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CULTIVATION OF MEDICINAL **ISABGOL** (*PLANTAGO OVATA*) IN ALKALI SOILS IN SEMIARID REGIONS OF NORTHERN INDIA

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ABSTRACT

There is growing global demand for medicinal drugs including **isabgol** (*Plantago ovata*). With increasing demand of food for an ever-increasing population in India, it is not possible to bring arable lands under cultivation for aromatic and medicinal plants. Salt-affected lands (both saline and alkali) occupy about 8·6 million ha. Due to poor physical properties and excessive exchangeable Na^+, most of these lands do not support good vegetation cover. The marginal and salt-affected lands could be successfully utilized for the cultivation of aromatic and medicinal plants. We achieved almost complete germination of **isabgol** seeds using up to 5000 ppm salt-solution. Grain yield (including husk) was 1·47 to 1·58 t ha^{-1} at pH 9·2 showing no significant yield reduction as compared to normal soil. At pH 9·6 the grain yield was 1·03 to 1·12 t ha^{-1}. At higher pH there was significant reduction in yield. Sowing in good moisture (at field capacity) of soil was found best, but to save time sowing at shallow depth in dry soil, followed by irrigation was also suitable as compared to broadcasting seeds. The chlorophyll content was greater 70 days after sowing compared to younger stages (50 days after sowing). The total chlorophyll and plant biomass were lower from crops grown by broadcasting methods of sowing as compared to two other methods of sowing. The leaf area index (LAI) was higher for the broadcasting method of sowing as compared to the other two methods. Na^+ absorption increased and K^+ and K^+/Na^+ ratio decreased with increase in pH. Results reported in this paper clearly indicate that **isabgol** can successfully be grown on moderately alkali soils up to pH 9·6 without the application of any amendment. Copyright © 2006 John Wiley & Sons, Ltd.

KEY WORDS: medicinal and aromatic plants; alkali/sodic soil; leaf area index (LAI); exchangeable sodium percentage (ESP); **isabgol** (*Plantago ovata*); hypercholesterolemia; India

INTRODUCTION

The global demand for herbal products is not only large, but is also growing. The largest markets for medicinal and aromatic plants are China, France, Germany, Italy, Japan, Spain, UK and USA. In 1999, the world market for herbal remedies was US$ 19·4 billion, with Europe in the lead (US$ 6·7 billion), followed by Asia (US$ 5·1 billion), North America (US$ 4·0 billion), Japan (US$ 2·2 billion) and the rest of the world with US$ 1·4 billion (Laird and Pierce, 2002). India is a major exporter of raw and processed plant-based drugs. Exports of crude drugs in 1994–95 were valued at US$ 53 219 million and for essential oils US$ 13 250 million (Lambert *et al*., 1997). Important crude drugs included: *Plantago ovata* (psyllium), *Panax* spp. (ginseng), *Cassia* spp. (senna), and *Catharanthus roseus* (Madagascar periwinkle). To meet the internal consumption and to earn foreign exchange, the production of these commodities needs to be increased.

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In India, the arable lands used for food production are shrinking fast due to developmental activities and cannot be brought under non-conventional crops, including medicinal and aromatic crops. Therefore, we are left with no option other than to bring the marginal, including salt-affected, lands under judicious cultivation for these crops. In India, about 8·6 million ha land is salt-affected, which includes about 3 million ha alkali lands (Singh, 1992). Some aromatic and medicinal plants withstand soil salinity and alkalinity to a considerably higher level than do traditionally grown agricultural crops (Anwar *et al*., 1996; Patra and Singh, 1998; Dagar, 2003; Dagar *et al*., 2004).

