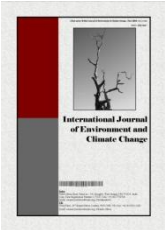

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Effect of Zinc and Iron on Growth and Productivity of Relay Grass Pea (*Lathyrus sativus* L.) in New Alluvial Zone of West Bengal

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was designed to validate the effect of Zinc and Iron on growth and productivity of relay Grass pea (*Lathyrus sativus* L.) in New Alluvial Zone of West Bengal. The experiment was carried out in BCKV, Kalyani, West Bengal, India during *rabi* seasons of 2016-17 and 2017-18, following split-split plot design taking relay sowing of lathyrus in main plots [S_1: Satabdi (IET 4786), S_2: Swarna (MTU 7029)], three lathyrus varieties in sub plot (V_1: Nirmal, V_2: Prateek and V_3: Ratan) and four foliar sprays at pre-flowering and pod development stages in sub – sub plot (F_1: Control, F_2: 0.5% $FeSO_4$, F_3: 0.5% $ZnSO_4$ and F_4: 0.5% $FeSO_4$ + 0.5% $ZnSO_4$) with three replications. First date of sowing (S1) i.e., relay sowing of lathyrus in satabadi (IET 4786) and foliar spray of Fe and Zn, either alone or in combination performed better in terms of plant height, dry matter accumulation, CGR, LAI, LAD, seed yield, stover yield and harvest index of different lathyrus varieties due to higher radiation use efficiency and profile moisture contribution.

Keywords: Zinc; Ion; Productivity; Grasspea.

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1. INTRODUCTION

Indian agriculture is predominately cereal based. Traditional long duration rice varieties during *kharif* season impediments the sowing of succeeding *rabi* crops. In addition to this, short winter duration, fast receding of residual soil moisture after harvesting of rice, soil compaction and hardiness due to puddle rice and erratic post monsoon rainfall limit the prospect of growing *rabi* crops in these areas. Consequently, 31.25% of rainfed *kharif* rice land of Indo Gangetic Plain (IGP) remains fallow during *rabi* season [1]. In India, rice fallow area of West Bengal (1.72 mha) accounts for about 37.2% of the kharif rice area [2]. Moreover, intensive cropping with high yielding varieties of major cereal crops (rice, wheat and maize) leads to heavy mining of major as well micronutrients. As a result, in recent years, the deficiency of micronutrients appears as a serious threat to bring down the productivity of crops. Out of the eight micronutrients, the deficiency of iron (Fe) and zinc (Zn) is wide spread in Indian soils. Zn deficiency is a major problem in states like West Bengal, Karnataka, MP, AP, TN, Meghalaya, Orissa, UP and Bihar. 49% of Indian soils are potentially deficient in Zn [3]. Zinc promotes the auxin biosynthesis, and plays a pivotal role in many physiological and biochemical processes as well as stress resistance mechanisms in plants [4]. Fe has significant influence in oxidation-reduction reaction in plants through ferrodoxin during photosynthesis [5]. Besides it has most important role in biological nitrogen fixation (BNF) in legume as Fe is the metalo-protein of nitrogenase enzyme [6,7]. It also acts as precursor of chlorophyll [8] and contributes towards chlorophyll synthesis, cell division and cell elongation. With foliar fertilization, these micro-nutrients can reach to the site of food synthesis directly leaving no wastage [9] along with quick supply of nutrients [10]. Introduction of legumes in crop sequence also subjugates the problem of nutrient mining of continuous rice-rice monocropping or cereal based cropping. Lathyrus commonly known as chickling pea, grass pea, *khesari*, *lakhodi* etc. is one of the important pulse crops as it's a very rich source of vegetable protein (28 %), carbohydrate (56.6 – 61%) and minerals especially calcium (90-110 mg), phosphorus (317-500 mg) and iron [11].

2. MATERIALS AND METHODS

2.1 Location

The experiment was carried out during two successive *rabi* seasons (October to February) of 2016-17 and 2017-18 at the District Seed Farm (DSF), AB block, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India. The study site belongs to New Alluvial zone of West Bengal under sub-tropical humid climate with short and mild winter. The crop was grown exclusively under rainfed condition. Weather condition during the period of experiment has been presented in monthly basis (Table 1a & 1b).

2.1.1 Physico-chemical properties of initial soil of experimental field (0–15 cm depth)

Soil of the experimental field belonged to the textural class of sandy loam. According to the criteria of critical soil test values laid by Muhr et al. [12], the available nitrogen content of the soil was low. While the available phosphorus and potassium content was medium in range. The soil was neutral in reaction. The organic carbon content of the soil was medium.

2.1.2 Treatment and experimental Details

Lathyrus seeds were broadcasted in standing rice field 10-15 days before harvesting of rice. Rice was harvested when the crops are fully matured (October - November) with the help of sickle retaining a stubble height of 25 cm.

