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Application of Phosphate Solubilizing Bacteria and Its Ecological Effect on Growth and Yield of Winter Maize (Zea Mays L.)

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Abstract: *A study was conducted on* ***"Application of Phosphate Solubilizing Bacteria & its Ecological effect on growth and yield of winter maize (Zea mays L.)"****for two successive winter seasons at Bamin Michi village, Lower Subansiri District Arunachal Pradesh. In split plot design, the experiment was conducted and replicated three times. To the main plots, the three PSB treatments viz., control (T_1), seed inoculation with PSB (T_2) and PSB inoculation along with 5t FYM ha^{-1} were allotted. Due to PSB inoculation along with FYM, the values of all growth parameters (plant height, green leaves, leaf area, LAI and dry matter production plant^{-1}) recorded higher and remained lower under control. However, on number of days to 50% silking, maturity and barren plants plot^{-1} , the effect of PSB inoculation alone, PSB added with 5t FYM ha^{-1} and the control found at par to each other though these characters remained higher and lower with PSB added with FYM and the control correspondingly. With the inoculation of PSB added with FYM the values of almost all the yield attributes as well as grain and stover yields were recorded maximum. With the PSB inoculation along with 5t FYM ha^{-1} , maximum content of NPK content in grain and stover, as well as their uptake by grain, stover and total uptake by crop were recorded maximum. With inoculation of PSB along with 5t FYM ha^{-1}, the available NPKcontent in soil at crop harvest also remained maximum. In respect of protein and carbohydrates in grain, inoculation on PSB along with 5t FYM ha^{-1} (T_3) found superior*

Key Words: *Hybrid maize; Planting methods; Nutrient management*

I. Introduction

Maize (Zea mays L.) is an important cereal crop and ranks third in production after rice and wheat in India. Due to higher yield potential, short growing period, high value for food, forage and feed for livestock, poultry and a cheaper source of raw material for agro-based industry, it is increasingly gaining an important position in the cropping system. It has greater nutritional value as it contains about 72% starch, 10% protein, 4.8% oil, 8.5% fiber, 3% sugar and 17% ash (Chaudhry, 1983). Requirement of about 305 mt of food grains is anticipated for 1.4 billion population of India, and the substantive insist for individual food grains has been expected to about 120 mt for rice, 95mt for wheat, 25 mt for maize and 24-26 mt for pulses by the year 2025 (Tiwari,2001). This decisive state of affairs budding vast strain upon the policy planners for which the response is bigger, diversified as well as sustainable and more rapid grain production.

After the revolution in rice and wheat production, as opined by the Noble laureate, Dr. Norman E. Borlaug, the next few decades will be known as maize era (Rai, 1998).

Phosphate solubilizing bacteria are carrier based preparation in agriculture which may aid in increasing crop productivity by serving in solubilization of insoluble phosphorus, stimulating plant growth by providing hormones, vitamins and other growth factors. In soil pH, EC, O_2, CO_2 concentration and the presence of organic material, influence the degree of solubilization . As the only sources of organic matter, role of farmyard manure can never be ignored without which soil can never be productive. Farm yard manure (FYM) supplies all the essential nutrients for plants and increase the activity of phosphorus solubilizing bacteria in addition to this.

In view of above mentioned factors, it is desirable to build up cost effective, eco- friendly, sustainable systems, where the supply of phosphorus along with other nutrient to plants be secured. Based on research findings, It has been established that Phosphorus-solubilizing bacteria may play a demanding role in increasing the availability of Phosphorus to the crop plants. Although studies are available on summer maize cultivation with reference to planting time but survey of literature reveals that information is lacking on winter maize cultivation.

The present study, keeping the above facts in view was undertaken to find out the **Application of Phosphate Solubilizing Bacteria & its Ecological effect on growth and yield of winter maize (Zea mays L.)**

II. Materials And Methods

The present investigations were carried out on maize (*Zea mays* hybrid variety all rounder) during the winter seasons of 2011-12 and 2012-13 at Bamin Michi village, Lower Subansiri District Arunachal Pradesh.

The present field study was laid out in split plot design. The three treatments viz, control T_1, seed inoculation with PSB T_2 and seed inoculation with PSB along with 5t FYM ha^{-1} T_3 were allotted to plots. Using Fisher and Yates random table (Panse and Sukhatme, 1985) the treatments were allocated to each plot in three replications. There were 9 such plots.

