International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2021; 9(2): 1136-1140

Received: 10-01-2021
Accepted: 13-02-2021

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Effect of planting geometry and nutrient levels on growth and yield of Isabgol (*Plantago ovata*) under eastern dry zone of Karnataka

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Abstract
The experiment was laid out in a Factorial Randomized Block Design with sixteen treatments and replicated three times. The result indicated that the spacing of 22.5cm recorded significantly maximum plant height (35.09 cm), number of leaves (65.70), number of tillers (13.05), number of spikes (36.50), seed yield (1221 kg /ha) and husk yield (305 kg/ha). Among the different nutrient levels, maximum plant height (34.13 cm), number of leaves (63.95), number of tillers (13.47), number of spikes (35.79), seed yield (904 kg /ha) and husk yield (225 kg/ha) were obtained with the application of 75% RDF (37.5:18.75:22.50 + 7.5 t FYM.) and the interaction of row spacing of 22.5 cm and 75% RDF recorded maximum growth and yield.

Keywords: Isabgol, *Plantago ovata*, spacing, nutrients, growth, yield, seed, husk

Introduction
India is the bowl of medicinal and aromatic plants in the world due to its diversified ecosystems. Isabgol (*Plantago ovata* Forsk) is one of the important medicinal crop belongs to the family plantaginaceae. Only two species of genus *Plantago* are under cultivation *viz*., *P. ovata* and *P. psyllium*. The seed husk of *P. ovata* is superior in terms of swelling qualities, colourlessness, better pharmaceutical and cosmetic importanceand therefore, it has replaced the *P. psyllium* from the world market.

The name of Isabgol has been derived from two Persian words, `*asp'* and `*ghol'* meaning a horse-ear, referring to its boat shaped characteristic seeds. *Plantago* name derived from Latin language, it mean that `sole of the foot' and it is characteristic of the leaf shape, while *ovata* refers to the ovate shape of the leaves. The word psyllium is derived from the Greek, meaning `flea' in reference to the colour, size and shape of seeds (flea seed).

The plant is indigenous to Persia and West Asia, extending upto Sutlej to Sind and West Pakistan. The plant has acclimatized well in Mexico and Mediterranean regions.

Isabgol is stem less or short stemmed highly cross pollinated annual herb attains a height of 30 to 40 cm, has alternate leaves, clasping the stem, strap-like recurved, 2.5 to 7.5 cm long, narrow, varying from 6.0 mm to12.0 mm in width, tapering to point, three nerved, entire or toothed, coated with fine hairs. The flowers are white, minute, four parted in length. The capsule is ovate, 8.0 mm long, 2-celled, the top half lifting up when ripe, releasing the smooth, dull, ovate seeds, 1.8 to 3.8 mm long, pinkish-grey brown or pinkish white with a brown streak on the convex surface. The seeds are covered with translucent membrane, known as husk, which is odourless and tasteless (Jat *et al*., 2015) [9].

Isabgol, known as “Blond Psyllium” in English and “Shlakshnajira Shignabya” in Sanskrit. Its seed and husk (bhussi) are used for medicinal purposes. The seeds of isabgol are mainly valued for their mucilaginous husk as it contains about 30 per cent mucilage and hemicellulose which is mainly composed of xylose, arabinose, galacturinic acid, rhaminose and galactose. The mucilage comprises of reserve carbohydrates mainly pantosans (Karawya *et al*., 1971) [10]. In addition to mucilage, the seeds also contain semi drying fatty acids (5 per cent), small amount of acubin and tannin, an active ingredient exhibiting acetyl chlorine like action. It has a high water absorbing capacity and therefore, it is used as an antidiarrhoea drug. Being natural medicine with no side effects, its demand in USA and other West European countries

as a household medicine is increasing. It is used as a cervical dilator for termination of pregnancy (Anonymous, 1978) [3]. It is also used in the dyeing calico printing and in ice cream industry as a stabilizer (Upadhyay *et al*., 1978) [30]. The seed stabilizer husk is used as a cattle feed and contains 17-19 per cent protein.

The Isabgol has replaced French psyllium from the world market due to its maximum yield potential and quality of seed husk. At present, Isabgol is regarded as `dollar earner' crop of north Gujarat, where it is being cultivated in an about 50,000 hectares with a production of 40,000 tonnes. About 75-80 per cent of the total annual produce of north Gujarat is exported and earns foreign exchange in crores of rupees annually. India continues to hold a monopoly in its production and trade in the world. Though India is leader in production and export of Isabgol, hardly 50 per cent of the requirement of U.S.A. could be met. It has been introduced in Southern Rajasthan, Punjab and to a very small extent in Maharastra and Uttar Pradesh. In view of its sustained demand, there is scope to enhance the area and production through intensified cultivation.

