International Scholars Journals

Advanced Journal of Microbiology Research ISSN 2241-9837 Vol. 14 (11), pp. 001-010, November, 2020. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Growth, photosynthetic efficiency, yield and swelling factor in *Plantago indica* under semi-arid condition of Gujarat, India

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Accepted 12 July, 2020

An experiment was carried out with Black Isabgol (*Plantago indica* L) an annual herb cultivated recently as a medicinal plant at Directorate of Medicinal and Aromatic Plants Research (DMAPR) in India, aiming on the effect at different stages of growth under the influence of different sowing dates and spacings on growth, seed yield and seed swelling factor as a part of good agricultural practices (GAP). No detail morpho-physiological work has been carried out in this species including yield. Results revealed that growth and yield were significantly influenced by sowing dates and spacings. The best time for sowing of *P. indica* was found to be between 15-30th November and the suitable spacing was either 50 or 60 × 15 cm. Swelling factor was not influenced by these factors, however, a positive trend was observed towards suitable date of sowing and spacing. The finding was a step forward towards determining good agricultural practices (GAP) of *P. indica*, probably an alternative of *P. ovata* in future.

Key words: *Plantago indica*, Sowing date, spacing, growth, yield, swelling factor.

INTRODUCTION

Black Isabgol (*Plantago indica* L) is an annual herb cultivated recently as a medicinal plant at Directorate of Medicinal and Aromatic Plants Research (DMAPR) in India. Its seed contains mucilage, fatty oil, large quan-tities of albuminous matter, a pharmacologically inactive glucoside and is supposed to be competing with already established *P. ovata* (Isabgol). The genus *Plantago* contains over 200 species. Isabgol, a short-stemmed annual herb belonging to the Plantaginaceae family is a plant of west Asian origin introduced into India in the middle age. India continues to hold a monopoly in its production and trade in the world market. Thus, isabgol is a major foreign exchange earner.

This crop is one of the most important crops among the cultivated medicinal plants grown for husk and seeds (Aishwath and Ram, 2008; Galindo et al., 2000; Maiti and Mandal, 2000; Lal et al., 1999; Handa and Kaul, 1999; Wolver et al., 1994; Gupta, 1987) and there is need to work on all other species like *P. indica* and *P. psyllium* so as to compare with already established species i.e. *P. ovata*. The mucilage present in its husk has medicinal properties and used against constipation, irritation of digestive tract etc. and is a diuretic, alleviates kidney and bladder complaints, gonorrhea, arthritis and hemorrhoids (Ansari and Ali, 1996; Zargari, 1990).

Lot of work has been done to develop package of practices of *Plantago ovata* and few varieties were also developed albeit with less yield potential and low swelling factor. Hence, there is need to breed varieties for higher yield and swelling factor and need to look for an alter-native either through bringing some other commercial species into cultivation or through advanced means. *P. indica* is one such species of the same family brought to cultivation recently by DMAPR grown for its husk and seeds. The mucilage content present in their husk has medicinal properties and used against constipation and are grown as Rabi crop in India. Cultivation of *P. indica* has started of late but yet to achieve its important place to compete with already established crop species *P. ovata* in terms of yield and quality aspect. The farmers in this area of the country have shown lot of interest in this particular species and they are interested to know whether it"s a superior type than *P. ovata* or is of similar type without any superiority.

In addition the biosynthesis of the secondary metabolites is controlled genetically and affected strongly

by environmental factors (Omidbaigi, 2000; Yanive and Palevitch, 1982), of which the sowing date and spacing are prerequisite for assuring optimal ecological conditions during the plant growth and development. In this context, at Anand, which is located in semi-arid region of Gujarat, the sowing of isabgol (*P. ovata*) is ideal between mid-October and mid-November (Aishwath and Ram, 2008; Maiti and Mandal, 2000). Late sowing, adversely affects seed yield due to a short growth period. However, Kalyansundram et al. (1984) reported that sowing of *P. ovata* during the first week of December is considered to be ideal under Jammu condition (India) which is altogether a different story than the report given by Koul and Sareen (1999) that sowing of isabgol is proposed to be ideal between mid-October and mid-November.

With the experience of the cultivation of *P. ovate,* this present study is thus aimed at determining the effect of some climatic factors, such as sowing dates and spacing, which could be used for cultivation of black isabgol (*P. indica*) to increase the quantity and improve the quality of isabgol for commercialization. At present due to several reasons the production of black isabgol is not as much as expected in isabgol (Lal et al*.,* 2007). Therefore, there is a need to develop superior variety of Isabgol for high seed and husk yield and also there is need to bring other species of Isabgol for example *P. indica* into cultivation so as to realize its potential having commercial base. Moreover, no such study on date of sowing and spacing as a part of Good Agricultural Practices (GAP) was carried out on this particular species with detailed study on its physiological aspects. Therefore, an attempt has been made to carry out experiments for two years (2006 to 2008) to evaluate growth and yield of *P. indica* including its swelling factor as quality parameter so as to understand its behaviour under semi-arid condition of Gujarat where it could be used as a potential alternative of *P. ovata*.

MATERIALS AND METHODS

Studies were conducted for two years at research farm of Directorate of Medicinal and Aromatic Plants Research (DMAPR), Boriavi, Gujarat, India located at 22.5° N latitude and 73.0° E longitudes. The study (2006 to 2008) was carried out taking two experiments on six dates of sowing (T1– 30th October, T2– 15th November, T3 – 30th November, T4– 15th December and T5- 30th December) and five row-row spacings (T6– 50 ×15 cm, T7– 60×15 cm, T8– 65 ×15 cm, T9 – 70×15 cm, T10- 75 ×15 cm and T11-80×15 cm) to study their influence on growth and yield of *Plantago indica* including swelling factor. Row spacing from 50 to 60 cm was chosen arbitrarily and there is no specific reason for this. Plant to plant spacing has been kept same, that is, 15 cm in all the cases varying only row spacing.

