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Optimization of growth and yield of Lathyrus through zinc-biofortification

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Abstract
A field experiment was conducted during the Rabi of 2020-21 at research farm of Tirhut college of Agriculture, Dholi (Muzaffarpur) in randomized block design with eight treatments, replicated thrice. The treatment comprised as T_1 - control, T_2 -RDF 100% (NPKS-20:17:16:20 kg ha^{-1} +PSB + Rhizobium), T_3- RDF100%+ $ZnSO_4$ @ 10 kg ha^{-1} as basal application, T_4 - RDF 100%+ $ZnSO_4$ @ 15 kg ha^{-1} as basal application, T_5 - RDF 100%+ $ZnSO_4$ @ 20 kg ha $^{-1}$ as basal application, T_6 - RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre flowering, T_7 - RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre flowering and pod initiation and T_8 - RDF 100% + Seed priming with 0.05% Zinc solution W/v soaked for six hours. Growth attributes i.e., plant height, dry matter accumulation, crop growth rate, and number of branches per plant were recorded higher under treatment RDF 100%+ $ZnSO_4$ @ 20 kg ha $^{-1}$ as basal application which was found to be at par with RDF 100%+ $ZnSO_4$ @ 15 kg ha^{-1} as basal application, and RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre flowering and pod initiation and significantly superior than application of RDF100% + 10 kg ha^{-1} Zn application and RDF 100% + one foliar spray at pre flowering stage of Lathyrus. RDF 100%+ $ZnSO_4$ @ 20 kg ha $^{-1}$ as basal application recorded higher number of pods per plant and at par with RDF 100%+ $ZnSO_4$ @ 15 kg ha^{-1} as basal application, and RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre flowering and pod initiation over control and other zinc application treatments. Grain and straw yield were significantly affected by various doses and application method of zinc. RDF 100%+ $ZnSO_4$ @ 20 kg ha $^{-1}$ as basal application enhanced grain yield and straw yield than foliar application and no zinc application. Among different application method, basal application recorded higher grain and straw yield but no significant effect was found on harvest index. Basal application of $ZnSO_4$ @ 20 kg ha^{-1} was remained at par with basal application of Zinc sulphate @ 15 kg ha^{-1} and two foliar application of 0.5% $ZnSO_4$ at pre flowering and pod initiation stage. Among the different application method higher gross return, net return, B: C ratio were fetched out in RDF 100%+ $ZnSO_4$ @ 20 kg ha $^{-1}$ as basal application than foliar and seed priming and control (no nutrient application) method of zinc sulphate application under Lathyrus crop.

Keywords: Zinc sulphate, biofortification, Lathyrus, fertilizer

Introduction
Grass pea (*Lathyrus sativus* L.) is a precious pulse crop for sustainable production of foodstuff and feedstuff, it is rich in protein and various important trace-nutrients, adds to poor people's dietary survival in Myanmar, Ethiopia, Nepal, Eritrea, India and parts of China. Lathyrus having soft consistency and better taste as fodder for animal feed; the seed is also useful in animal feed. Grass pea is a drought tolerant legume crop which contains 31.9% protein (Tomar *et al*., 2011) [15], 41% carbohydrates and 17% dietary fibers. The successor crop requires fewer nutrient supply, thereby lowering cultivation costs.
Pulses were cultivated on 29.03 million ha of land in India, producing 23.40 Mt with a productivity of 806 kg ha^{-1} (Directorate of Economics and Statistics, DAC & FW govt.). Total area under grass pea in Bihar 2018-19 was estimated to be 0.504 lakh ha and production 0.513 lakh tons with an average mean productivity of 1018 kg ha^{-1} (Directorate of Economics and Statistics, Government of Bihar, 2018-19). Among them Chhattisgarh ranks 1st in the area and production (66.68% and 60.54%) *fb* Bihar (13.10% and 16.95%) and Madhya Pradesh.
Obviously, lathyrus is a pulse crop which is grown without proper nutrient management and care. But, alkaline soil show Zn deficiency to the crop. Also, sulphur and zinc deficiency are common in pulse-growing areas, limiting pulse growth and output quality. In large pulse-growing areas, 44 percent of districts have 40-61% sulphur deficit, while more than 80 districts having a 45-60% Zn deficiency. And, foliar Zn application can be beneficial, especially in areas where soil fertilizer application can cause nutrient locking or failure.

