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STANDARDIZATION OF NUTRIENT BUDGET FOR ISABGOL (*Plantago ovate* L.)

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ABSTRACT

Isabgol (*Plantago ovata* L.) is an important medicinal and commercial crop valued for its seed husk, which possesses high dietary fiber content and pharmaceutical applications. Optimization of nutrient management is crucial to enhance its growth, yield, and quality while ensuring sustainable soil health. The present study was undertaken to standardize the nutrient budget for Isabgol under varying fertilizer regimes. Field experiments were conducted using different combinations of nitrogen, phosphorus, and potassium, along with organic manures, to determine nutrient uptake, yield response, and nutrient use efficiency. Data on soil nutrient status before sowing and after harvest, biomass accumulation, seed yield, husk yield, and nutrient uptake were analyzed to establish the crop's nutrient requirement and balance sheet. Results indicated that an integrated approach combining recommended doses of NPK with organic amendments improved yield potential, nutrient-use efficiency, and soil fertility compared to sole chemical fertilization. The standardized nutrient budget developed from this study provides a scientific basis for site-specific nutrient management in Isabgol cultivation, ensuring both economic profitability and environmental sustainability.

Keywords: Isabgol, *Plantago ovata*, nutrient budget, nutrient-use efficiency, integrated nutrient management, sustainable cultivation.

Introduction

Isabgol, also known as *Plantago ovata* L., is a plant that is a member of the family Plantaginaceae. It is a crop that is grown during the rabi season and is grown largely for its seeds and seed husk, both of which are abundant in mucilage and have potential therapeutic use. The states of Gujarat, Rajasthan, and Madhya Pradesh are where the majority of the country's harvesting of Isabgol takes place. India is the world's leading producer and exporter of this product. As a natural laxative, dietary fibre supplement, and stabilising agent, the husk that is produced from the seeds is utilised extensively in the pharmaceutical, nutraceutical, and food sectors. The ever-increasing demand for different kinds of herbal products all over the world has greatly increased the economic significance of the cultivation of isabgol. Even though it has a high economic value, isabgol is frequently cultivated in circumstances that are marginal and poor in input, which results in yields that are less than ideal. Because of its shallow root structure and rather sluggish beginning development, the crop is extremely susceptible to the supply of nutrients in the rhizosphere. For the purpose of generating high output and outstanding husk quality, it is vital to have a nutrient supply that is both balanced and appropriate, particularly nutrients such as nitrogen, phosphorus, and potassium. On the other hand, fertilisation that is either inadequate or indiscriminate can result in nutrient mining, decreased soil fertility, and enhanced efficiency in the utilisation of nutrients. To understand the notion of a nutrient budget, one must first quantify the nutrient inputs, which include fertilisers, manures, and other amendments, and then compare these inputs to the nutrient outputs, which include crop absorption and potential losses. With this method, it is possible to ascertain the precise nutrient requirements for optimal crop production while simultaneously preserving the nutrient balance of the soil. A nutrient budget that is standardised for Isabgol will not only be helpful in the process of establishing site-specific nutrient management methods, but it will also encourage sustainable production by limiting the depletion of nutrients or the buildup of an excessive amount of nutrients in the soil. The amount of study that has been conducted on integrated nutrient management and nutrient budgeting in this crop is minimal, despite the fact that there have been some studies that have explored the influence of nitrogen and phosphorus on the growth and production of Isabgol. Therefore, the present work attempts to create an optimised nutrient budget for Isabgol by analysing the impact of alternative fertiliser regimens and organic amendments on yield, nutrient absorption, and soil nutrient dynamics. The findings of this research will be used as a scientific guideline for the production of Isabgol in a manner that is both sustainable and lucrative, regardless of the agroclimatic conditions that are present.

Nutrient Requirement and Fertilizer Management

Several studies have indicated that Isabgol responds positively to nitrogen application, as it enhances vegetative growth, tillering, and seed formation [1]. Nitrogen also influences the mucilage content in the husk, which is a primary quality parameter. Phosphorus plays a vital role in root development and energy transfer, improving nutrient uptake efficiency and contributing to better seed set [2]. Potassium, though required in smaller quantities, enhances stress tolerance, improves seed filling, and contributes to overall plant health [3].

Integrated Nutrient Management (INM)

The concept of integrated nutrient management—combining inorganic fertilizers with organic manures, green manures, or biofertilizers—has gained attention for its potential to enhance soil fertility and improve crop productivity sustainably [4In Isabgol, the use of farmyard manure (FYM) along with recommended NPK doses has been reported to improve yield and quality while maintaining soil organic carbon [5].