Medicinal **isabgol** (*Plantago ovata* Forsk., family Plantaginaceae) also known as blond white psyllium, produces seeds used commercially for the production of mucilage. The mucilage is obtained by mechanically grinding off the outer layer of the seed (often referred to as husk or psyllium husk). The milled seed mucilage is a dull white fibrous material that is hydrophilic. It is laxative and mainly used as a dietary fibre. The use of soluble-fibre cereals is an effective and well-tolerated part of a prudent diet for treatment of mild to moderate hypercholesterolemia and for reducing blood glucose (Abraham and Mehta, 1988; Anderson *et al*., 1990; Bell *et al*., 1990). In India, it is used as an indigenous Ayurvedic and Unani medicine as a demulcent and laxative, and in the treatment of chronic constipation, amoebic dysentery and diarrhoea. Isabgol is cultivated mainly in Rajasthan and Gujarat in an area of about 55 000 ha, and from 1997 to 1999 psyllium husk exports were worth Rs. 1425·09, 1183·89 and 1134·38 million (US$ 29·32, 24·36, and 23·34 million). During the same period seed exports were worth Rs. 163·37, 189·86 and 139·87 million (GOI, 1997–1999). The medicinal and economic importance and the performance of its cultivation in different alkali soils has been evaluated in this paper.

MATERIAL AND METHODS

Study Area and Climate

The study was conducted at Central Soil Salinity Research Institute, Karnal (latitude 29° 43′ N, longitude 76° 58′ E, altitude 245 m a.s.l.) in Haryana State, India. The climate of the area is subtropical, semiarid with little or no water surplus, megathermic and monsoonal. The actual mean annual rainfall measured at the Institute during 1980–2001 was found to be 794 mm while open-pan evaporation was 1510 mm. The maximum rainfall (78 per cent) occured during July to September. The mean maximum and minimum daily temperatures were 31·3 °C and 17·8 °C, respectively. The relative humidity was maximum (81 per cent) in the month of August while the sunshine hours were maximum (9·9) in May. The experiments were conduced during **rabi** (winter) seasons (November–March) of the years 1996–97, 1997–98 and 2002–03. The total rainfall during the experiment in these years was 50·2, 210·4, and 62·4 mm, respectively. The temperature remained low (mean daily minimum 5 °C) in December–January and started rising in February. The mean maximum and minimum temperatures of February were 22·1 and 7·5 °C, respectively. In March, these temperatures were 28·2 and 11·8 °C, respectively. The crop was harvested in the first week of April.

Experimental Details

The experiment was conducted in 12 micro-plots each 3 m × 6 m in size. The alkali soils of pH 8·4, 9·2, 9·6 and 9·9 were transported from the field and filled in the micro-plots. The soil was allowed to settle for at least three years. Before bringing the soil from field, it was analysed so that we could get soil of different pH. The precaution was taken that three workable replications of each range of pH were available in the micro-plots. During this period crops were grown without application of any amendment so that the pH of the entire plot remained uniform. The soil profile in all the plots was 90 cm deep. Before initiation of this experiment intensive soil sampling of micro-plots was done at 0–15 and 15–30 cm soil depths. Because the root system of the crop is shallow (< 30 cm) only these two depths were considered.

After grinding, the air-dried soil samples were passed through a 2 mm sieve and analysed for different soil parameters. The mechanical analysis was done by the Pipette method (Piper, 1966). The soil pH was determined using a digital pH meter in a soil:water suspension (1:2). For electrical conductivity measurement, the soil-saturated extract was obtained by subjecting the soil paste to a vacuum pump as described by Richards (1954) and the electrical conductivity of the extract (ECe) was measured using a microprocessor conductivity meter. For determination of exchangeable sodium percentage (ESP), cation exchange capacity (CEC) was determined as described by Richards (1954) and the ESP was calculated as:

$$\mathrm{ESP} = \frac{\text{Exchangeable Na}^{+}\ (\text{cmol kg}^{-1})}{\text{CEC}\ (\text{cmol kg}^{-1})} \times 100$$

After raising crops for two years (during 1996–97 and 1997–98) other crops were grown in 12 micro-plots. Another experiment was planned during the year 2002–03, therefore, soil pH was again determined before initiation of this experiment.