This approach allows nutrients to access the metabolic system directly, resulting in little waste and a major reduction in fertilizer demand. Zinc improves crop physiological efficiency as well as photosynthetic potential. Furthermore, Zn is required for plant development and growth, it also increases seed germination and seedling vigor (Auld. 2001) [17]. Zinc increases the productivity of water usage (Khan *et al*., 2004) [18], the nodule formation mechanism and N-fixation in roots of leguminous crops. When the crops are grown under nutrient deficient soils especially micro nutrients, the crop yield and quality is low, Consumption of the grain of such crops leads to malnutrition in human beings. It has been experienced that this crop attains bumper growth and gives higher yield as compared to most of the *Rabi* pulse crops. Though this is considered as minor pulse crop but taking into account the pulse production, it can be increased to a considerable extent. Besides, this crop is also a great fertility restorer of the soil.

Methodology

The research experiment was conducted during the *Rabi* season of 2020-21 in the research farm of Tirhut College of Agriculture, Dholi (Muzaffarpur), Bihar. There was no effective rain shower during the crop period however the crop has received a total rainfall (fig. 1) of 10.00 mm. The average maximum temperature was 25.4 ºC and the average lower temperature recorded 11.8 ºC from the second week of November to the last week of March. Experimental plot initial nutrient containing 197 kg ha^{-1} available N, 19 kg ha^{-1} available P, 137 kg ha^{-1} available K and 0.59 ppm Available Zn.

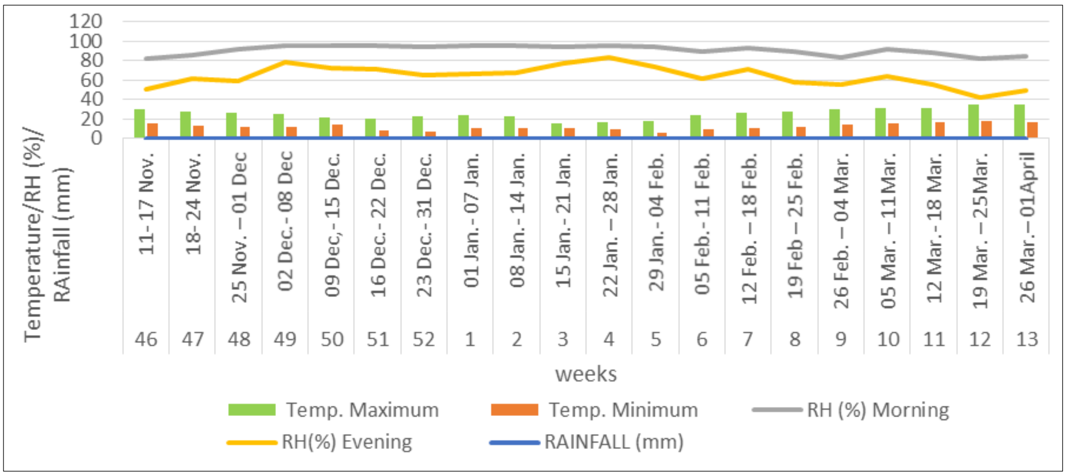

Fig 1: Weekly data for weather parameters during the crop growing season 2020-21

A total of 8 treatments were taken for testing in the experiment- one control, one RDF (N: P: K: S + biofertilizers), three RDF + $ZnSO_4$ level (10,15,20 kg ha^{-1}) with basal application, two RDF + $ZnSO_4$ foliar application @ 0.5% concentration and one with RDF + seed priming with $ZnSO_4$. The soil of experimental plot was calcareous and sandy loam in nature. Sowing of seed was done by *kera* method with seed rate @ 60 kg ha^{-1} of the variety *Parteek*, with a spacing of 30× 10 cm. Plant growth parameters and yield attributing characters were taken by five randomly chosen plants from each plot. While, grain and straw yield taken at harvest from net plot area and finally converted yield into kg ha^{-1}.

