RESEARCH ARTICLE

Phosphate solubilizing bacteria impact on butter beans (*Phaselous lunatus* L.) cult vated in Kodai hills on vegetat ve growth, yield, and metabolism

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Butter beans (*Phaseolus lunatus* L.) are a high-protein food grown in the Kodai Hills and belong to the Fabaceae family. For phosphorus deficiency, the soil is usually adequately treated with phosphatic chemical fertilisers. Butter bean crop production is poor due to insufficient fertilization. The widespread use of artificial fertilisers would devastate the ecosystem, and farmers have complained that the price is too high. As a result, it is critical to limit the usage of chemical fertilisers in favour of organic fertilisers derived from microbial biomes such as Phosphate-Solubilizing Bacteria (PSB). The experiment consisted of 15 treatments with phosphate solubilizing bacteria with three levels (control, tricalcium phosphate, and PSB) in a randomised complete block design with three replications in order to examine the influence of PSB on butter bean growth, yield, and metabolic characteristics. The administration of PSB to the butter bean crop resulted in improved growth, yield, and metabolic parameters, resulting in higher seed output and a possible crop yield increase, according to this study.

Key Words: Phosphate solubilizing bacteria; Growth; Yield; Metabolism

INTRODUCTION

The Kodai Hills are home to the high-quality, protein-rich crop known as butter beans. Due to inadequate fertilisation, butter bean crops produce little. The ecology will suffer greatly from the extensive use of chemical fertilisers. The soil is often appropriately addressed for phosphorus shortage using phosphatic chemical fertilisers. However, its potential use would be harmful to the ecosystem. By converting to organic fertilisers, ideally microbial biome fertilisers, it can be reduced to a minimum. As a consequence, PSB may be used as a biofertilizer to promote plant growth, productivity, and phosphate solubilization by modifying the synthesis of phytohormones and secondary metabolites.

MATERIALS AND METHODS

The field experiment was conducted Kodai Hills, Tamilnadu, and PSB this used for BT-(11-15) test conduct.

Experimental protocol

The test experiment was conducted using randomized complete block design and it was done with the following treatments.

- **BT-(1-5):** Sterile soil mixed with water (Blank).
- **BT-(6-10):** Sterile soil mixed with tri calcium phosphate and water (Control).
- **BT-(11-15):** Sterile soil mixed with tri calcium phosphate, phosphate solubilizing bacteria and water (TEST).

Field experiment

An experiment was carried out on a field of butter bean plants in the Kodai Hills of Tamil Nadu, India. The experiment was conducted using a plot-based randomised full block design with three replications. In a number of plots marked BT, butter bean seeds (*Phaselous lunatus* L.) were planted. Plant height, whole plant fresh weight, whole plant dry weight, shoot length, and dry seed weight are growth and metabolic indicators. Active acid phosphatase, amino acid content, ascorbic acid content, indole-3-acetic acid content, phosphorus content, protein content, reducing sugar content, starch content, total phenolic content, total soluble sugar content, anthocyanin content, chlorophyll content was evaluated after growth of carrot plants [1-4].

Field experiment on Kodai Hills in the field of butter beans plants (Figures 1 and 2)

Figure 1) *30 DAS*

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Figure 2) *At harvest*

RESULTS AND DISCUSSION

Effect of PSB on growth and yield parameters of butter beans plants

A randomised complete block design with three replications was employed for a field research of butter bean plants in the Kodai Hills. Plant height, yield, metabolic characteristics, and acid phosphatase activity were all assessed at harvest. When compared to other sets, the PSB treated set BT-(11-15) showed a more favourable effect on growth, yield, and metabolism (Blank and control).

On butter bean plants, the BT-(1-15) test samples were put to the test in the open. The vegetative development, yield, and metabolic characteristics of butter bean plants were all assessed. The study found that butter bean vegetative growth, yield, and quality indices were increased when butter bean plants were treated with PSB strain BT-(11-15) (Tables 1 and 2). During the growing period, the PSB treatments and their combinations performed much better than the control crops. The information may be found in Figures 3 and 4 [5].