The study was conducted following RBD in four replicates for each experiment separately for each treatment. Seeds were sown in 50 cm apart and spaced 15 cm apart for date of sowing experiment and other intercultural practices like weeding and irrigation were followed in both the experiments. No inorganic fertilizers were applied accept FYM @ 15 t/ha applied prior to sowing as recommended for *P. ovate* (Maiti and Mandal, 2000).

The study area falls under the climatic zone VII, of the semi-arid region of India.

The crop was raised in 24 m^2 plots for each treatment with seed rate of 4 kg ha^{-1}. The experimental soil was Fluventic Ustochrept and sandy loam in texture. Physico-chemical characteristics of the soil were EC 0.18, pH 8.2 and organic carbon 0.26%. Soil was low fertile and having available N, P and K as 115.0, 9.8 and 123.4 kg ha^{-1}, respectively. The crops were harvested at 138 DAS and then their seeds and straw yield were recorded (weather figure during the growth period of the crop is given in Figure 7). Different growth (plant height, shoot dry weight, leaf numbers, leaf fresh and dry weight, leaf area, leaf area index, root growth) and gas exchange (photosynthetic rate: Pn, respiration rate: Rn) parameters were recorded at 45-50, 60-75 and 90 DAS. Total Chlorophyll content was also determined following method of Arnon (1949). This crop species shows lodging after 90-100 days of sowing and the leaves start senescence which becomes difficult to determine leaf area and its growth and therefore it was 90 DAS which was considered to be last growth stage after the start of senescence and lodging.

At harvest, different yield and yield parameters including swelling factor were determined. When plants turned yellow and spikes turned brown, they were harvested (Najafi and Moghadam, 2002). One square meter of three central rows were taken from each plot to determine the seed and biological yield and 10 plants were sampled from each plot to measure yield components, namely, spike length, plant height, seed swelling factor and mucilage contents. Harvest index (HI) is calculated using the formula as: HI = Seed yield^{-1} / Total biomass plant^{-1} × 100. Seed yield is converted into q/ha on the basis of data obtained from selected 10 plants from each treatment. To determine the swelling factor, 1 g of seed was put into beaker of 25 ml capacity and 20 ml distilled water was added. The swelling of seeds was calculated after 24 h (Sharma and Koul, 1986). Mucilage contents in the seed were also determined according to Sharma and Koul (1986). Swelling of 1 g mucilage was calculated by the following equation:

Swelling of 1 g mucilage = (swelling factor ×100)/mucilage contents

For taking dry weight, samples such as leaf were oven dried at 70°C for 48 h. Leaf area was determined per plant basis using LI-COR Model LI-3100C Area meter, USA and leaf area index (LAI) using Plant Canopy Analyzer Model LAI-2000 and Sensor Model LAI-2050 PCH-1779, USA. Rate of photosynthesis (µ mol CO_2 m^{-2} s^{-1}), respiration (µ mol CO_2 m^{-2} s^{-1}) and transpiration of either 4th or 5th leaf from bottom were measured using Infra Red Gas Analyzer of LI-COR Model LI-6400 portable photosynthesis system, USA at 50, 70 and 90 DAS. Immediately after photosynthesis measure-ment, the leaf was excised and the leaf area was measured (Subrahmanyam and Dutta, 2000). At harvest total dry weight and seed yield were recorded which included seed yield, total biomass and test weight. Analysis of variance (ANOVA) was done in statistical software MSTAT 4.0 C package for computers (Michigan State University, USA) following the method of Gomez and Gomez (1976). Results of two years were pooled for both the experiments separately. Differences among treatment were compared using LSD values at the 0.05 level of significance and correlation analyses were performed using MS Excel-2003 for showing significant difference between the treatments in the field and also to reflect the association of one parameter with the other.

RESULTS AND DISCUSSION

To understand the link between genotype and phenotype, comparison at the gross morphological state of a plant is necessary. Here we attempted to standardize that state

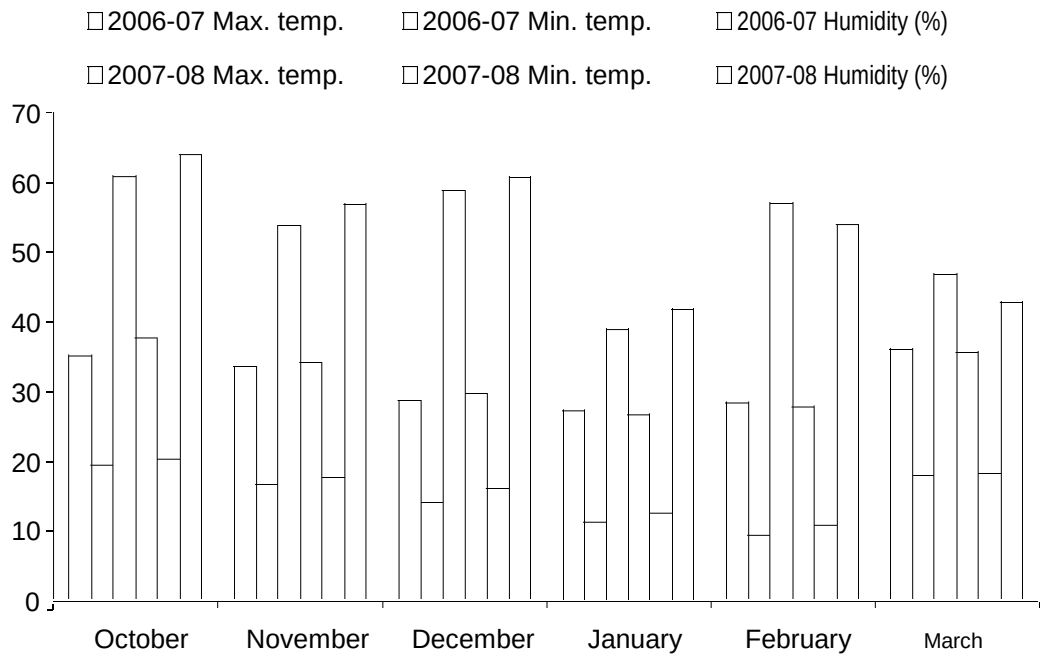

Figure 1. Monthly data for Maximum and Minimum temperature (°C) and Humidity (%) during the growth period (2006-08) of *Plantago indica.*