Raising the Crop

During the first year (1996–97) the seeds of **isabgol** were sown at shallow depth (about 1 cm deep) in well-prepared moist (at field capacity) soil in 10 cm spaced rows with 20 g seeds per micro-plot sown during the first week of November. Nitrogen and phosphorus were applied at 40 kg and 15 kg ha^{-1}, respectively. The entire dose of phosphorus (P_2O_5) and half of the nitrogen (in the form of urea) was applied at the time of sowing and the remaining half of nitrogen was applied at the initiation of flowering. Irrigation was given on in 'as needed' basis. During the second year, the micro-plots were divided into three subplots (each of 2 m $\times$ 3 m size) and along with other medicinal plants **isabgol** was planted in one subplot. During the year 2002–03, each micro-plot was divided into three subplots and three methods of sowing were used: (1) broadcasting in dry soil followed by irrigation; (2) sowing in rows at shallow depth (1 cm) in dry soil followed by irrigation; and (3) sowing in rows at shallow depth with sufficient moisture. In each subplot 6 g of seeds were sown. The fertilizer use was the same as that mentioned above for the first year. Every year the crop was harvested in the first week of April. Harvested biomass was recorded and seeds were removed mechanically after drying in air.

During last phase of the experiment, several growth parameters such as plant height, root length, spike length, grain weight of 1000 seeds, chlorophyll estimation and leaf area index were determined. Roots were excavated after taking out monoliths (after harvesting the crop) of 20 cm diameter and 10 cm depth. These were carefully washed with the help of a water-jet.

Leaf area index (LAI) was determined using LAI-2000 Plant Canopy Analyzer (LI-COR Trade Mark) at flowering stage. Seed-germination studies were conducted in sterilized petridishes in the laboratory during the first week of November, using salt solutions of different concentrations ranging from 1000 to 10 000 ppm prepared using NaCl. Distilled water served as a control. The petridishes were lined with a double layer of Whatman filter paper. In each petridish 20 seeds were kept and these were moistened with 10 ml of the representative solution. Germination was observed daily.

Analysis of Plant Samples

During the first year, plant samples were taken from micro-plots of different pH at the time of harvest. These were oven-dried at 80°C for 24 hours, ground up and digested in a mixture of HNO_3:$HClO_4$ (3:1) for determination of Na^+, K^+, Ca^{2+} and Mg^{2+}. The Na^+ and K^+ were determined with the help of flame photometer (Richards, 1954) while the Ca^{2+} and Mg^{2+} were determined using a spectrophotometer as per standard procedures (Jackson, 1967). Chlorophyll content was determined at two stages of growth (50 and 70 days after sowing) following the method used by Arnon (1949).

RESULTS AND DISCUSSION

Seed Germination

The common Indian name **isabgol** comes from the Persian words '*isap*' and '*ghol*' meaning horse ear, which is descriptive of the shape of the seed. The seed are minute weighting about 2 g per 1000 seeds. These show some

Table I. Seed germination of **isabgol** in solutions of different salinity

Parameters	Salinity (ppm) of solution							
	Control	1000	2000	3000	4000	5000	LSD $p = 0.01$	CV (%)
Germination (%)	100	100	98·75	97·50	88·75	82·50	5·47	3·31
Standard deviation	0	0	2·17	2·50	4·15	2·50	—	—
	When brought in distilled water from salt solution (ppm) of							
	6000	7000	8000	9000	10 000	LSD $p = 0.01$	CV (%)	
Germination (%)	83·75	68·75	50·00	42·50	37·50	10·103	8·28	
Standard deviation	4·15	5·45	3·53	2·50	2·50	—	—	

innate dormancy of about three months following harvest. Seeds of the previous year showed complete germination in distilled water and salinity up to 1000 ppm. These also showed very good germination (97·5 per cent) using 3000 ppm of salt solution, while at 5000 ppm the germination was 82·5 per cent. All the seeds germinated within six days. Using solutions of above 5000 ppm, there was no germination, but when the seeds were rinsed in distilled water the germination ranged from 83·75 per cent (when brought from 6000 ppm) to 37·5 per cent when brought from 10 000 ppm solution (Table I). Effects of salinity on delaying and reducing germination are well known but species vary in their tolerance (Ayers and Westcot, 1985). Salt-tolerant plants have evolved a number of germination mechanisms for establishment in saline environments such as osmotic stress, specific ion toxicity and nutrient deficiencies (Adam, 1990; Ungar, 1991).

