves is important indicator of total source available to plant for production of photosynthates.The above results are in conformity with the findings reported by Singh *et al*. (2006).

Interaction effect was found to be non significant in respect of number of functional leaves at all the crop growth stages.

Chlorophyll content plant^{-1} (%)

Data on chlorophyll content plant^{-1} as influenced by various treatments at different growth phases are shown in Table 3.

The irrigation scheduling at 50 CPE provides higher soil moisture availability due to which plant absorbed more water and resulted in higher chlorophyll content as compared to other levels. This might be due to more and frequent irrigations resulted in better green leaves, synthesizing activity and assimilation rate leading to increase in chlorophyll content.

The irrigation scheduling significantly influenced the chlorophyll content plant^{-1} at all the stages of crop growth except at 90 DAS.

At 45 and 60 DAS, maximum chlorophyll content plant observed with irrigation scheduling at 1.0 IW/CPE and it was significantly higher over other levels. However, 0.6IW/CPE and 0.8 IW/CPE at par with each other.

Irrigation level at 1.0 IW/CPE recorded highest chlorophyll content plant^{-1}at all the crop growth stages. The chlorophyll content plant^{-1} after 90 DAS decreased due to drying of leaves.

The effect of spacing had no significant influence on the chlorophyll content plant^{-1}. However, at all the growth stages spacing of 30 cm recorded numerically higher values.

Interaction effect was found to be non significant in respect of chlorophyll content plant^{-1} at all the crop growth stages.

Table 3. Chlorophyll content plant^{-1} (%) as influenced by different irrigation levels and spacings.

Treatments	45 DAS	60 DAS	90 DAS
Irrigation levels			
I1 (0.6 IW/CPE)	9.21	15.59	6.54
I2 (0.8 IW/CPE)	9.36	15.75	7.47
I3 (1.0 IW/CPE)	10.49	16.41	8.26
SE (m) ±	0.32	0.21	3.23
CD (P = 0.05)	0.97	0.62	NS
Spacing			
S1 (15 cm)	9.54	15.70	7.43
S2 (22.5 cm)	9.75	15.97	7.39
S3 (30 cm)	9.77	16.09	7.44
SE (m) ±	0.32	0.21	3.23
CD (P = 0.05)	NS	NS	NS
Interaction Irrigation x Spacing			
SE (m) ±	0.56	0.36	5.59
CD (P = 0.05)	NS	NS	NS
General Mean	9.69	15.92	7.42

Total Dry matter plant^{-1} (g)

Data in respect of total dry matter plant^{-1} as influenced by various treatment of irrigation regime and spacing at all the crop growth stages are presented in Table 4.

In general total dry matter increased continuously up to harvest. Maximum mean dry matter plant^{-1} was recorded at harvest. Mean total dry matter increased from 0.60 g at 30 DAS, 1.15 g at 45 DAS, 3.56 g at 60 DAS, at 90 DAS and 8.84 g at harvest.

Data in respect of mean dry matter accumulation (g) plant^{-1} shows significant differences at all the stages of crop growth except at 15 DAS. At 45 DAS, significantly higher dry matter accumulation plant^{-1} was observed in irrigation scheduling at 1.0 IW/CPE over 0.6 IW/CPE, however, it was at par with 0.8 IW/CPE. The growth parameters showed a decreasing trend with decreasing IW/CPE ratio up to 0.6.

At 60 and 90 DAS significantly higher dry matter accumulation plant^{-1} was observed under irrigation scheduling at 1.0 IW/CPE and it was significantly higher over 0.8 IW/CPE and 0.6IW/CPE. While 0.8 IW/CPE

Table 4. Total dry matter accumulation per plant^{-1} (g) as influenced by different irrigation levels and spacings.

Treatments	45 DAS	60 DAS	90 DAS	At harvest
Irrigation levels				
I1 (0.6 IW/CPE)	1.53	3.27	7.79	8.65
I2 (0.8 IW/CPE)	1.65	3.46	7.88	8.66
I3 (1.0 IW/CPE)	2.05	3.95	8.49	9.21
SE (m) ±	0.08	0.09	0.16	0.32
CD (P = 0.05)	0.25	0.26	0.49	NS
Spacing				
S1 (15 cm)	1.65	3.44	7.80	8.56
S2 (22.5 cm)	1.67	3.49	7.94	8.97
S3 (30 cm)	1.93	3.75	8.42	9.00
SE (m) ±	0.08	0.09	0.16	0.32
CD (P = 0.05)	0.25	0.26	0.49	NS
Interaction Irrigation x Spacing				
SE (m) ±	0.14	0.15	0.29	0.56
CD (P = 0.05)	NS	NS	NS	NS
General Mean	1.74	3.56	8.05	8.84

and 0.6IW/CPE were at par with each other.

