



Research Article

Screening of *Plantago* species for physiological parameters in relation to seed yield

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(Received: 15 Sep 2010; Accepted: 31 Oct 2010)

Abstract:

Isabgol is a major export oriented medicinal crop of India. The genetic variability available in this crop is limited owing to the narrow gene pool existing in our country. The physiological and growth characteristics of selected 7 species of *Plantago* were studied at DMAPR, Boriavi to investigate the relationship with the seed yield. Among the species studied, the lowest SLA (specific leaf area) of $0.15 \text{ cm}^2 \text{ g}^{-1}$ was noticed in *P. lanceolata*. SLW (specific leaf weight) was recorded the lowest in *P. coronopus* (4.82 g cm^{-2}) which was at par with *P. indica*. LAI also varied significantly among the species studied with the lowest being in *P. arenaria* (2.16) and *P. serraria* had the highest LAI (3.87) among the species studied. *P. ovata* produced the highest biomass ($21.49 \text{ g plant}^{-1}$), while *P. psyllium* had comparable DM, however produced low seed yield ($1.09 \text{ g plant}^{-1}$) with HI of 0.061. *P. lanceolata* and *P. ovata* showed higher thousand seed weight among the species. *P. indica* ($29.99 \mu\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1}$) had the highest net photosynthetic rate among the species. P_n values for all the studied species were negatively correlated with their mean area of individual leaf ($R^2 0.366$) and also with mean dry weight of leaves ($R^2 0.366$). However, total biomass of plant was positively correlated with seed yield ($R^2 0.366$). Thousand seed weight of studied species were significantly and positively correlated with the seed yield per plant ($R^2 0.771$). In conclusion, leaf characteristics like high SLA, P_n , g_s and TSW will positively contribute to the seed yield. These characters may be considered in the breeding programmes for the yield improvement of isabgol.

Key words: *Isabgol*, *Plantago* species, physiological parameters, seed yield.

Introduction

Isabgol (*Plantago ovata* Forsk.) is an important medicinal plant. It is cultivated during winter season (Rabi) in North Gujarat, parts of Rajasthan, Madhya Pradesh, to a small extent in Haryana, Uttar Pradesh and Karnataka (Maiti and Mandal, 2000) in about 1,30,000 ha (2006-07). India is the major producer and exporter of isabgol, seed husk fetching about Rs. 200 crores annually. The husk, derived from the seed gained importance as medicine as laxative throughout the world. It has been used in the indigenous medicine for many centuries (Chopra *et al.*, 1958). *Plantago* is one of the most important genus in the family *Plantagenaceae* which comprises about 200 species, of which 10 occurs in India. The center of origin of this species is the Mediterranean region. Since it is an introduced crop to India, the gene pool available in the country is very narrow and within the species of *P. ovata*, the variability for economically important traits are narrow (Lal *et al.*, 2000). Consequently, the efforts for generating genetic variability for its improvement are met with limited success. The isabgol varieties released so far in our country hardly show any morphological variation or morphological markers to distinguish them from each other and are similar in their yield potential. A RAPD analysis of different *Plantago* species by Singh *et al.*

(2009) showed high level of polymorphism on the species level, but within species only low level of polymorphism was observed and from the RAPD study, the accessions were not differentiated, but intra-specific differences recorded in all three species were much less (range for *P. ovata*, 2-17%; for *P. lanceolata*, 3-15%, and for *P. major*, 2-11%) in comparison to inter-specific diversity.

Because of its commercial importance and new IPR regime, our efforts to collect the exotic collections of isabgol germplasm from the native lands of this species are increasingly difficult. One of the alternative ways to make variability for its improvement is through interspecific hybridization. The selection of such species must be based on certain scientific principles that can be obtained only through systematic study on various aspects in these species. Information available in these aspects is scanty and unreliable. Hence, the present study was undertaken to investigate the physiological, biochemical and anatomical characteristics of selected species of *Plantago*. The selected species in addition to *P. ovata* have agronomic interest, because some of them may be a source of valuable traits for future isabgol breeding and to improve seed quality, disease resistance, heat and cold tolerance,

photosynthetic rates, early vigour, and micronutrient acquisition. The crop improvement in any crop will require a thorough understanding of physiology of the crop along with its genetics and agronomic requirements. The objectives for this study were to collect field data on plant characters in selected species of *Plantago* and study the growth and physiological aspects with reference to dry matter production and seed yield.