Material and Method

The study was laid out in FRCBD with sixteen treatment combinations having three replications having T_1- 22.5 cm Row spacing + 75% RDF (37.5:18.75:22.50 + 7.5 t FYM),T_2- 22.5 cm Row spacing + 100% RDF (50:25:30 + 10 t FYM),T_3- 22.5 cm Row spacing + 125% RDF (62.5:31.25:37.50 + 12.5 t FYM),T_4- 22.5 cm Row spacing + 100% RDN through FYM + 10 t FYM, T_5- 30 cm Row spacing + 75% RDF (37.5:18.75:22.50 + 7.5 t FYM), T_6- 30 cm Row spacing + 100% RDF (50:25:30 + 10 t FYM), T_7- 30 cm Row spacing + 125% RDF (62.5:31.25:37.50 + 12.5 t FYM), T_8- 30 cm Row spacing + 100% RDN through FYM + 10 t FYM, T_9- 37.5 cm Row spacing + 75% RDF (37.5:18.75:22.50 + 7.5 t FYM), T_{10}- 37.5cm Row spacing + 100% RDF (50:25:30 + 10 t FYM),T_{11}- 37.5cm Row spacing + 125% RDF (62.5:31.25:37.50 + 12.5 t FYM),T_{12}- 37.5 cm Row spacing + 100% RDN through FYM + 10 t FYM, T_{13}- 45 cm Row spacing + 75% RDF (37.5:18.75:22.50 + 7.5 t FYM), T_{14}- 45 cm Row spacing + 100% RDF (50:25:30 + 10 t FYM), T_{15}- 45 cm Row spacing + 125% RDF (62.5:31.25:37.50 + 12.5 t FYM),T_{16}- 45 cm Row spacing + 100% RDN through FYM + 10 t FYM.

Method of imposing the treatments: Full dose of FYM applied one week before sowing and mixed well with soil. Nitrogen in the form of urea, phosphorous in the form of single super phosphate and potash in the form of muriate of potash were applied. Fifty per cent of nitrogen and full dose of phosphorous and potassium were applied to plot at 7-10 cm depth in the lines just before sowing of seeds and remaining fifty per cent of nitrogen was top dressed at 45 days after sowing.

The seeds from net plot area (7.20 m^2) were harvested and husk from the seeds were seperated and weighed separately. The net plot yield was used to compute the yield per hectare.