TABLE 1

Effect of PSB on growth parameters of butter beans plants

S. no.	Plant height			Number of leaves per plant		
	45 DAS	90 DAS	120 DAS	45 DAS	90 DAS	120 DAS
BT-1	36.83 ± 0.52	73.36 ± 0.35	125.1 ± 0.57	8	28	54
BT-2	35.62 ± 0.66	70.78 ± 0.68	121.3 ± 0.63	9	24	52
BT-3	34.84 ± 0.74	69.63 ± 0.64	127.6 ± 0.66	11	20	48
BT-4	39.80 ± 0.63	78.56 ± 0.56	134.7 ± 0.45	10	15	35
BT-5	36.70 ± 0.77	73.74 ± 0.63	130.6 ± 0.71	15	25	43
BT-6	43.95 ± 0.85	87.82 ± 0.82	148.9 ± 0.69	21	62	118
BT-7	40.93 ± 0.88	81.81 ± 0.77	144.9 ± 0.80	18	58	114
BT-8	46.62 ± 0.80	92.62 ± 0.76	152.8 ± 0.82	24	56	110
BT-9	116.8 ± 0.78	233.8 ± 0.92	298.9 ± 0.56	20	52	108
BT-10	117.8 ± 0.74	234.9 ± 0.71	296.8 ± 0.78	22	55	106
BT-11	125.7 ± 0.84	250.9 ± 0.86	310.8 ± 0.92	28	67	138
BT-12	122.8 ± 0.94	244.5 ± 0.74	308.7 ± 0.85	27	61	127
BT-13	127.1 ± 0.92	253.8 ± 0.94	314.6 ± 0.86	25	64	124
BT-14	126.9 ± 0.50	253.7 ± 0.63	315.9 ± 0.78	29	68	133
BT-15	127.2 ± 0.61	253.8 ± 0.86	318.9 ± 0.84	30	74	140

TABLE 2

Effect of PSB on growth parameters of butter beans plants

S. no.	Shoot length			Whole plant Fresh weight	Whole plant Dry weight
	45 DAS	90 DAS	120 DAS	120 DAS	120 DAS
BT-1	42.83 ± 0.45	144.6 ± 0.63	142.4 ± 0.43	138.79 ± 0.93	47.38 ± 0.29

BT-2	35.21 ± 0.53	71.83 ± 0.66	135.7 ± 0.57	135.87 ± 0.86	44.70 ± 0.69
BT-3	64.74 ± 0.64	128.8 ± 0.49	128.7 ± 0.58	130.21 ± 0.64	31.70 ± 0.53
BT-4	36.63 ± 0.72	72.24 ± 0.17	130.8 ± 0.64	139.70 ± 0.88	32.74 ± 0.63
BT-5	33.82 ± 0.43	67.75 ± 0.58	127.8 ± 0.85	151.78 ± 0.95	38.79 ± 0.58
BT-6	75.56 ± 0.69	150.8 ± 0.50	207.8 ± 0.69	110.74 ± 0.61	50.82 ± 0.66
BT-7	74.75 ± 0.87	148.6 ± 0.80	203.9 ± 0.78	118.61 ± 0.79	54.80 ± 0.70
BT-8	72.98 ± 0.67	145.8 ± 0.78	198.9 ± 0.63	113.13 ± 0.84	52.33 ± 0.91
BT-9	73.77 ± 0.74	147.1 ± 0.65	195.6 ± 0.57	117.62 ± 0.69	54.78 ± 0.65
BT-10	74.63 ± 0.95	148.7 ± 0.57	197.8 ± 0.80	119.65 ± 0.76	53.60 ± 0.67
BT-11	102.3 ± 0.57	204.2 ± 0.49	259.4 ± 0.61	102.71 ± 0.63	62.90 ± 0.78
BT-12	99.17 ± 0.77	198.1 ± 0.92	248.6 ± 0.82	101.38 ± 0.18	65.22 ± 0.83
BT-13	101.4 ± 0.61	201.9 ± 0.86	254.2 ± 0.71	100.82 ± 0.58	63.39 ± 0.72
BT-14	108.7 ± 0.63	217.8 ± 0.61	270.9 ± 0.94	108.80 ± 0.56	67.23 ± 0.90
BT-15	98.87 ± 0.95	199.8 ± 0.85	246.9 ± 0.84	109.91 ± 0.55	61.35 ± 0.79