Table 1a. Mean Monthly Meteorological data pertainin\g to the period of experimentation (Oct, 2016 to March, 2017)

Month	Temperature (℃)		Relative humidity (%)		BSSH (hr day^{-1})	Rainfall (mm)	ET (mm)
	Max.	Min.	Max.	Min.			
October	33.0	23.9	96.0	68.5	7.1	3.3	2.2
November	29.7	17.7	93.4	58.7	6.6	0.6	1.3
December	26.3	13.2	93.8	59.1	5.3	0	1.0
January	26.0	10.9	91.3	49.7	6.6	0.0	1.2
February	30.3	15.2	89.9	45.4	6.6	0.0	2.1
March	33.3	20.5	91.8	48.3	7.4	0.3	3.3

Table 1b. Mean Monthly Meteorological data pertaining to the period of experimentation (Oct, 2017 to March, 2018)

Month	Temperature (℃)		Relative humidity (%)		BSSH (hr day^{-1})	Rainfall (mm)	ET (mm)
	Max.	Min.	Max.	Min.			
October	32.1	24.4	97.5	75.2	5.6	7.7	1.8
November	29.3	17.8	93.1	57.3	7.6	1.2	1.6
December	25.9	14.3	93.5	61.5	6.1	0.5	1.0
January	24.4	8.8	90.9	47.7	6.6	0.0	1.2
February	30.8	15.7	90.0	44.4	6.2	0.0	2.1
March	35.1	21.1	89.5	40.1	6.9	0.0	-

Chart 1. Treatment details of the experiment

Treatment		Details
Main plot	Sowing time	**S1**: Relay sowing of lathyrus in Satabdi (IET 4786) **S2**: Relay sowing of lathyrus in Swarna (MTU 7029)
Sub plot	Lathyrus Variety	**V1**: Nirmal **V2**: Prateek **V3**: Ratan
Sub – sub plot	Foliar spray at pre-flowering and pod development stage (RDF: 20:40:20 kg N:P_2O_5:K_2O ha^{-1})	**F_1**: RDF (control) **F_2**: RDF + 0.5% $FeSO_4$, $7H_2O$ in two stages (Pre-flowering and Pod initiation stages of lathyrus) **F_3**: RDF + 0.5% $ZnSO_4$, $7H_2O$ in two stages (Pre-flowering and Pod initiation stages of lathyrus) **F_4**: RDF + 0.5% $FeSO_4$,$7H_2O$+ 0.5% $ZnSO_4$,$7H_2O$ in two stages (Pre-flowering and Pod initiation stages of lathyrus)

Table 2. Details of the experiment

Sl. No.	Experimental Details	
i.	Year of experiment	2016–17 and 2017–18
ii.	Rice variety	Swarna (MTU 7029), Satabdi (IET 4786)
iii.	Lathyrus variety	Nirmal, Prateek, Ratan
iv.	Experimental design	Split-Split Plot Design
vii.	Number of Treatment combination	2 × 3 × 4 = 24
viii..	Number of replications	Three (3)
xi.	Total Number of plots	72
xii	Plot Size	4 m × 3 m

2.2 Data Recording

2.2.1Plant height

Height of five randomly selected plants in each plot was recorded in cm and then average was worked out and used for statistical analysis. Plant height was measured from ground surface to upper most leaf top at 45, 60, 75, 90 DAS and at harvest.

2.2.2 Leaf area index (LAI)

Leaf area index (LAI) was calculated by dividing the leaf area plant^{-1} by the land ground area occupied by single plant [13]. LAI was calculated by the following formula:

$$\mathrm{LAI} = \frac{Total\ leaf\ area\ for\ a\ given\ land\ area}{Land\ area\ considered}$$

2.2.3 Leaf area duration (LAD)

It is the measure of the ability of a crop to produce leaf area on unit area of land throughout its life.

$$LAD = \left\{\frac{L_1 + L_2}{2} \times (\mathrm{T}_2 - \mathrm{T}_1)\right\} + \cdots + \left\{\frac{L_{n-1} + L_n}{2} \times (\mathrm{T}_n - \mathrm{T}_{n-1})\right\}$$

Where, L is leaf area of plant at time T

2.2.4 Dry matter accumulation plant^{-1} (g)

Five randomly selected plants were uprooted carefully along with the root, after that root and pods were detached and remaining portion of the plant was air dried followed by drying in hot air oven at 60-65°C temperature for 72 hours till constant weight was obtained. The samples were weighed on an electronic balance and then average was worked out by dividing the summation by five to get dry matter accumulation plant^{-1}.

2.2.5 Crop growth rate (CGR)

Crop growth rate measures the efficiency of land area. It is the amount of dry matter accumulated in unit land area per unit time. Crop growth rate was calculated by using the following formula (Watson, 1952) and expressed as g m^{-2} day^{-1}

$$CGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_1 and W_2 were the dry weight of the aerial plant parts at t_1 and t_2 days after sowing respectively.