Result and Discussion

Growth parameters

The row spacing of 22.5 cm has recorded significantly taller plants with 17.18 cm, 29.04 cm and 35.09 cm at 30, 60 and 90 days after sowing, respectively and was *on par* with the row spacing of 30 cm (16.94 cm, 28.58 cm and 34.76 cm at 30, 60 an 90 days after sowing respectively). Whereas, the lower plant height was recorded at the row spacing of 45 cm during all the crop growth stages. The increased plant height with closer spacing may be due to linear growth of the plant because of the inter plant competition for space and light as a result of higher plant density. These results are in accordance with findings of Khan *et al*. (2005) [11, 12] in isabgol, Sathish (2002) [21] in golry lilly and Shambu *et al*. (2019) [22] in chandrasur. Plants supplied with 75% RDF (37.5:18.75:22.50+ 7.5 t FYM) has recorded significantly maximum plant height of 16.79 cm, 27.49 cm and 34.13 cm at 30, 60 and 90 days after sowing, respectively. Whereas, the lower plant height was recorded with 100% RDN through FYM + 10 t FYM. Increment in plant height might be due to stimulation of biological activities in the presence of balanced supply of nutrients. These results are in confirmity with findings of Singh *et al.* (2002) [24, 25] & Lekhchand (2004) [14] in isabgol, Sundharaiah *et al*. (2005) in *Solanum khasianum.* The interactions of spacing and nutrients also showed significant difference in the plant height at all the growth stages. The maximum plant height of 18.00 cm, 30.48 cm and 37.28 cm was observed with 22.5 cm row spacing + 75% RDF (37.5:18.75:22.50 + 7.5 t FYM), which was *on par* with 30 cm row spacing + 100% RDF (50:25:30 + 10 t FYM) and the minimum plant height of 15.05 cm, 20.30 cm and 27.78 cm at 30, 60 and 90 days after sowing respectively, with 45 cm row spacing + 100% RDN through FYM + 10 t FYM. The increased plant height might be due to ideal plant densities and increased cell division and cell elongation under optimum level of nutrients. The plant has certain limitation in potential uptake and utilization of nutrients for its growth and metabolism, beyond which excess application of nutrients will be of no use that in turn reduces the plant height. Similar findings were also reported by Desai *et al.* (2017) [8] in ashwagandha and Sreeramu & Farooqui (2000) [26] in Roselle. The Different spacing levels had significant influence on the number of leaves per plant. The row spacing of 22.5 cm recorded maximum number of leaves per plant (26.71, 58.58 and 65.70 at 30, 60 and 90 days after sowing, respectively). While, 45 cm row spacing recorded the minimum number of leaves (25.88, 39.43 and 51.44 per plant at 30, 60 and 90 days after sowing, respectively). Limitation to crop yield is frequently sought in either photosynthates (the source of assimilates) or in the sink (the site of assimilate utilization). Leaves are the main assimilate synthates and are positively influenced by planting geometry. These results are in line with results obtained by Pal *et al.* (2017) [19] in isabgol, Sathish (2002) [21] in glory lilly and Lakshmipathaiah *et al.* (2011) [13] in babchi. The nutrient level of 75% RDF (37.5:18.75:22.50+ 7.5 t FYM) recorded significantly maximum number of leaves (26.87, 56.34 and 63.95 at 30, 60 and 90 DAS respectively). The minimum numbers of leaves (25.69, 44.78 and 50.93) at 30, 60 and 90 days after sowing, respectively, was recorded when plants were supplied with 100% RDN through FYM + 10 t FYM. The increase in number of leaves might be due to application of balanced nutrition in the form of N, P, K and FYM. These results are in comparison with Utgikar *et al.* (2007) [31] & Tripathi *et al.* (2013) [28] in isabgol, Umesh *et al*. (2007) [29] in makoi and Bhuvaneshwari *et al.* (2002) [6] in anise. 22.5 cm row spacing + 75% RDF (37.5:18.75:22.50 +7.5 t FYM) registered the maximum (27.31, 63.63 and 72.58 number of leaves per plant at 30, 60 and 90 days after sowing respectively). The increase in number of leaves might be due to increased plant height with optimum levels of NPK. These results are in accordance with the findings of Mary *et al.* (2018) [16, 17] in chia and Anupama *et al.* (2017) [4] in kasuri methi. The row spacing of

22.5 cm induced maximum (13.05) number of tillers per plant at harvest followed by row spacing of 30 cm (12.93). These results revealed that optimum spacing has resulted in the production of more tillers per plant. This might be attributed to the sufficient space available for individual plants and cause exposer of plants to light and thus causing proper development of tillers. These results are in agreement with the findings of Shivran (2013) [23] & Khan *et al.* (2005) [11, 12] in isabgol & Abbaszadeh *et al.* (2014) [1] in *Satureja sahendica.* The production of tillers was significantly influenced by different nutrients at 60 and 90 days after sowing. The nutrient level of 75% RDF (37.5:18.75:22.50 + 7.5 t FYM) recorded significantly maximum (13.47) number of tillers per plant at harvest. The minimum number of tillers per plant was(10.83) with 100% RDN through FYM + 10 t FYM. The increase in number of tillers per plant might be due to increased growth of plant in the form of height and number of leaves, which accumulated more photosynthates and thereby increased number of tillers per plant. These results are in conformity with Degra (2000), Maheshwari *et al*. (2000) [15] & Tripathi *et al*. (2013) [28] in isabgol. The maximum number of tillers (12.98, and 14.45) was recorded with 22.5 cm row spacing + 75% RDF (37.5:18.75:22.50 + 7.5 t FYM) at 60 and 90 DAS, respectively. which was *on par* with 30 cm row spacing + 75% RDF (37.5:18.75:22.50 + 7.5 t FYM) and the minimum number of tillers 8.33 and 9.60 at 60 and 90 days after sowing respectively was noticed with the treatment 45 cm row spacing + 100% RDN through FYM + 10 t FYM. This might be due to the profound impact of plant spacing and nutrient level which reflected in terms of number of tillers per plant.