Results

Height of plant (cm)

Table 1: Influence of foliar and soil application of Zn on height of plant (cm) and number of branches/ plant

		Plant height (cm)				No, of branches/plant	
	Treatment	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS
T1	Control	19.16	35.93	42.14	43.67	3.00	5.67
T2	RDF 100% (NPKS-20:17:16:20 kg ha^{-1} +PSB + Rhizobium	20.23	39.91	44.87	47.24	3.33	6.33
T3	RDF100%+ $ZnSO_4$ @ 10kg ha^{-1} as basal application	22.90	44.32	55.03	56.46	4.00	9.33
T4	RDF 100%+ $ZnSO_4$ @ 15 kg ha^{-1} as basal application	22.77	47.24	58.79	60.10	4.33	11.67
T5	RDF 100%+ $ZnSO_4$ @ 20 kg ha $^{-1}$ as basal application	23.52	49.63	61.92	63.59	4.00	12.33
T6	RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre flowering	21.20	39.80	50.06	51.53	4.00	7.33
T7	RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre-f1owering and pod initiation	22.64	40.23	52.09	54.19	4.33	8.67
T8	RDF 100% + Seed priming with 0.05% Zinc solution W/v soaked for six hours.	20.01	39.15	48.53	50.40	3.67	7.00
	S.Em (±)	0.98	1.85	2.16	2.06	0.31	0.40
	CD (5%)	NS	5.62	6.54	6.24	NS	1.20

Plant height at 30 days after sowing has non-significantly difference due to various treatments (Table 1). However, treatment T_5 - RDF 100%+ $ZnSO_4$ @ 20 kg ha^{-1} as basal application gave highest plant height (23.52 cm), while treatment T_1 - control has lowest plant height (19.16 cm) than other treatments. At 60 DAS, the treatment T_2, T_6, T_7 and T_8 utilizing the same quantity of nutrients. Hence the plant height of these treatments were almost similar (they are available RDF of NPK and S) at this stage. At 60 DAS treatment T_5 – RDF 100% + $ZnSO_4$ @ 20 kg ha^{-1} recorded significantly higher plant height (49.63) than other treatments and this was statistically equivalent to T_4 and followed by T_3. At 90DAS and at harvest treatment T_5 - RDF 100%+ $ZnSO_4$ @ 20 kg ha^{-1} as basal application shown maximum plant height (61.92 cm and 63.59cm) which was equivalent to T_4 - RDF 100%+ $ZnSO_4$ @ 15 kg ha^{-1} as basal application (58.79 cm and 60.1 cm) and both the treatments were significantly super than others. Application of Zn spray at about 80 days (pre-flowering) gave comparatively superior plant height over treatment T_2 and T_8 but overall was inferior than T_5. Control - T_1 (42.14 cm and 43.67) gave lowest plant height.

Number of branches per plant

Data presented in Table No. 2 on number of branches/ plant at 30 days after sowing revealed that application of Zn has non-significantly effect. However, treatment T_5- RDF 100%+ $ZnSO_4$ @ 20 kg per hectare as basal application shown maximum number of branches/ plant (4.33) and treatment T_1-control having the minimum branches (3.00) over the rest of treatments. At 60 DAS, treatment T_5 - RDF 100%+ $ZnSO_4$ @ 20 kg ha^{-1} as basal application counted highest No. of branches per plant (12.33) which was statistically equal to treatment T4 - RDF 100%+ $ZnSO_4$ @ 15 kg ha^{-1} as basal application (11.67) and found significantly higher than remaining treatments. T_1- control gave lowest number of branches per plant (5.67).