Material and Methods

The experiments were conducted at the research farm of Directorate of Medicinal and Aromatic Plants Research, Boriavi, Anand, Gujarat, India (73° E, 22.5° N). Nine accessions of *P. ovata* and six other *Plantago* species were used in the present study. Plants were raised in rows 30 cm apart with 20 cm between plants. The design used was RBD with five replications. The leaf area was measured by using portable leaf area meter (LI-3000A, LI-COR.). Leaf samples from each species were collected randomly between 10.00 and 11.00 hrs from the field and leaf area was determined immediately in laboratory using leaf area meter. Leaf Area Index (LAI) was recorded using Plant Canopy Analyzer (LAI-2000, Li-cor Inc, USA). The LAI was recorded in the field at 50% flowering (75-90 DAS) either during the morning between 9.00 and 10.00 hrs or evening, between 4.00 and 5.00 hrs in order to avoid the direct sun light which may cause reflections from canopy resulting in the lower LAI value. Care was taken to avoid changing light conditions and cloud movements during the measurement cycles. The canopy light probe was kept steadily at a particular level above the ground uniformly for all the readings to eliminate the errors in LAI values. Fresh weight/dry weight (DW) ratio, specific leaf area (SLA), specific leaf weight (SLW) were calculated in different genotypes. Leaf gas exchange parameters (net CO₂ assimilation, stomatal conductance and intercellular CO₂ concentration) were measured using a portable open infrared gas analyzer (LI-6400, LI-COR Inc., Lincoln, USA). Measurements were made using a standard leaf chamber (2×3 cm) having transparent top during active photosynthetic period (10:00–11:30 and 14:00–15:00 hrs) under clear sky at ambient CO₂ and relative humidity. Required statistical analysis was done using MSTAT-C version 1.4 (Crop and Soil Science Division, Michigan State University, USA).

Results and Discussion

Leaf characteristics varied widely at post anthesis and seed maturation stage among *Plantago* species. Mean single leaf fresh weight was the lowest in *P. arenaria* (120.33 mg) which was at par with that of *P. psyllium*

and it was the highest in *P. lanceolata* (2555.80 mg) (Table 1). Correspondingly, the leaf dry weight (LDW) was lowest in *P. arenaria* (16.13 mg) which was at par with that of *P. psyllium* and the highest LDW was recorded in *P. lanceolata* (353.76 mg). Mean area of individual leaf did not vary greatly among the Isabgol accessions studied. Mean leaf area (LA) of single leaf was the lowest in *P. arenaria* (2.81 cm²) which was at par with that of *P. psyllium* and *P. lanceolata* had the highest (LA) (54.06 cm²). While in the accessions of *P. ovata* there was less variation among genotypes, JI-4 had the highest (15.54 cm²) and the lowest was recorded in EC-1243 (12.16 cm²).

Among the species studied, the lowest specific leaf area (SLA) of 0.15 cm² g⁻¹ was noticed in *P. lanceolata*. Specific leaf weight (SLW) was the lowest in *P. coronopus* (4.82 g cm⁻²) which was on par with *P. indica*. LAI also varied significantly among the species studied with the lowest being in *P. arenaria* (2.16) and *P. serraria* had the highest LAI (3.87) among the species studied. In the cultivated *P. ovata*, as expected the variation in the LAI was lower among different accessions of *P. ovata* (Table 1). In many field crops, strong correlation exists between LAI and total biomass production. In the higher LAI group consisting of *P. ovata*, *P. syllium*, *P. lanceolata* and *P. indica* strong correlation was observed for LAI and seed yield (R² = 0.78). There was a wide variation among the species studied for the biomass (BM) production, seed yield potential and harvest index (Table 2). Among the species *P. ovata* produced high biomass (21.49 g) per plant with compact plant, thereby resulting in higher LAI. *P. psyllium* had comparable DM, however produced low seed yield (1.09 g plant⁻¹) with HI of 0.061. This species produced higher vegetative growth resulting in very low seed production and low harvest index. Other species of *Plantago* produced much lesser biomass in comparison to *P. ovata*. Least BM producers were *P. indica* followed by *P. arenaria*.