Nutrient Budgeting in Crops

Nutrient budgeting is an emerging approach to quantify the balance between nutrient inputs and outputs in an agricultural system ([6]. By measuring nutrient inflows (fertilizers, manures, irrigation water) and outflows (crop uptake, leaching, volatilization), researchers can determine the sustainability of current nutrient management practices. While this approach is well-documented in cereal and oilseed crops [7], limited studies have been conducted on Isabgol. Developing a crop-specific nutrient budget can guide farmers towards more precise, site-specific recommendations, reducing environmental losses and input costs.

Objectives of the Study

1. To assess the effect of different nutrient management regimes (inorganic, organic, and integrated) on the growth, yield, and quality of Isabgol.
2. To quantify nutrient uptake and utilization efficiency of Isabgol under varying fertilizer and manure combinations.

MATERIALS AND METHODS

The present experiment was conducted from December 2006 to April 2007. The main objective was to standardize the most suitable level of nitrogen and phosphorous for quantitative, qualitative and economical point of view for Isabgol (*Plantago ovata*) in this region. The details of the various materials and methods adopted in the present investigation have been described below:

Experimental site:

The present investigation "Standardization of nutrient budget of Isabgol (*Plantago ovata*)" cv. Niharika was conducted at the research farm of Department of Botany at Baring Union Christian College, Batala; during winter season (December – March) of 2005-06 and 2006-2007.

Climate and weather:

Batala is situated at an elevation of 249 meters above the mean sea level, at 31.820N latitude and 75.20E longitude has a tropical and sub-tropical climate with extremes of summer and winter. During the winter months, especially during December and January the temperature drops at low as 4-20 C, while during summer, the temperature reaches more than 450C. The average rainfall is about 100 cm with maximum during July to September with a few occasional showers during the winter months.

Table 1:- Meteorological data during the period (2005-06) of experiment-I

Month	Weeks	Temperature 0 C		Relative humidity		Rainfall
		Max.	Min.	Max.	Min.	(mm)
December	1st week	15.5	14.6	92.2	35.5	0.00
	2nd week	12.6	12.0	93.5	30.2	0.00
	3rd week	11.7	11.3	95.0	34.8	0.00
	4th week	11.8	11.2	93.4	35.0	0.00
January	1st week	13.0	12.3	92.4	43.7	0.00
	2nd week	11.2	10.6	92.7	40.1	0.00
	3rd week	10.8	10.4	94.7	52.0	0.75
	4th week	9.98	9.60	96.1	57.4	1.3
February	1st week	14.6	14.0	93.1	58.4	1.7
	2nd week	26.2	10.7	94.0	56.0	0.36
	3rd week	29.6	13.4	92.0	36.0	0.00
	4th week	29.8	12.0	90.8	41.2	0.00
March	1st week	32.7	15.5	83.0	32.0	0.00
	2nd week	33.0	10.9	83.0	36.0	1.67
	3rd week	32.5	16.5	85.0	34.0	0.00
	4th week	34.2	15.4	84.5	33.0	0.00
April	1st week	35.6	19.00	88.00	28.00	0.00
	2nd week	34.6	19.00	90.00	28.50	0.00

Table 2:- Meteorological data during the period (2006-07) of experiment-II

Month	Weeks	Temperature 0 C		Relative humidity		Rainfall
		Max.	Min.	Max.	Min.	(mm)
December	1st week	15.5	14.6	92.2	35.5	0.00
	2nd week	12.6	12.0	93.5	30.2	0.00
	3rd week	11.7	11.3	95.0	34.8	0.00
	4th week	11.8	11.2	93.4	35.0	0.00
January	1st week	13.0	12.3	92.4	43.7	0.00
	2nd week	11.2	10.6	92.7	40.1	0.00
	3rd week	10.8	10.4	94.7	52.0	0.75
	4th week	9.98	9.60	96.1	57.4	1.3
February	1st week	14.6	14.0	93.1	58.4	1.7
	2nd week	26.2	10.7	94.0	56.0	0.36
	3rd week	29.6	13.4	92.0	36.0	0.00
	4th week	29.8	12.0	90.8	41.2	0.00
March	1st week	32.7	15.5	83.0	32.0	0.00
	2nd week	33.0	10.9	83.0	36.0	1.67
	3rd week	32.5	16.5	85.0	34.0	0.00
	4th week	34.2	15.4	84.5	33.0	0.00
April	1st week	35.6	19.00	88.00	28.00	0.00
	2nd week	34.6	19.00	90.00	28.50	0.00

Source: Agro-meteorological Department, Raja Sansi Airport, Amritsar (35 Km away from the research site).