Soil Characteristics of the Experimental Plots

Most of the alkali soils of the Indo-Gangetic plains have been formed under the influence of sodium carbonate. Hydrolysis of this salt imparts high pH and ESP, which affect the physico-chemical and biological properties of such soils adversely. The clay, silt, and sand contents of our studied soils ranged from 20·6 to 23·3 per cent, 29·8 to 31·2 per cent, and 45·5 to 48·5 per cent, respectively. The soil pH (soil:water ratio 1:2) of the 0–15 cm layer was 8·4, 9·2, 9·6, and 9·9 while for the 15–30 cm layer it was 8·3, 9·3, 9·7 and 10·0, respectively.

Exchangeable sodium percentage (ESP) values of the upper 0–15 cm layer were 18, 26, 43, and 59 while for 15–30 cm these were 17, 28, 46, and 63, respectively. The electrical conductivity of saturation extract of soil (ECe) ranged from 2·0 to 3·8 dS m^{-1}.

Crop Performance in Alkali Soils of Different pH

The results of the first two years (Table II) showed that there was no reduction in plant height, straw yield and seed yield up to pH 9·2. However, there was a 35 and 31 per cent seed yield reduction during first and second year, respectively, at pH 9·6. At higher pH, the reduction was more (63 and 57 per cent) showing the suitability of the crop for moderate alkali soils up to pH 9·6 without application of any amendment. The seed:husk ratio was 2·98:1 and pH had no effect on it.

While comparing three methods of sowing (i.e. by broadcasting in dry soil followed by irrigation, sowing in rows in dry soil followed by irrigation, and sowing in rows in good moist soils), it was found that at the initial stage, there was almost complete germination when seeds were broadcasted. Initially there was a thick seedling population under this treatment. But because tillering was less in broadcast plots the number of tillers remained low in the end. The crop was best when seeds were sown in good moist soils (at field capacity). Due to the growth of other crops between 1997–98 and 2002–03, the soil was ameliorated slightly; therefore, there was no significant difference in yield at different pH but there was significant difference when the crop was grown by different

Table II. Effect of pH on performance of **isabgol** in alkali soils

Initial soil pH (1:2)	First year			Second year			Average		
	Plant height (cm)	Fresh straw ($g\,m^{-2}$)	Seed* (including husk) ($g\,m^{-2}$)	Plant height (cm)	Fresh straw ($g\,m^{-2}$)	Seed* (including husk) ($g\,m^{-2}$)	Plant height (cm)	Fresh straw ($g\,m^{-2}$)	Seed* ($g\,m^{-2}$)
8·4	26·8	546	159	27·3	562	175	27·0	554	167
9·2	27·0	475	147	28·2	493	169	27·6	484	158
9·6	26·1	269	103	26·4	301	121	26·2	285	112
9·9	24·7	102	58	25·9	136	76	25·3	119	67
LSD ($p = 0{\cdot}01$)	NS	92·4	38·4	NS	117·8	48·5	—	—	—
CV (%)	7·2	8·8	10·9	6·9	10·7	13·1	—	—	—

*Seed:husk ratio 2·98:1.

Table III. Relative performance of **isabgol** under three method of sowing in alkali soils

