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The Effects of Irrigation Intervals and Manure on Quantitative and Qualitative Characteristics of *Plantago ovata* and *Plantago psyllium*

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Abstract: The yield, yield components and quality of two species of Isubgol (*Plantago ovata*) and Psyllium (*Plantago psyllium*) as affected by irrigation intervals under organic cultivation was studied. Field trial was conducted in 2002 in Faculty of Agriculture, Ferdowsi University of Mashhad (in Iran) with a split-factorial design based on a complete randomized block arrangement with three replications. Water stress was imposed by three different irrigation intervals (10, 20 and 30 days) which were allocated to main plots and a combination of three levels of animal manure at 5, 10 and 15 t ha^{-1} with two species allocated to subplots in a factorial manner. A complementary laboratory experiment was also conducted to determine the cardinal temperatures for seed germination. Constant temperatures of 5, 7, 10, 15, 20, 25, 30 and 35°C were arranged in a completely randomized design with four replications for the two species and the effect of these temperatures on percent and rate of germination were determined. Results showed that water stress had a negligible negative effect on most parameters evaluated except length of spike and seed yield which were affected negatively by increasing the length of irrigation intervals. Highest yield in both species were obtained with 10 and 20 day intervals between irrigations. Animal manure had significant effect only on yield and the maximum yield were obtained with 5 t ha^{-1} for Isubgol and 15 t ha^{-1} for Psyllium. There was no correlation between mucilage content, swelling factor and seed size. Results of laboratory trial showed that maximum rate of germination was obtained at 20 and 25°C and maximum percentage of seed germination was obtained at 15 and 25°C in Isubgol and Psyllium, respectively. Optimum germination ranged from 10-20 and 15-25°C for Isubgol and Psyllium, respectively. Based on a linear regression between rate of germination and temperature, cardinal temperatures (minimum, optimum and maximum) were 4.4, 19 and 25.5, 9.4, 28.8 and 35°C for Isubgol and Psyllium, respectively.

Key words: Isubgol, *Plantago psyllium*, Psyllium, cardinal temperature, irrigation

INTRODUCTION

Plantago belongs to the Plantaginaceae family with two valuable medicinal species of Isubgol (*Plantago ovata*) and Psyllium (*Plantago psyllium*) (Naghdi Badi *et al*., 2004). Isubgol is native to Iran, India and some Middle East countries (Gonzalez-Melero *et al*., 1997) and presently India is the largest exporter of Isubgol seed (Godawat, 1999). Psyllium is native to Mediterranean regions and is cultivated in a large scale in France and Spain (Javidtash, 1997). Economic value of these species are mainly related to mucilage content of the seed mainly used in medicine and industry (Ebrahimzadeh Mabood *et al*., 1998). Mucilage content of Isubgol have been reported to reach as high as 10-30% (Aynehchi, 1986; Blumental *et al*., 2000) and in Psyllium between 10-15% (Blumental *et al*., 2000). Fiber content of Isubgol has also been referred to as an agent for reduction of cholesterol, fat and sugar in blood (Naghdi Badi *et al*., 2004).

Based on WHO statistics, 80% of the world population are attached to medicinal and natural wild products for primary healthcare (Chatterjee, 2002; Dalal and Sriram, 1995). In the recent decade, there has been a tendency towards organic production of medicinal and aromatic plants (Carrubba *et al*., 2002; Schippmann *et al*., 2002). Organic production of these plants have been reported to enhance quality of their chemical compounds (Griffe *et al*., 2003). Furthermore, use of animal manure in production of medicinal plant has been successful and this material beside improving physical, chemical and biological criteria of soil has been found to increase yield (Sharma, 2002; Chatterjee, 2002). Singh *et al*. (1998) found

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that plant biomass of some medicinal plants including Isubgol was increased by application of compost in soil. There are other reports confirming these findings (Akbarinia *et al*., 2003; Sharifi Ashorabadi, 2001; Scheffer *et al*., 1993).