Soil and soil sampling:

In order to study the physical and chemical analysis of soil, a composite soil sample was taken from 10-30 cm soil depth with the help of soil auger. The soil samples were mixed together, air-dried, finely powered and again mixed. A representative soil sample of 5 gm for each analysis was then drawn and subjected to mechanical and chemical analysis.

Mechanical analysis:

The mechanical analysis was done by Bouyoucus hydrometer method. The result of the analysis is given below:

Table 3:- Physical analysis of soil

Components	Percentage
Sand Silt Clay	60.60 19.30 20.10
Textural class	Sandy loam

Chemical analysis:

The chemical analysis was done for nitrogen, phosphorus, potassium, pH, EC and organic carbon. The result of the analysis has been presented in the following table.

Table 4:- Chemical analysis of soil

Components	Quantity	Method employed
Organic carbon %	0.28	Walkley and black (1956)
Nitrogen Kg/ha	210	Alkaline permanganates method (Subbaiah and Asija, 1956)
Phosphorus (P2O5) kg/ha	18.50	Olsen's Colorimetric method (Olsen et al. 1954)
Potassium (K2O5) Kg/ha	240	Flame Photometer (Toth and Princ 1949)
pH	7.3	Digital electronic pH meter.
EC (dSm-1)	0.32	Conductivity meter (Systronics)

It is evident from the above table that the soil of the experimental plot was sandy loam in texture, poor in nitrogen, comparatively rich in phosphorus and potash with slightly alkaline in nature.

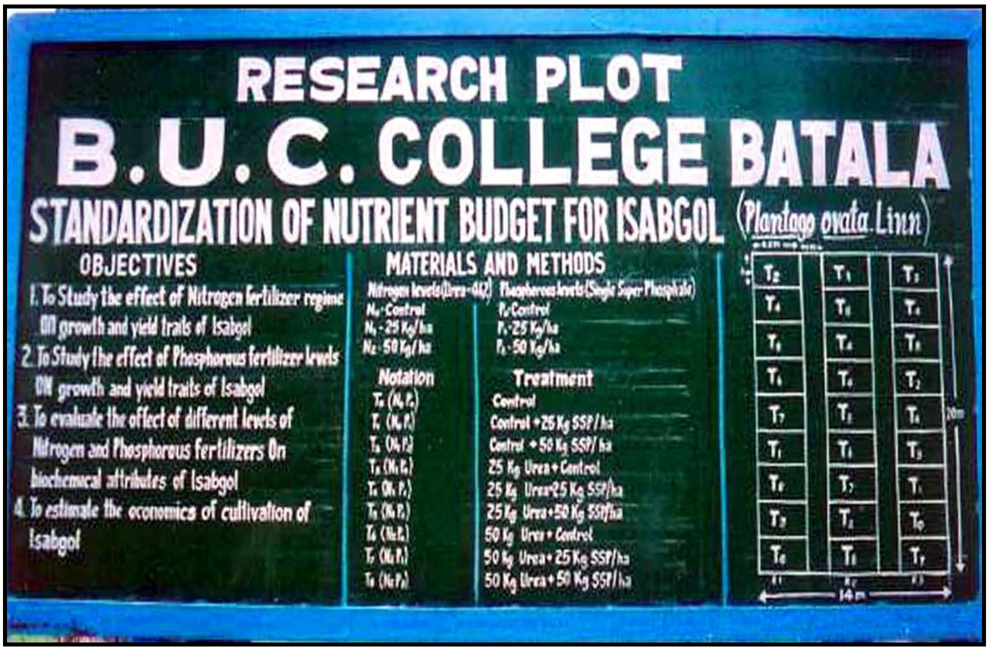

Plate 1:- Display board with experimental detail

(Objective, treatment combination and layout)

RESULTS AND DISCUSSION

Table 5:- Effect of Nitrogen, Phosphorous and interaction on plant height (cm) of Isabgol (*Plantago ovata*) at 20, 40, 60, 80,100 and 120 DAS.