Plant dry matter accumulation (g $plant^{-1}$)

Data showed in Table 3 and fig no. 2 on plant dry matter accumulation at 60, 90 days after sowing as well as at harvest. At 30 DAS observation on plant dry matter accumulation showed non- significant difference due to different treatments. However, treatment T_5 yielded maximum plant dry matter accumulation (1.66 g/ plant) while minimum plant dry matter accumulation (l.05 gm $plant^{-1}$) was obtained by treatment T_1 (1.05 g per plant).

Among all treatments at 60DAS, T_5 recorded the maximum plant dry matter accumulation (5.76 g/ plant) which was statistically on par with T_4 (5.60) and significantly superior than others.

Observation recorded on 90 DAS and at harvest revealed treatment T_5 recorded the higher plant dry matter accumulation (16.03 g/ plant and 19.60 g/plant) which was significantly greater over T_1, T_2, T_8 and T_6 and was statistically on par with T_4 (15.48 and 19), T_7 (14.26 and 15.7) and T_3 (14.07 and 15.2).

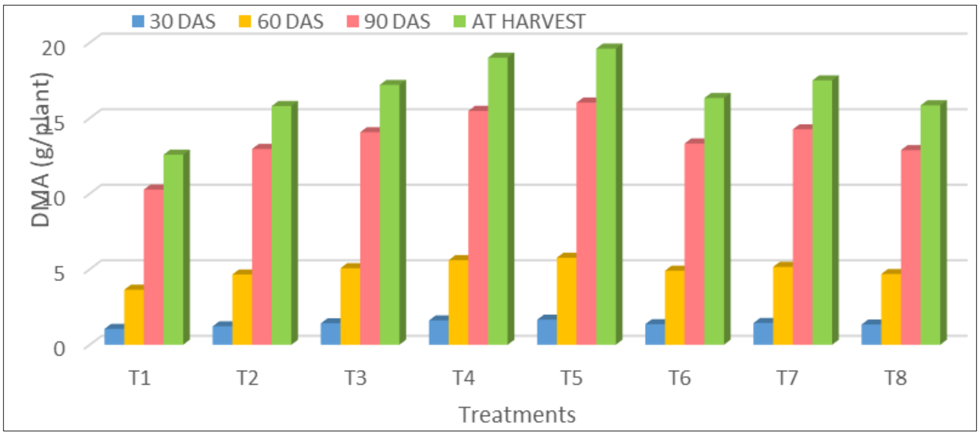

Fig 2: Impact of foliar and soil application of Zn on plant dry matter accumulation (g $plant^{-1}$)

Table 2: Impact of foliar & soil application of zinc on plant dry matter accumulation (g $plant^{-1}$)

Treatment		30 DAS	60 DAS	90 DAS	At harvest
Tl	Control	1.05	3.64	10.27	12.58
T2	RDF 100% (NPKS-20:17:16:20 kg ha^{-1} +PSB + Rhizobium	1.22	4.50	12.96	15.80
T3	RDF100%+ $ZnSO_4$ @ 10kg ha^{-1} as basal application	1.42	5.07	14.07	17.20
T4	RDF 100%+ $ZnSO_4$ @ 15 kg ha^{-1} as basal application	1.61	5.60	15.48	19.00
T5	RDF 100%+ $ZnSO_4$ @ 20 kg ha $^{-1}$ as basal application	1.66	5.76	16.03	19.60
T6	RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre flowering	1.36	4.50	13.32	16.33
T7	RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre flowering and pod initiation	1.44	4.60	14.26	17.50
T8	RDF 100% + Seed priming with 0.05% Zinc solution W/v soaked for six hours.	1.34	4.68	12.88	15.85
S.Em (±)		0.12	0.35	0.73	0.84
CD (5%)		NS	1.06	2.23	2.55