2.3 Seed and Stover Yield

At maturity, the varieties with different treatment were harvested and seed yield were recorded plot wise after threshing and sun drying.

The harvest index was determined from seed yield ha^{-1} and biological yield ha^{-1} at the time of harvest using formula given by Donald [14].

$$HI = \frac{Economic\ (seed) yield}{Biological\ yield} \times 100$$

3. RESULTS

3.1 Plant Height

Significant influence of sowing time was noticed in plant height at all growth stages of lathyrus starting from 45 DAS (Table 2). First date of sowing i.e., broadcasting of lathyrus in standing crop of rice variety Satabdi noted highest plant height throughout the growth stages from 45 DAS to harvest in both the years of investigation.

Among the three lathyrus varieties Nirmal attained maximum plant height at 45 DAS (37.4 cm), 90 DAS (101.8 cm) and at harvest (115.2 cm) followed by Ratan and lowest was noticed in Prateek during first year. The trend was slightly differed in second year i.e., variety Ratan registered highest plant height at 45 DAS and at harvest which was statistically at par with Nirmal.

Micronutrient foliar applications boost plant height of lathyrus over control prominently from 60 DAS onwards. Based on pooled across the years, maximum plant height of lathyrus was registered in F3 at 75 and 90 DAS and in F4 at harvest. In all these growth stages both F3 and F4 remained statistically at par during both the years of experiment.

3.2 Dry Matter Accumulation

Sowing of lathyrus at two different rice varieties had significant effect on dry aerial biomass of lathyrus across the years of observation. Early sowing (S1) recorded significantly highest biomass accumulation throughout the growth period from 45 DAS to harvest (Table 3).

Despite of sowing time and foliar spray treatments, the lathyrus varieties differed significantly in terms of aerial biomass accumulation. Among the three lathyrus varieties, Ratan (V3) registered maximum dry matter accumulation at 75 DAS and at harvest during both the years of experiment. During first year of experiment maximum dry matter was accumulated in variety Ratan (V3) at 60 DAS (134.3 g m^{-2}), 75 DAS (217.0 g m^{-2}) and at harvest (319.3 g m^{-2}) which was statistically at par with Prateek (V2) in all the growth stages. In 2017, the variety Prateek recorded highest areal biomass accumulation at early to mid-growth stages i.e., 45 and 60 DAS. Data recorded from 75 DAS to harvest indicated maximum biomass accumulation with variety Ratan followed by Prateek.

No significant difference was noticed at 45 DAS for micronutrient foliar application but the effect was prominent for rest of the period from 60 DAS and gradually increased upto crop harvest. Combined application of Zn and Fe @ 0.5 % at pre flowering and pod development stages exhibited significantly highest biomass accumulation for all the growth stages in both the years followed by sole application of Zn @ 0.5 % and lowest was recorded with no spray.

Pooled analysis revealed that, among the cultivars total dry matter accumulation exhibited significant variations throughout the crop growing

period irrespective of fertilizer levels except at 45 DAS. Highest dry matter accumulation was observed in Nirmal at 45 DAS (70.5 g m^{-2}), Ratan at 75 DAS (219.4 g m^{-2}), 90 DAS (280.7 g m^{-2}) and at harvest (323.7 g m^{-2}) and Prateek (136.6 g m^{-2}) at 60 DAS. Among the foliar fertilization treatments highest dry matter accumulation was observed throughout the crop growth period except at 45 DAS with F4 fertilizer levels. Dry matter accumulation was 138.97 g m^{-2}, 222.60 g m^{-2}, 284.60 g m^{-2} and 328.20 g m^{-2} in 60 DAS, 75 DAS, 90 DAS and at harvest respectively.

3.3 Crop Growth Rate (g m^{-2} day^{-1})

The crop growth rate is one such physiological parameter of crop which is determined by evaluating the increase in dry weight of plants over a fixed interval of days. The crop growth rate of lathyrus was increased upto 75 DAS, showed a steady phase at flowering and pod filling stages then declined gradually and reached lowest at harvest (Table 4).

Sowing times of lathyrus did not mark any significant influence on crop growth rate over the years of experiment except at the intervals between 45–60 DAS. Though, higher crop growth rate of lathyrus was recorded in early sowing (S1) throughout the stages of observation.

The crop growth rate of lathyrus varied significantly among the varieties in all the growth stages. Based on pooled over the years, the crop growth rate of lathyrus varied between 4.06 to 4.43 g m^{-2} day^{-1} at the intervals between 45–60 DAS, 5.27 to 5.60 g m^{-2} day^{-1} at 60–75 DAS, 3.88 to 4.18 g m^{-2} day^{-1} at 75–90 DAS and 2.58 to 2.86 g m^{-2} day^{-1} at 90 DAS–harvest. At 45 – 60 DAS, the variety Prateek (V2) recorded maximum crop growth rate (4.40 g m^{-2} day^{-1} and 4.46 g m^{-2} day^{-1}) during both the years of experiment. Whereas, at 60–75 DAS and at 90 DAS–harvest Ratan (V3) attained maximum crop growth rate across the years of experiment.