The inter row spacing maintained was 60 cm with intra row spacing at 25 cm. The observations on growth and yield characteristics of the crop were recorded by using the standard procedures. The data obtained by various observations was subjected to statistical analysis by adopting Method of 'Analysis of Variance' (Cochron and Cox.1992) for determining the significance of difference between the treatment means and to draw valid conclusions.

III. Results & Discussion

1. Effect Of Treatment On Growth & Developemental Characters

In respect to growth parameters, the crop responded absolutely to PSB inoculation. Due to different variables, maize plant population did not have significant variation(Table 4.3). Due to PSB inoculation along with FYM, the values of all growth parameters (plant height(Table 4.2), green leaves (Table 4.3), leaf area(Table 4.4), LAI(Table 4.5) and dry matter production $plant^{-1}$(Table 4.6)) recorded higher and remained lower under control. However, on number of days to 50% silking, maturity and barren plants $plot^{-1}$ (Table 4.7), the effect of PSB inoculation alone, PSB added with 5t FYM ha^{-1} and the control found at par to each other though these characters remained higher and lower with PSB added with FYM and the control correspondingly.

Table: 1 Effect of treatments on initial and final maize plant population $plot^{-1}$

Treatments	Initial		Final	
	2011	2012	2011	2012
PSB				
T_1	67.43	67.51	63.10	62.14
T_2	67.45	67.59	63.17	62.22
T_3	67.48	67.47	63.37	62.25
SEm±	0.03	0.08	0.09	0.13
CD (P=0.05)	NS	NS	NS	NS

Table 4.2 Effect of treatments on plant height (cm)

Treatments	30 DAS		60 DAS		90 DAS		120 DAS		At Harvest	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
PSB										
T_1	08.80	09.06	32.08	29.75	115.22	114.34	215.42	211.38	225.76	218.01
T_2	09.09	09.23	33.49	30.71	119.87	117.00	219.77	216.01	230.79	222.26
T_3	09.63	09.58	35.62	32.25	127.44	122.50	228.29	223.02	238.88	229.58
SEm±	0.24	0.14	0.50	0.45	1.92	0.92	2.00	1.13	1.16	0.96
CD (P=0.05)	NS	NS	1.47	1.33	5.60	2.69	5.85	3.31	3.39	2.80

Table 4.3 Effect of treatments on number of green leaves $plant^{-1}$

Treatments	30 DAS		60 DAS		90 DAS		120 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
PSB								
T_1	2.01	1.93	5.69	5.70	08.83	08.76	6.63	6.52
T_2	2.10	2.01	5.86	5.83	09.04	08.95	6.88	6.67
T_3	2.24	2.12	6.11	6.05	09.41	09.29	7.28	6.97
SEm±	0.06	0.05	0.10	0.07	0.11	0.09	0.08	0.11
CD (P=0.05)	NS	NS	0.28	0.22	0.33	0.25	0.22	0.33

Table 4.4 Effect of treatments on leaf area $plant^{-1}$ (cm^2)

Treatments	30 DAS		60 DAS		90 DAS		120 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
PSB								
T_1	70.96	65.18	905.85	841.16	5352.35	5257.47	4672.98	4650.9
T_2	72.14	66.41	936.40	892.48	5623.45	5520.23	4901.22	4860.9
T_3	74.56	68.38	996.16	968.45	6010.19	5963.45	5265.34	5166.5
SEm±	1.73	0.74	12.18	6.30	76.92	28.55	49.06	27.61
CD (P=0.05)	NS	2.15	35.55	18.38	224.48	83.33	143.19	80.57

Table 4.5 Effect of treatments on leaf area index

Treatments	30 DAS		60 DAS		90 DAS		120 DAS	
	2011	2012	2011	2012	2011	2012	2011	2012
PSB								
T_1	0.047	0.043	0.58	0.54	3.55	3.49	3.10	3.08
T_2	0.047	0.044	0.62	0.58	3.73	3.66	3.25	3.22
T_3	0.049	0.045	0.65	0.63	4.00	3.96	3.49	3.43
SEm±	0.001	0.0005	0.01	0.004	0.05	0.02	0.03	0.02
CD (P=0.05)	NS	0.001	0.02	0.01	0.15	0.06	0.10	0.05

Table 4.6 Effect of treatments on dry matter accumulation (g plant^{-1})