of plant and to develop an ontology that describes plant growth stages as progressive events visible to the naked eye. This is presented here as the 'whole plant growth stage ontology". Black Isabgol (*Plantago indica* L) is an annual herb cultivated recently as a medicinal plant in India. No study on date of sowing and spacing as a part of Good Agricultural Practices (GAP) has been carried out on this particular species with detailed study on its physiological aspects. Therefore, an attempt has been made to carry out experiments to evaluate growth and yield of *P. indica* including its swelling factor as quality parameter so as to understand its behaviour under semi-arid condition of Gujarat where it could be used as a potential alternative of *P. ovata*.

Growth was influenced due to different dates of sowing and spacing in *P. indica*. There was significant increase in plant height at 90 days after sowing (DAS). Maximum plant height of 110 cm was obtained in plants sown on 15th November (T_2) which was 12 and 34% more as compared to plant height at 30th October (early sowing) and 30th December (late sowing) sowing, respectively. Again in spacing experiment, maximum plant height of 107 cm was recorded in spacing of 50 × 15 cm (T_6) at 90 DAS followed by 104 cm in T_7 (60 ×15 cm) which was 10.5% more as compared to spacing of 80×15 cm (T_{11}). However, results of plant height was at par between T_2 and T_3 (date of sowing) and in between T_6 and T_7 (spacing) (Figures 2 and 3).

Similarly number of branches and leaf growth were significantly influenced by different dates of sowing and spacings and followed the similar trend as plant height. Mean number of branches per plant varied from 16-22 at 90 DAS and maximum number was attained by 15th November sowing (21) and in spacing of 50×15 cm (22) which was 40 and 47% more as compared to the minimum, that is, 30th December sowing (15.6) and 80 × 15 cm spacing (17.5) (Figures 2 and 3). Leaf growth (leaf number, leaf area and leaf dry weight) was also maximum on 15th November sowing and in 50 × 15 cm spacing, however, results of T_2 (15th November sowing) and T_3 (30th November sowing) and the results of T_6 (50×15 cm) and T_7 (60×15 cm) were at par (Figures 2 and 3). Maximum Leaf area index (LAI) of 1.81 could be recorded also in 15th November sowing (T_2) followed by T_3 (1.73) at 75 DAS and thereafter at 90 DAS it declined due to rolling and senescence of leaves at later stage which was also observed with decreased leaf number and leaf dry weight at 90 DAS in both date of sowing and spacing experiment (Figures 2 and 3). Average minimum to maximum leaf area per plant was in the range of 466 to 825 cm^2 in date of sowing experiment and 685-915 cm^2 in spacing experiment at 90 DAS, 15th November sowing and 50 ×15 cm spacing had maximum leaf area.

Total Chlorophyll content (TCC) was found to be significant at all the stages of crop growth (50, 70 and 90 DAS) in both the sets of experiment suggesting that significant increase in leaf growth could be a determining factor for this important pigment (Figure 5 A and B). However, there was non-significant decrease in TCC at 90 DAS similar to that of leaf growth from 70 DAS onwards. Again, November 15th sowing and 50×15 cm spacing had maximum chlorophyll content. The rates of

