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Effect of Phosphorus on the leaf yield, nutrient uptake and P-use efficiencies of sun cured chewing tobacco (*Nicotiana tobacum*) grown in Tamil Nadu

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ABSTRACT

A field experiment was conducted during 2005-2009 to study the effect of various P management practices on the productivity, chewing quality, nutrient uptake, P-use efficiencies on chewing tobacco. There is a dire need to reduce the P requirement for chewing tobacco (*Nicotiana tabacum* L.), as it is costlier and scarce. First grade leaf yield (FGLY) and total cured leaf yield (TCLY) with 50,75 and 100% recommended P with or without phospho bacteria (PSB) are comparable. The FGLY and TCLY increase varied between 7 to 20 % and 19 to 30 % respectively over no P. Phosphorus application irrespective of the levels improved the chewability (Score >60) over no P. The uptake of NPK and soil available P improved with levels of P with or without PSB over no P. Phosphorus application every year improved the soil available P. The P balance showed loss of P in all the treatments. P-use efficiency (39.5- 42.3 kg/kg), P-uptake efficiency (0.12 - 0.15 kg/kg) , agronomic efficiency (0.12 - 0.15 kg/kg) , recovery efficiency (7.27 - 7.55 %) and partial factor productivity (138 - 148 kg/kg) was higher at 50% P with or without PSB. Physiological efficiency was higher at 100% P +PSB (315 kg/ha) in the first year and 50% P (395.3 kg/ha) in the second year. Net returns and B:C ratio with 100% P was comparable with 75 and 50 % P with or without PSB. It was concluded that 50% recommended P (22 kg P/ha) would be sufficient for higher yield , net returns, better leaf chemistry and P-use efficiency.

Key words: Chewing tobacco, First grade leaf yield, Phosphorus, P-use efficiencies

Chewing tobacco (*Nicotiana tabacum* L) is an economically viable commercial crop of Tamil Nadu, where the water availability is restricted to 3 to 4 months (Manoharan *et al.* 2002).The chewing tobacco crop is cultivated in an area of about 15 000 to 20 000 ha under irrigated condition. The crop is grown in varied type of soils like sandy gravel, red soil, loamy soil etc., and a basal manuring of 25 tonnes farmyard manure with 44 kg P applied every year. As the soil is fertilized with 44 kg P /ha every year, possibilities are there for P build up in the soil. Gopalachari and Manga Reddy (1972) reported that the addition of P to the soils having high soil P suppressed the cured leaf yield and higher levels of applied P decreased the reducing sugars and increased the nicotine content of leaf. Higher levels of P creates imbalance in soil solution making nutrients like zinc and calcium unavailable to the crop (Krishnamurthy *et al*. 2003). In recent years the P fertilizer has become costlier and scarce too. Hence, an experiment was conducted with an objective to obtain optimum cured leaf yield of chewing tobacco under reduced P levels.

MATERIALS AND METHODS

A field experiment was conducted during 2005-2009 at the farm of Central Tobacco Research Institute-Regional Station, Vedasandur, Tamil Nadu (latitude 10^{0} 32′N longitude 77^{0} 57′) with an objective to obtain optimum cured leaf yield of chewing tobacco under reduced P levels. The soil was sandy gravel having a pH of 8.1, medium in organic C (0.46%), low in available N (168 kg/ha) , medium in P (9.1 kg/ha) and high in K (170 kg/ha). The experiment was conducted with twelve treatment combinations for chewing tobacco in the first year (2005-06 and 2007-08) and in second year (2006-07 and 2008-09). The treatments were 50% P + PSB(Phospho bacteria) – 100% P (T1), 75 % P + PSB – 100% P (T2), 100% P + PSB– 100% P (T3), 50% P + PSB – 75% P (T4), 75% P + PSB– 75% P (T5), 100% P + PSB– 75% P (T6), 50% P + PSB– 50% P (T7), 75% P + PSB– 50% P (T8), 100% P + PSB– 50% P (T9), 100% P – 100% P (T10), 100% P – No P (T11), No P – 100% P (T12). The experiment was laid out in a randomized block design with three replications. Farmyard manure 25