The dry matter accumulation plant^{-1} is the resultant of photosynthesis activity. Increase in irrigation frequency increased dry matter accumulation (g) plant^{-1}. Irrigation scheduled at 1.0 IW/CPE, increased the number of leaves, leaf area which increases the production of photosynthates produced and accumulated at a higher rate and quantity through process of plant metabolism which ultimately replaced in dry matter production at higher rate. These results are in accordance with the findings of Singh *et al*. (2014) and Yadav *et al*. (2012).

Total dry matter accumulation g^{-1} plant^{-1} was influenced significantly by various spacing except at harvest.

At 45 and 60 maximum dry matter accumulation plant^{-1} under spacing of 30 cm and was significantly higher over pacing of 22.5 cm and 15 cm. While 22.5 cm and 15 cm were at par to each other.

At 90 DAS, maximum dry matter accumulation plant^{-1} was observed in spacing of 30 cm which was significantly higher over spacing of 15 cm, however it was at par with spacing of 22.5 cm.

Interaction effect was found to be non significant in respect of total dry matter plant^{-1} at all the crop growth stages.

Light interception (%)

Data on light interception affected by various treatments at different growth stages are given in Table 5.

Irrigation scheduling at 1.0 IW/CPE recorded highest light interception followed by irrigation scheduling at 0.8 IW/CPE and minimum 0.6 IW/CPE.

The highest light interception was recorded with spacing 30 cm followed by 22.5 cm and 15 cm.

Growth analysis

Data on height of plant, leaf area per plant and total dry matter production per plant were further subjected to growth function viz. AGR, RGR and NAR at various growth stages of crop and are exhibited on mean basis.

Absolute growth rate (AGR) for dry matter

Data on AGR for dry matter as affected by various treatments at different growth stages are given in Table 6.

The AGR for dry matter was significantly influence at 60-75 DAS and non significant at all other stages.

At 60-75 DAS, irrigation scheduling at 1.0 IW/CPE recorded highest values of AGR which was significantly higher over 0.8 IW/CPE and 0.6 IW/CPE. Irrigation regime 0.6 IW/CPE and 0.8 IW/CPE were at par to each other.

The AGR for dry matter was found non significantly influence at all growth stages. But numerically higher value was recorded fewer than 30 cm spacing.

Interaction effect was found to be non significant in respect of AGR for dry matter at all the crop growth stages.

Relative growth rate (RGR) for dry matter

Data on Relative growth rate (RGR) for dry matter as affected by various treatments at different growth stages are given in Table 7.

It is evident from the data presented in table 7 that, RGR for dry matter, did not differ significantly due to irrigation levels.The effect of spacing was no significant influence on the RGR for dry matter at all crop growth stages. Interaction effect was non significant.

Net assimilation rate (NAR)

Data on Net assimilation rate (NAR) as affected by various treatments at different growth stages are given in Table 8.

It was evident from the data presented in Table 8 that, value of NAR did not differ significantly due to irrigation levels at all stages of observation. The effect of spacing had no significant influence on the values of NAR at all crop growth period. Interaction effect was non significant at all crop growth period.

Soil moisture studies

Table 5. Light interception as influenced by different irrigation levels and spacings

Treatments	90 DAS	At harvest
Irrigation		
I1 (0.6 IW/CPE)	71.50	55.10
I2 (0.8 IW/CPE)	76.40	59.10
I3 (1.0 IW/CPE)	81.20	63.20
Spacing		
S1 (15 cm)	68.24	51.58
S2 (22.5 cm)	76.46	60.41
S3 (30 cm)	84.40	65.41
General Mean	76.36	59.13

Table 6. Absolute growth rate (AGR) for dry matter (g day^{-1} $plant^{-1}$) as influenced by different irrigation levels and spacings