Treatment	20 DAS		15 Days15 Days15 40 DAS		60 DAS		80 DAS		100DAS		120 DAS	
	2005-2006	2006-2007	2005-2006	2006-2007	2005-2006	2005-2007	2005-2006	2006-2007	2005-2006	2006-2007	2005-2006	2006-2007
T0 (Control)	3.81	3.69	09.38	08.92	14.33	14.40	18.91	18.91	28.57	28.78	29.25	28.85
T1	3.85	3.93	09.08	08.61	14.46	14.46	19.97	19.97	28.81	28.87	29.74	28.90
T2	3.08	3.10	10.09	09.73	14.63	14.60	20.23	20.23	30.33	30.18	31.01	30.21

T3	2.65	2.62	10.51	10.07	14.81	14.70	20.29	20.29	30.36	30.26	31.15	30.31
T4	2.31	2.20	10.85	10.15	14.78	14.73	20.33	20.33	30.51	30.39	31.91	30.41
T5	2.59	2.53	10.90	10.22	14.83	14.83	20.38	20.38	30.57	30.55	32.71	30.65
T6	2.60	2.54	10.93	10.22	14.87	14.89	20.61	20.61	30.75	30.73	31.56	30.72
T7	2.58	2.58	11.19	10.34	16.32	16.02	20.66	20.66	31.80	31.70	33.36	32.09
T8	2.98	3.05	11.31	10.42	16.37	16.14	20.86	20.86	32.50	32.28	33.63	32.22
F-test	NS	NS	S	S	S	S	S	S	S	S	S	S
S.Ed(±)	1.1416	1.2887	0.2380	0.2882	0.0570	0.0468	0.1477	0.3181	0.1865	0.2123	0.5340	0.0765
C.D.(p=0.05)	2.9569	3.3377	0.6166	0.7464	0.1477	0.1213	0.8240	0.8240	0.4832	0.5500	1.3833	0.1982

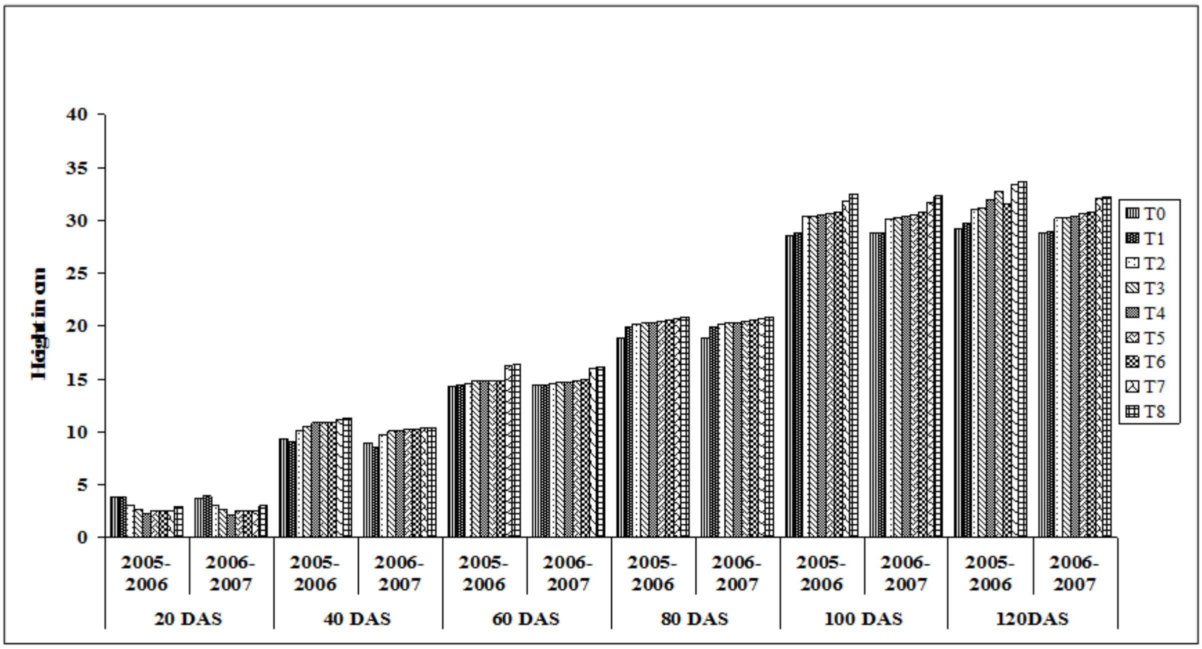

Fig. 1 :- Effect of Nitrogen, Phosphorous and their interaction on plant height in cm of Isabgol (*Plantago ovata*).