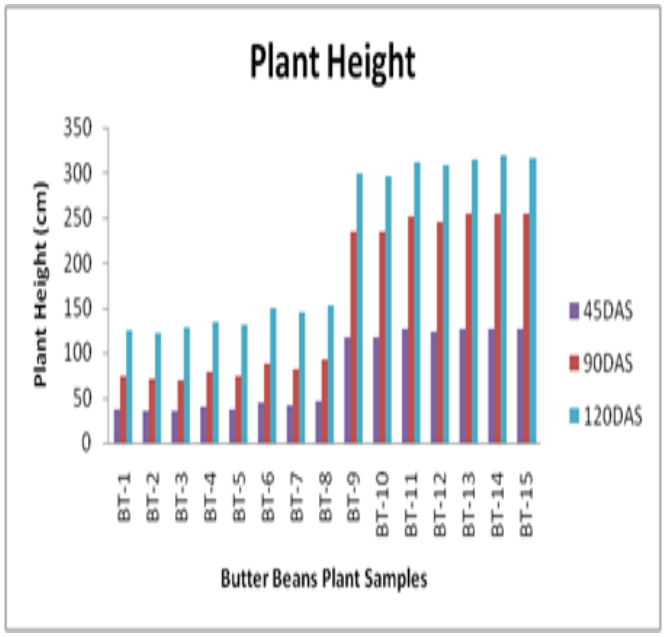

Figure 3) *Plant height*

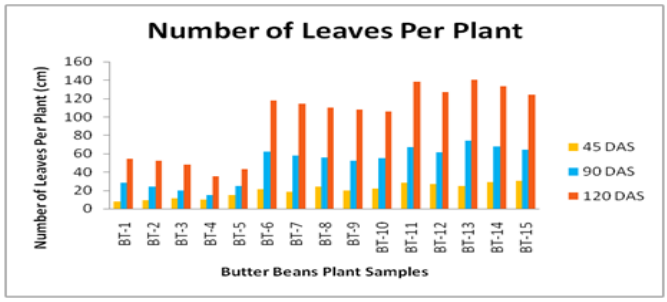

Figure 4) *Number of leaves per plant*

Effect of PSB on vegetative growth and yield of butter beans plants

The PSB-treated plants outperformed the other plant treatments in terms of plant height, leaf production, and vegetative development as measured by shoot length, whole plant fresh weight, whole plant dry weight, and quantitative measurements including leaf weight and plant weight. The maximum output and related attributes came from PSB treatments (Tables 3 and 4). The PSB-treated plants had the highest fresh pod weight, dry seed weight, fresh seed weight per pod, and quantitatively in fresh seed weight per pod when compared to other plant treatments (Figures 5 and 6) [6].

TABLE 3

Effect of PSB on yield parameters of butter beans plants

S. no.	Fresh pod weight	Fresh seed weight per pod	Dry seed weight	Number of pods per cluster	Pod width
BT-1	6.92 ± 0.68	3.86 ± 0.61	57.46 ± 0.24	2	1.71 ± 0.27
BT-2	6.24 ± 0.64	2.61 ± 0.74	59.67 ± 0.53	1	1.48 ± 0.24
BT-3	5.65 ± 0.74	4.89 ± 0.52	58.39 ± 0.30	3	1.34 ± 0.40
BT-4	6.64 ± 0.65	5.92 ± 0.37	57.15 ± 0.72	2	1.47 ± 0.30
BT-5	4.33 ± 0.82	5.18 ± 0.56	56.76 ± 0.64	3	1.53 ± 0.44
BT-6	7.80 ± 0.79	4.74 ± 0.89	38.93 ± 0.77	5	1.44 ± 0.20