Treatments	30-45 DAS	45-60 DAS	60-75DAS	75-90 DAS	90 DAS -At harvest
Irrigation levels					
I1 (0.6 IW/CPE)	0.062	0.124	0.126	0.134	0.044
I2 (0.8 IW/CPE)	0.064	0.126	0.127	0.139	0.046
I3 (1.0 IW/CPE)	0.067	0.156	0.174	0.180	0.071
SE (m) ±	0.012	0.013	0.011	0.021	0.014
CD (P = 0.05)	NS	NS	0.033	NS	NS
Spacing					
S1 (15 cm)	0.062	0.135	0.147	0.134	0.039
S2 (22.5cm)	0.063	0.135	0.149	0.139	0.050
S3 (30 cm)	0.067	0.137	0.151	0.160	0.072
SE (m) ±	0.012	0.013	0.011	0.021	0.014
CD (P = 0.05)	NS	NS	NS	NS	NS
Interaction Irrigation x Spacing					
SE (m) ±	0.022	0.023	0.019	0.036	0.023
CD (P = 0.05)	NS	NS	NS	NS	NS
General Mean	0.064	0.135	0.149	0.144	0.054

Table 7. Relative growth rate (RGR) for dry matter (g day^{-1} $plant^{-1}$) as influenced by different irrigation levels and spacings

Treatments	30-45 DAS	45-60 DAS	60-75DAS	75-90 DAS	90 DAS-At harvest
Irrigation levels					
I1 (0.6 IW/CPE)	0.057	0.055	0.031	0.017	0.006
I2 (0.8 IW/CPE)	0.057	0.058	0.033	0.018	0.006
I3 (1.0 IW/CPE)	0.063	0.059	0.033	0.028	0.007
SE (m) ±	0.009	0.008	0.002	0.003	0.003
CD (P = 0.05)	NS	NS	NS	NS	NS
Spacing					
S1 (15 cm)	0.059	0.056	0.031	0.021	0.005
S2 (22.5 cm)	0.059	0.057	0.032	0.021	0.007
S3 (30 cm)	0.061	0.059	0.034	0.022	0.007
SE (m) ±	0.009	0.008	0.002	0.003	0.003
CD (P = 0.05)	NS	NS	NS	NS	NS
Interaction Irrigation x Spacing					
SE (m) ±	0.016	0.014	0.004	0.006	0.006
CD (P = 0.05)	NS	NS	NS	NS	NS
GM	0.059	0.057	0.032	0.021	0.006

Data in respect of consumptive use and water use efficiency based on mean values influenced by various treatments are presented in Table 9.

Total water requirement

From the data represented in Table 9, it is observed that mean total water requirement was 451.30 mm.

Data indicated that with increase in irrigation total water requirement also increases. Highest total water requirement of 500 mm was recorded by 1.0 IW/CPE followed by 0.8 IW/CPE (437.39 mm), 0.6 IW/CPE (416.50 mm).

The spacing treatment showed difference in total water requirement. The spacing of 22.5 cm recorded highest water requirement (451.33 mm) followed by spacing of 15 cm (451.23). Spacing of 30 cm (451.22 mm) recorded minimum total water requirement.

Water use efficiency

From the data presented in Table 9, the mean value of water use efficiency was observed to be 3.10kg ha^{-1} mm.

Irrigation scheduling at 0.6 IW/CPE recorded highest water use efficiency 3.71 kg ha^{-1} mm followed by irrigation scheduling at 0.8 IW/CPE 2.99 kg ha^{-1} mm, and minimum 1.0 IW/CPE 2.56 kg ha^{-1} mm. The above findings agree with those reported by Behera *et al*. (2015), Singh *et al*. (2014), Kumar *et al*. (2015) and Sounda *et al*. (2006).

The highest water use efficiency was recorded with spacing 22.5 cm (3.14 kg ha^{-1}) mm followed by 30 cm (3.09 kg ha^{-1}) mm and 15 cm (3.02 kg ha^{-1}) mm.

Yield attributes and yield

The data in respect of no. of spikes $plant^{-1}$, spike length cm, swelling factor, seed yield as affected by various treatments are shown in Table 10.

Mean value of spike $plant^{-1}$, spike length (cm), swelling factor, seed yield kg^{-1} were, 8.50, 7.71, 33.50 and 7.20 respectively which were significantly influenced due to irrigation levels and spacing.

Number of Spikes $plant^{-1}$

The data presented in Table 10 revealed that number of spikes $plant^{-1}$ was affected significantly due to various treatments and mean number of spike was 26.