Treatments	30 DAS		60 DAS		90 DAS		120 DAS		At Harvest	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
PSB										
T_1	0.24	0.23	3.80	3.78	35.53	34.44	153.84	149.20	261.61	254.43
T_2	0.25	0.23	3.97	3.93	37.70	36.21	157.14	151.88	275.20	267.29
T_3	0.26	0.24	4.22	4.14	41.24	39.22	163.57	156.44	298.07	290.19
SEm±	0.01	0.005	0.07	0.05	0.73	0.08	2.08	0.57	3.74	3.62
CD (P=0.05)	NS	NS	0.19	0.16	2.14	0.23	6.07	1.66	10.91	10.56

Table 4.7 Effect of treatments on developmental phases and crop lodging

Treatments	Days to 50% tasseling		Days to 50% silking		Days to 50% maturity		Barren plant plot^{-1}		Crop lodging (No. of plant plot^{-1})	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
PSB										
T_1	107.28	105.05	113.36	110.32	132.07	128.35	6.98	7.40	1.20	1.20
T_2	106.82	104.57	112.69	109.87	131.36	127.68	6.51	7.17	1.09	1.09
T_3	106.30	103.91	111.48	109.17	130.33	126.77	5.72	6.54	1.42	1.37
SEm±	0.78	0.54	0.43	0.22	0.43	0.36	0.14	0.14	0.12	0.10
CD (P=0.05)	NS	NS	1.26	0.64	1.26	1.04	0.41	0.41	NS	NS

2. Effect Of Treatments On Yeild And Yeild Attributes

With the inoculation of PSB added with FYM as compared to PSB alone or the control, the values of almost all the yield attributes as well as grain and stover yields (Table 4.8.1 to 4.10) were recorded maximum.

Table 4.8.1 Effect of treatments on yield attributes

Treatments	Cobs plant^{-1}		First cobs plot^{-1}		Second cobs plot^{-1}		Cob length (cm.)		Cob girth (cm.)		Kernel rows cob^{-1}	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
PSB												
T_1	0.87	0.85	53.21	51.85	1.77	1.52	13.10	13.06	09.73	09.62	12.17	12.13
T_2	0.88	0.86	53.73	52.12	2.00	1.97	13.41	13.38	10.00	09.89	12.32	12.27
T_3	0.90	0.89	54.72	52.78	2.57	2.66	13.96	13.91	10.42	10.29	12.55	12.51
SEm±	0.009	0.003	0.24	0.24	0.07	0.05	0.11	0.10	0.15	0.16	0.13	0.12
CD(P=0.05)	0.026	0.01	0.69	0.70	0.19	0.15	0.33	0.30	0.45	0.47	NS	NS

Table 4.8.2 Effect of treatments on yield attributes

Treatments	Kernels row^{-1}		Grains cob^{-1}		Test weight (g.)		Grain weight cob^{-1} (g)		First cobs grain yield (kg plot^{-1})		Second cobs grain yield (kg plot^{-1})	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
PSB												
T_1	26.71	26.74	395.22	393.85	233.82	232.32	93.81	92.46	4.39	4.17	0.18	0.16
T_2	27.91	27.55	415.65	408.66	238.00	235.66	99.98	97.05	4.77	4.43	0.21	0.20
T_3	29.98	28.90	451.29	434.22	247.27	242.10	11191	105.51	5.49	4.93	0.30	0.29
SEm±	0.17	0.16	4.26	3.93	2.50	1.88	1.57	1.18	0.08	0.07	0.01	0.01
CD(P=0.05)	0.48	0.47	12.44	11.47	7.29	5.49	4.41	3.44	0.23	0.20	0.02	0.02

Table 4.9 Effect of treatments on shelling percentage and harvest index (HI)

Treatments	Shelling percentage		Harvest index in %(HI)	
	2011-2012	2012-2013	2011-2012	2012-2013
PSB				
T_1	74.97	74.77	35.11	35.08
T_2	75.54	75.42	35.27	35.23
T_3	76.85	76.78	35.56	35.42
SEm±	0.24	0.26	0.16	0.25
CD(P=0.05)	0.71	0.77	NS	NS

Table 4.10 Effect of treatments on grain and stover yields (kg ha^{-1})

Treatments	Grain yield		Pooled Grain Yield	Stover Yield	
	2011-2012	2012-2013	2011-2012	2012-2013	
PSB					
T_1	5469	5229	5349	9152	8772
T_2	5873	5530	5701	9786	9240
T_3	6661	6105	6383	11025	10155
SEm±	92	70	62	169	159
CD(P=0.05)	269	205	182	493	464

3. Effect Of Treatments On Nutreint Content And Its Uptake And Available Nutreint In Soil

With the PSB inoculation along with 5t FYM ha^{-1} , maximum content of Nitrogen, phosphorus and potassium content in grain and stover, as well as their uptake by grain, stover and total uptake by crop were recorded maximum . With inoculation of PSB along with 5t FYM ha^{-1}, the available Nitrogen, phosphorus, and potassium content in soil at crop harvest also remained maximum (Table 4.11 to 4.13).