Crop growth rate (CGR) g m^2 day^{-1}

The CGR at 0-30, 30-60, 60-90 days after sowing also at harvest was influenced by the application and application method of zinc and showed significant differences among the various treatments. The concerned data represented in Table No. 4 and portrayed in fig 3, respecting. CGR at 0-30 days after sowing was found to be unaffected among various treatments of Zn application. However, higher crop growth rate was recorded with T_5 (1.85) and minimum was recorded with T_1 (1.17) than others. CGR at 30 to 60 DAS was significantly influenced among zinc application and its different method of application. The treatment T_5 - RDF 100%+ $ZnSO_4$ @ 20 kg ha^{-1} as basal application registered significantly maximum crop growth rate (4.55) which was at par to T_3 (.06), T_4 (4.43) and T_8 (3.71) and significantly superior than other treatment. 60- 90 DAS, significantly greater CGR g m^2 day^{-1} found under treatment T_5 (11.41) which was at par to treatment T_3 (9.99), T_4 (10.98), T_6 (9.80) and T_7 (10.73) and all were superior over T_1 (7.37) treatment. The crop growth rate at harvest had shown non-significant difference due to different treatments.

Table 3: Impact of foliar and soil application of Zinc on CGR (g m^2 day^{-1})

Treatment		0-30 DAS	30-60 DAS	60-90 DAS	90DAS-At harvest
T1	Control	1.17	2.54	7.37	2.57
T2	RDF 100% (NPKS-20:17:16:20 kg ha^{-1} +PSB + Rhizobium	1.36	3.64	9.40	3.16
T3	RDF100%+ $ZnSO_4$ @ 10kg ha^{-1} as basal application	1.57	4.06	9.99	3.48
T4	RDF 100%+ $ZnSO_4$ @ 15 kg ha^{-1} as basal application	1.79	4.43	10.98	3.91
T5	RDF 100%+ $ZnSO_4$ @ 20 kg ha $^{-1}$ as basal application	1.85	4.55	11.41	3.97
T6	RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre flowering	1.51	3.48	9.80	3.01
T7	RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre-flowering and pod initiation	1.60	3.51	10.73	3.60
T8	RDF 100% + Seed priming with 0.05% Zinc solution W/v soaked for six hours.	1.49	3.71	9.23	3.30
S.Em (±)		0.13	0.30	0.53	0.36
CD (5%)		NS	0.90	1.61	NS

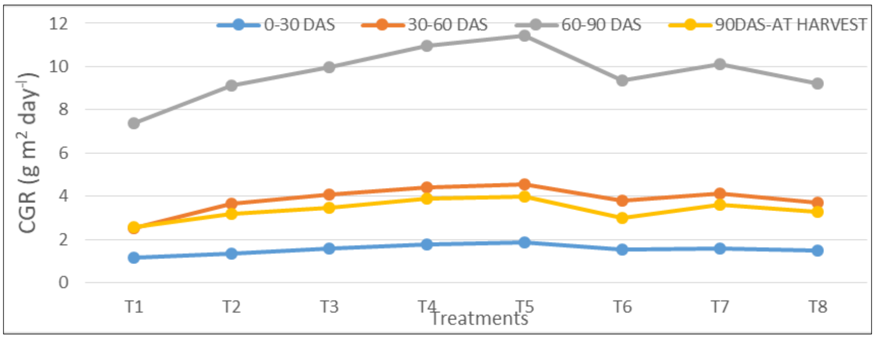

Fig 3: Influence of foliar and soil application of Zn on CGR (g m^2 day^{-1})

Yield attributes and yield of Lathyrus crop

Observation recorded on number of pods/plant (Table 5) revealed that various treatment significantly affected on number of pods plant^{-1}. Treatment T_5 (21.55) recorded Higher no. of pods plant^{-1} which was significantly superior than T_1 (14.33), T_2 (18.04), T_8 (18.08), and T_6 (18.60) while remaining treatments were at par i.e. T_4 (21.05), T_7 (19.56) and T_3 (18.94). Number of grains per pod had showed a non-significant interaction due to different treatments. However, treatment T_5 gave highest number of grains pod^{-1} (3.64) while, treatment T_1 recorded minimum number of grains pod^{-1} (2.57). 100-seed weight (g) disclosed that there was no-significant impact of Zn application on seed index (g) of Lathyrus crop.