Irrigation scheduling at 1.0 IW/CPE recorded 27

Table 8. Net assimilation rate (NAR) (g cm^{-2} $plant^{-1}$) as influenced by different irrigation levels and spacings

Treatments	30-45 DAS	45-60 DAS	60-75 DAS	75-90 DAS	90 DAS-At harvest
Irrigation levels					
I1 (0.6 IW/CPE)	0.0032	0.005	0.0017	0.0002	0.0066
I2 (0.8 IW/CPE)	0.0042	0.0049	0.0016	0.0006	0.0073
I3 (1.0 IW/CPE)	0.0042	0.0051	0.0018	0.0008	0.0077
SE (m) ±	0.0003	0.0001	0.0001	0.0001	0.0005
CD (P = 0.05)	NS	NS	NS	NS	NS
Spacing					
S1 (15 cm)	0.0036	0.0052	0.0018	0.0004	0.0075
S2 (22.5 cm)	0.0043	0.0053	0.0015	0.0009	0.0073
S3 (30 cm)	0.0037	0.0047	0.0017	0.0005	0.0074
SE (m) ±	0.0002	0.0002	0.0001	0.0002	0.0004
CD (P = 0.05)	NS	NS	NS	NS	NS
Interaction Irrigation x Spacing					
SE (m) ±	0.0005	0.0003	0.0003	0.0003	0.0009
CD (P = 0.05)	NS	NS	NS	NS	NS
General Mean	0.0039	0.0051	0.0017	0.0006	0.0074

Table 9. Total Water Requirement and Water Use Efficiency as influenced by different irrigation levels and spacings

Treatments	Yield (kg ha^{-1})	Total Water Requirement (mm)	WUE (kg ha^{-1} mm^{-1})
Irrigation levels			
I1 (0.6 IW/CPE)	718.37	416.50	3.71
I2 (0.8 IW/CPE)	750.54	437.39	2.99
I3 (1.0 IW/CPE)	829.32	500.00	2.56
Spacing			
S1 (15 cm)	784.65	451.23	3.02
S2 (22.5 cm)	765.22	451.33	3.14
S3 (30 cm)	748.36	451.22	3.09
General Mean	766.08	451.30	3.10

number of spike which was significantly superior over other irrigation levels. Similarly, 0.8 IW/CPE recorded 26 number of spike which was significantly superior over 0.6 IW/CPE, Because of frequent irrigation at 1.0 IW/CPE, this treatment might have created favorable moisture conditions for the crop growth consequently increased the values of the yield attributes than other treatments.

Spacing effect was found to be non significant in respect of number of spikes $plant^{-1}$ at all the crop growth stages.

Interaction effect was found to be non significant in respect of number of spike $plant^{-1}$ at all the crop growth stages.

Spike length (cm)

The data presented in Table 10 revealed that spike length was affected significantly due to various treatments and mean spike length was 3.16.

Spike length was significantly influenced due to irrigation scheduling 1.0 IW/CPE recorded 3.47 spike length which was significantly superior over 0.8 and 0.6 IW/CPE. Because of frequent irrigation under at 1.0 IW/CPEtreatment might have created favorable moisture conditions for the crop growth consequently increased the values of the yield attributes than other treatments. Similar trend was reported by Yadav *et al*. (2012). Spacing effect was non-significant during investigation. Interaction effect was non-significant during investigation.

Table 10. No. of spike, spike length, seed yield and swelling factor as influenced by different irrigation levels and spacings

Treatments	No of spikes $plant^{-1}$	Spike length (cm)	Seed yield (kg ha^{-1})	Swell-ing factor cc gm^{-1}
Irrigation levels				
I1 (0.6 IW/CPE)	25	2.95	718	10.49
I2 (0.8 IW/CPE)	26	3.06	751	11.23
I3 (1.0 IW/CPE)	27	3.47	829	11.87
SE (m) ±	0.4	0.11	8	0.38
CD (P = 0.05)	1	0.32	23	NS
Spacing				
S1 (15 cm)	25	3.20	785	11.23
S2 (22.5 cm)	26	3.11	765	11.32
S3 (30 cm)	27	3.17	748	11.03
SE (m) ±	0.4	0.11	8	0.38
CD (P = 0.05)	NS	NS	23	NS
Interaction Irrigation x Spacing				
SE (m) ±	0.6	0.18	13	0.66
CD (P = 0.05)	NS	NS	NS	NS
General Mean	26	3.16	766	11.19

Swelling factor (cc gm^{-1})

The data presented in table 10 in respect of swelling capacity of seeds in isabgol due to effect of different treatments was found non-significant.