However, water deficit is a limiting factor in production of many field crops (Kafi and Mahdavi Damghani, 2001; Munns, 2002) and water stress causes different morphological, physiological and biochemical changes including: leaf area reduction, leaf senescence and reduction in cell development (Kafi and Mahdavi Damghani, 2001), stomatal closure (Safar Nezhad, 2003; Kafi and Mahdavi Damghani, 2001) and photosynthetic limitation (Kafi and Mahdavi Damghani, 2001; Hassani and Omid Beighi, 2002). It appears that the effect of water stress on economic yields of medicinal plants which are mainly secondary metabolites, are somehow positive (Baher *et al*., 2002). In many cases, a moderate stress could enhance the content of secondary metabolites. There are reports which indicate resistance of Isubgol to water stress (Patra *et al*., 1999), However, Psyllium has been reported (Ebrahimzadeh Mabood *et al*., 1998) to be more susceptible to water stress. Results of researches conducted in India (Ganpat *et al*., 1992; Gupta *et al*., 1994) showed that Isubgol is irrigated 4-5 times during the growth period. Nadjafi (2002) however reported that provision of adequate water improved yield of Isubgol.

Rapid plant establishment is an important factor in crop production and this is highly dependent on environmental factors particularly temperature and moisture (Koocheki and Momen Shahroudi, 1996). Effect of temperature on seed germination could be expressed by cardinal temperatures (Copeland and McDonald, 1995).

There are reports (Ramin, 1997) showing a linear relationship between temperature and rate of seed germination. Optimum temperatures for Isubgol and Psyllium have not been reported in the literature. The objective of this study was primarily, to determine cardinal temperature for these two plant species under laboratory condition and secondly, to evaluate the effect of animal manure and water stress on quantitative and qualitative characteristics of Isubgol and Psyllium.

MATERIALS AND METHODS

Laboratory trials: Constant temperatures of 5, 7, 10, 15, 20, 25, 30 and 35°C were imposed on seeds of Isubgol and Psyllium in a germinator in completely randomized arrangement with four replications. For each replication 50 average seeds were selected (1000-seed weight of 1.88 and 0.81 g for Isubgol and Psyllium, respectively), sterilized with 1% sodium hypochlorite (NaOCl) for 5 min and subsequently rinsed thoroughly with distilled water and located in Whatman filter paper moistened with distilled water in petri dishes (Cadho and Rajender, 1995; Nadjafi, 2002). Germination percentage was calculated on the basis of total number of germinated seeds and the rate of germination was calculated by Maguire equation (Maguire, 1962) state the equation. Minimum, optimum and maximum temperatures were determined by linear regression between rate of germination and temperature in which temperature was considered as the independent variable (x-axis) and the rate of germination as dependent variable (y-axis) (Wiese and Binning, 1987). By fitting regression lines (based on a triangular model) on both sides of optimal point (Sub-optimal and Supra-optimal points) the intercept of fitted regression lines with x-axis (temperature) were minimum and maximum estimated temperature (Aflakpui *et al*., 1998; Ramin, 1997). The regression lines were fitted in such a way that firstly with highest correlation coefficient and distribution of actual point around the fitted line show a logical trend. Regression equation was calculated as:

$$Y = a + b X \qquad (1)$$

Where:

Y = Germination rate.
X = Temperature.
a = Intercept.
b = Slope of the line. By putting Y = 0, X was calculated and therefore minimum and maximum temperatures were obtained (Jordan and Haferkamp, 1989). Before statistical analysis angular transformation (Dinda and Craker, 1998; Suzuki and Khan, 2000) was made on the data with percentage nature.

Field trials: This experiment was conducted at Faculty of Agriculture, Ferdowsi University of Mashhad (in Iran), Experimental design was a split-factorial arrangement based on randomized complete block with three replications. Irrigation intervals of 10, 20 and 30 days was the main factor and a combination of three levels of animal manure at 5, 10 and 15 t ha^{-1} with two plant species (*Plantago ovata* and *Plantago psyllium*) were allocated as sub plot of 7×3 m. Seeds were sown on rows 50 cm apart in early April 2002. Irrigation was scheduled accordingly and all other field practices were based on the normal procedures of the area conducted by the farmers.. Plant height, length of spike, number of spikes per plant, number of seeds per spike, 1000-seed weight, straw and seed yield were evaluated.