Yield parameters

Plants grown at a row spacing of 22.5 cm has recorded maximum number of spikes (36.50) followed by 30 cm row spacing. The optimum spacing might have resulted in the production of more number of spikes per plant. This may be attributed to the optimum space available for individual plant for exposer to light and thus causing proper development of spikes. These results agree with the findings of Shivran (2013) [23] and Khan *et al.* (2005) [11, 12] in isabgol and Abbaszadeh *et al.* (2014) [1] in *Satureja sahendica.* The plants suppied with 75% RDF (37.5:18.75:22.50 + 7.5 t FYM) recorded maximum number of spikes (35.79) followed by plants suppied with 100% RDF (50:25:30 + 10 t FYM). The increase in number of spikes may be due to the fact that NPK and FYM application accelerated the enhanced of leaf number, which are positively correlated with the number of spikes. Similar results were reported by Degra (2000), Utgikar *et al.* (2007) [31] and Maheshwari *et al.* (2000) [15] in isabgol. The row spacing of 22.5 cm and 75% RDF (37.5:18.75:22.50 + 7.5 t FYM) recorded maximum number of spikes per plant (39.28) and was *on par* with the 22.5 cm row spacing +100% RDF (50:25:30 + 10 t FYM), 30 cm row spacing + 75% RDF (37.5:18.75:22.50 + 7.5 t FYM) and 30 cm row spacing + 100% RDF (50:25:30 + 10 t FYM). The minimum number of spikes (25.46) per plant was recorded with 45 cm row spacing + 100% RDN through FYM. This increase may be attributed to optimum plant density and supplied balanced nutrients and their combined synergetic effects. The row spacing of 22.5 cm has recorded significantly maximum seed and husk yield (1221 and 305 kg/ha). The lower seed and husk (496 and 123 kg/ha) was recorded at the wider row spacing of 45 cm. The seed and husk yield of isabgol was more at optimum plant population. The maximum seed and husk yield might be due to higher plant population per unit area as compared to wider spacing and adequate supply of NPK and FYM to plants in balanced proportion increased seed and husk yield. These results are in accordance with the findings of Shivran (2013) [23], Phatak *et al*. (2016) [20] in glory lily and Agba *et al.* (2015) [2] in *Mucuna flagellipes.*

Application of optimum levels of NPK through 75% RDF (37.5:18.75:22.50) + 7.5 t FYM, significantly increased seed and husk yield. The increased seed and husk yield might be due to better nutritional status of the crop in the soil as evidenced by their uptake in the plant. The optimum supply of NPK and FYM and their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters and resulted in increased seed and husk yield. The results of present investigation are in line with those of Singh and Sharma (2002) [24, 25], Utgikar *et al.* (2007 and Tripathi *et al*. (2013) [31, 28] in isabgol and Phatak *et al*. (2016) [20] in glory lilly.

The maximum seed and husk yiled (1348 kg /ha and 337 kg/ha) was recorded with 22.5 cm Rrow spacing + 75% RDF (37.5:18.75:22.50 + 7.5 t FYM). This increase may be attributed to optimum plant density and balanced nutrients and their combined effects. The results of present investigation are in confirmity with those of Bature *et al.* (2018) [5] in mucuna, Mary *et al.* (2018) [16, 17] in chia and Meena *et al*. (2016) [18] in fenugreek.

Table 1: Influence of planting geometry and nutrient levels on growth parameters at different stages of growth in Isabgol

Treatment	Plant height(cm)			Number of leaves			Number of tillers		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Spacing (S)									
S_1: 22.5 cm	17.18	29.04	35.09	26.71	58.58	65.70	7.65	11.87	13.05
S_2: 30 cm	16.94	28.58	34.76	26.58	55.35	64.20	7.62	11.40	12.93
S_3: 37.5cm	15.57	25.33	31.77	25.96	50.38	56.77	7.29	10.21	11.89
S_4: 45 cm	15.47	21.09	29.56	25.88	39.43	51.44	7.28	9.78	10.95
S.Em ±	0.13	0.19	0.24	0.17	0.40	0.43	0.06	0.09	0.09
CD @ 5%	0.38	0.56	0.71	0.51	1.16	1.26	0.18	0.26	0.27
Nutrient levels (N)									
N_1: 75% RDF (37.5:18.75:22.50 + 7.5 t FYM)	16.79	27.49	34.13	26.87	56.34	63.95	8.01	11.97	13.47
N_2: 100% RDF (50:25:30 + 10 t FYM)	16.75	26.70	33.47	26.48	52.90	61.37	7.61	11.18	12.34
N_3: 125% RDF (62.5:31.25:37.50 + 12.5 t FYM)	16.19	26.10	32.78	26.06	49.69	61.83	7.39	10.45	12.15
N_4: 100% RDN through FYM + 10 t FYM)	15.41	23.73	30.79	25.69	44.78	50.93	6.80	9.65	10.83
S. Em ±	0.13	0.19	0.24	0.17	0.40	0.43	0.06	0.09	0.09
CD @ 5%	0.38	0.56	0.71	0.51	1.16	1.26	0.18	0.26	0.27
Interaction (SXN)									
S_1N_1	18.00	30.48	37.28	27.31	63.63	72.58	8.29	12.98	14.45