BT-7	8.96 ± 0.83	6.89 ± 0.58	37.74 ± 0.60	4	1.47 ± 0.36
BT-8	9.46 ± 0.90	6.11 ± 0.79	35.64 ± 0.79	5	1.55 ± 0.29
BT-9	9.19 ± 0.84	6.11 ± 0.25	35.20 ± 0.92	5	1.68 ± 0.85
BT-10	9.26 ± 0.66	6.81 ± 0.90	38.99 ± 0.55	4	2.53 ± 0.35
BT-11	12.96 ± 0.70	6.86 ± 0.47	17.96 ± 0.54	6	2.77 ± 0.83
BT-12	10.75 ± 0.77	5.87 ± 0.49	19.75 ± 0.94	6	2.64 ± 0.77
BT-13	11.97 ± 0.56	7.05 ± 0.88	15.44 ± 0.78	6	2.49 ± 0.44
BT-14	10.94 ± 0.86	6.81 ± 0.95	12.81 ± 0.91	6	2.50 ± 0.81
BT-15	13.92 ± 0.72	7.63 ± 0.74	11.81 ± 0.82	7	2.89 ± 0.80

TABLE 4

Effect of PSB on yield parameters of butter beans plants

S. no.	Number of pods per plant	Pod length	Number of seeds per plant	Pod yield per plant	Weight of seeds per plant	Single seed weight
BT-1	20	14.14 ± 0.60	80	195.5 ± 0.37	110.88 ± 0.46	0.46 ± 0.14
BT-2	16	10.86 ± 0.65	85	155.8 ± 0.45	90.88 ± 0.58	0.38 ± 0.11
BT-3	18	11.49 ± 0.48	82	180.3 ± 0.21	105.65 ± 0.64	0.56 ± 0.27
BT-4	10	12.85 ± 0.75	79	107.2 ± 0.49	64.82 ± 0.57	0.77 ± 0.17
BT-5	15	10.73 ± 0.56	67	150.2 ± 0.58	88.97 ± 0.60	0.67 ± 0.25
BT-6	45	17.65 ± 0.56	105	348.6 ± 0.90	198.56 ± 0.73	0.77 ± 0.16
BT-7	43	19.83 ± 0.73	102	336.3 ± 0.80	191.90 ± 0.68	1.14 ± 0.12
BT-8	41	16.11 ± 0.83	98	329.3 ± 0.78	185.80 ± 0.75	1.11 ± 0.49
BT-9	40	13.97 ± 0.91	95	324.8 ± 0.53	182.63 ± 0.80	1.11 ± 0.77
BT-10	38	16.89 ± 0.85	97	312.6 ± 0.70	175.99 ± 0.78	1.12 ± 0.50
BT-11	53	19.68 ± 0.59	128	450.5 ± 0.71	238.87 ± 0.85	1.25 ± 0.15
BT-12	51	18.87 ± 0.68	120	417.8 ± 0.78	231.75 ± 0.87	1.65 ± 0.43
BT-13	46	22.03 ± 0.71	125	403.2 ± 0.88	210.76 ± 0.95	1.86 ± 0.72
BT-14	44	23.33 ± 0.68	123	424.8 ± 0.92	257.84 ± 0.83	1.83 ± 0.58
BT-15	55	24.68 ± 0.81	134	509.3 ± 0.66	262.77 ± 0.93	1.96 ± 0.10