Soil pH (1:2)		Seed ($g\,m^{-2}$)	Fresh straw biomass ($g\,m^{-2}$)	Plant height (cm)	Root length (cm)	Spike length (cm)	Tillers (no. m^{-2})	1000 seed weight (g)	Chlorophyll ($mg\,g^{-1}$) a	b	Total	LAI
	A	101	450	25·1	7·5	2·5	1403	2·098	1·15	2·57	3·72	3·75
8·2	B	121	569	27·6	7·6	3·1	1764	2·107	1·52	3·50	5·02	3·56
	C	127	642	27·2	7·6	3·2	2023	2·064	1·50	3·09	4·59	3·15
	A	87	464	26·7	7·4	2·6	1343	2·251	1·12	2·63	3·75	3·53
8·8	B	111	563	28·4	7·7	3·3	1600	2·033	1·35	3·18	4·53	3·43
	C	124	615	29·2	7·9	3·2	1843	1·955	1·41	3·63	5·04	3·19
	A	74	458	23·4	7·2	1·8	1735	2·081	1·43	3·09	4·52	3·44
9·2	B	108	527	27·2	7·4	3·2	1909	2·218	1·63	3·53	5·16	3·30
	C	114	648	28·3	7·3	3·2	2271	1·784	1·60	3·55	5·15	3·04
	A	87	437	22·6	6·6	1·5	1296	2·196	1·41	3·52	4·83	3·40
9·7	B	104	488	25·7	7·0	3·0	2403	2·103	1·52	3·42	4·94	3·07
	C	107	577	26·3	7·2	2·9	2445	1·932	1·44	3·26	4·90	2·35
LSD ($p = 0{\cdot}05$)												
pH		NS	NS	1·68	NS	0·25	NS	NS	0·13	0·22	1·202	0·18
Sowing method		6·9	39·45	1·3	NS	0·2	371·8	0·1	0·09	0·16	0·2	0·15
Interaction		NS	NS	NS	NS	0·4	NS	0·2	NS	0·31	0·4	NS
CV (%)		7·6	8·5	5·5	5·3	7·4	23·9	5·3	7·32	5·6	5·3	5·34

A = Sowing by broadcasting of seeds followed by irrigation, B = Sowing in rows followed by irrigation, C = Sowing in rows in good moist soil. NS = not significant. LAI = leaf area index.

methods. Though there was less difference between the last two methods; however the yield was best when seeds were sown in good moist soils (Table III).

All the eleven growth parameters shown in Table III, were analysed for their correlation. It was found that seed yield was positively correlated with straw yield, shoot length, root development, spike length and number of tillers but no relation was found with chlorophyll content or leaf area index (LAI). There was significant correlation between LAI and 1000 seeds weight and negative correlation between LAI and total chlorophyll (Table IV).

These results indicate that **isabgol** can be cultivated on moderately alkali soil (up to pH 9·6) in semiarid conditions. The results are similar to those of Singh and Anwar (1985), Anwar *et al*. (1996), Patra and Singh (1998), Dagar (2003) and Dagar *et al*. (2004) who advocated the cultivation of aromatic grasses like palmarosa and lemon grass in moderately alkali soil. **Isabgol** is clearly tolerant of salinity. Tomar and Minhas (2003) found that

Table IV. Correlation, intercept and slope values between different growth parameters of **isabgol**

1		2	3	4	5	6	7	8	9	10	11
1	a	0·735**	0·632**	0·359*	0·700**	0·348*	0·281^{NS}	0·295^{NS}	0·318^{NS}	−0·233^{NS}	−0·325*
	b	170·43	17·65	6·24	0·29	675·72	1·13	2·60	3·73	3·79	2·37
	c	3·461	0·083	0·011	0·024	10·658	0·003	0·006	0·009	−0·005	−0·003
2	a		0·494	0·154^{NS}	0·621**	0·386*	0·339*	0·328*	0·366*	−0·380*	−0·478**
	b		19·05	6·85	0·40	456·24	1·04	2·47	3·50	4·18	2·55
	c		0·014	0·001	0·004	2·510	0·001	0·001	0·002	−0·002	−0·001
3	a			0·587**	0·779**	0·164^{NS}	0·207^{NS}	0·176	0·213^{NS}	−0·150^{NS}	−0·328*
	b			3·85	−2·48	795·64	1·02	2·51	3·47	3·90	2·65
	c			0·133	0·199	38·062	0·015	0·028	0·046	−0·024	−0·022
4	a				0·526**	−0·033^{NS}	0·011^{NS}	−0·111^{NS}	−0·062^{NS}	0·046^{NS}	−0·150^{NS}
	b				−1·58	2051·42	1·40	3·82	5·12	3·03	2·39
	c				0·593	−33·669	0·004	−0·077	−0·059	0·032	0·044
5	a					0·352*	0·294^{NS}	0·177^{NS}	0·244^{NS}	−0·263^{NS}	−0·267^{NS}
	b					911·52	1·18	2·94	4·11	3·73	2·26
	c					320·014	0·086	0·110	0·205	−0·165	−0·069
6	a						0·236^{NS}	0·346*	0·365*	−0·300^{NS}	−0·326*
	b						1·29	2·82	4·07	3·64	2·24
	c						0·0	0·000	0·000	−0·000	−0·000
7	a							0·645**	0·819**	−0·372*	−0·229
	b							1·30	1·33	4·40	2·36
	c							1·368	2·355	−0·798	−0·204
8	a								0·960**	−0·343	−0·263
	b								0·46	4·39	2·43
	c								1·302	−0·347	−0·110
9	a									−0·407*	−0·299
	b									4·69	2·50
	c									−0·303	−0·092
10	a										0·464**
	b										1·44
	c										0·192
11											