Foliar spray of Fe and Zn brought significant difference in crop growth rate of lathyrus either independently or in combination throughout the stages of observation. Among the foliar spray treatments, maximum crop growth rate of lathyrus was noted in F4 at 45–60 DAS and 60–75 DAS during both the years of experiment. Based on pooled across the years of experiment, maximum crop growth rate of lathyrus was registered with F3 at 75–90 DAS (4.15 g m^{-2} day^{-1}) and 90 DAS–harvest (2.82 g m^{-2} day^{-1}). In these growth phases, F4 remained statistically at par with F3.

3.4 Leaf Area Index (LAI)

The leaf area index is a measure of proportionate canopy coverage over ground. Crop growth depends on adequate formation of leaf area for efficient interception of light. A careful study of data, revealed that leaf area index of all three lathyrus varieties increased gradually from 45 DAS to 90 DAS. LAI did not differ significantly over time of sowing of lathyrus across the years of study (Table 5). Though, higher LAI of lathyrus was recorded in S1 throughout the stages of observation. The pooled over the years revealed that Ratan accounted maximum LAI at 45 DAS (0.47) and 75 DAS (1.28). Though, Maximum LAI of lathyrus was observed in F4 throughout the stages of observation over the years foliar spray of Zn and Fe did not bring any significant difference.

3.5 Leaf Area Duration (LAD)

It was evident from the table that maximum LAD of lathyrus was obtained in S1 in all the growth phases. Ratan recorded significantly higher LAD at 45–60 DAS (10.28) and 60–75 DAS (16.52) and Prateek at 75–90 DAS (21.25) during 1st year of experiment. In the second year maximum LAD of lathyrus was obtained in Prateek at 45–60 DAS (10.79) and 60–75 DAS (16.74) and in Ratan at 75–90 DAS (21.13). During second year of experiment, the variety Ratan maintained statistical parity with Prateek at 45 – 60 DAS and 60 – 75 DAS.

Foliar spray of micronutrients was notably superior over control in both the years (Table 6). Among the foliar spray treatments, F4 recorded maximum LAD throughout the stages of observation during both the years of experiment. F3 remained statistically at par with F4 in 60–75 DAS and 75–90 DAS over the years.

Table 2. Effect of sowing time, variety and foliar spray of Zinc and Iron on plant height (cm) of lathyrus

Treatment	45 DAS			60 DAS			75 DAS			90 DAS			Harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Time of Sowing															
S1	38.7	40.2	39.5	62.47	64.3	63.4	87.7	82.8	85.3	101.5	104.6	103.1	110.4	115.6	113.0
S2	31.6	37.2	34.4	55.39	51.5	53.4	78.3	74.6	76.4	92.3	97.6	94.9	96.7	100.7	98.7
SEm (±)	0.10	0.44	0.23	0.92	0.50	0.52	0.14	0.62	0.68	1.25	0.64	0.70	2.13	1.69	1.36
LSD	0.59	2.71	0.89	5.60	3.06	2.06	0.86	2.42	4.11	7.62	3.88	2.67	12.99	10.28	5.34
Variety															
V1	37.4	39.2	38.3	59.25	61.6	60.4	83.5	83.3	83.4	101.8	104.4	103.1	115.2	109.1	112.2
V2	31.5	36.5	34.0	53.63	54.9	54.3	78.8	73.7	76.2	92.5	97.4	95.0	96.5	104.8	100.7
V3	36.6	40.4	38.5	63.92	57.3	60.6	86.9	79.0	82.9	96.4	101.4	98.9	98.9	110.5	104.7
SEm (±)	0.23	0.55	0.30	0.65	0.30	0.36	1.10	0.69	0.75	2.07	1.03	1.16	1.57	1.02	0.93
LSD	0.74	1.80	0.89	2.12	0.98	1.07	3.58	2.08	2.45	6.75	3.36	3.47	5.11	3.33	2.80
Foliar Spray															
F1	35.7	39.5	37.6	56.83	53.7	55.2	82.5	76.7	79.6	93.6	98.4	96.0	99.6	104.7	102.2
F2	34.7	37.7	36.2	57.50	56.6	57.1	81.5	78.7	80.1	94.5	100.2	97.3	101.7	105.6	103.7
F3	35.3	38.3	36.8	60.61	62.4	61.5	84.2	79.8	82.0	101.3	102.5	101.9	105.6	111.3	108.5
F4	34.8	39.4	37.1	60.78	58.9	59.8	83.9	79.4	81.6	98.1	103.2	100.7	107.3	110.8	109.1
SEm (±)	0.55	0.75	0.46	0.80	0.52	0.48	0.72	0.54	0.51	1.31	1.00	0.82	1.77	0.94	1.00
LSD	NS	NS	NS	2.30	1.49	1.35	2.06	1.51	1.45	3.74	2.87	2.32	5.08	2.68	2.82