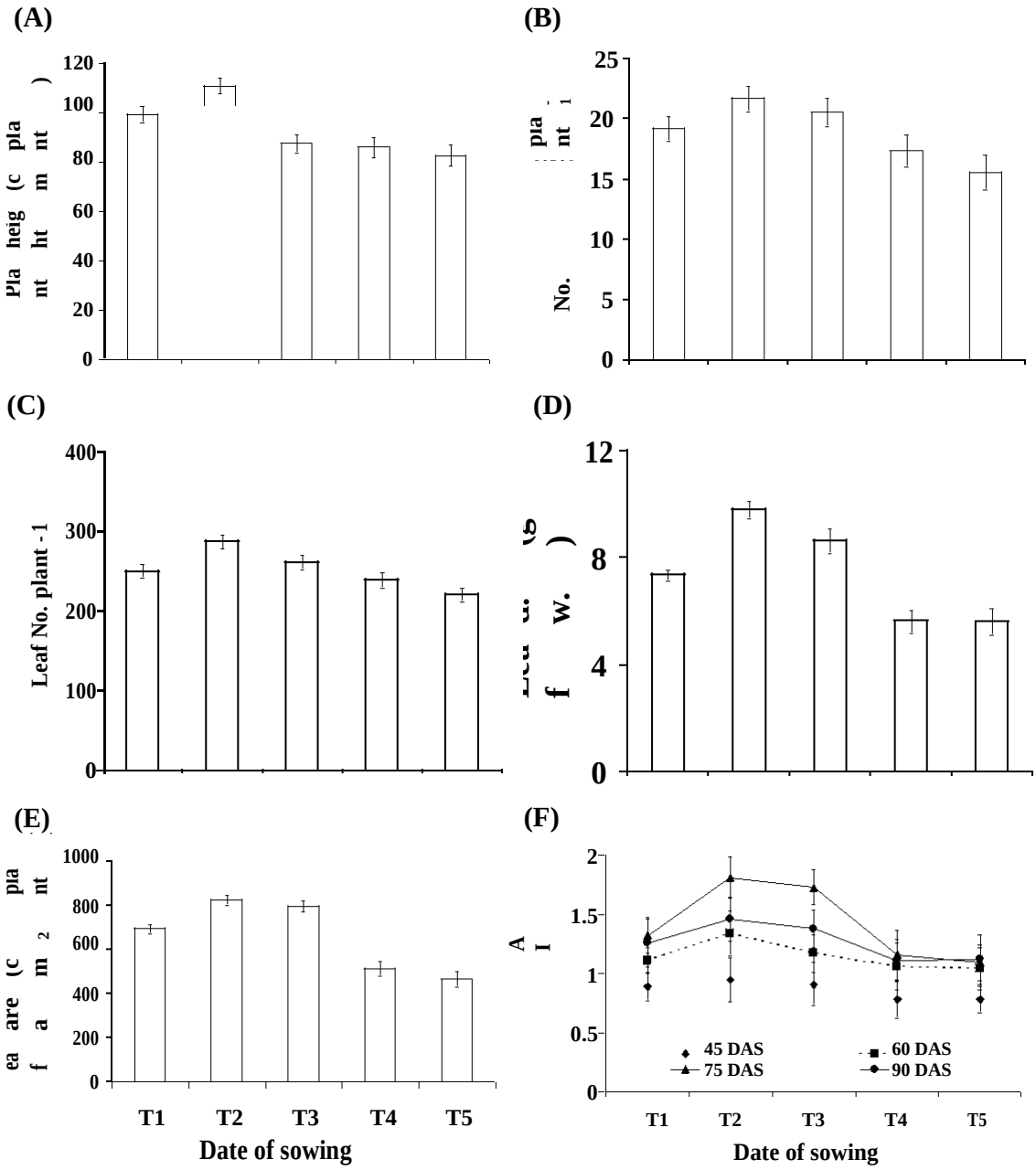

Figure 2. Plant growth characters in *P. indica* at 90 DAS under the influence of different dates of sowing. Bars represent SEm (n =10) at LSD (*P* = 0.05). LSD for A, B, C, D and E are 4.62, 1.57, 6.89, 1.12 and 67.4, respectively; while for LAI (F), LSD is 0.11. 0.08, 0.10 and 0.08 at 45, 60, 75 and 90 DAS, respectively. T1: 30th Oct, T2: 15th Nov., T3: 30th Nov., T4: 15th Dec., T5: 30th Dec.

maximum photosynthetic CO_2 assimilation (P_n), dark respiration (R_n), and transpiration were measured under the light intensity of 1,200 µmol photons $m^{-2}s^{-1}$ with 1,000 µmol mol^{-1} CO_2 with short dark pulses when needed. The rate of dark respiration was high immediately after illumination and then decreased to a steady level. The rates of dark respiration (R_n) were taken from this steady rate of respiration during 15 to 20 min after darkening. This rate of dark respiration was approximated as the rate of respiration under light from process as other than photorespiration. P_{max} was corrected for dark respiration and it was referred to the maximum gross photosynthetic CO_2 assimilation (Pg_{max}) in this study. The rates of Pg_{max} with dates of sowing and spacing at different growth stages were shown in Figure 5. The maximum values of Pg_{max} were quite high in treatments T_2 and T_3 in dates of sowing and T_6 and T_7 in spacing experiment indicating that the plants were healthy. On other occasions the