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tonnes/ha was applied as basal manure, ridges and furrows were formed at a spacing of 75 cm and 45 days old seedlings were planted at a spacing of 75 cm. Phosphorus as per the treatments in the form of super phosphate was mixed with four times of sieved farmyard manure and spot applied. The variety of chewing tobacco grown was Abirami. The variety Abirami is a sun cum smoke cured type of tobacco with a medium internodal length (5.5 to 6.0 cm diameter) with leaf characters, ovate, moderately puckered surface having prominent mid ribs and venation. Nitrogen 75 kg/ha was top dressed through urea in two equal splits for tobacco, first dose on 45^{th} day and the second dose on 60^{th} day. The experimental net plot size was 4.5 × 3.0 m. Five plants from the net plot area were selected at random and tagged. The tagged plants were used for recording the leaf length and width. The tobacco crop was irrigated once in 4 days and harvested at 120 days by stalk cut method. The first grade leaf yield (FGLY), total cured leaf yield (TCLY) and leaf samples were recorded after sun curing and standard fermentation process. The samples collected were chopped ,air dried and then oven dried at 65 ± 5°C until attaining constant weight. The leaf samples were used for estimating lamina chemical quality, viz. nicotine, reducing sugars (Harvey *et al*. 1969) and chlorides (Hanumantha Rao *et al*. 1980). The soil sample drawn from 0-22.5 cm depth was analyzed for available P as per the standard procedures. The quality in terms of chewability was evaluated by various parameters, viz. body of the leaf (10), aroma (10), whitish incrustation (10), taste (10), pungency (10), saliva secretion (10), retention of pungency (10), stiffness in mouth, totaling to 80 (Palanichamy and Nagarajan 1999). A score of 60 and above was considered to indicate preferably the better quality for chewing purposes. The total rainfall received was 485.2, 135.2, 449.8 and 178.2 mm during the years 2005-06, 2006-07, 2007-08 and 2008-09 respectively. The maximum and minimum temperature recorded were 30.5, 31.1, 31.4, 31.6 °C and 18.5, 18.1, 20.2, 19.1 °C during 2005-06, 2006-07, 2007-08 and 2008-09 respectively. Economics was calculated based on the prevailing market rate of the inputs and economic produce (total cured leaf yield). The measures of P-use efficiencies were worked out as per the method suggested by Damodhar Reddy (2002). The data were subjected to statistical analysis following normal procedures.

RESULTS AND DISCUSSION

Growth and yield

Leaf length during the first year was significantly influenced by levels of P in combination with PSB. Recommended dose of 100 % P (44 kg P/ha) was comparable with 75 and 50 % P in combination with PSB. Leaf width of the first year did not show any significant differences between the levels of P with PSB. However, P application with or without PSB increased the leaf width over no P.

Leaf length during the second year was not significantly influenced by levels of P and PSB. However, P application alone or in combination with PSB increased the leaf length as compared to no P. Similar trend was observed with the leaf width also. Dry matter production (DMP) during the first year (2005-06 and 2007-08) showed a increased trend from no P to 50% P + PSB (Fig 1). Similar trend of increased DMP was noticed in second year also. The addition of P to soil improved the root system thereby increased absorption of nutrients and DMP. First grade leaf yield was significantly influenced by the levels of P and PSB during both the years. Levels of P (50, 75 and 100 %) with or with out PSB and 100 % P alone significantly increased the first grade leaf yield (FGLY) of chewing tobacco over no P (Table 1). The percentage of yield increase during the first year with the levels of P + PSB and 100 % P alone varied between 19 to 20 % over no P.The direct effect of P improved the root growth, thereby increased absorption of nutrients,

Table 1 Growth attributes of chewing tobacco as influenced by levels of P (Pooled)