Note: DAS -Days after sowing; S1-Relay sowing of lathyrus in Satabdi; S2- Relay sowing of lathyrus in Swarna; V1-Nirmal.; V2-Prateek; V3-Ratan; F1- No Spray; F2-$FeSO_4$. $7H_2O$ Spray (twice); F3- $ZnSO_4$ $7H_2O$ spray(twice); F4- $FeSO_4$. $7H_2O$ + $ZnSO_4$ $7H_2O$ spray(twice)

Table 3. Effect of sowing time, variety and foliar spray of Zinc and Iron on dry aerial biomass (g m^{-2}) of lathyrus

Treatment	45 DAS			60 DAS			75 DAS			90 DAS			Harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Time of Sowing															
S1	70.3	76.9	72.2	136.6	143.4	138.6	217.3	226.0	220.3	278.2	287.9	281.7	324.0	332.2	326.7
S2	67.7	71.5	68.3	129.3	134.2	130.4	209.5	215.3	211.0	268.6	276.2	271.0	304.3	319.4	310.4
SEm (±)	0.23	0.17	0.14	0.40	0.49	0.32	0.33	0.41	0.26	0.16	0.45	0.24	0.58	0.66	0.44
LSD	1.42	1.05	0.57	2.41	3.01	1.24	2.03	2.49	1.02	0.97	2.71	0.93	3.55	4.03	1.72
Variety															
V1	70.6	73.2	70.5	130.8	135.0	131.5	209.5	214.4	210.6	267.0	273.4	268.8	305.2	320.2	311.3
V2	67.6	75.4	70.1	133.7	142.3	136.6	213.7	223.0	217.0	277.2	284.7	279.6	317.8	326.3	320.7
V3	68.7	74.1	70.0	134.3	139.1	135.4	217.0	224.6	219.4	276.0	288.1	280.7	319.3	330.8	323.7
SEm (±)	0.43	0.35	0.28	0.36	0.58	0.34	0.78	0.47	0.45	0.38	0.59	0.35	0.92	0.53	0.53
LSD	1.40	1.15	NS	1.16	1.90	1.02	2.53	1.54	1.36	1.24	1.92	1.05	3.01	1.74	1.60
Foliar Spray															
F1	69.7	74.3	70.6	127.0	133.0	128.61	201.7	211.0	205.0	257.3	271.0	262.8	293.4	313.9	302.
F2	69.0	74.3	70.3	132.1	138.0	133.68	214.0	219.9	215.5	274.0	281.5	276.4	315.1	325.0	318.6
F3	68.3	74.0	69.8	135.7	140.4	136.70	217.8	223.9	219.5	280.1	286.0	281.7	322.5	330.6	325.2
F4	68.9	74.2	70.2	136.8	143.9	138.97	220.1	227.8	222.6	282.3	289.6	284.6	325.4	333.7	328.2
SEm (±)	0.53	0.33	0.31	0.64	0.44	0.39	0.83	0.56	0.50	0.78	0.62	0.50	1.04	0.61	0.60
LSD	NS	NS	NS	1.83	1.25	1.09	2.37	1.60	1.41	2.23	1.77	1.40	2.99	1.75	1.70

Note: DAS -Days after sowing; S1-Relay sowing of lathyrus in Satabdi; S2- Relay sowing of lathyrus in Swarna; V1-Nirmal.; V2-Prateek; V3-Ratan; F1- No Spray; F2-$FeSO_4$. $7H_2O$ Spray (twice); F3- $ZnSO_4$ $7H_2O$ spray(twice); F4- $FeSO_4$. $7H_2O$ + $ZnSO_4$ $7H_2O$ spray(twice)

Table 4. Effect of sowing time, variety and foliar spray of Zinc and Iron on Crop Growth Rate (CGR) of lathyrus (g m^{-2} day^{-1})