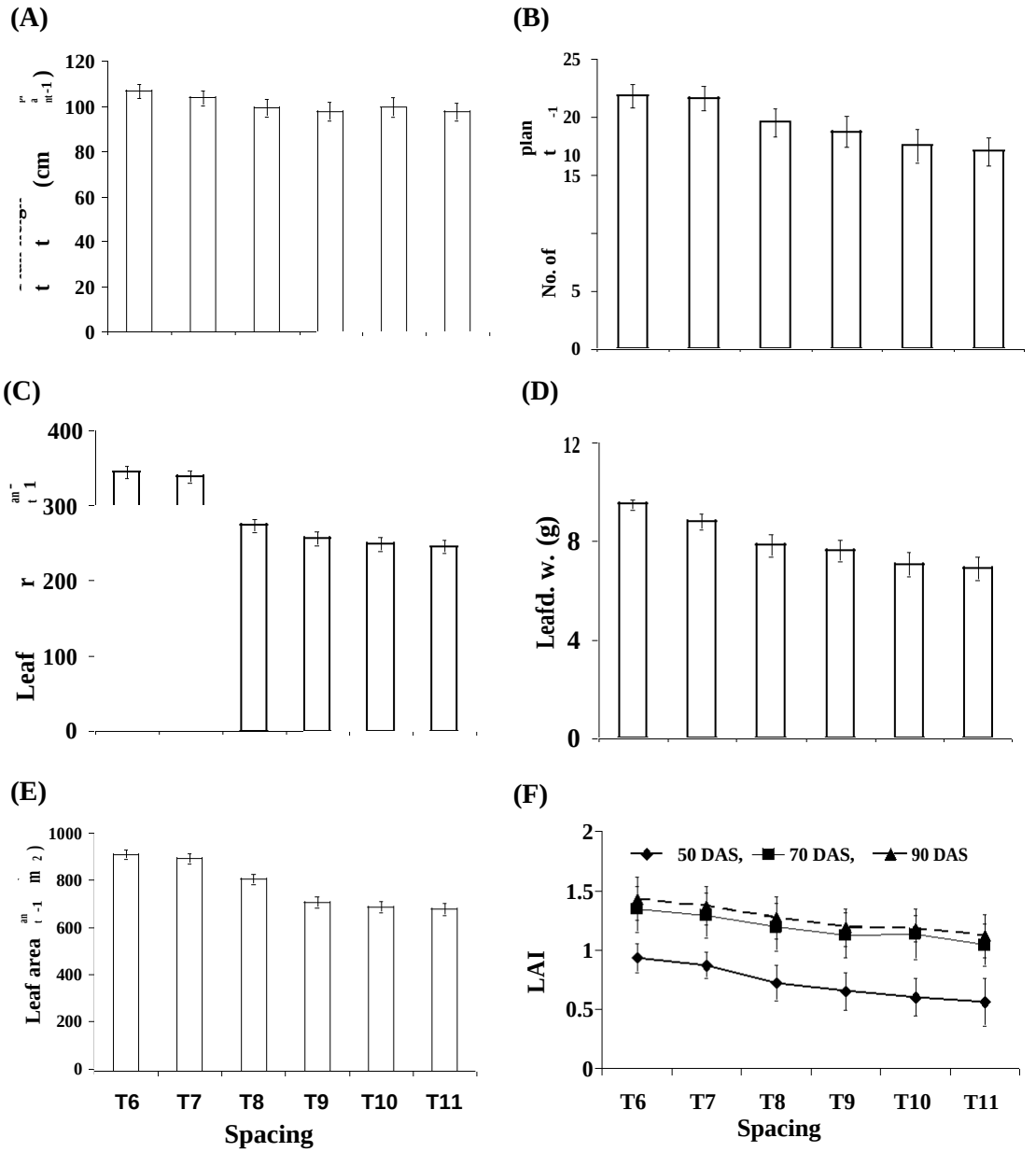

Figure 3. Plant growth characters in *P. indica* at 90 DAS under the influence of different spacing treatments. Bars represent SEM (n=10) at LSD (*P* = 0.05). LSD for A, B, C, D and E are 3.56, 1.43, 6.17, 0.93 and 70.7, respectively; while for LAI, LSD is 0.13. 0.09 and 0.10 at 50, 70 and 90 DAS, respectively. T6: 50×15 cm, T7: 60×15 cm, T8: 65×15 cm, T9: 70×15 cm, T10: 75×15 cm and T11: 80×15 cm.

rates of Pg_{max} decreased during development (Figures 3 and 4). Subramanyam and Dutta (2000) also got such trend in buck wheat while measuring leaf photosynthetic characteristics.

In yield data, results revealed that economic yield (seed) is highly significant and the yield recorded was maximum in T_2 (15th November sowing) and T_16 (50×15 cm spacing) giving an yield of 10.8 to11.6 q ha^{-1} followed by T_3 (30th November sowing) which is on par with T_2 and T_7 (60×15 cm spacing) which is on par with T_6, whereas, minimum yield was recorded to the tune of 5.8 to 6.3 q ha^{-1} which is 87% less as compared to the maximum (Figure 6). Harvest index (HI) was also significant and was in the range of 6.2% (T_5) to 14.6% (T_2) in date of sowing experiment, whereas it was in the range of 9.8 (T_{11}) to 18.3% (T_6) in spacing experiment with a test weight (1000 seeds) in the range of 1.209 g (T_5) to 1.478 g (T_2) and 1.180 g (T_{11}) to 1.520 g (T_6). These results are in agreement with the work done in *P. ovata* by several workers (Ryan and Joiner, 2001; Ramash et al., 1989; Ganpat et al., 1992; Baghalian, 1999).