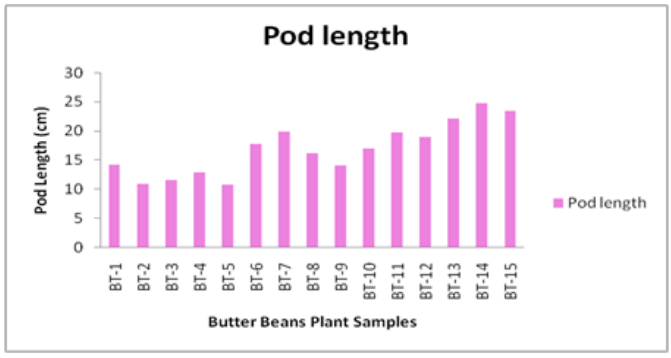

Figure 5) *Pod length*

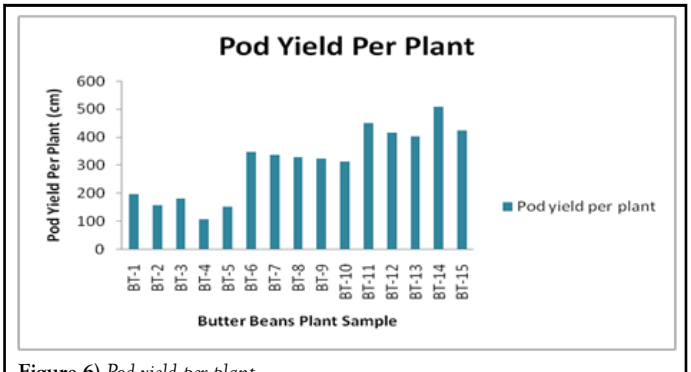

Figure 6) *Pod yield per plant*

Effect of PSB on yield of butter beans plants

The productivity of plants was higher in those metabolites that act on plants, increase phosphorus content, and stimulate positive growth responses, compared to metabolites that act on plants, decrease phosphorus content, and stimulate negative growth responses (Tables 5-7 and Figure 7-14) [7].

TABLE 5

Effect of PSB on metabolic parameters of butter beans plants-I

Test sample	Reducing sugar content (mg/g of leaves)	Total sugar content (mg/g of leaves)	Non-reducing sugar content (mg/g of leaves)	Starch content (mg/g of leaves)	Protein content (mg/g of leaves)	Amino acid content (mg/g) of leaves of leucine equivalent
BT-(1-5)	4.823 ± 0.19	17.72 ± 0.58	13.23 ± 0.23	22.82 ± 0.13	19.05 ± 0.89	0.70 ± 0.04
BT-(6-10)	6.501 ± 0.54	20.36 ± 0.38	13.37 ± 0.55	25.82 ± 0.18	15.31 ± 0.94	0.63 ± 0.04
BT-(11-15)	9.756 ± 0.27	23.49 ± 0.61	13.71 ± 0.44	31.80 ± 0.28	13.88 ± 0.83	0.45 ± 0.08

TABLE 6

Effect of PSB on metabolic parameters of butter beans plants-II

Test sample	Chlorophyll-a	Chlorophyll-b	Total chlorophyll (mg/g of leaves)	Total carotenoid content (mg/g of leaves)	Anthocyanin content (mg/g of leaves)
BT-(1-5)	0.65 ± 0.01	0.14 ± 0.02	0.78 ± 0.01	0.26 ± 0.03	0.83 ± 0.05
BT-(6-10)	0.64 ± 0.02	0.27 ± 0.02	0.85 ± 0.05	0.27 ± 0.03	0.65 ± 0.05
BT-(11-15)	0.55 ± 0.04	0.49 ± 0.01	1.08 ± 0.11	0.28 ± 0.01	0.55 ± 0.02

TABLE 7

Effect of PSB on metabolic parameters of butter beans plants-III

Test sample	Total phenolics content (mg/g of leaves)	Ascorbic acid content (mg/g of leaves)	Indole-3-acetic acid content (mg/g of leaves)	Shoot phosphorus content (mg/g of DW of shoot)	Acid phosphatase activity (mU/ml)
BT-(1-5)	15.46 ± 0.61	0.06 ± 0.01	0.25 ± 0.04	3.154 ± 0.32	14.81 ± 0.24
BT-(6-10)	13.81 ± 0.18	0.07 ± 0.01	0.32 ± 0.02	6.868 ± 0.12	49.32 ± 0.22
BT-(11-15)	9.53 ± 0.46	0.11 ± 0.01	0.64 ± 0.07	8.199 ± 0.44	81.38 ± 0.56