Plant height at 80 DAS:

A close perusal of data depicted that plant height at 80 DAS was found to be significant for Isabgol. However, highest plant height was exhibited by treatment T_8 (20.86cm) followed by treatment T_7 (20.66 cm), T_6 (20.61cm), T_5 (20.38 cm), T_4(20.33cm), T_3 (20.29cm), T_2 (20.23cm) , T_1 (19.97cm) andT_0 control(18.91cm)in first year (2005-06) and in the second year (2006-2007) same pattern of growth is followed i.e. maximum plant height was observed in the treatment T_8 (20.86cm), followed by T_7 (20.66cm), T_6 (20.61cm), T_5 (20.38cm) T_4 (20.33cm) T_3 (20.29cm), T_2 (20.23cm) T_1 (19.97cm) and T_0 control(18.91cm) respectively.

It was observed that with the continuous increase of Nitrogen and Phosphorous the height of plant is also increasing continuously in the 2006-07 and minimum plant height at this location was observed in T_0 control for both the years (18.91cm) respectively

Plant height at 100 DAS:

A close perusal of data depicted that plant height at 100 DAS was found to be significant for Isabgol. However, highest plant height was exhibited by treatment T_8 (32.50cm) followed by treatment T_7 (31.80cm), T_6 (30.75cm), T_5 (30.57cm), T_4(30.51cm), T_3 (30.36cm), T_2 (30.33cm) , T_1 (28.81cm) andT_0 control(28.57cm)in first year (2005-06) and in the second year (2006-2007) same pattern of growth is followed i.e. maximum plant height was observed in the treatment T_8 (32.28cm) followed by T_7 (31.70cm), T_6 (30.73cm), T_5(30.55cm), T_4 (30.39cm), T_3 (30.26cm), T_2(30.18 cm), T_1 (28.87cm) and T_0 control (28.78cm) respectively.

It was observed that with the continuous increase of Nitrogen and Phosphorous the height of plant is also increasing continuously in the 2006- 07 and minimum plant height at this location was observed in T_0 control for both the years (28.57cm & 28.78cm) respectively

Plant height at 120 DAS:

A close perusal of data depicted that plant height at 120 DAS was found to be significant for Isabgol. However, highest plant height was exhibited by treatment T_8 (33.63 cm) followed by treatment T_7 (33.36cm), T_6 (31.56cm), T_5 (32.71cm), T_4(31.91cm), T_3 (31.15cm), T_2 (31.01cm) , T_1 (29.74cm) andT_0 control (29.25cm)in first year (2005-06) and in the second year (2006-2007) same pattern of growth is followed i.e. maximum plant height was observed in the treatment T_8 (32.22cm), followed by T_7 (32.09cm), T_6 (30.72cm), T_5(30.65cm) T_4 (30.41cm), T_3 (30.31cm), T_2 (30.21cm), T_1 (28.90cm) and T_0 control(28.85cm) respectively. It was observed that with the continuous increase of Nitrogen and Phosphorous the height of plant is also increasing continuously in the 2006-07 and minimum plant height at this location was observed in T_0 control for both the years (29.25cm & 28.85cm) respectively. The interaction effect between the levels of nitrogen and Phosphorous was found also significant.

The increase in plant height with increasing the level of nitrogen & phosphorous was due to better plant growth as influenced by balanced supply of nitrogen and phosphorus to the plants[8]. Same observations have also been reported by [9] on increasing the plant height of Isabgol with the application of higher dose of nitrogen.

Table 6:- Effect of Nitrogen, Phosphorous and their interaction on number of tillers /plant of Isabgol (*Plantago ovata*) at 50, 80, 110 DAS

Treatment	**50 DAS**		**80 DAS**		**110 DAS**	
	2005 - 2006	**2006 - 2007**	**2005 - 2006**	**2006 - 2007**	**2005 - 2006**	**2006 - 2007**
T_0 (Control)	2.00	2.33	3.66	4.00	5.00	4.33
T_1	3.00	2.66	5.33	5.66	6.66	6.00
T_2	3.00	2.66	6.00	6.66	7.00	7.00
T_3	3.60	3.60	7.33	7.00	7.66	8.00
T_4	5.00	5.33	9.33	9.33	9.66	10.00
T_5	5.00	5.33	9.00	9.00	9.33	9.00
T_6	4.33	4.66	8.33	8.00	8.66	9.00
T_7	4.00	4.00	7.66	8.00	8.00	8.66
T_8	4.00	4.00	7.66	7.33	8.00	8.00
F-test	S	S	S	S	S	S
S.Ed(±)	0.288675	0.509175	0.573326	0.612372	0.495348	0.561083