1 = seed yield, 2 = straw, 3 = shoot length, 4 = root length, 5 = spike length, 6 = tillers, 7 = chlorophyll a, 8 = chlorophyll b, 9 = total chlorophyll, 10 = leaf area index, 11 = 1000 grain weight.
a = Correlation, b = Intercept, c = Slope. **Significant at $p = 0{\cdot}01$, *Significant at $p = 0{\cdot}05$, NS = Not significant.

plant growth and unhusked seed yield was the same when 3–4 irrigations were applied with water of low salinity (EC 4–5 $dS\,m^{-1}$), water of high salinity (EC 12 $dS\,m^{-1}$), and water of low and high salinity alternately. The average yield with these waters was 1·27 $t\,ha^{-1}$. They also optimized the doses of nitrogen and phosphorus when applied with saline irrigation, and found that the optimum doses of nitrogen and phosphorus (P_2O_5) were 25 and 20 $kg\,ha^{-1}$, respectively. Singh and Pal (2001), however, found that the application of saline water (EC 12 $dS\,m^{-1}$) decreased with the grain and husk yield and the uptake of potassium and zinc. This decrease seems to be due to interaction with fertilizer applications.

Absorption of Cations

Ionic contents (Na^+, K^+, Ca^{2+} and Mg^{2+}) in different plant parts (Table V) indicate that Na^+ accumulation increased and K^+ decreased with an increase in pH both in shoot and root. These were found negatively correlated ($r = -0{\cdot}772$, $p = 0{\cdot}01$). At higher pH, K^+ is not available to the plant but the availability increased at lower pH with amelioration of soil, while Ca^{2+} and Mg^{2+} did not show any trend. When these ions were correlated Na^+ was found negatively correlated with Ca^{2+} but positively correlated with Mg^{2+} but Ca^{2+} and Mg^{2+} were positively

Table V. Cation contents (mg g^{-1}) in shoot and root of **isabgol** in alkali soil of different pH

Initial soil pH (1:2)	In shoot					In root				
	Na	K	Ca	Mg	K/Na	Na	K	Ca	Mg	K/Na
8·4	19·43	23·23	8·75	7·63	1·21	12·82	22·49	4·04	7·09	1·75
9·2	22·84	26·20	9·15	7·68	1·15	14·70	24·44	3·27	7·06	1·63
9·6	30·26	22·05	9·46	8·15	0·73	13·31	10·49	2·87	6·95	0·80
9·9	37·55	16·05	6·71	8·31	0·43	17·09	7·12	3·36	7·39	0·42
LSD $p = 0{\cdot}05$	1·25	2·21	1·45	NS	0·12	1·14	0·89	2·08	NS	0·07
CV (%)	3·69	8·22	13·86	6·60	11·13	6·39	4·49	5·01	5·95	4·90

Table VI. Correlation, intercept and slope values between different cation contents in shoot and root of **isabgol**