Treatment		At harvest				First grade leaf (kg/ha)		Total cured leaf (kg/ha)		Quality score (out of 80)	
		Leaf length (cm)		Leaf width (cm)							
I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
50%P+PSB	100% P	75.7	71.0	46.2	40.1	2 393	2 549	3 186	3 116	71	71
75%P+PSB	100% P	73.6	70.9	44.3	39.6	2 472	2 390	3 175	3 165	70	72
100%P+PSB	100% P	75.7	69.7	45.2	39.4	2 478	2 742	3 322	3 378	73	73
50%P+PSB	75% P	74.3	69.9	44.8	40.2	2 508	2 558	3 098	3 074	71	70
75%P+PSB	75% P	75.8	69.2	46.6	39.4	2 361	2 622	3 132	3 115	70	70
100%P+PSB	75% P	74.3	68.6	43.1	38.8	2 307	2 472	3 215	3 499	71	71
50%P+PSB	50% P	75.1	68.6	45.7	38.8	2 444	2 627	3 254	3 038	69	70
75%P+PSB	50% P	74.1	70.4	44.3	38.3	2 256	2 499	3 076	3 185	70	71
100%P+PSB	50% P	76.3	69.3	44.8	39.9	2 316	2 664	3 035	3 102	70	70
100%P	100% P	73.3	71.2	44.5	40.2	2 336	2 481	3 190	3 158	73	72
100%P	No P	74.0	68.4	44.0	38.1	2 341	2 356	3 057	2 683	69	62
No P	100% P	73.1	69.5	43.2	38.0	1 965	2 420	2 670	3 298	64	70
SEm±	0.86	1.03	0.95	0.76	63.6	77.4	107.4	109.4			
CD (P=0.05)	2.40	NS	NS	NS	176.2	214.5	297.8	303.1			

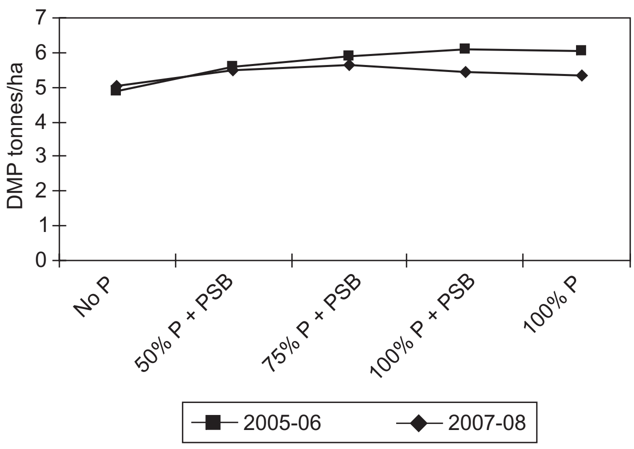

Fig. 1 Effect of P on DMP (1 year)

DMP and FGLY. During the second year, FGLY increased to the tune of 7 to 16 % with 50, 75 and 100 % P over no P. The increase in FGLY during the second year could be attributed to the direct and residual effect of P resulting in enlargement of leaves.

Total cured leaf yield (TCLY) during first and second year were significantly influenced by different P management practices. Phosphorus 50 % with PSB significantly increased the TCLY over no P during the first year. Phosphorus at 75 % and 100 % P with or without PSB recorded a comparable TCLY. The yield increase varied from 19 to 24 % over no P. In the second year , the TCLY increase with 50, 75 and 100 % P varied from 23 to 30 % over no P. It is well established that rapid and vigorous development of young plants is stimulated by a high level of available P(Flower 1999). The addition of P to soil increased the available P in soil which in turn increased the root growth as indicated through root volume (Fig 2) in both the years, thereby increased FGLY and TCLY. Root volume during both the years were higher with the P applied treatments as compared to no P . The applied N and P along with basal FYM might have created better microbial growth, soil physical condition thereby higher root growth. Kachot *et al.*(2001) reported stimulated microbial growth and favored root growth under improved soil physical condition.