Qualitative parameters measured were mucilage content, swelling factor and swelling rate per gram mucilage (Ebrahimzadeh Mabood *et al*., 1997). Means were compared using Duncan's multiple range test ($p<0.05$)

RESULTS AND DISCUSSIONS

Laboratory trials: Based on the procedure for determining optimum temperatures (Fig. 1, 2) the minimum and maximum temperatures were obtained by intercept between the fitted line and x-axis, were 4.4 and 25.5°C for Isubgol and 9.4 and 35°C for Psyllium. There were significant differences between the two species in terms of germination rate ($p<0.05$).

Minimum temperature for Isubgol was much lower (5°C) than for Psyllium (15°C) (Table 1) and the maximum rate of germination for Isubgol was achieved in a lower temperature (20°C) compared with Psyllium (25°C). However, maximum germination percentage in Isubgol was achieved at 15°C compared with 25°C for Psyllium. Although germination for Isubgol started at 5°C, the optimal range was between 10 and 20°C and for Psyllium this range was from 15 and 25°C. Nadjafi (2002) found a range of 4 and 10°C for Isubgol germination. McNeil and Duran (1992) recorded optimal temperature of 14°C for Isubgol. However the optimum temperature for Isubgol and Psyllium were calculated as 19 and 28.8°C, respectively. Optimal and maximal temperatures of 15-30 and 30-40°C have been reported for many plant species (Copeland and McDonald, 1995). Minimum, optimum and maximum temperatures for Isubgol and Psyllium were 4.4, 19 and 25.5°C and 9.4, 28.8 and 35°C, respectively (Fig. 1, 2).

Field trials

Yield and yield components: Irrigation intervals had no effect on plant height, number of spikes per plant, number of seeds per spike, 1000-seed weight and straw yield. However, the length of spike and seed yield were negatively affected by increasing intervals of irrigation. There was no significant interactive effect between irrigation and plant species on plant height, length of spike, number of spikes per plant, number of seeds per spike, seed and straw yield (Table 2). By increasing irrigation intervals most of the above parameters were reduced for both species and this reduction was more pronounced for Psyllium compared with Isubgol and this could be a good indication of better resistance of Isubgol to water stress (Table 2).

Irrigation intervals had no effect on seed yield of Isubgol although increased intervals of irrigation reduced yield of Psyllium considerably (Table 2). Table 2 shows that the reduction in seed and straw yield of Psyllium associated with increasing intervals of irrigation is mostly attributed to its negative effect on yield components such as number of spikes per plant and number of seeds per

Table 1: Effect of temperatures on percentage and rate of seed germination of *P. ovata* and *P. psyllium*

Temperature (°C)	Germination (%) *P. ovata*	Germination (%) *P. psyllium*	Germination rate (No. day^{-1}) *P. ovata*	Germination rate (No. day^{-1}) *P. psyllium*
5	15.5^{e}	0.0^{c}	0.60^{f}	0.00^{c}
7	92.5^{c}	0.0^{c}	5.38^{d}	0.00^{c}
10	99.0^{ab}	0.0^{c}	15.97^{c}	0.00^{c}
15	100.0^{a}	98.0^{a}	23.57^{b}	13.09^{b}
20	98.5^{b}	97.5^{a}	28.33^{a}	14.06^{b}
25	27.0^{d}	99.0^{a}	2.73^{e}	28.04^{a}
30	0.0^{f}	90.0^{b}	0.00^{f}	27.12^{a}
35	0.0^{f}	0.0^{c}	0.00^{f}	0.00^{c}

Means in each column followed by the same letter(s) are not significantly different ($p<0.05$)