Thousand seed weight (TSW) which is very important yield component, showed wide variation among the species. It ranged between 0.179 g in *P. serraria* to 1.488 in *P. lanceolata* (Table 2). Among the 7 species studied, *P. lanceolata* and *P. ovata* showed higher TSW. *P. indica* with the TSW of 1.238 g, closely followed the former species. Owing to the lower total BM, *P. indica* had the highest (0.294) harvest index (HI) among the species, which was higher than cultivated *P. ovata*. However, the seed yield per plant was the highest (4.15g) in *P. ovata* followed by *P. lanceolata* (4.12g). Stomata frequencies of individual plants change according to

environmental conditions. However, numbers of stomata and their distributions tend to show similar pattern in species of same genus in a particular environmental condition. *Plantago* species showed nearly equal stomatal frequency (amphistomatic) in lower and upper leaves (data not shown). However, a small variation was found among the species. *P. arenaria* had highest stomata frequency in upper and lower surfaces i.e. 37.7 and 34.0 mm⁻² respectively.

The *Plantago* species studied under field conditions showed wide variations in their morphological, physiological characteristics and seed yield due to their growth habits and canopy structures. Since these species originated in different ecological regions, they require different growth conditions for normal growth and higher biomass production. *P. lanceolata* and *P. serraria* had higher individual leaf weight compared to *P. ovata* and these species had lower SLA and high SLW. Lower leaf number and broader leaf blade contributed to these parameters. High LAI in *P. lanceolata* and *P. ovata* maximised light interception by canopy and maintained the supply of assimilates to the reproductive organs, resulting in higher grain yield. In other studies, increased LAI under high photon flux density favour higher biomass accumulation (Nassiri and Elgersma 1998) and improved seed yield under field conditions in grass species. Among the species, *P. ovata* had high mean LA of individual leaf, mean DW of leaf, SLA and SLW. It also recorded high LAI, high P_n, higher stomatal conductance and transpiration rate. In addition to the leaf characteristics and gas exchange values, high TSW and HI also favorably contributed to increased seed yield recorded in the accessions. Among high LAI group, *P. lanceolata* and *P. coronopus* had higher SLW and lower SLA due to thicker leaves. Studies have shown that SLA appeared to be the most important factor explaining variation in RGR and hence species with a high SLA had the highest RGR (Villar et al., 2005). Apparently fast growers produced leaves with a low investment in biomass. Differences in SLA can be ascribed either to morphological factors (thickness of the leaves, vein structure) or to the chemical composition of leaf biomass. Hence, investment in leaf area has the incentive of higher carbon gain and faster growth. Studies on *Taraxacum* (Roetman and Sterk 1986) and in two *Plantago* subspecies (Dijkstra and Lambers 1986) and for eight wild species Poorter and Remkes (1990) reported similar positive relationship between leaf area and DM accumulation. Potter and Jones (1977) claimed that leaf area partitioning (LAP, the ratio between newly formed leaf area and new plant weight) is the important factor explaining genotypic differences in growth.

Photosynthetic and other gas exchange parameters of different species showed significant variations at flowering stage. *P. indica* (29.99 μmol CO₂ m⁻²s⁻¹) had the highest net photosynthetic rate (P_n) among the species. It was nearly 50% higher than the cultivated *P. ovata* which had a mean P_n of 19.57 μmol CO₂ m⁻²s⁻¹ (Fig 1-A). Lowest P_n of 15.3 μmol CO₂ m⁻²s⁻¹ was recorded in *P. lanceolata*. Leaf dark respiratory rate (R_d) showed similar trend as P_n. *P. serraria* had the highest R_d while least was recorded in *P. lanceolata*. Most of the other species including *P. ovata* showed R_d in the range of 3.2-3.8 μmol CO₂ m⁻²s⁻¹. Leaf stomatal conductance (g_s) and transpiration (Tr_{leaf}) showed similar trend in the species studied (Fig 1-B). Highest g_s and leaf Tr was recorded in *P. ovata*, whereas, *P. serraria* had the lowest g_s and *P. lanceolata* showed the lowest Tr_{leaf} among the species. P_n values for all the studied species were negatively correlated with their mean area of individual leaf (R² 0.366, P < 0.05, Figure 2-A) and also with mean dry weight of leaves (R² 0.366, P < 0.05, Figure 2-B). However, total biomass of plant was positively correlated with seed yield (R² 0.366, P < 0.05, Figure 3-A). Interestingly, thousand seed weight of studied species were significantly and positively correlated with the seed yield per plant (R² 0.771, P < 0.05, Figure 3-B).