Grain and straw yield (kg ha^{-1})

Perusal of recorded mean data revealed that grain yield of Lathyrus crop had been significantly affected by foliar and basal application of zinc which is shown in table 5. Amongst various treatments, the treatment T_5 yielded higher seeds and straw (2136 kg ha^{-1} and 4340 kg ha^{-1}) which was on par to T_4 (2055 kg ha^{-1} and 4340 kg ha^{-1}) and T_7 (1897 kg ha^{-1} and 3980 kg ha^{-1}) this treatment was noted down to be significantly superior over T_3 (1787 kg ha^{-1} and 3785 kg ha^{-1}), T_6 (1725 kg ha^{-1} and 3663 kg ha^{-1}), T_8 (1645 kg ha^{-1} and 3590 kg ha^{-1}) and T_2 (1617 kg ha^{-1} and 3600 kg ha^{-1}). Control, that is farmer's practice under which no any nutrients are applied, gave significantly poor grain yild of Lathyrus crop (1272 kg ha^{-1} and 2853 kg ha^{-1}).

Harvest index (%)

The observed mean data concerning harvest index exposed that non-significant effect of Zn application and various method of application had been observed. However, treatment T_5 (32.98%) documented maximum harvest index over the treatment T_1- control (30.44%) lowest harvest index.

Table 4: Impact of foliar and basal application of Zn on crop yield contributing characters, crop grain and stover yield (kg ha^{-1}) and harvest index (%)

TREATMENT		No. of pods per plant	No. of grains per pod	100 Grain Weight (gm)	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Harvest index (%)
T1	Control	14.33	3.49	7.63	1272	2853	30.44
T2	RDF 100% (NPKS-20:17:16:20 kg ha^{-1} +PSB + Rhizobium	18.04	3.51	7.67	1617	3600	31.04
T3	RDF100%+ $ZnSO_4$ @ 10kg ha^{-1} as basal application	18.94	3.58	7.91	1787	3785	32.09
T4	RDF 100%+ $ZnSO_4$ @ 15kg ha^{-1} as basal application	21.05	3.61	8.11	2055	4240	32.63
T5	RDF 100%+ $ZnSO_4$ @ 20kg ha^{-1} as basal application	21.55	3.64	8.17	2136	4340	32.98
T6	RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre flowering	18.60	3.55	7.84	1725	3663	31.99
T7	RDF 100% + $ZnSO_4$ @ 0.5% foliar spray at pre-flowering and pod initiation	19.56	3.59	8.09	1897	3980	32.27
T8	RDF 100% + Seed priming with 0.05% Zinc solution W/v soaked for six hours.	18.08	3.53	7.74	1645	3590	31.42
S.Em (±)			0.91	0.18	0.41	157.14	1.22
CD (5%)			2.77	NS	NS	476.56	NS

Discussion

Growth parameters of Lathyrus

Growth parameters in terms of Germination, height of plant, number of branches/plant, dry matter accumulation (g plant^{-1}), and CGR are very key factors which indirectly affected the seed yield. Various nutrient management practices greatly influenced the plant height of Lathyrus. Height of plant on 30 DAS was not-significant influenced by the basal and foliar application of Zn, and significantly higher plant height (cm) at 60, 90 days after sowing also at harvest was found in T_5- RDF 100% + $ZnSO_4$ @ 20 kg ha^{-1} as basal application, major changes in plant from 60-90 days has been reported. Rise in height might be due to taking up of zinc in plant, zinc produces the auxin and availability of zinc to the leaves in plant in apical portion which enhance the plant height. Similar plant height was also noticed in T_4 and T_7 these findings are also endorsed by Upadhyay and Singh (2016) [14]. Significantly lower height was recorded in control (T_1) at 30, 60, 90 days after sowing and at harvest plots may be due to insufficient nutrient available to plant.