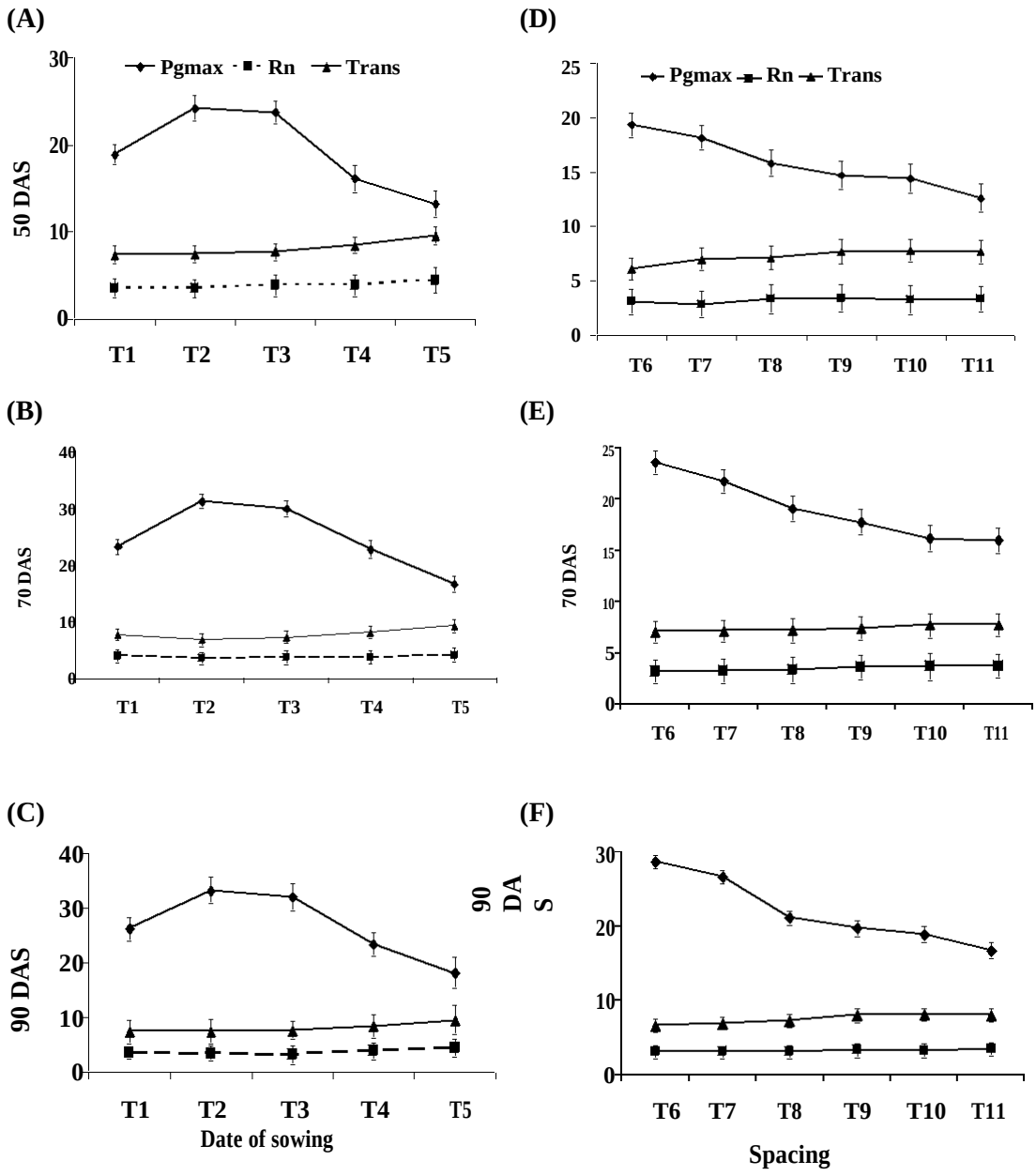

Figure 4. Total chlorophyll content (mg chl. g^{-1} f.w) at 50, 70 and 90 DAS in *P. indica*. Bars represent SEM (n = 5) at LSD (*P* = 0.05). A: Date of sowing (T1-T5); B: Spacing (T6-T11). n = 5 means 5 replications from each plot (total 4 plots) from each treatment.

The results revealed that sowing between 15-30 November would be beneficial for the better growth of the plant and sowing early and late in the months of October and December would not be suitable for this crop. Results of Yield data further revealed that all the yield parameters were significant and maximum yield could be achieved in T_2 (15th November sowing) and spacing at 50 × 15 cm would produce more growth in terms of plant height, leaf growth and dry matter accumulation in leaf, stem and root and yield followed by spacing at 60×15 cm.

Results indicated that the sowing date had highly significant effects on plant height, number of branches and number of flowers per plant, seed yield, swelling factor and weight of 1000 seeds (*P* = 0.05). The mean comparisons of the above-mentioned characters which were planted on 15th November grew much better compared with those planted on other sowing dates except 30th November sowing, which was at par (Figures 1 to 7). On the other hand, seeds sown on 30th November showed significantly (*P* = 0.05) more swelling compared