	Cation in shoot			
Shoot	Na	K	Ca	Mg
Na	a. Correlation	−0·772**	−0·524**	0·521**
	b. Intercept	33·73	11·48	6·86
	c. Slope	−0·430	−0·108	0·039
	d. Standard error	0·076	0·037	0·014
K	a		0·699**	−0·308 NS
	b		2·88	8·86
	c		0·257	−0·042
	d		0·056	0·028
Ca	a			0·521*
	b			6·86
	c			0·039
	d			0·014
Mg				
	Cation in root			
Na	a	−0·434*	$-0{\cdot}077^{NS}$	0·576**
	b	41·19	3·65	5·29
	c	−1·731	−0·018	0·127
	d	0·765	0·050	0·038
K	a		0·489*	$-0{\cdot}157^{NS}$
	b		2·92	7·26
	c		0·029	−0·009
	d		0·11	0·012
Ca	a			$0{\cdot}086^{NS}$
	b			6·85
	c			0·080
	d			0·199
Mg				

**Significant at $p = 0{\cdot}01$, *Significant at $p = 0{\cdot}05$, NS = Not significant.

correlated (Table VI) in shoots showing selective ion absorption in **isabgol**. In roots an almost similar trend was observed but as the samples were taken at the time of harvest, the ions might have migrated to shoots and all the contents were lower in roots as compared to shoots. Prasad *et al*. (1997) also observed that increase in ESP and therefore also pH, enhanced the Na^+ and decreased K^+, Ca^{2+} and Mg^{2+} in vegetation tissues of both palmarosa and lemon grass as compared with the control. Anwar *et al*. (1996) also observed that, in vetiver, nitrogen, phosphorus and K^+ accumulation decreased in plant parts with increase in soil pH.

Table VII. Chlorophyll content (mg g^{-1} dry weight) in leaf of **isabgol** after 50 and 70 days of sowing in soils of different pH

Soil pH	At 70 days after sowing			At 50 days after sowing		
	Chl-a	Chl-b	Total	Chl-a	Chl-b	Total
9·7	1·324	3·340	4·463	0·980	2·654	3·634
9·2	1·122	2·831	4·053	0·920	2·530	3·450
8·8	1·032	2·716	3·748	0·791	2·212	3·003
8·2	1·056	2·751	3·807	0·961	2·536	3·497
LSD $p = 0{\cdot}05$	NS	0·3541	NS	0·0563	0·2231	0·2834
CV %	15·11	7·61	11·99	3·86	4·85	4·51

Chlorophyll Content

There was no clear trend in chlorophyll content (Table VII) at different pH at inflorescence stages; however, the content was greater 70 days after sowing compared to the younger stage (50 days after sowing). This is contrary to the aromatic grasses, which showed a reduction in chlorophyll with a rise in pH. Rao *et al*. (1999) found that in salt bush (*Salvadora persica*) about 2250 micro-moles of Na^+ was needed to reduce chlorophyll content of leaves by 50 per cent, compared to leaves of plants growing in a non-saline environment. When chlorophyll content was compared for crops grown with different methods of sowing, the contents were lower in those produced from broadcast sowing. However, there was no significant difference in crops produced by the other two methods of sowing.

CONCLUSION AND RECOMMENDATIONS

Psyllium (*Plantago ovata*), known as **isabgol** in India, is a medicinal crop of global demand. It is a salt-tolerant crop of the winter season. The seed can germinate in salt solution up to 5000 ppm. The crop can be grown successfully in moderate alkali soil up to pH 9·2 without application of any amendment in semiarid regions of India. It can tolerate high pH but there is significant yield reduction at higher pH. It can also be grown successfully with saline water up to EC 12 dS m^{-1}. The crop can be grown in rows at field capacity (in good moist soil) or in dry soil followed by irrigation. Broadcasting is an inferior method of sowing compared to sowing in rows.

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REFERENCES

Abraham ZD, Mehta T. 1988. Three-week psyllium husk supplementation: effect on plasma cholesterol concentrations, fecal steroid excretion, and carbohydrate absorption in men. *American Journal of Clinical Nutrition* **47**: 67–74.

Adam P. 1990. *Salt Marsh Ecology*. Cambridge University Press: New York, NY.

Anderson JW, Deakins D, Floore T, Smith B, Whitis S. 1990. Dietary fiber and coronary heart disease. *Crit. Rev. Food Sci. Nutr.* **29**: 95–147.