Highest dry matter accumulation was noted down with T_5- RDF 100% + $ZnSO_4$ @ 20 kg ha^{-1} as basal application at all growth stages like 30, 60, 90 days after sowing and at harvest, which was statistically alike with treatment T_4 and T_7 and lower dry matter accumulation was noted down with T_1 (control). Dry matter accumulation in the plants increased largely because of higher number of leaves, chlorophyll synthesis and height. Variation in response of growth attributes are due to more availability of major nutrients like NPK. Application of rhizobium and PSB microorganisms increase the rhizosphere micro environment, thus enhancement in P nutrition along with higher nitrogen fixation might be contributed to improved plant growth and dry matter accumulation. These outcomes are similar with result of Sarkar *et al*. (1990) and Weldua *et al*. (2012) [11]. The least dry matter accumulation was found in control at whole growth phases may be due to serve competition for growth factors mainly nutrient quantity and quality. Related result was witnessed by Jha *et al*. (2015) [12].

More number of branches produces more flowers and leaves and dry matter by producing more photosynthates and thus improve the yield of plant. No significantly higher number of branches plant^{-1} registered at 30 DAS but higher number of branches plant^{-1} recorded at 30 DAS (4.33) in T_5 and at 60 DAS (12.33) it may be due to zinc application increase the photosynthesis and growth of plant and also the root nodule numbers and activity which provide the better nutrition to plant and increased growth and development which increase number of branches, minimum branches observed in control (T_1) at 30 and 60 DAS. Similar result observed has also been by Mahilane and Singh (2018) [8].

With age of crop, the crop growth rate increased considerably. The mean growth rate of the crop was found increasing from 0-30 DAS, 30-60 DAS and then reached at peak from 60 to 90 DAS and thereafter it declined. The highest crop growth rate was observed in RDF 100% + $ZnSO_4$ @ 20 kg ha^{-1} as basal application. The enhancement in CGR due to higher uptake of nutrients which facilitated in creation of more protoplasm and thereby rapid increase in cell division and cell elongation which shown faster rate of plants development. Application of zinc also increased the carbonic anhydrase enzyme activity which help in transport the CO_2 for photosynthesis activity and applied sulphur is also a part of ferredoxin enzyme which helped plants to make more energy for growth and development which ultimately impact on crop growth rate. CGR was found in T_4 and T_7 was equally good because least competition for nutrients and enhanced enzymes activity, enhanced photosynthetic rate of the crop which provided sufficient photosynthates and higher nitrogen and phosphorus which also helped in plant to make more structurally sufficient which finally lead to increase in crop growth rate. Sai Kishore *et al*. (2020) [1] also represented the similar results. Minimum CGR was noticed in control (T_1) at all growth stages may be due to insufficient nutrition. Similar outcomes were also reported by Thamake *et al*. (2019) [9].

Effect on yield attributing characters and yield of Lathyrus crop

Effect on yield attributes

Yield attributing characters like number of pods plant^{-1}, number of grains pod^{-1}, 100-grain weight (g), grain yield, stover yield and harvest index affected by 'Impact of foliar and basal application of zinc' which has been described in earlier chapter and the relevant data has been given in table 4.6. Yield of a crop is ultimate expression of overall performance of crop plants i.e. pre and after- harvest characters. At the same time, the other yield attributing characters *viz*., number of grains pod^{-1} and 100 grain weight were not affected by zinc application because they are varietal characters which were bound to genetic or breeding approaches. Adequate nutrient application influenced all the yield attributing characters. Thus, the pathway of enhanced photosynthesis efficiency in pre and post - anthesis growth and development of crop, nutrient application and balanced nutrition provided by the microorganisms through the increased in root surface area, moisture uptake, apart from making available phosphorus and nitrogen to the crop. Hence, in our finding enhancement in number of pods plant^{-1} easily changed by adoption of zinc application through soil and foliar method. The maximum value of this yield attributing character must be due to high nutrient uptake, enhanced in the metabolic activity of the plant and photosynthesis rate and translocation of more photosynthates to sink from source under T_5 - RDF 100% + $ZnSO_4$ @ 20 kg ha^{-1} as basal application in Lathyrus crop. Related conclusions were found by Pathak *et al.*, (2012) [7], Moswatsii *et al*. (2013) [6] and Roy *et al*. (2014) [5].