The data from table revealed that maximum swelling capacity of seeds was recorded under the irrigation treatment 1.0 IW/CPC. Spacing effect was non-significant during investigation. Interaction effect was non-significant during investigation.

Seed Yield (q ha^{-1})

The data presented in Table 10.revealed that seed yield of isabgol affected significantly due to various treatments. Mean seed yield was 7.66 q ha^{-1}.

Irrigation scheduling significantly influenced the seed yield of isabgol. Irrigation scheduled at 1.0 IW/CPE produced maximum seed yield (829 kg ha^{-1}) which was significantly higher over other levels. Irrigation scheduling at 0.8 IW/CPE recorded significantly higher seed yield over 0.6 IW/CPE. The increased seed yield was mostly attributed to more spike bearing and dry matter accumulation in the treatments. The lowest values of the yield attributes were observed in case of IW/CPE of 0.6.

In rabi season large amount of water was lost through evaporation from soil and transpiration from vegetation which exerted more pressure on water demand and this demand was fulfilled due to frequent irrigation at 1.0 IW/CPE resulting in higher number of spikes. The increase in all growth attributes under the treatment 1.0 IW/CPE might be due to additional moisture supply due to application of frequent irrigation helps in promoted the growth and cell multiplication activities, better availability of nutrients enhance the vegetative and reproductive. Favourable plant water balance maintained through irrigation might have resulted in better translocation of photosynthates and maintenance of cell turgidity, consequently leading to higher yield traits. Same trend was reported by Yadav *et al*. (2012).

Improvement in different yield attributes due to optimum space and more plant population at 15 cm spacing.

Maximum seed yield was recorded with spacing of 15 cm which was significantly superior over 30 cm but at par with 22.5 cm. This was due to the more plant population with spacing 15cm compared to other treatment.

Interaction effect between irrigation scheduling and spacing was non significant in respect to seed yield.

Nutrient uptake

Nitrogen uptake (kg ha^{-1})

Nitrogen uptake in seed and straw is presented in Table 11.

Irrigation levels at different growth stages significantly influenced the nitrogen uptake of isabgol crop.Successive increase in number of irrigations significantly increased the nitrogen uptake by isabgol crop. The significantly high uptake of nitrogen by seed and straw of nitrogen by plant were 35 recorded by irrigation scheduled at 1.0 IW/CPE which was significantly superior over 0.6 IW/CPE and 0.8 IW/CPE. Higher uptake of nitrogen in straw at irrigation scheduled 1.0 IW/CPE over 0.8 IW/CPE.

Uptake of N, P and K was the highest when the crop was irrigated at IW/CPE ratio of 1.0. This might be due to optimal air and water balance in the soil, which consequently increased the mobilization of the nutrients along with the absorbed water through well developed root system. At lower irrigation frequency insufficient soil moisture might not have facilitated mass flow, root interception and diffusion processes to mobilize the nutrients for uptake. The uptake pattern mostly followed the biomass yield trend due to different irrigation regimes. Similar result was found Tripathy *et al*. (2012).

Spacing at different growth stages non significantly influenced the nitrogen uptake of isabgol crop. Interaction effect between irrigation scheduling and spacing in respect of nitrogen content in isabgol due to different treatment was found non significant.

Phosphorus uptake (kg ha^{-1})

Phosphorus uptake in seed and straw is presented in Table 11.

Phosphorus uptake by seed and straw was significantly influenced by irrigation scheduling. Irrigation scheduled at 1.0 IW/CPE recorded maximum phosphorus uptake by seed and straw which was significantly superior over 0.6 IW/CPE and 0.8 IW/CPE. Similar result was found Singh *et al*. (2014).

Phosphorus uptake by seed and straw was significantly influenced by irrigation scheduling. Irrigation scheduled at 1.0 IW/CPE recorded maximum phosphorus uptake by seed and straw which was significantly superior over 0.6 IW/CPE and 0.8 IW/CPE. Similar result was found Singh et al. (2014).

Spacing effect did not reach to the level of significance. Interaction effect also did not reach to the level of significance

Potassium uptake (kg ha^{-1})

The data in respect of potassium uptake by seed and straw are presented in Table 11.