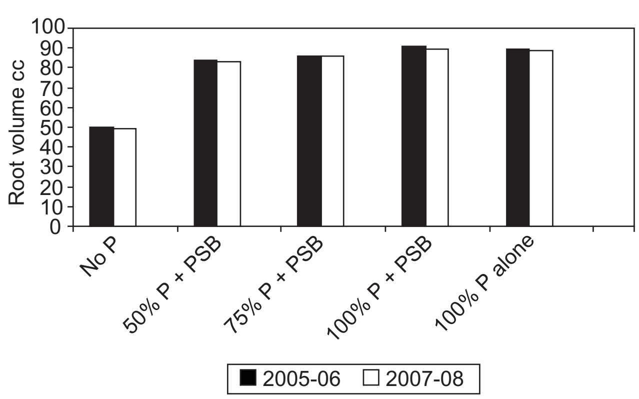

Fig 2 Effect of P on root volume (I year)

Preferable chewing quality of score more than 60 out of 80 was observed with all the P management practices except with no P in both the years. Phosphorus application increased the root growth, absorption of nutrients resulting in enlargement of leaves, thickness of the leaves, optimum level of nicotine and reducing sugars, which improved the physical and chewability parameters thereby higher chewing scores.

Nutrient uptake

Nitrogen uptake was significantly influenced by the P management practices. Phosphorus at different levels in combination with PSB and P at 100 % level are comparable with respect to N uptake . As the uptake is a function of N content and dry matter production, the increased dry matter production due to P application resulted in increased N uptake. No P recorded a lower N uptake. Similar trend was observed with K uptake in both the years. Phosphorus uptake was significantly higher with P applied treatment or in combination with PSB (Table 2). As basal dose of FYM is applied , the organic materials form a cover on sesquioxide and reduce the phosphate fixing capacity of soil (Das Anup *et al.* 2004), thereby increased availability of P , DMP, P content in plant and uptake.

Residual soil P and leaf chemistry

Residual soil P significantly increased with P application in both the years as compared to no P. Levels of P with PSB and 100 % P application alone had comparable residual soil P. Application of P every year increased the residual soil P. The water soluble P in single super phosphate increased the soil available P (Kumaresan *et al.* 2003). Skipping P decreased the residual soil P . Leaf chemistry, viz. nicotine, reducing sugars and chlorides did not show significant difference between the various treatments in both the years. In FCV tobacco , Vasuki *et al.*(2004) reported that the leaf chemistry was not affected by levels of P.

Phosphorous balance sheet

Phosphorus addition to the soil was higher with 100% P, followed by 75 % P. Higher P addition to the soil is due to the fertilizer P and farmyard manure (25 tonnes/ha). The initial soil P of the year 2005-06 and 2007-08 (first year) showed an increased initial P (11.3 kg/ha) with 100 % P when applied every year. The no P of the first year recorded the lowest available initial P of 7.2 kg/ha. In the second year (2006-07 and 2008-09), higher initial P ranging from 11.4 to 11.7 kg/ha was noticed with 100% P. Higher available P in this treatment is due to the higher P applied with basal FYM of 25 tonnes/ha (Table 3). The P uptake in both the years (first and second) were higher with 100% P. Application of P every year resulted in higher soil available P, thereby higher P uptake. The expected balance worked out showed an increased level of P (99.3 to 110.3 kg/ha) at 100% P in the first year and 108.4 to 110.7 kg/ha in the second year. In both the years no P recorded a lower

Table 2 NPK uptake, soil available P and leaf chemistry as influenced by levels of P (Pooled)