C.D.(p=0.05)	0.747668	1.318763	1.484916	1.586044	1.282953	1.453206

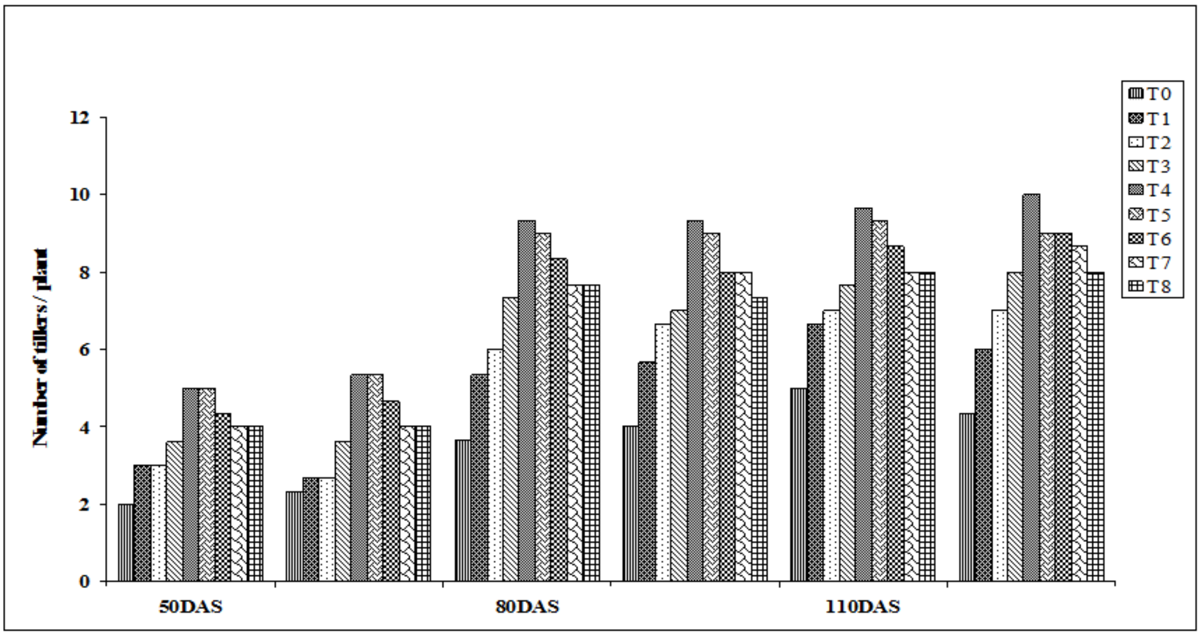

Fig. 2 :- Effect of Nitrogen, Phosphorous and their interaction on number of tillers / plant of Isabgol (Plantago ovata) at 50 DAS, 80 DAS and 110 DAS.

Number of spikes at 90 DAS:

A close perusal of data depicted that number of spikes/plant at 90 DAS was found to be significant for Isabgol. However, highest number of spikes/plant was exhibited by treatment T4(8.66), followed by treatment T5 (7.66), T6 (7.00), T7 T8 & T3(6.66), T2 (5.00) , T1 (4.00) , and T0 control(2.66) in first year (2005-06) and in the second year (2006-2007) same pattern of growth is followed i.e. maximum number of spikes/plant was observed in the treatment T4(9.00), followed by treatment T5,(8.33), T6 (7.66), T7 (7.33), T8 (7.00), T3 (6.33), T2(6.00), T1 (5.33) and T0 control(3.33). Again it was observed that with the continuous increase of Nitrogen and Phosphorous up to 12.5 kg/ha Nitrogen and 25kg/ha which were applied at sowing time + half of the Nitrogen (12.5 kg/ha) applied after 30 - 40 DAS gave maximum number of spikes/plant. Any further increasing of Nitrogen and Phosphorous decreased the number of spikes/plant.

Table 7: - Effect of Nitrogen and Phosphorous on number of spikes /plant of Isabgol (*Plantago ovata*) at 60, 90, 120 DAS

Treatment	15 Days15 Days15 60 DAS		90 DAS		120 DAS	
	2005-2006	2006-2007	2005-2006	2006-2007	2005-2006	2006-2007
T_0 (Control)	1.66	2.00	2.66	3.33	4.66	4.33
T_1	2.00	2.66	4.00	5.33	5.33	5.66
T_2	3.00	2.66	5.00	6.00	6.66	7.00
T_3	3.66	3.33	6.66	6.33	7.00	7.66
T_4	4.33	5.33	8.66	9.00	9.00	9.66
T_5	4.00	5.00	7.66	8.33	8.66	9.00
T_6	4.00	4.33	7.00	7.66	8.00	9.00
T_7	3.33	4.00	6.66	7.33	8.00	8.66
T_8	3.33	3.66	6.66	7.00	7.66	7.66
F-test	S	S	S	S	S	S
S.Ed(±)	0.44095	0.39086	0.63464	0.49534	0.63464	0.597060
C.D.(p=0.05)	1.14208	1.01234	1.64373	1.28295	1.64373	1.546387