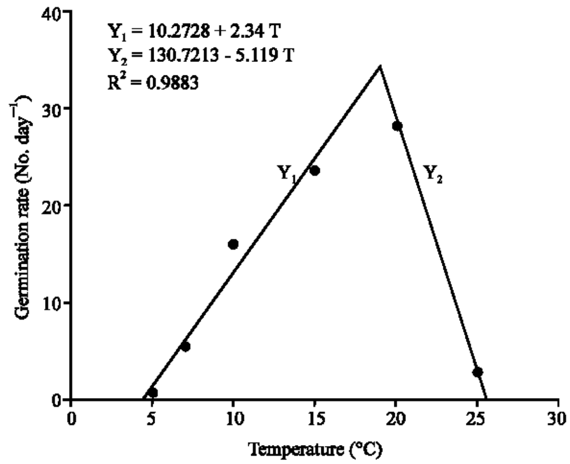

Fig. 1: Effect of temperatures on seed germination of *P. ovata*

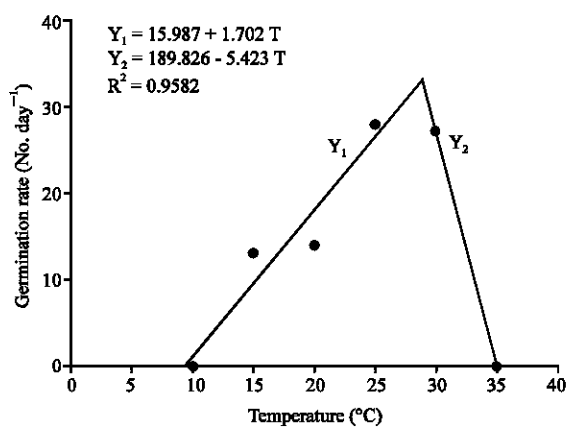

Fig. 2: Effect of temperatures on seed germination of *P. psyllium*

Table 2: Effect of irrigation intervals and manure on yield and yield components of *P. ovata* and *P. psyllium*

	Plant height (cm)		No. of spikes per plant		Spike length (cm)		No. of seeds per spike	
Treatments	*P. ovata*	*P. psyllium*	*P. ovata*	*P. psyllium*	*P. ovata*	*P. psyllium*	*P. ovata*	*P. psyllium*
Irrigation intervals (day)								
10	21.23^{b}	29.99^{a}	11.86^{bc}	29.75^{a}	2.40^{a}	1.58^{c}	54.37^{a}	40.72^{b}
20	19.90^{b}	20.81^{b}	8.86^{c}	19.81^{b}	2.23^{ab}	1.26^{d}	49.88^{a}	27.45^{c}
30	19.56^{b}	18.89^{b}	10.64^{bc}	10.03^{c}	2.21^{b}	1.08^{e}	53.25^{a}	20.13^{d}
Manure (t ha^{-1})								
5	20.47^{a}	22.32^{a}	9.47^{b}	17.58^{ab}	2.20^{a}	1.25^{b}	50.72^{a}	30.02^{b}
10	19.92^{a}	23.61^{a}	11.13^{b}	21.13^{a}	2.34^{a}	1.37^{b}	53.05^{a}	28.79^{b}
15	20.31^{a}	23.36^{a}	10.75^{b}	20.86^{a}	2.30^{a}	1.30^{b}	53.71^{a}	29.48^{b}

	1000 seed weight (g)		Straw yield (kg ha^{-1})		Seed yield (kg ha^{-1})	
Treatments	*P. ovata*	*P. psyllium*	*P. ovata*	*P. psyllium*	*P. ovata*	*P. Psyllium*
Irrigation intervals (day)						
10	1.88^{a}	0.81^{c}	813.6^{b}	1612.0^{a}	409.57^{a}	235.17^{b}
20	1.67^{b}	0.81^{c}	505.6^{b}	725.8^{b}	448.59^{a}	102.99^{c}
30	1.81^{ab}	0.73^{c}	634.2^{b}	517.4^{b}	405.07^{a}	43.19^{c}
Manure (t ha^{-1})						
5	1.85^{a}	0.80^{b}	593.4^{a}	784.7^{a}	549.03^{a}	113.21^{c}
10	1.79^{a}	0.83^{b}	684.0^{a}	988.7^{a}	389.89^{b}	126.57^{c}
15	1.70^{a}	0.72^{b}	675.8^{a}	1081.7^{a}	324.31^{b}	141.57^{c}