Treatment		Nutrient uptake (Kg/ha)						Residual soil		Leaf chemistry					
		N		P		K		P (kg/ha)		Nicotine (%)		Reducing sugars (%)		Chlorides (%)	
I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
50%P+PSB	100% P	100	120	9.5	11.9	117.3	130.9	11.5	13.0	2.59	2.90	0.57	0.44	5.48	5.49
75%P+PSB	100% P	99	123	10.0	12.5	113.5	140.7	12.0	13.6	2.50	2.89	0.53	0.50	5.49	5.47
100%P+PSB	100% P	100	120	10.5	12.7	119.6	139.5	12.8	13.0	2.62	2.79	0.58	0.54	5.80	5.61
50%P+PSB	75% P	98	118	9.4	11.9	114.8	144.4	11.3	12.5	2.41	2.63	0.50	0.59	6.06	5.36
75%P+PSB	75% P	104	118	10.0	11.9	118.5	133.4	11.3	12.5	2.55	2.72	0.55	0.45	5.95	5.57
100%P+PSB	75% P	100	122	9.5	12.0	117.3	133.3	11.7	12.7	2.40	2.73	0.58	0.51	5.00	5.40
50%P+PSB	50% P	101	119	9.9	11.9	116.1	133.9	10.7	12.5	2.38	2.97	0.60	0.48	5.78	5.55
75%P+PSB	50% P	107	110	9.9	11.9	116.1	133.5	11.0	12.6	2.45	2.78	0.57	0.49	5.81	4.87
100%P+PSB	50% P	110	111	10.6	11.9	112.4	132.9	11.3	12.5	2.43	2.74	0.67	0.51	5.19	5.51
100%P	100% P	101	127	10.6	11.9	113.6	141.9	12.3	12.6	2.69	2.85	0.49	0.57	5.72	5.40
100%P	No P	111	103	10.1	8.9	116.1	109.9	11.7	9.8	2.44	2.92	0.56	0.53	5.68	5.58
No P	100% P	88	130	7.8	12.1	103.7	133.3	8.83	12.5	2.56	2.72	0.44	0.57	5.77	5.67
SEm±	4.32	3.53	0.54	0.32	3.22	4.32	0.40	0.43	0.19	0.20	0.05	0.04	0.35	0.40	
CD (P=0.05)	12.0	9.79	1.50	0.89	8.94	11.99	1.11	1.20	NS	NS	NS	NS	NS	NS	

Table 3 Phosphorus balance sheet as influenced by levels of P applied

Treatment		Initial P (kg/ha)		P added * (kg/ha)		P uptake (kg/ha)		Expected balance (Kg/ha)		Net gain (+)/ Loss(–) of P	
I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
50%P+PSB	100% P	8.6	9.4	77	99	9.5	11.9	76.1	108.4	– 64.6	– 96.9
75%P+PSB	100% P	9.2	10.5	88	99	10.0	12.5	87.2	109.5	– 75.2	– 97.0
100%P+PSB	100% P	10.8	11.4	99	99	10.5	12.7	99.3	110.4	– 86.5	– 97.7
50%P+PSB	75% P	8.6	9.2	77	88	9.5	11.9	76.1	97.2	– 64.8	– 85.3
75%P+PSB	75% P	9.5	9.5	88	88	10.5	11.9	97.5	97.5	– 87.0	– 85.6
100%P+PSB	75% P	9.9	10.2	99	88	9.5	12.0	108.9	98.2	– 99.4	– 86.2
50%P+PSB	50% P	7.7	8.5	77	77	9.9	11.9	84.7	85.5	– 74.8	– 73.6
75%P+PSB	50% P	9.5	8.8	88	77	9.9	11.9	97.5	85.8	– 87.6	– 73.9
100%P+PSB	50% P	10.0	8.9	99	77	10.7	11.9	109.0	85.9	– 98.3	– 74.0
100%P	100% P	11.3	11.7	99	99	10.7	11.9	110.3	110.7	– 99.6	– 98.8
100%P	No P	9.1	8.0	99	55	10.2	8.9	108.1	63.0	– 97.9	– 54.1
No P	100% P	7.2	9.5	55	99	7.8	12.1	62.2	108.5	– 54.4	– 96.4

* P added through fertilizer and FYM

theoretical balance of P. The gain or loss worked out showed that there was a loss (–) of P in all the treatments which could be attributed to the fixation of P in the soil.