Higher P_n achieved by *P. indica* is attributed to the smaller and narrow leaf blade as well as high SLA coupled with lower SLW. Higher stomatal conductance is also attributed to higher P_n observed in many other species and inherently low conductance (both mesophyll and stomatal) impairs plant photosynthetic productivity under favourable conditions (Niinemets et al. 2009). Lower SLA and higher SLW was responsible for the lowest P_n observed in *P. lanceolata*. The leaves were larger and broader in this species also results in low P_n and lower g_s. High correlation of leaf growth characteristics like mean LA of individual leaf and DWL among the species is also found as reason for the variation in P_n.

There was a remarkable variation in the seed yield among the seven *Plantago* species studied. The higher biomass partitioning in seeds was noticed in only few species like, *P. ovata*, *P. lanceolata* and *P. indica* which showed HI of above 0.20. *P. serraria* and *P. arenaria* had the least among them. There was a positive correlation between total biomass and seed yield among the species. Seed mass appears to be the principal driver of variation in productivity of seed yield, and consequently is among the most important dimensions of ecological variation across species (Henery and Westoby, 2001). In conclusion, leaf



characteristics high SLA, high P_n coupled with elevated g_s with high TSW will positively contribute to the seed yield. High correlation ($R^2 = 0.77$) between TSW and seed yield among the species may contribute to high HI. These characters may be considered in the breeding programmes for the yield improvement of isabgol.

or specific leaf area depends on the time scale.
Plant and Soil, **272**: 11–27

Acknowledgement

Authors are thankful to the Director, DMAPR for providing facilities for this work.

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Table 1. Leaf characteristics of *Plantago* species

Name of the species	Mean Fresh weight of leaf (mg)	Mean Dry weight of leaf (mg)	Mean LA (cm ²)	SLA (cm ² g ⁻¹)	SLW (g cm ⁻²)	LAI
<i>P. ovata</i> cv. <i>Pb-96</i>	647.33	74.47	13.82	0.19	5.33	3.52
<i>P. ovata</i> cv. <i>A-24</i>	600.67	78.20	13.22	0.17	6.01	3.00
<i>P. ovata</i> cv. <i>GI-2</i>	649.07	80.67	14.11	0.18	5.66	3.46
<i>P. ovata</i> cv. <i>p-33</i>	595.47	79.93	13.55	0.17	5.91	3.35
<i>P. ovata</i> cv. <i>MIB-122</i>	591.60	73.93	14.21	0.19	5.24	2.54
<i>P. ovata</i> cv. <i>EC-1243</i>	506.47	72.73	12.16	0.17	5.96	3.04
<i>P. ovata</i> cv. <i>Niharika</i>	655.20	80.07	13.42	0.17	5.94	3.47
<i>P. ovata</i> cv. <i>JI-4</i>	786.73	110.27	15.54	0.17	7.04	2.92
<i>P. ovata</i> cv. <i>PS-19</i>	623.93	80.73	14.80	0.19	5.44	3.62
<i>P. coronopus</i>	838.07	71.13	14.79	0.21	4.82	2.48
<i>P. serraria</i>	1119.73	103.47	16.49	0.16	6.28	3.87
<i>P. arenaria</i>	162.00	23.80	4.20	0.17	5.84	3.81
<i>P. arenaria</i> <i>EC-453105</i>	120.33	16.13	2.81	0.18	5.72	2.16
<i>P. psyllium</i>	122.80	20.33	3.23	0.16	6.39	2.65
<i>P. lanceolate</i>	2555.80	353.67	54.06	0.15	6.53	3.57
<i>P. indica</i>	309.27	32.53	6.50	0.20	5.03	3.43
<i>CD (p=0.05)</i>	48.56	13.60	1.24	0.02	0.63	0.58

LA-leaf area, SLA- specific leaf area, SLW- specific leaf weight, LAI-leaf area index

Table 2. Plant dry matter content and seed yield of different *Plantago* species

Name of Species	Weight of whole plant (g)	Seed yield per plant (g)	Thousand seed weight (g)	Harvest index
<i>P. ovata</i> *	21.49	4.15	1.445	0.193
<i>P. coronopus</i>	12.95	0.51	0.192	0.039
<i>P. serraria</i>	12.23	0.53	0.179	0.043
<i>P. arenaria</i> +	11.91	0.67	0.899	0.056
<i>P. psyllium</i>	17.88	1.09	0.936	0.061
<i>P. lanceolata</i>	16.37	4.12	1.488	0.251
<i>P. indica</i>	11.41	3.35	1.238	0.294
<i>CD (p=0.05)</i>	1.57	0.42	0.13	0.034