Means in each column followed by the same letter(s) are not significantly different ($p<0.05$)

Table 3: Effect of irrigation intervals and manure on qualitative characteristics of *P. ovata* and *P. psyllium*

	Mucilage content (%)		Swelling factor (mL)		Swelling rate per gram mucilage	
Treatments	*P. ovata*	*P. psyllium*	*P. ovata*	*P. psyllium*	*P. ovata*	*P. psyllium*
Irrigation intervals (day)						
10	38.03^{a}	7.10^{b}	9.20^{b}	4.05^{c}	24.93^{b}	93.03^{a}
20	35.73^{a}	6.23^{b}	10.03^{a}	4.10^{c}	28.63^{b}	91.82^{a}
30	39.81^{a}	6.98^{b}	10.41^{a}	4.42^{c}	27.32^{b}	77.49^{a}
Manure (t ha^{-1})						
5	40.39^{a}	6.50^{b}	9.96^{a}	4.20^{b}	26.15^{b}	84.26^{a}
10	36.93^{a}	6.67^{b}	10.02^{a}	4.28^{b}	27.82^{b}	94.07^{a}
15	36.26^{a}	7.14^{b}	9.65^{a}	4.08^{b}	26.91^{b}	84.01^{a}

Means in each column followed by the same letter(s) are not significantly different ($p<0.05$)

spike. Other yield components were not affected. This has been confirmed elsewhere (Bhagat, 1980). However, a contradictive result on the positive effect of applying higher rate of irrigation on Isubgol have been reported (Patel *et al*., 1996a, b; Ganpat *et al*., 1992; Nadjafi, 2002). In this case Patel *et al*. (1996b) and Nadjafi (2002) found that increasing rate of irrigation increased yield of Isubgol. However, it appears that this effect is more pronounced at higher frequency of irrigation.

Animal manure had no effect on yield and yield components of both species but there was a slight decrease in yield of Isubgol associated with application of the highest rates of animal manure could be related to sensitivity of this plant at the time of establishment and this was also confirmed by visual observation (Table 2). However the effect of application of animal manure is mostly related to soil improvement (Sharma, 2002) and direct effect may not be expected. There are reports (Yadav *et al*., 2002) which indicate positive effect of combination of 25% Urea and 75% FYM on yield and yield components of Isubgol. A positive effect of animal manure on Ajwain (*Trachyspermum ammi*) has also been reported (Akbarinia *et al*., 2003).

No interacting effect was observed on yield and yield components of two species.

Quality criteria: Irrigation intervals showed no effect on mucilage content, swelling factor and rate of swelling per gram mucilage for two species (Table 3). The same result has been reported elsewhere (Nadjafi, 2002). The mucilage content of Isubgol was 5 times higher compared with that of Psyllium and the swelling factor twice as much as Psyllium. However swelling rate per gram mucilage for Psyllium (87.44) was much higher than for Isubgol (26.95) which seems to be a species dependent factor. Superiority of Isubgol over Psyllium in terms of mucilage content and swelling factor has been shown in other reports (Ebrahimzadeh Mabood *et al*., 1997). Animal manure also showed no effect on these parameters (Table 3).

In conclusion it appears that Isubgol is more resistant to water stress and better adapted to water shortage. In relatively better response of Psyllium to irrigation rate seems to be mainly attributed to number of spikes per plant and number of seeds per spike. Animal manure had no significant effects on growth and yield of both species. Also in terms of quality criteria, Isubgol due to its higher mucilage content and swelling factor, is preferred compared with Psyllium. There was no effect of irrigation intervals and manure application on quality parameters of the two plant species.

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