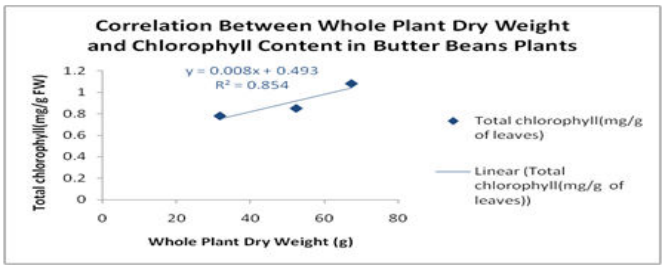

Figure 7) *Correlation between whole plant dry weight and chlorophyll content butter beans plants*

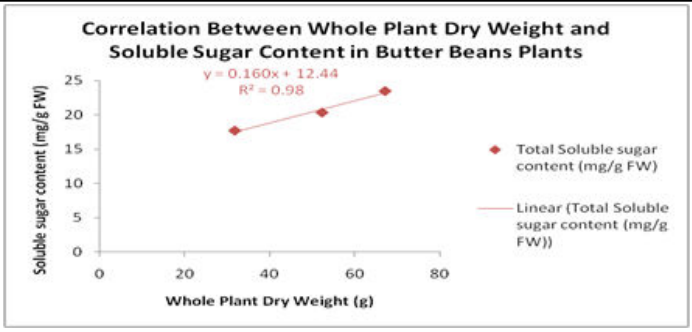

Figure 8) *Correlation between whole plant dry weight and soluble sugar content butter beans plants*

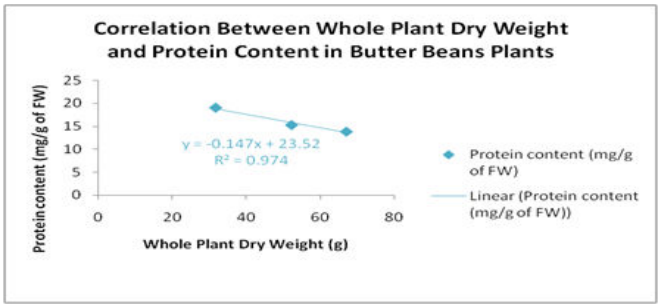

Figure 9) *Correlation between whole plant dry weight and protein content butter beans plants*

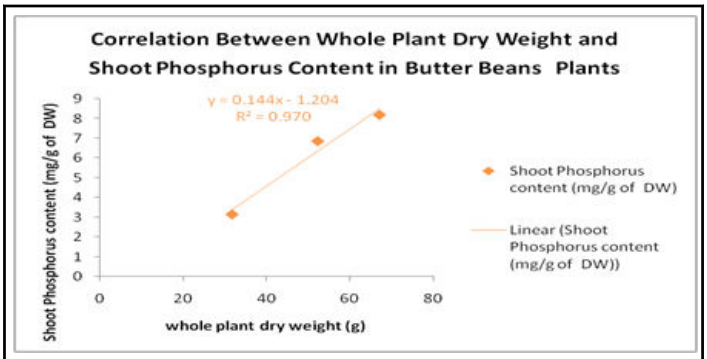

Figure 10) *Correlation between whole plant dry weight and shoot phosphorus content in butter beans plants*

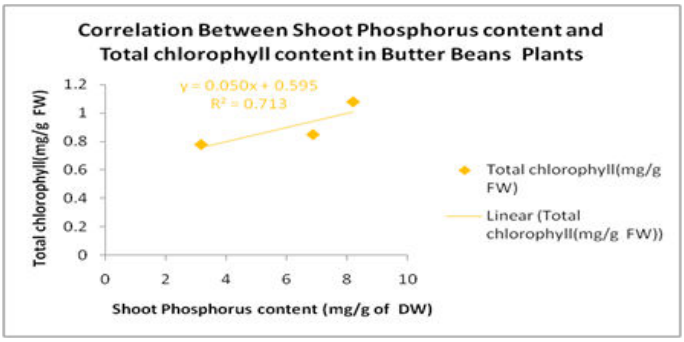

Figure 11) *Correlation between shoot phosphorus content and total chlorophyll content in butter beans plants*