* mean of 9 accessions

+ mean of two accessions

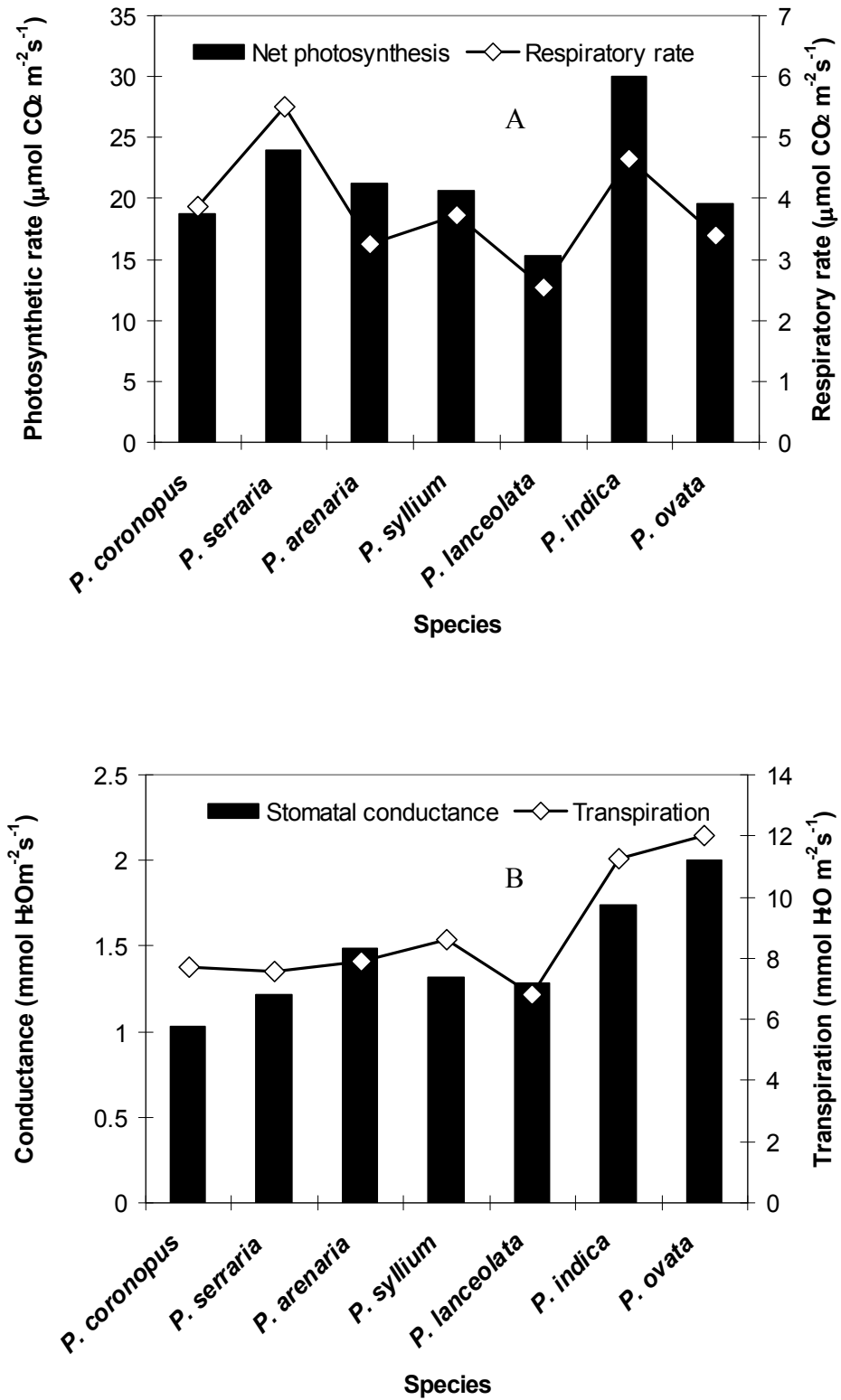


Figure 1. Variation in gas exchange parameters of *Plantago* species, net photosynthesis - dark respiration (A) and stomatal conductance - transpiration (B) at flowering.