Treatment	45-60 DAS			60-75 DAS			75-90 DAS			90-harvest		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Time of Sowing												
S1	4.42	4.43	4.42	5.38	5.51	5.44	4.06	4.12	4.09	3.05	2.77	2.91
S2	4.10	4.18	4.14	5.35	5.40	5.38	3.94	4.06	4.00	2.38	2.71	2.54
SEm (±)	0.01	0.03	0.01	0.05	0.06	0.03	0.03	0.05	0.03	0.05	0.07	0.04
LSD	0.07	0.18	0.06	NS	NS	NS	NS	NS	NS	0.30	NS	0.17
Variety												
V1	4.01	4.12	4.06	5.25	5.29	5.27	3.83	3.93	3.88	2.55	2.60	2.58
V2	4.40	4.46	4.43	5.34	5.38	5.36	4.24	4.11	4.18	2.70	2.78	2.73
V3	4.37	4.33	4.35	5.51	5.70	5.60	3.93	4.24	4.08	2.89	2.84	2.86
SEm (±)	0.04	0.04	0.03	0.07	0.04	0.04	0.06	0.05	0.04	0.06	0.05	0.04
LSD	0.12	0.13	0.08	NS	0.15	0.12	0.20	0.16	0.12	0.21	0.15	0.12
Foliar Spray												
F1	3.82	3.91	3.87	4.98	5.20	5.09	3.70	4.00	3.85	2.41	2.68	2.54
F2	4.21	4.24	4.22	5.46	5.46	5.45	4.00	4.11	4.06	2.73	2.73	2.72
F3	4.50	4.43	4.46	5.47	5.56	5.51	4.16	4.14	4.15	2.83	2.80	2.82
F4	4.53	4.64	4.58	5.55	5.60	5.58	4.14	4.12	4.12	2.88	2.76	2.81
SEm (±)	0.06	0.04	0.04	0.08	0.04	0.04	0.08	0.06	0.05	0.09	0.05	0.05
LSD	0.19	0.11	0.11	0.22	0.11	0.12	0.23	NS	0.14	0.25	NS	0.15

Note: DAS -Days after sowing; S1-Relay sowing of lathyrus in Satabdi; S2- Relay sowing of lathyrus in Swarna; V1-Nirmal.; V2-Prateek; V3-Ratan; F1- No Spray; F2-$FeSO_4$. $7H_2O$ Spray (twice); F3- $ZnSO_4$ $7H_2O$ spray(twice); F4- $FeSO_4$. $7H_2O$ + $ZnSO_4$ $7H_2O$ spray(twice)

Table 5. Effect of sowing time, variety and foliar spray of Zinc and Iron on Leaf Area Index (LAI) of lathyrus

Treatment	45 DAS			60 DAS			75 DAS			90 DAS		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Time of Sowing												
S1	0.45	0.48	0.46	0.90	0.92	0.91	1.23	1.27	1.25	1.46	1.49	1.47
S2	0.44	0.48	0.46	0.88	0.91	0.90	1.22	1.25	1.24	1.45	1.44	1.45
SEm (±)	0.003	0.003	0.002	0.006	0.003	0.004	0.003	0.005	0.003	0.015	0.016	0.011
LSD	NS	NS	NS	NS	NS	0.014	NS	NS	0.010	NS	NS	NS
Variety												
V1	0.45	0.47	0.46	0.83	0.87	0.85	1.15	1.22	1.19	1.30	1.40	1.35
V2	0.43	0.48	0.45	0.90	0.96	0.93	1.25	1.27	1.26	1.58	1.46	1.52
V3	0.44	0.49	0.47	0.93	0.92	0.93	1.27	1.29	1.28	1.49	1.53	1.51
SEm (±)	0.005	0.004	0.003	0.004	0.009	0.005	0.007	0.006	0.005	0.017	0.013	0.010
LSD	0.015	0.012	0.009	0.014	0.030	0.016	0.023	0.020	0.014	0.055	0.041	0.031
Foliar Spray												
F1	0.44	0.47	0.46	0.87	0.89	0.88	1.21	1.24	1.22	1.43	1.42	1.42
F2	0.43	0.48	0.45	0.89	0.91	0.90	1.22	1.26	1.24	1.44	1.47	1.45
F3	0.44	0.48	0.46	0.89	0.92	0.91	1.23	1.27	1.25	1.47	1.48	1.47
F4	0.45	0.49	0.47	0.90	0.94	0.92	1.23	1.28	1.26	1.48	1.49	1.49
SEm (±)	0.006	0.007	0.005	0.008	0.013	0.008	0.007	0.011	0.006	0.016	0.021	0.013
LSD	NS	NS	NS	NS	NS	0.022	NS	NS	0.018	NS	NS	0.036

Note: DAS -Days after sowing; S1-Relay sowing of lathyrus in Satabdi; S2- Relay sowing of lathyrus in Swarna; V1-Nirmal.; V2-Prateek; V3-Ratan; F1- No Spray; F2-$FeSO_4$. $7H_2O$ Spray (twice); F3- $ZnSO_4$ $7H_2O$ spray (twice); F4- $FeSO_4$. $7H_2O$ + $ZnSO_4$ $7H_2O$ spray (twice)

Table 6. Effect of sowing time, variety and foliar spray of Zinc and Iron on seed yield, stover yield and harvest index of lathyrus