Anwar M, Patra DD, Singh DV. 1996. Influence of soil sodicity on growth, oil yield and nutrient accumulation in vetiver (*Vetiveria zizanioides*). *Annals of Arid Zone* **35**: 49–52.

Arnon DJ. 1949. Copper enzymes in isolated chloroplasts. *Plant Physiology* **24**: 1–25.

Ayers RS, Westcot DW. 1985. Water quality for agriculture, irrigation and drainage. *Paper No. 29*. FAO: Rome; 97 pp.

Bell LP, Hectorn K, Reynolds H, Hunninghake D. 1990. Cholesterol lowering effects of soluble-fiber cereals as part of a prudent diet for patients with mild to moderate hypercholesterolemia. *American Journal of Clinical Nutrition* **52**: 1020–1026.

Dagar JC. 2003. Biodiversity of Indian saline habitats and management and utilization of high salinity tolerant plants with industrial application for rehabilitation of saline areas. In *Desertification in the Third Millennium*, Alsharhan AS, Wood WW, Goudie AS, Fowler A, Abdellatif EM (eds). Balkema: Lisse; pp. 151–172.

Dagar JC, Tomar OS, Kumar Y, Yadav RK. 2004. Growing three aromatic grasses in different alkali soils in semi-arid regions of Northern India. *Land Degradation & Development* **15**: 143–151.

GOI. 1997–1999. *Monthly Statistics of the Foreign Trade of India 1997–99* (Vol. 1). *Exports and Re-exports*. Directorate General of Commercial Intelligence & Statistics, Ministry of Commerce, Government of India: Calcutta.

Jackson ML. 1967. *Soil Chemical Analysis*. Asia Publishing House: New Delhi.

Laird SA, Pierce AR. 2002. Promoting sustainable and ethical botanicals: Strategies to improve commercial raw material sourcing. Rainforest Alliance: New York, NY.

Lambert J, Srivastava J, Vietmeyer N. 1997. *Medicinal Plants: Rescuing a Global Heritage*. The World Bank: Washington, DC.

Patra P, Singh DV. 1998. Medicinal and aromatic crops. In *Agricultural Salinity Management in India*, Tyagi NK, Minhas PS (eds). Central Soil Salinity Research Institute: Karnal; pp. 499–506.

Piper CS. 1966. *Soil and Plant Analysis.* Hans Publishers, Bombay, India.

Prasad A, Kumar D, Singh DV. 1997. Effect of soil sodicity on the growth and cation composition of palmarosa and lemon grass. *Journal of Herbs, Spices and Medicinal Plants* **5**: 51–60.

Rao GG, Polar VN, Babu R. 1999. Salt tolerance studies in *Salvadora persica*: A facultative halophyte. *Indian Journal of Soil Conservation* **27**: 55–63.

Richards LA (ed.). 1954. *Diagnosis & Improvement of Saline & Alkali Soils*. Agriculture Handbook No. 60. United States Department of Agriculture: Washington, DC.

Singh DV, Anwar MA. 1985. Effect of soil salinity on herb and oil yield and quality of some *Cymbopogon* species. *Journal of the Indian Society of Soil Science* **33**: 362–365.

Singh L, Pal B. 2001. Effect of saline water and fertility levels on the yield, potassium and zinc content and uptake by blonde psyllium (*Plantago ovata* Forssk.). *Crop Research* **22**: 210–216.

Singh NT. 1992. Land degradation and remedial measures with reference to salinity, alkalinity, waterlogging and acidity. In *Natural Resources Management for Sustainable Agriculture and Environment*, Deb DL (ed.). Ankor Publication: New Delhi.

Tomar OS, Minhas PS. 2003. Irrigation and fertilizer requirement of isabgol under saline irrigation. *CSSRI Annual Report*. Central Soil Salinity Research Institute: Karnal; pp. 61–62.

Ungar LA. 1991. Seed germination. In Ungar LA (ed). *Ecophysiology of Vascular Halophytes*. CRC Press: Boca Raton, FL; pp. 9–48.