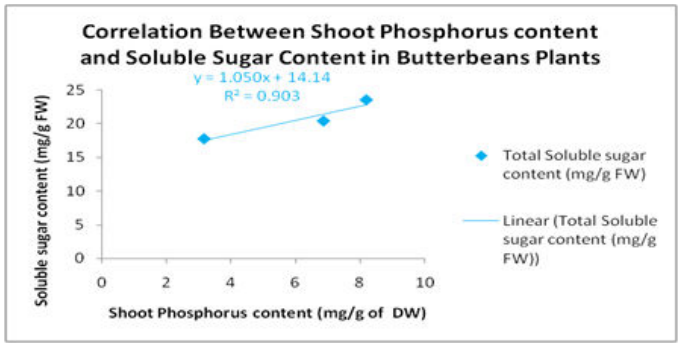

Figure 12) *Correlation between shoot phosphorus content and soluble sugar content in butter beans plants*

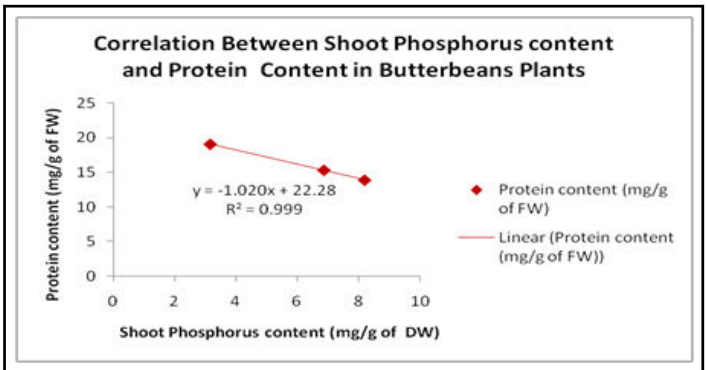

Figure 13) *Correlation between shoot phosphorus content and protein content in butter beans plants*

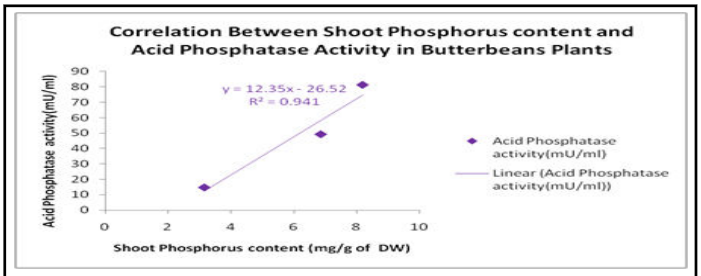

Figure 14) *Correlation between shoot phosphorus content and acid phosphatase activity in butter beans plants*

Effect of PSB on metabolism of butter beans plants

The butter bean plants received PSB treatments, which increased the production of growth hormones and caused the plants to develop vegetatively. The maximum photosynthetic potential of the plants may have been stimulated by the use of PSB bio-fertilizers, resulting in enhanced yield-related attributes. By working in concert with inorganic fertilisers like calcium phosphate, the increased phosphorus absorption capacity's potential to solubilize phosphate may have contributed to improving nutrient uptake effectiveness. This may have sped up metabolic activity, chlorophyll synthesis, and cell division as well as lengthening. The obtained results were in accordance with in butter beans and in butter beans [8].

CONCLUSION

By solubilizing the inaccessible soil phosphate, PSB effectively enhances phosphorus absorption when compared to other treatments, and their application increased butter bean growth, quality, and productivity. Simultaneous calcium phosphate and PSB inoculation of butter bean plants produced significantly more leaves, plant height, whole plant fresh weight, whole plant dry weight, shoot length, and dry seed weight than the other treatments. Therefore, butter bean crops treated with PSB may result in higher seed yields and overall butter bean production.

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