Treatment	Grain Yield (kg/ha)			Stover Yield (kg/ha)			HI (%)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Time of Sowing									
S1	2038	1993	2015	3448	3505	3476	37.13	36.30	36.71
S2	1886	1850	1868	3363	3451	3407	35.87	34.92	35.39
SEm (±)	3.42	2.85	15.9	7.06	8.02	5.33	0.24	0.22	0.16
LSD	20.84	17.35	62.5	42.95	48.83	20.94	NS	1.32	0.64
Variety									
V1	1855	1821	1838	3331	3406	3368	35.73	34.93	35.33
V2	2048	1929	1988	3424	3465	3444	37.39	35.75	36.58
V3	1984	2014	1999	3460	3563	3512	36.38	36.14	36.25
SEm (±)	4.75	4.46	12.2	23.06	23.64	16.51	0.24	0.22	0.16
LSD	15.48	14.55	36.6	75.20	77.09	49.49	0.77	0.71	0.48
Foliar Spray									
F1	1772	1740	1756	3351	3315	3333	34.54	34.48	34.51
F2	2008	1940	1974	3405	3447	3426	37.03	36.06	36.55
F3	2027	1980	2004	3445	3549	3497	37.05	35.54	36.43
F4	2043	2025	2034	3420	3600	3510	37.38	36.34	36.72
SEm (±)	6.72	9.45	11.0	16.32	34.57	19.12	0.21	0.25	0.16
LSD	19.29	27.11	30.9	46.82	99.15	53.90	0.61	0.70	0.46

Note: DAS -Days after sowing; S1-Relay sowing of lathyrus in Satabdi; S2- Relay sowing of lathyrus in Swarna; V1-Nirmal.; V2-Prateek; V3-Ratan; F1- No Spray; F2-$FeSO_4$. $7H_2O$ Spray (twice); F3- $ZnSO_4$ $7H_2O$ spray(twice); F4- $FeSO_4$. $7H_2O$ + $ZnSO_4$ $7H_2O$ spray(twice)

Table 7. Effect of sowing time, variety and foliar spray of Zinc and Iron on Leaf Area Duration (LAD) of lathyrus

Treatment	45-60 DAS			60-75 DAS			75-90 DAS		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
Time of Sowing									
S1	10.09	10.48	10.28	15.98	16.41	16.19	20.16	20.70	20.43
S2	9.83	10.49	10.16	15.69	16.24	15.97	20.03	20.17	20.10
SEm (±)	0.05	0.03	0.03	0.07	0.02	0.04	0.10	0.12	0.08
LSD	NS	NS	0.12	NS	0.09	0.14	NS	NS	0.31
Variety									
V1	9.60	10.09	9.84	14.86	15.67	15.26	18.36	19.65	19.01
V2	9.99	10.79	10.39	16.13	16.74	16.43	21.25	20.52	20.89
V3	10.28	10.58	10.43	16.52	16.57	16.55	20.67	21.13	20.90
SEm (±)	0.04	0.07	0.04	0.07	0.09	0.06	0.15	0.08	0.09
LSD	0.11	0.23	0.12	0.23	0.29	0.17	0.50	0.27	0.26
Foliar Spray									
F1	9.85	10.26	10.05	15.60	15.98	15.79	19.79	19.92	19.86
F2	9.90	10.46	10.18	15.84	16.27	16.06	19.98	20.42	20.20
F3	9.97	10.55	10.26	15.93	16.43	16.18	20.25	20.61	20.43
F4	10.12	10.68	10.40	15.97	16.61	16.29	20.37	20.78	20.58
SEm (±)	0.08	0.11	0.07	0.09	0.12	0.08	0.13	0.19	0.11
LSD	NS	NS	0.19	0.25	0.36	0.21	0.36	0.55	0.32

Note: DAS -Days after sowing; S1-Relay sowing of lathyrus in Satabdi; S2- Relay sowing of lathyrus in Swarna; V1-Nirmal.; V2-Prateek; V3-Ratan; F1- No Spray; F2-$FeSO_4$. $7H_2O$ Spray (twice); F3- $ZnSO_4$ $7H_2O$ spray(twice); F4- $FeSO_4$. $7H_2O$ + $ZnSO_4$ $7H_2O$ spray(twice)

3.6 Yield and Harvest Index

3.6.1 Grain yield

Significant variation of lathyrus grain yield with respect to different treatment combinations was noticed in both the years of investigation (Table 7). During 2016-17 yield varies between 1772 kg ha^{-1} to 2048 kg ha^{-1} and in 2017-18 it was ranges from 1740 kg ha^{-1} to 2025 kg ha^{-1}. The negligible variation in grain yield among the years may be attributed to weather variables. During the year 2016-17 grain yield was recorded highest in S1 (Broadcasting of lathyrus in standing Satabdi rice). Similar trend was followed in pooled analysis with 7.87 % higher yield in S1 than S2.

During first year, highest yield was registered by Prateek (2048 kg ha^{-1}) followed by Ratan (1984 kg ha^{-1}). In the second year, Ratan (2014 kg ha^{-1}) recorded maximum seed yield followed by Prateek (1929 kg ha^{-1}). Pooled analysis showed that highest yield was observed with Ratan (1999 kg ha^{-1}) and lowest was noticed with the variety Nirmal (1838 kg ha^{-1}).