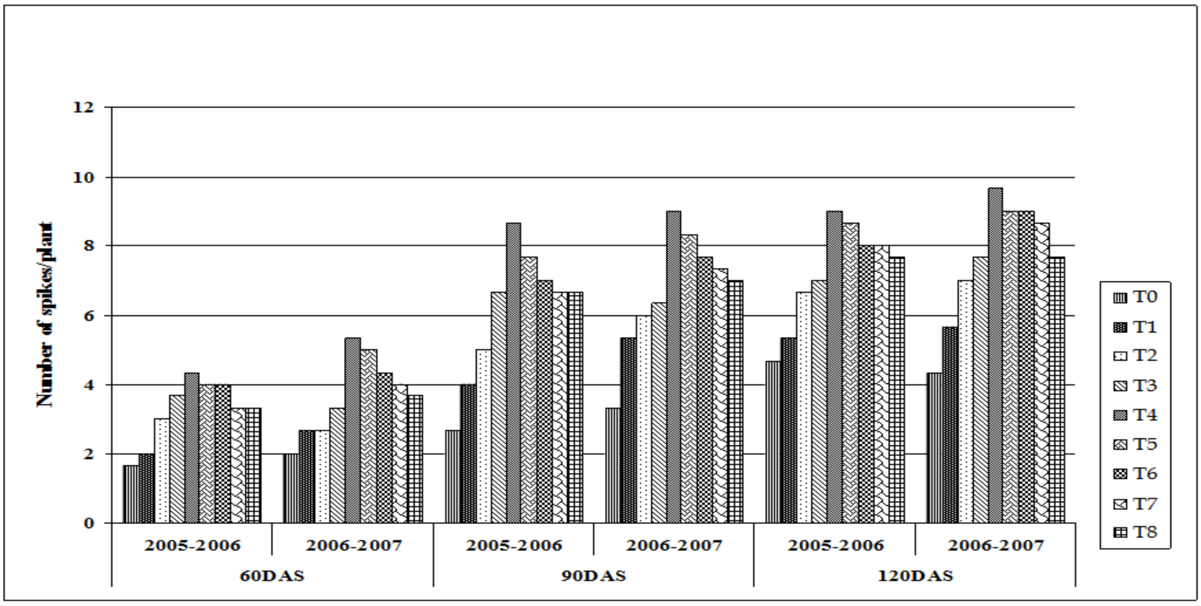

Fig. 3:- Effect of Nitrogen, Phosphorous and their interaction on number of spikes/plant in Isabgol (*Plantago ovata*) 60, 90 and 120 DAS.

Number of spikes at 120 DAS:

A close perusal of data depicted that number of spikes/plant at 120 DAS was found to be significant for Isabgol. However, highest number of spikes/plant was exhibited by treatment T4(9.00), followed by treatment T5 (8.66), & T6& T7 (8.00), T3(7.00), T2(6.66), T1(5.33) and T0 control(4.66) in first year (2005-06) and in the second year (2006-2007) same pattern of growth is followed i.e. maximum number of spikes/plant was observed in the treatment T4(9.66), followed by treatment T5 & T6 (9.00), T7 (8.66), T8 & T3 (7.66) , T2(7.00), T1 (5.66) and T0 control(4.33). Again a similar trend was observed that with the continuous increase of Nitrogen and Phosphorous up to 12.5 kg/ha Nitrogen and 25kg/ha which were applied at sowing time + half of the Nitrogen (12.5 kg/ha) applied after 30 - 40 DAS gave maximum number of spikes/plant. Any further increasing of Nitrogen and Phosphorous decreased the number of spikes/plant Experiment conducted by[10] . (2003 with 4 levels of nitrogen (0, 25.50 and 75 kg/ha) had also predicted that Nitrogen at 50 kg/ha gives the highest number of tillers and spikes per plant.