Potassium uptake by seed and straw was significantly influenced by irrigation scheduling. Irrigation scheduled 1.0 IW/CPE recorded maximum potassium uptake by straw and seed which was significantly superior over 0.6 IW/CPE but it was at par with 0.8 IW/CPE. Potassium uptake by seed and straw was significantly influenced by irrigation scheduled. The treatment 1.0 IW/CPE recorded maximum potassium uptake which was significantly superior over all other levels. Similar result was found Tripathy *et al*. (2012).

Spacing effect did not reach to the level of significance. Interaction effect also did not reach to the level of significance.

Table 11. NPK uptake as influenced by different irrigation levels and spacings

Treatments	N (kg ha^{-1})		P uptake (kg ha^{-1})		K (kg ha^{-1})	
	Seed	Straw	Seed	Straw	Seed	Straw
Irrigation levels						
I1 (0.6 IW/CPE)	32.1	23.1	10.4	11.5	10.2	23.2
I2 (0.8 IW/CPE)	32.6	23.4	10.3	11.6	11.2	23.8
I3 (1.0 IW/CPE)	35.3	25.8	11.6	12.9	11.9	24.8
SE (m) ±	0.8	0.8	0.4	0.4	0.4	0.4
CD (P = 0.05)	2.5	2.3	1.1	1.2	1.2	1.3
Spacing						
S1 (15 cm)	33.1	23.4	10.7	11.9	10.9	23.0
S2 (22.5 cm)	32.8	24.2	10.3	11.5	11.1	24.0
S3 (30 cm)	34.2	24.9	11.3	12.7	11.3	24.8
SE (m) ±	0.8	0.8	0.4	0.4	0.4	0.4
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
Interaction Irrigation x Spacing						
SE (m) ±	1.5	1.3	0.7	0.7	0.7	0.7
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
General Mean	33.4	24.2	10.7	12.0	11.1	23.9

Table 12. Gross monetary return (GMR), Net monetary return (NMR) and B:C ratio as influenced by different irrigation levels and spacings

Treatments	Cost of Cultivation	GMR (₹ ha^{-1})	NMR (₹ ha^{-1})	B:C Ratio
Irrigation levels				
I1 (0.6 IW/CPE)	17170	31633	14463	2.01
I2 (0.8 IW/CPE)	16120	32352	16233	1.89
I3 (1.0 IW/CPE)	17832	34725	16893	1.82
SE (m) ±	149	695	546	-
CD (P = 0.05)	447	2085	1637	-
Spacing				
S1 (15cm)	17336	32151	14815	2.02
S2 (22.5cm)	16119	31838	15719	1.94
S3 (30cm)	17667	34722	17055	1.75
SE (m) ±	149	695	546	-
CD (P = 0.05)	447	2085	1637	-
Interaction Irrigation x Spacing				
SE (m) ±	258	1205	946	-
CD (P = 0.05)	NS	NS	NS	-
General Mean	17041	32903	15863	-

Gross Monetary Returns, Net Monetary Returns and B:C ratio

The data emerged in respect of gross monetary returns, net monetary returns and B:C ratio as affected by various treatment are presented in Table 12.

Gross monetary returns and net monetary returns were significantly influenced by irrigation scheduling. Irrigation scheduled 1.0 IW/CPE had recorded significantly higher gross monetary returns and net monetary returns than other irrigation scheduling. Significantly lowest gross monetary returns and net monetary returns were registered under 0.6 IW/CPE. The higher gross monetary returns and net monetary returns might be due to the differences in the seed yield that might have reflected in the higher gross monetary returns and net monetary returns. But Irrigation scheduled at 0.6 IW/CPE had recorded higher B:C ratio than at 1.0 and 0.8 IW/CPE. The irrigation scheduled 0.6 IW/CPE had highest B:C ratio due to less cost of cultivation than other treatments. Similar result was found Singh *et al*. (2014).

Gross monetary returns and net monetary returns was significantly influenced by spacing. Spacing 30 cm had recorded significantly higher gross monetary returns and net monetary returns than other spacing. Significantly lowest gross monetary returns and net monetary returns was registered under spacing 15 cm. The higher B:C ratio was recorded with spacing at 30 cm. The higher gross monetary returns, net monetary returns and B:C ratio might be due to the differences in the seed yield that might have reflected in the higher gross monetary returns, net monetary returns and B:C ratio. A similar result was also reported by Singh *et al*. (2006). Interaction effect was found to be non significant.

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