S_1N_2	17.55	29.48	35.81	27.08	61.89	68.00	7.72	12.43	13.13
S_1N_3	17.11	29.07	35.23	26.62	58.78	67.36	7.65	11.73	13.18
S_1N_4	16.04	27.12	32.05	25.81	50.00	54.85	6.94	10.37	11.48
S_2N_1	17.87	30.25	36.75	27.59	62.73	71.06	8.23	13.03	14.43
S_2N_2	17.38	29.28	35.85	26.66	59.04	67.77	7.75	11.78	13.34
S_2N_3	16.95	28.13	34.41	26.41	51.61	63.65	7.61	10.21	12.53
S_2N_4	15.54	26.65	32.05	25.67	48.04	54.31	6.88	10.61	11.39
S_3N_1	16.17	27.38	32.08	26.57	56.51	60.36	7.79	11.04	12.74
S_3N_2	15.85	27.04	32.71	26.11	50.67	59.36	7.46	10.48	12.21
S_3N_3	15.25	26.04	31.01	25.66	47.79	54.69	7.22	10.01	11.72
S_3N_4	15.01	20.86	31.28	25.51	46.56	52.68	6.68	9.33	10.88
S_4N_1	15.12	21.88	30.42	26.05	42.53	51.83	7.74	10.84	12.29
S_4N_2	16.25	21.02	29.54	26.11	40.03	50.39	7.55	10.07	10.69
S_4N_3	15.47	21.18	30.50	25.58	40.62	61.64	7.12	9.89	11.19
S_4N_4	15.05	20.30	27.78	25.78	34.56	41.89	6.71	8.33	9.60
S.Em ±	0.26	0.39	0.49	0.35	0.80	0.87	0.12	0.18	0.19
CD @ 5%	0.77	1.12	1.43	1.03	2.32	2.53	NS	0.53	0.55

Note: DAS= Days After Sowing, RDF= Recommended Dose of Fertilizers, RDN= Recommended Dose of Nitrogen, FYM= Farm Yard Manure, NS= Non Significant

Table 2: Influence of planting geometry and nutrient levels on yield parameters in Isabgol

Treatment	Number of spikes	Seed yield	Husk yield
Spacing (S)			
S_1 (22.5 cm)	36.50	1221	305
S_2 (30 cm)	36.11	902	225
S_3 (37.5cm)	31.97	661	165
S_4 (45 cm)	27.55	496	123
S.Em ±	0.31	6.08	1.33
CD @ 5%	0.89	17.58	3.86
Nutrient levels (N)			
N_1-75% RDF (37.5:18.75:22.50 + 7.5 t FYM)	35.79	904	225
N_2- 100% RDF (50:25:30 + 10 t FYM)	34.47	866	216
N_3-125% RDF (62.5:31.25:37.50 + 12.5 t FYM)	32.81	803	200
N_4-100% RDN through FYM + 10 t FYM)	29.05	706	176
S.Em ±	0.31	6.08	1.33
CD @ 5%	0.89	17.58	3.86
Interaction (SXN)			
S_1N_1	39.28	1348	337
S_1N_2	37.98	1311	327
S_1N_3	36.98	1199	299
S_1N_4	31.79	1028	257
S_2N_1	39.16	1006	251
S_2N_2	38.21	976	244
S_2N_3	35.67	868	216
S_2N_4	31.41	758	189
S_3N_1	34.57	705	176
S_3N_2	33.91	683	170
S_3N_3	31.85	668	167
S_3N_4	27.57	588	147
S_4N_1	30.17	556	138
S_4N_2	27.83	496	123
S_4N_3	26.76	478	119
S_4N_4	25.46	452	113
S.Em ±	0.62	12.17	2.67
CD @ 5%	1.79	35.16	7.72

Note: DAS= Days After Sowing, RDF= Recommended Dose of Fertilizers, RDN= Recommended Dose of Nitrogen, FYM= Farm Yard Manure

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