Number of seeds /spike at 120 DAS

It is evident from table 4.6 and figure 4.6 that the levels of Nitrogen and Phosphorous significantly affected the seed yield/spike. Also the interaction effect between the levels of the nitrogen and Phosphorous remained significant. A close perusal of data depicted that seed yield/spike was found to be significant for Isabgol. However, highest seed yield/spike was exhibited by treatment T4(81.33), followed by treatment, T5 (73.33), T6 (71.33), T7 (65.00), T8 (61.33), T3 (54.66), T2(51.33) , T1(47.66) , and T0 control (41.33) in first year (2005-06) and in the second year (2006-2007) same pattern of growth is followed i.e. maximum seed yield observed in the treatment T4(84.00), followed by treatment T5 (73.66), T6 (71.33), T7 (67.00), T8 (63.33), T3 (56.66), T2(50.33) , T1(46.33) , and T0 control (42.66). It was observed that with the continuous increase of Nitrogen and Phosphorous up to 12.5 kg/ha Nitrogen and 25kg/ha which were applied at sowing time + half of the Nitrogen (12.5 kg/ha) applied after 30 - 40 DAS gave maximum seed yield /spike. Any further increasing of Nitrogen and Phosphorous decreased the seed yield /spike. The higher number of seeds per spike was due to the adequate increase in nitrogen level and spike length. The present findings match with the results of [10],[11],[12],[13].

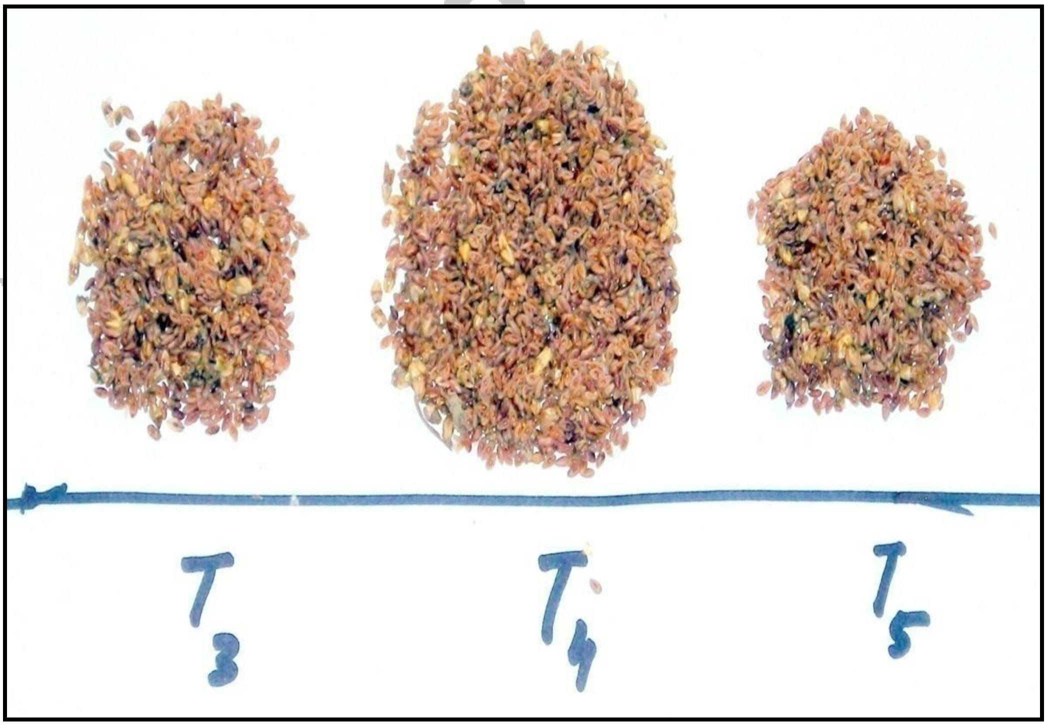

Plate 2:-Seeds of Isabgol (*Plantago ovata*) in three different treatments (Enlarged view)

CONCLUSION

On the basis of findings presented earlier and discussion in preceding pages, it may be concluded that out of nine treatments, T4 (N1P1) i.e. 12.5kg/ha Nitrogen and 25kg/ha Phosphorous as basal dose + 12.5 kg/ha Nitrogen as aerial dose was worth by showing high performance for different growth and yield parameters. Regarding biochemical attributes, i.e. for protein, fat, xylose and arabinose relative (%) content in seeds, we can conclude that out of nine treatments, T4 was worth by showing per se high performance. As far as economics was concerned, again it may be concluded that out of nine treatments, T4 was worth by showing per se high benefit cost ratio. So, the treatment T4 should be considered as a standard dose for Isabgol (*Plantago ovata*) to get maximum quantitative, qualitative and economic benefit.

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