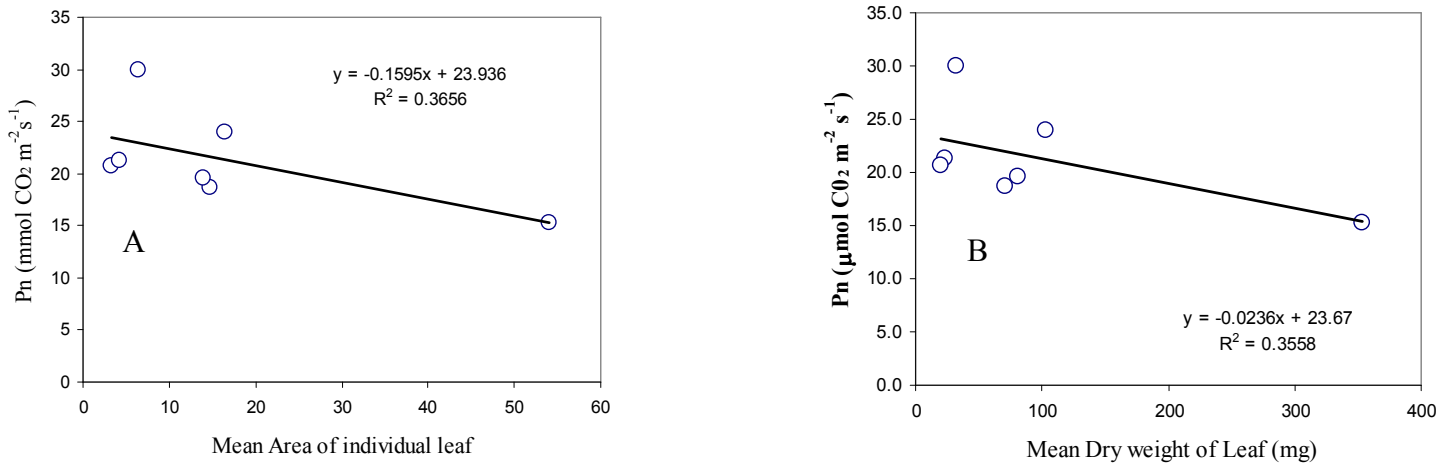


Figure 2. Relationship between Pn and two growth variables: mean area of individual leaf (A) and dry weight of leaf (B) of *Plantago* species.

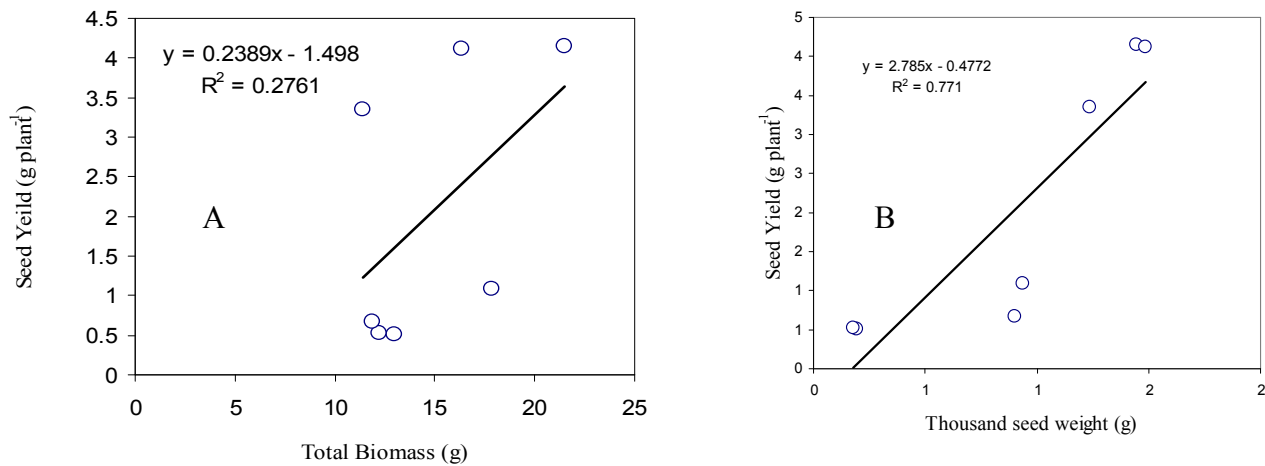


Figure 3. The relationship of seed yield of *Plantago* species with total biomass (A) and thousand seed weight (B)