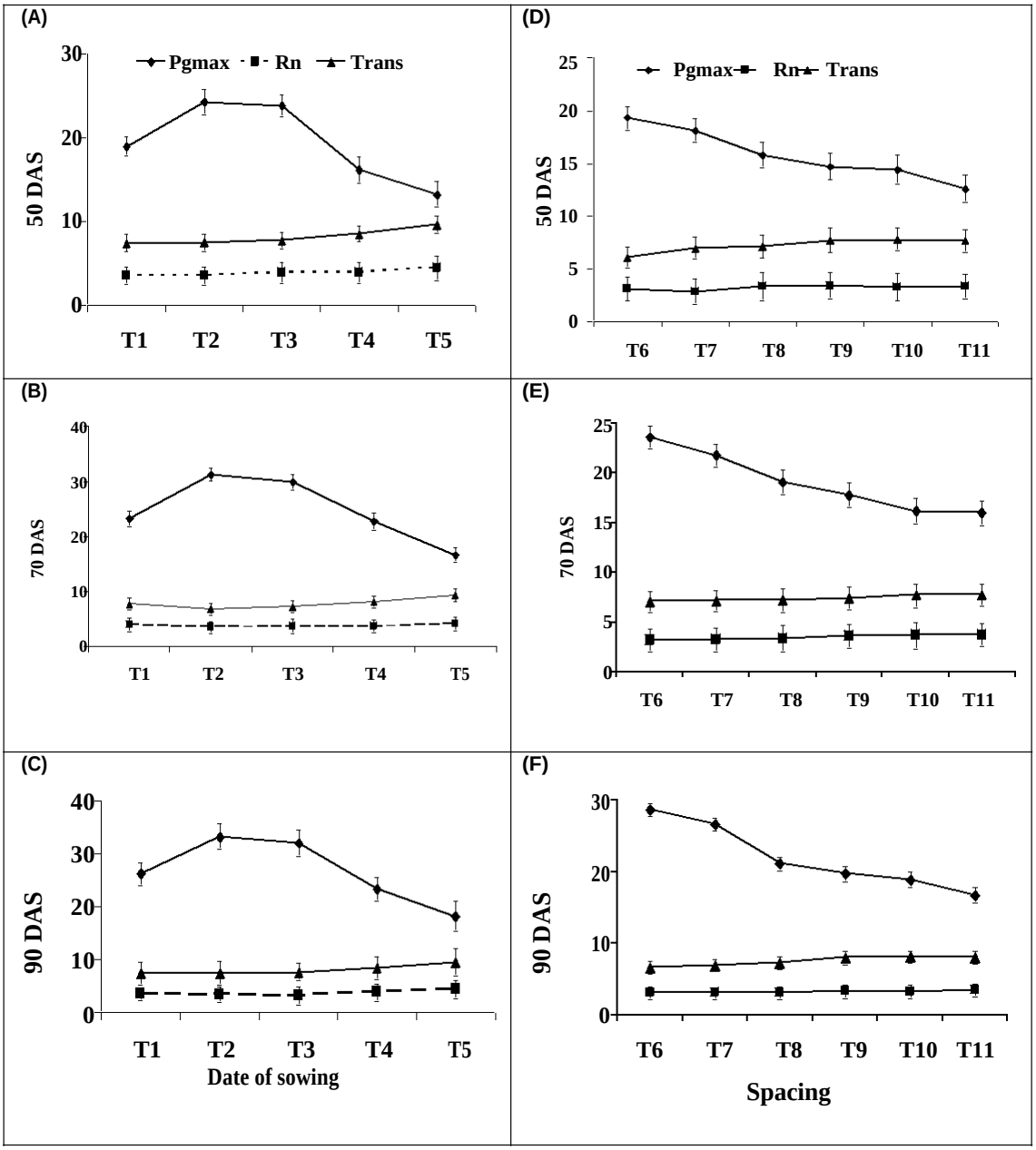

Figure 5. Response of net photosynthetic rate ($P_{gmax:}$ µmol m^{-2} s^{-1}), respiration (Rn: µmol m^{-2} s^{-1}) and transpiration (mmol m^{-2} s^{-1}) to different dates of sowing and spacing in *P. indica* at 50, 70 and 90 DAS. Bars represent SEM (n=4) for each treatment at LSD (*P* = 0.05). A-B-C represent dates of sowing and D-E-F represent spacing effect at 50, 70 and 90 DAS, respectively.

to those sown on other dates (Figure 7). Hence, it can be concluded that the sowing date played an important role on the growth parameters and seed characteristics of *P. indica*. Ramash et al. (1989) also indicated similar trend in *P. ovata*. The correlation testing indicates that only the seed yield trait among other independent variables tested showed a significant positive effect (*P* = 0.05) on seed swelling.

Plants known as medicinal are rich in secondary metabolites and have potential as drugs. The biosynthesis of the secondary metabolites of the medicinal plants is under genetic control, and environmental factors play an important role (Yanive and Palevitch, 1982; Omidbaigi, 2000). Environmental factors such as cultivation practices (such as sowing date, geometry and water supply) have marked effects on plant growth and the production of secondary metabolities (Randhawa et al., 1992; Ryan and Joiner, 2001; Yanive and Palevitch, 1982).

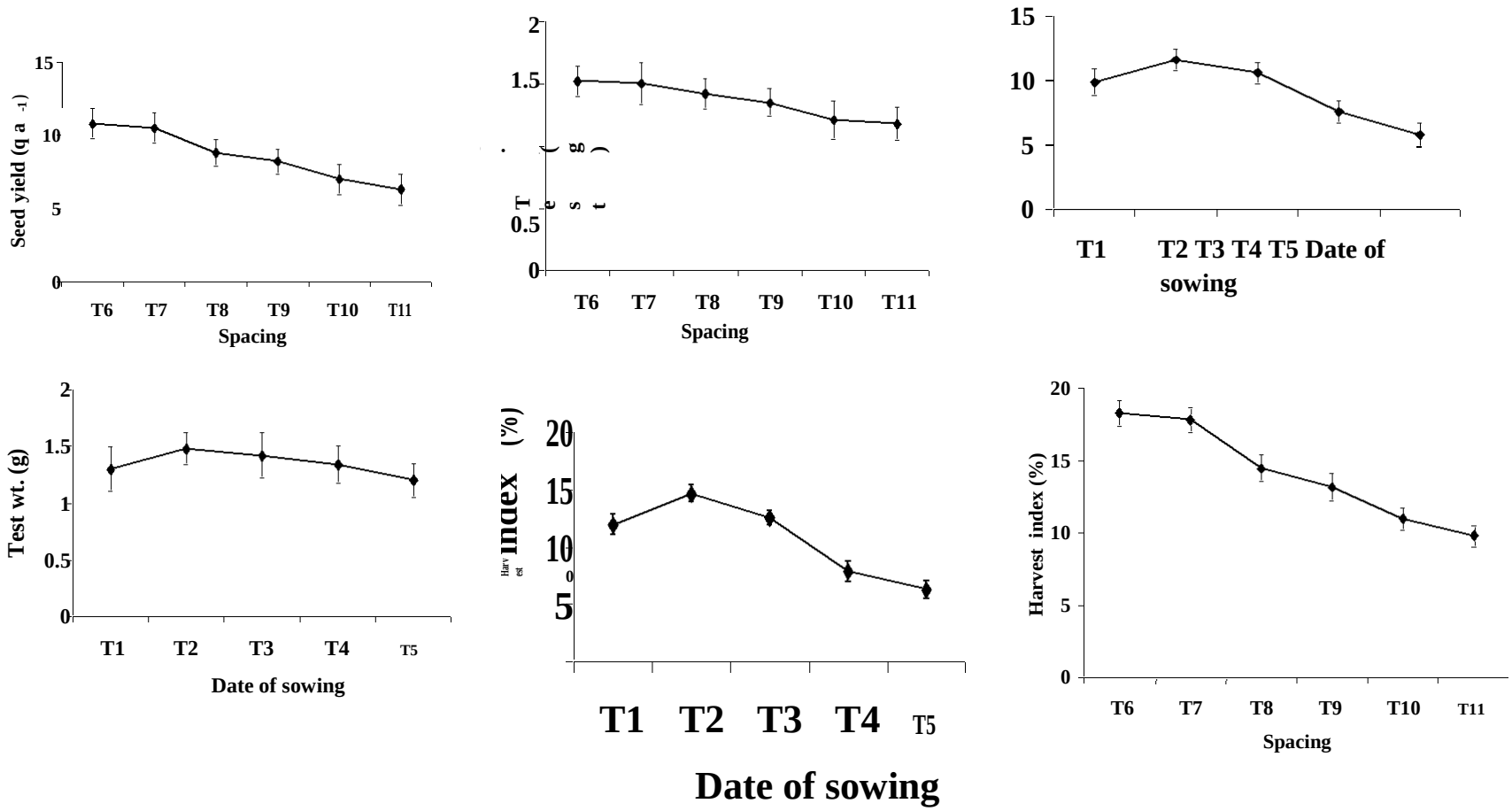

Figure 6. Test weight, seed yield and HI of *P. indica* under the influence of dates of sowing and spacing. Bar lines represent SEM (n=4) at LSD (P = 0.05); T1: 30th Oct, T2: 15th Nov., T3: 30th Nov., T4: 15th Dec., T5: 30th Dec., T6: 50×15 cm, T7: 60×15 cm, T8: 65×15 cm, T9: 70×15 cm, T10: 75×15 cm and T11: 80×15 cm.