P- use efficiency

The P- use efficiency during the first year (2005-06 and 2007-08) was higher with 50 % P + PSB and the P-use efficiency values ranged between 40.2 to 42.3 kg/kg. Similarly during second year (2006-07 and 2008-09) also, lower the applied P higher the P-use efficiency . The P-use efficiency values with 50 % P ranged between 39.5 to 41.4 kg/kg. Higher dose of P application resulted in lower P-use efficiency. An increase in P level led to corresponding decrease in P-use efficiency (Kumar and Sinha 2008).

The P-uptake efficiency during both the years was higher at 50 % P with or without PSB. The uptake efficiency values with 50 % P + PSB during the first year ranged between 0.12 to 0.13 kg/kg. During the second year the value with 50 % P was 0.15 kg/kg (Table 4). Lower level of P supply with 50 % P, increased the P uptake efficiency. Higher P supply at 75 and 100 % P lowered the P-uptake efficiency.

The P-utilization efficiency was higher (338 kg/kg) with 100 % P + PSB during the first year as compared to 50%P + PSB. Whereas during the second year 75% P application recorded higher (292 kg/kg) P-utilization efficiency value. Higher leaf yield coupled with P uptake could be attributed for the higher P-utilization efficiency.

Agronomic efficiency during first year was higher with 50 % P + PSB as compared to the higher levels of P + PSB. The efficiency values ranged between 19.5 to 26.6 kg/ha. Similarly during second year also, 50 % P recorded higher agronomic efficiency values, ranged between 16.1 to 22.8 kg/ha as compared to 100% P. As the agronomic efficiency is the ratio of increase in yield due to P application and amount of P applied, the comparable yield with 50 % P over 75 and 100 % P with or without PSB application resulted in increased agronomic efficiency. Agronomic efficiency was lower at 100 % P with or without PSB. Higher amount of P with lesser yield increment resulted in lower agronomic efficiency.

Recovery efficiency during first year with 50 % P + PSB was higher as compared to the other two levels of P with PSB. The recovery efficiency 50 % P + PSB ranged form 7.55 to 9.59 % . Recovery efficiency during the second year was higher (14.1 %) with 50 % P as compared to the other two levels of P. Higher P uptake with lower P supply resulted in increased recovery efficiency.

Physiological efficiency in the first year was higher with 100 % P + PSB (315.0 kg/ha), when 75% P was given for the succeeding tobacco crop. Whereas in the second year, the physiological efficiency was higher (395.3 kg/ha) with 50 % P, when 100 % + PSB was applied for the preceding tobacco crop. Physiological efficiency at 100 or 75 % P application was generally low. The higher or lower physiological efficiency at higher dose of P could be ascribed to less incremental increase in yield with increase in P uptake (Gangaiah and Ahlawat, 2008).

Table 4 P-use efficiency of chewing tobacco as influenced by various P management practices (Pooled)

Treatment		P-use efficiency (Kg/kg)		P-uptake efficiency (Kg/kg)		P-utilization efficiency (Kg/kg)		Agronomic efficiency (Kg/ha)		Recovery efficiency (%)		Physiological efficiency (Kg/ha)		Partial factor productivity (Kg/kg)	
I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
50%P+PSB	100% P	41.4	31.5	0.13	0.12	335	262	23.5	9.84	7.77	3.70	301.8	265.6	145	71
75%P+PSB	100% P	36.1	32.0	0.11	0.13	318	253	15.3	10.9	6.67	5.25	229.6	208.7	96	72
100%P+PSB	100% P	33.6	33.7	0.11	0.13	316	266	14.8	15.8	6.12	6.00	240.2	263.3	75	76
50%P+PSB	75% P	40.2	34.9	0.12	0.14	330	258	19.5	11.9	7.55	5.15	257.8	230.0	141	93
75%P+PSB	75% P	35.6	35.4	0.11	0.14	313	262	15.5	13.1	6.78	6.03	229.6	217.1	96	94
100%P+PSB	75% P	32.5	36.4	0.10	0.14	338	292	12.4	15.6	3.93	6.52	315.0	240.0	73	97
50%P+PSB	50% P	42.3	39.5	0.13	0.15	329	255	26.6	16.1	9.59	7.27	223.8	213.9	148	138
75%P+PSB	50% P	35.0	41.4	0.11	0.15	311	268	12.3	22.8	6.33	7.41	194.2	307.9	123	145
100%P+PSB	50% P	30.7	40.3	0.11	0.15	286	261	8.3	19.1	6.52	4.82	127.2	395.3	69	141
100%P	100% P	32.2	31.9	0.11	0.12	301	265	11.8	10.8	6.52	4.29	181.2	251.3	73	72
100%P	No P	30.9	48.8	0.10	0.16	303	305	8.8		5.41		162.6		69	
No P	100% P	48.5	33.3	0.14	0.12	342	273		13.9		5.02		278.3		75