Table 4.11 Effect of treatments on per cent N, P and K contents in grain and stover

Treatments	N content				P content				K content			
	Grain		Stover		Grain		Stover		Grain		Stover	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
PSB												
T_1	1.60	1.59	0.43	0.43	0.31	0.30	0.18	0.17	0.40	0.39	1.61	1.63
T_2	1.61	1.60	0.44	0.44	0.32	0.30	0.19	0.18	0.40	0.40	1.62	1.63
T_3	1.63	1.62	0.44	0.44	0.33	0.31	0.20	0.19	0.41	0.40	1.63	1.64
SEm±	0.01	0.01	0.01	0.004	0.003	0.003	0.003	0.002	0.01	0.005	0.01	0.004
CD(P=0.05)	0.03	0.02	0.02	0.011	0.01	0.01	0.01	0.006	0.02	0.015	0.02	0.013

Table 4.12 Effect of treatments on nitrogen and phosphorus uptake by grain and stover and its total uptake (kg ha^{-1})

Treatments	N uptake by				Total N uptake		P uptake by				Total P Uptake	
	Grain		Stover				Grain		Stover			
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
PSB												
T_1	87.75	83.22	40.73	38.58	130.49	123.81	17.10	15.01	17.18	15.65	36.29	32.67
T_2	95.58	89.46	44.12	41.17	141.71	132.64	19.29	16.62	19.75	17.59	41.05	36.21
T_3	111.11	101.16	51.74	46.89	164.86	150.06	23.54	19.90	24.54	21.53	50.09	43.43
SEm±	1.65	1.34	0.96	0.80	2.47	1.99	0.42	0.32	0.52	0.41	0.81	0.63
CD(P=0.05)	4.81	3.90	2.80	2.35	7.15	5.82	1.23	0.93	1.53	1.19	2.35	1.85

Table 4.13 Effect of treatments on potassium uptake by grain and stover and its total uptake (kg ha^{-1})

Treatments	K uptake by				Total K uptake	
	Grain		Stover			
	2011	2012	2011	2012	2011	2012
PSB						
T_1	22.64	20.98	149.74	144.71	174.38	167.71
T_2	24.27	22.07	160.56	152.51	186.84	176.58
T_3	29.05	25.79	183.01	169.06	214.07	196.86
SEm±	0.55	0.34	3.10	2.75	3.46	3.00
CD(P=0.05)	1.60	1.00	9.05	8.02	10.09	8.74

4. Effect Of Treatments On Quality

In respect of protein and carbohydrates in grain, inoculation on PSB along with 5t FYM ha^{-1} (T_3) found superior than inoculation with PSB alone and control (Table 4.14).

Table 4.14 Effect of treatments on percent protein and carbohydrate content in grain

Treatments	Protein		Carbohydrate	
	2011	2012	2011	2012
PSB				
T_1	09.01	9.97	63.75	63.85
T_2	09.19	9.16	63.88	63.92
T_3	09.49	9.43	64.85	65.11
SEm±	0.06	0.05	0.27	0.27
CD (P=0.05)	0.17	0.14	0.77	0.79

Table 4.15 Effect of treatments on available N, P and K (kg ha^{-1}) after crop harvest

Treatments	Nitrogen		Phosphorus		Potassium	
	2011	2012	2011	2012	2011	2012
PSB						
T_1	210.08	211.24	15.00	14.91	182.33	183.05
T_2	210.31	211.48	15.54	15.62	182.53	183.14
T_3	214.40	216.39	16.61	16.78	184.16	185.85
SEm±	0.75	0.72	0.24	0.29	1.14	1.00
CD(P=0.05)	2.20	2.10	0.71	0.83	NS	NS

IV. Conclusions

On the basis of above results, the following conclusions may be drawn:-

1. To maximize the yield of winter maize, seeds inoculated with PSB plus 5t FYM ha^{-1} was found best in rice based cropping system under agro-ecological region of Ziro.
2. The winter maize seeds inoculated with PSB plus 5t FYM ha^{-1} produced maximum grain & Stover yields.
3. Yield of winter maize seeds inoculated with PSB plus 5t FYM ha^{-1} was found most remunerative.

V. Recommendations

Winter maize be planted with PSB inoculation plus 5t FYM ha^{-1} for economic grain production.

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