In this work, sowing dates showed conspicuous effects on all growth and development examined on *Plantago indica*. These data are in agreement with those reported by Koul and Sareen (1999) and Karimzadeh and Omidbaigi (2004). Isabgol seeds sown between 15th-30th November were first grown normally and produced better growth and gave maximum yield, whereas, seeds sown in October and December could not produce much as the plants were reduced in growth and gave very poor yield. Gas exchange parameters, LAI and chlorophyll content were also influenced due to these dates of sowing and spacing. This information at this point becomes very important for a species which has been recently brought under cultivation. Further, information on gas exchange parameters and TCC give credence to the effect of different dates of sowing and spacing on growth and yield of plants. According to this, it can be deduced that *P. indica* is a growth sensitive crop, therefore, its seeds should not be

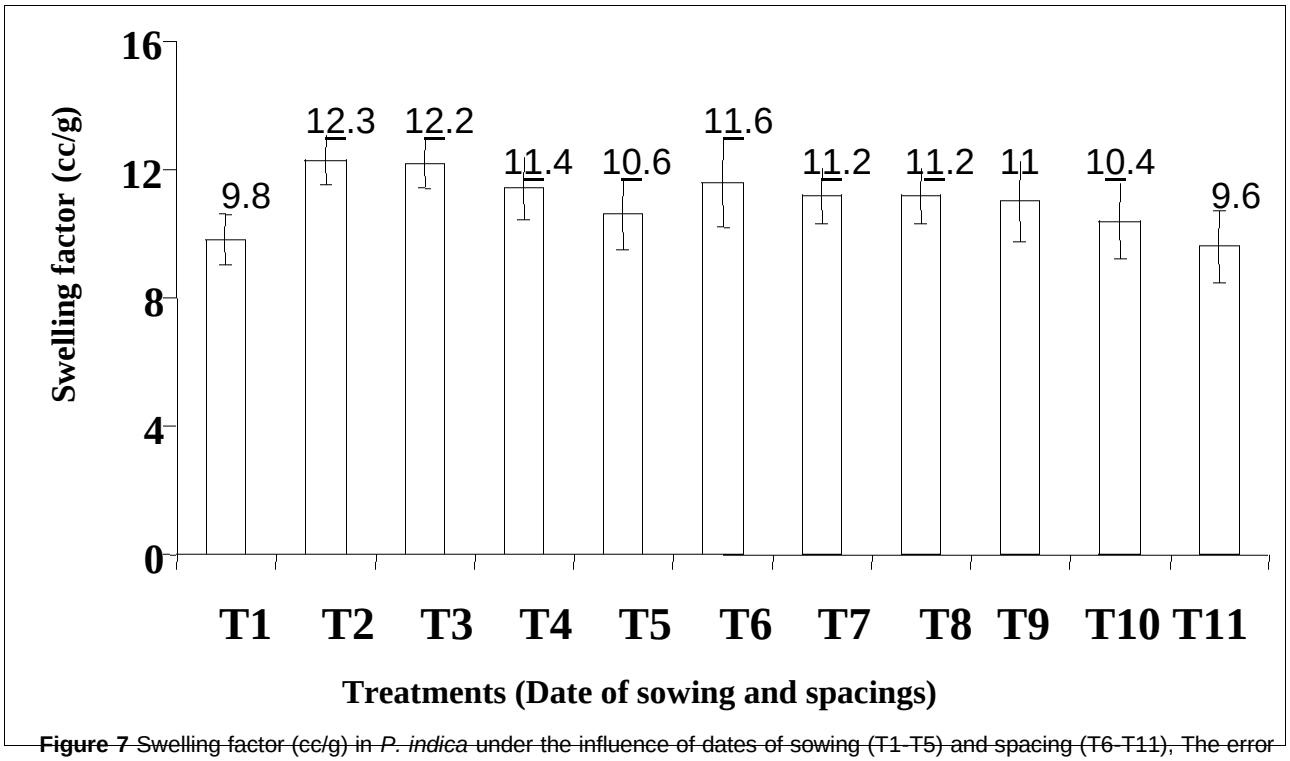

Figure 7 Swelling factor (cc/g) in *P. indica* under the influence of dates of sowing (T1-T5) and spacing (T6-T11), The error bars represent SEM (n=4) at LSD (*P* = 0.05). T1: 30th Oct, T2: 15th Nov., T3: 30th Nov., T4: 15th Dec., T5: 30th Dec., T6: 50×15 cm, T7: 60×15 cm, T8: 65×15 cm, T9: 70×15 cm, T10: 75×15 cm and T11: 80×15 cm

sown in the early October or later in the month of December. In other words, early sowing in the Anand region can damage the emergence of its seeds and potentially can restrict the early seed growth.

According to such resultant data, among five sowing dates studied, 15-30th November sowing with 50 × 15 cm spacing is suggested as the best sowing date and spacing for *Plantago indica* to produce more growth and better yield. There is need to focus on targeting genotypes of *P. indica* with higher swelling factor and more seed yield with a HI more than 20 % to compete with *P. ovata* in the commercial market.However, this species is not a better yielder than *P. ovata*, yet there is potential in this species which is evident from the results of seed yield and HI which is very close to *P. ovata*. This species needs further study with reference to development of better yielding genotypes with more swelling factor than *P. ovata.*

ACKNOWLEDGEMENT

Author profusely thanks Dr. Satyabrata Maiti, Director, Directorate of Medicinal and Aromatic Plants Research, Boriavi, Anand, Gujarat for giving advice and for providing necessary facilities for this study.

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