Grain and straw yield (kg ha^{-1})

Grain yield of crop is expression and impact of all growth and development characters. Grain yield is a complex character resulting from interaction of many inherent primary physiological characters of the plant with each-other and with the environment and input management. This is also because the total dry matter accumulation as well as efficiency of its conversion into economic yield, is responsive to different management practices and processes. The seed yield was significantly influenced by various method of foliar and soil application of Zinc. Highest grain yield (2136 kg ha^{-1}) was threshed in treatment T_5 - RDF 100% + $ZnSO_4$ @ 20 kg ha^{-1} as basal application which was noticed to be alike with T_4 - RDF 100% + $ZnSO_4$ @ 15 kg ha^{-1} as basal application (2055 kg ha^{-1}) and T_7 - RDF 100% + $ZnSO_4$ @ 0.5% foliar application at pre flowering and pod initiation (1897 kg ha^{-1}) (Table 4.7), This may be due to enhanced the availability of nutrients to crop plants resulting in favorable increased in vegetative growth, dry matter accumulation, increased photosynthetic activity due to increased leaf area, improved assimilates transport to sink, increased number of pods, seeds pod^{-1} and seed index and finally resulted improved grain yield of lathyrus. Better nutrient management and high nutrient uptake that lead to higher growth, better yield characters, and high dry weight and thus, more grain yield over the other treatments. Significant low grain yield was recorded in T_1 - control might be due to low nutrient availability to crop plant which affect growth and which ultimately resulted in the grain yield and thus crop plant which could not express the fullest yield potential. This finding is also supported by works of Saakshi *et al.* (2020) [4] and Behera *et al*. (2020) [3].

Straw yield is primarily a function of the vegetative growth of the plant in terms of height of plant, dry matter accumulation and other characters. Optimum plant population, better fertilization of crop and other agronomic management practices influenced the straw yield. Different Fertility levels had distinct influence on the straw yield. Application of RDF+ bio fertilizers + $ZnSO_4$ 20 kg ha^{-1} showed significantly influence on straw yield. The higher straw yield might be obtained by this treatment due to adequate quantities of balanced nutrient supplied to crop during the growth period, which enhanced the vegetative growth, dry matter accumulation, chlorophyll synthesis and photosynthesis activity increased total biomass and finally the straw yield.

Harvest index (%)

Harvest index in present investigation was not significantly affected under different treatments due to various doses and soil and foliar application of nutrient except in control which was lower than the other treatments. Low harvest index in control treatment may be due to unregulated nutrient management resulted the weak plants that inhibited the physiological growth of crop plants and hence low photosynthesis and low partitioning of photosynthates to grain. However, treatment RDF 100% + $ZnSO_4$ @ 20 kg ha^{-1} as basal application (32.98) noticed higher harvest index (%). This may be because of better photosynthesis and partitioning of photosynthates to grains, Saikishore *et al*. (2020) [10] and Masih *et al*. (2020) [2] detected related results.

Conclusion

Over all conclusion is that the application of RDF 100% + $ZnSO_4$ @ 20 kg ha^{-1} as basal application is recommended for better production and quality of Lathyrus crop and higher economic return as well as enhancing the soil nutrient status under calcareous soil of north Bihar. This experimental finding was based on experimentation for a one - year investigation. Performing this experiment for more than three years continuously may provide a valid conclusion on the integration effect of inorganic fertilizer (NPKS and Zn) combined with PSB and Rhizobium on growth, development, yield and quality under calcareous soil of Bihar.

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