Table 5 Economics as influenced by levels of P applied. (Pooled)

Treatment		Cost of cultivation (₹ × 10³)		Gross Returns (₹ × 10³)		Net Returns (₹ × 10³)		B:C ratio	
I year	II year	I year	II year	I year	II year	I year	II year	I year	II year
50%P+PSB	100% P	37.9	46.3	69.4	101.5	31.5	55.2	1.83	2.19
75%P+PSB	100% P	38.4	46.3	69.2	102.7	30.8	56.4	1.80	2.22
100%P+PSB	100% P	38.9	46.3	72.5	106.6	33.6	60.3	1.86	2.30
50%P+PSB	75% P	37.9	45.8	67.5	97.9	29.6	52.1	1.78	2.14
75%P+PSB	75% P	38.4	45.8	68.2	101.6	29.8	55.8	1.78	2.22
100%P+PSB	75% P	38.9	45.8	70.0	103.8	31.1	58.0	1.80	2.27
50%P+PSB	50% P	37.9	45.2	71.0	97.8	33.1	52.6	1.87	2.16
75%P+PSB	50% P	38.4	45.2	67.3	102.7	28.9	57.4	1.75	2.27
100%P+PSB	50% P	38.9	45.2	66.2	100.4	27.3	55.1	1.70	2.22
100%P	100% P	38.6	46.3	69.6	101.7	31.0	55.4	1.80	2.20
100%P	No P	37.2	44.2	65.2	84.8	28.0	40.6	1.75	1.92
No P	100% P	36.6	46.3	58.1	105.5	21.5	59.2	1.59	2.28
SEm±	-	-	1.23	2.37	1.16	2.37	0.03	0.01	
CD (P=0.05)	-	-	3.42	6.56	3.22	6.56	0.09	0.03	

*Price of TCLY during 2005-06: ₹ 20.80/kg; during 2006-07: ₹ 23.50/kg; during 2007-08: ₹ 29.90/kg; during 2008-09: ₹ 41.10/kg

Partial factor productivity during both the years was higher with 50 % P with or without PSB. In the first year, the partial factor productivity ranged between 141 to 148 kg/kg and in the second year it was between 138 to 145 kg/kg. The applied P being less at 50 % P and the economic yield with 50 % and 100 % P being comparable resulted in increased partial factor productivity.

Economics

The cost of cultivation was higher (₹ 38 900/ha) with 100% P + PSB application during the first year. Whereas during second year the cost of cultivation was ₹ 46 300 with 100% P application. Higher dose of P resulted in higher cost of cultivation. Gross return during first year was significantly higher with 100% P + PSB over no P and was comparable with 75 and 50 % P with PSB (Table 5). Similar trend of gross return was also observed in the second year. Net returns and benefit :cost ratio with 100% P + PSB was comparable with 75 and 50% P with or without PSB in both the years.

It may be concluded that phosphorus at higher levels, 75 or 100% of the recommended dose could not influence the FGLY or TCLY. Phospho bacteria application did not have significant effect on the yield, soil available P and nutrient uptake as the pH of the soil was higher. Application of 50% of recommended P (22 kg P/ha) would be sufficient for getting higher FGLY, TCLY, better leaf chemistry and net returns.

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