Maximum response of micronutrient application was exhibited when Zn and Fe were applied in combination @ 0.5% at pre flowering and pod development stages in both the years of investigation (2043 kg ha^{-1} in 2016-17 and 2025 kg ha^{-1} in 2017-18). Next superior treatment was F3 i.e., application of $ZnSO_4$ at pre flowering and pod development stage (2027 kg ha^{-1} in 2016-17 and 1980 kg ha^{-1} in 2017-18) followed by F2 (2008 kg ha^{-1} in 2016-17 and 1940 kg ha^{-1} in 2017-18). Pooled analysis revealed that yield has been increased by applying Zn and Fe in lathyrus at pre flowering and pod development stages, as compare to control varied from 12.41 % to 15.83 % and the trend can be explained as F4 (15.83 %) > F3 (14.12 %) > F2 (12.41%).

3.6.2 Stover yield

During 2016-17 being at par with Prateek (3424 kg ha^{-1}), Ratan (3460 kg ha^{-1}) yielded maximum. In 2017-18 Ratan (3563 kg ha^{-1}) registered maximum stover yield followed by Prateek (3465 kg ha^{-1}) which was statistically at par with Nirmal (3406 kg ha^{-1}). Micronutrient foliar application responded similarly for stover yield as in grain yield of lathyrus i.e., F4 registered maximum (3420 kg ha^{-1} 1^{st} year and 3600 kg ha^{-1} in 2^{nd} year) value followed by F3, F2 and lowest was in F1. This might be due to more dry matter accumulation in these treatments as influenced by micronutrients application either alone or in combination.

3.6.3 Harvest Index

Significant variation in Harvest Index (HI) of Lathyrus was observed due to variation in sowing time, variety and foliar fertilization of micronutrients (Table 7). It ranged from 35.87 % to 37.13 % and 34.92% to 36.30 % in different time of sowing in first and second year respectively. The variety Prateek in first year (37.39 %) and Ratan in second year (36.14 %) recorded significantly higher HI. Treatment F4 recorded substantially higher HI (37.38 % in 1^{st} and 36.34 2^{nd}year respectively) than others in both the years.

4. DISCUSSION

First date of sowing performed better in terms of plant height, dry matter accumulation, Nodule number, Nodule fresh weight and Nodule dry weight. This might be due to its conducive weather condition in first sowing. Elevated temperature and sunshine hour increase photo respiratory losses [15]. Yadavi et al., [16] and Munakamwe, [17] noticed significant influence of sowing dated on LAD in White bean and Pea respectively. In present study CGR was higher at flowering and pod development stages which is in close conformity with Srivastava and Singh, [18].

According to the pooled data of two years highest plant height at almost every stage was noticed with the sole application of 0.5% $ZnSO_4$ foliar application followed by combined application of $ZnSO_4$ and $FeSO_4$ @ 0.5 % at pre flowering and pod development stages. Combined application of Zn & Fe @ 0.5% at pre flowering and pod development stages recorded maximum dry matter accumulation, CGR, LAI and LAD followed by sole application of Fe and Zn. Combined application of $ZnSO_4$ and $FeSO_4$ also recorded significantly higher plant height [19,20,21,22], dry matter accumulation [20,22], leaf area index [20,22] and number of nodule [21,22] in pulses. Further, Nandan et al., 2018 have also emphasized that Zn (0.5%) and Fe (0.5%) foliar spray with recommended doses of fertilizer at pre flowering and pod development stages reported significantly increased dry matter accumulation and LAI in chickpea. Present study was in agreement with the fact as stated by Suhathiya and Ravichandran [23] that, foliar application of 0.50% $ZnSO_4$ + 0.50% $FeSO_4$

recorded the higher values of plant height and dry matter production over the control in rice-fallow black gram.

Higher vegetative biomass accumulation affects source to sink partitioning and reduce harvest index and grain yield [24]. Watson [35], Hedley and Ambrose [25], Saxena [26] and Siddique et al. [27] reported significant positive relation of final dry matter accumulation with yield. LAI and LAD also have significant influence on yield of legumes [28,29]. This is the reason why treatments with higher leaf area index yielded higher in this study. The finding of increased stover yield and harveat index along with seed yield by micronutrient foliar application either alone or in combination was similar to that obtained by Valenciano et al. [30], Jha et al. [20], Singh et al. [31], Nadi et al. [32], Duraisamy and Mani [33] and Rahman et al. [34] Nandan et al. [36].

5. CONCLUSION

Relay sowing of lathyrus in Satabdi rice variety) is a more prospective proposition in West Bengal plains than relay sowing of lathyrus in Swarna rice variety). It was evident from the study that foliar supplementation with Fe and Zn at crucial growth stages elevated the growth and productivity of lathyrus variety Prateek and Ratan under relay sowing, maybe through higher radiation interception, tiding over the drought stress in reproductive stage and soil moisture availability throughout the growth stages.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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