International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(5): 2980-2985

Received: 20-07-2018
Accepted: 21-08-2018

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Effect of phosphorus management on growth and yield of rice

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Abstract
A field experiment conducted during *kharif*, 2016-17 and 2017-18 on clay loam soils of Agricultural College Farm, Bapatla on phosphorus management in rice. The experiment was laid out in split plot design with 12 treatment combinations with four main plot treatments and three sub plot treatments were replicated thrice. The results showed that the highest plant height, drymatter accumulation, yield attributes and grain yield were observed with green manuring *in situ* with dhaincha along with PSB + 150% RDP to rice. However, the highest return per rupee invested (1.28) was with 50% RDP + green manuring *in situ* with dhaincha along with PSB and hence was found to be optimum and economical for the production of rice.

Keywords: Rice, phosphorus source, levels of phosphorus, yield and return per rupee invested

Introduction
Rice is a staple food crop not only in India but also for entire South Asia. Of the total rice (*Oryza sativa* L.) production in the world, more than 90% is in Asia, and it is increasing annually at the rate of 2.7% (IRRI, 1986) [1]. In India, rice is grown in an area of 43.49 million hactares with a production of 104.40 M t and productivity of 2.4 t ha^{-1} (CMIE, 2015-16) [2]. Nutrient management in rice under submerged condition is a difficult practice. Among the macronutrients NPK, phosphorus is reported to be a critical factor of many crop production systems due to its limited availability in soluble forms. The phosphorus deficiency is common in almost all the soils and crops (Raju *et al.*, 2005) [3]. The declining trend in the productivity of rice crop has become the major concern for the farmers, which is mainly due to decline in soil health. The loss of nutrients from the soil in mainly due to exhaustive cropping systems like rice-maize or rice-oilseeds. Recommended dose of NPK fertilizers alone does not sustain soil productivity under continuous intensive cropping (Kumar *et al.*, 2009) [4], whereas inclusion of organic manures improve soil fertility, crop yields and biological status of soil. Green manure crop like dhaincha (*Sesbania aculeata*) and bio-fertilizer, phosphorus solubilizing bacteria have an advantage and proven ability to enhance the productivity of rice cropping systems.

Material and Methods
The experimental soil was clay loam in texture, slightly alkaline in reaction and low in organic carbon, low in available nitrogen, medium in available phosphorus and high in potassium. The experiment was laid out in a split plot design with 12 treatments in *kharif* with three replications. The main plot includes sources of phosphorus *viz.*, inorganic fertilizer phosphorus through SSP, green manuring *in-situ* with dhaincha @ 25 kg ha^{-1}, phosphorus solubilizing bacteria bio-fertilizer @ 750 ml ha^{-1} and green manuring *in-situ* with dhaincha @ 25 kg ha^{-1} + phosphorus solubilizing bacteria bio-fertilizer @ 750 ml ha^{-1} and levels of phosphorus *viz.*, 50%, 100% and 150% RDP were allotted to sub plots during *kharif* season of 2016-17 and 2017-18. Green manuring crop of dhaincha at 45 DAS was incorporated fifteen days prior to transplanting of rice in the respective treatments during both the years of study. The most popular and fine grain quality rice variety *i.e.*, BPT-5204 was used during the experimental period. Data collected on growth parameters, yield attributes and yield of rice were subjected to standard statistical procedures.

Results and Discussion

Plant height was significantly influenced by source of phosphorus at all the growth stages but not by levels of phosphorus during both the years of experimentation. The interaction was found to be non-significant. At 30 DAT, maximum plant height of 56.9 cm was recorded with green manuring + PSB application which was at par with green manuring alone (55.8 cm) and found significantly superior to inorganic phosphorus through SSP and application of PSB alone. The differences in plant height of rice measured at 60, 90 DAT and at maturity were also followed the similar trend like 30 DAT during both the years of study and in pooled data (Table 1).

Incorporation of green manures and PSB enhanced the availability of nutrients, production of growth promoting substances and reduced phosphorus fixation by PSB chelating effects and also solubilization of unavailable forms of phosphorus, which might have enhanced the cell division and cell elongation resulting in taller plants. These results are in accordance with the findings of Yadav *et al.* (2015) [5].

Drymatter accumulation at 30, 60, 90 DAT and at maturity revealed that green manuring *in-situ* with dhaincha + PSB had significant effect on increasing drymatter accumulation which was at par with green manuring alone and found significantly superior to application of PSB alone and the lowest drymatter accumulation was observed when only inorganic phosphorus was applied and the interaction was found to be significant at 60 DAT in 2016-17 (Table 2).

Though the differences among levels of phosphorus found to be non-significant throughout the crop growth period, when it was combined with biological sources of phosphorus found to be significantly superior over inorganic source of phosphorus at each level of phosphorus (M_1). Interestingly PSB along with 50% RDP significantly superior over the application of 150% RDP alone. This might be due to PSB have enormous potential in providing soil phosphorus with extensive root system which inturn useful for uptake of all nutrients along with phosphorus resulted in higher drymatter accumulation. This indicates that lower doses of SSP with PSB could be more effective in reducing the phosphate fertilizers. These results are in agreement with Yadav *et al*. (2009) [6], Premalatha (2017) [7] and Naher and Paul (2017) [8] (Table 2a).

A perusal of the data on number of panicles m^{-2} indicated that it was significantly influenced by the various treatments during two consecutive years and in pooled data. During first year of study, among the sources of phosphorus green manuring + PSB recorded the maximum number of panicles m^{-2}, which was statistically at par with green manuring alone. Soil application of PSB alone showed the highest number of panicles m^{-2} which was significantly superior to inorganic phosphorus through SSP. The same trend was seen in second year and pooled data also. The increase in number of panicles m^{-2} might be due to continuous supply and solubilization of adequate phosphorus, which in turn, might have helped in faster cell division and enlargement thus producing more number of productive tillers. These results were in conformity with the findings of Prasad Rao *et al.* (2011) [9] and Roy *et al.* (2017) [10]. Application of different levels of phosphorus through SSP (50, 100 and 150%) had non significant effect on the number of panicles m^{-2} during the trial conducted for two years.

Maximum number of grains and filled grains panicle^{-1} obtained in green manuring + PSB which was statistically on a par with green manuring alone and significantly superior to application of PSB alone and inorganic phosphorus through SSP might be due to sufficient moisture and nutrients that were available to the plants due to deep penetration and wide spread of roots at panicle initiation and flowering stages which in turn might have increased the light interception because of wider spacing, thus resulting in more drymatter accumulation and partitioning into sink (panicles). This is in consensus with the findings of Harish *et al.* (2011) [11], Chaudhary *et al.* (2013) [12], Hasani and Aminpanah (2015) [13] and Yadav *et al.* (2015) [5] (Table 3).

The differences in number of grains panicle^{-1} with the treatments green manuring along with PSB (M_2, M_3 and M_4) at 50% RDP found on a par with application of 150% RDP through SSP. Similarly, the number of grains panicle^{-1} at different levels of phosphorus were not significant across the main plot treatments (phosphorus sources) except with application of inorganic phosphorus where application of 50% RDP found significantly inferior compared to application of 150% RDP. In waterlogged soils, green manure increases availability of phosphorus through the mechanism of reduction, chelation and favourable changes in soil pH, which in turn can influence solubility of phosphorus (Table 3a).

A significant increase in grain yields were recorded with green manuring + PSB *i.e.,* 6059 kg ha^{-1}, 6352 kg ha^{-1} and 6206 kg ha^{-1} during 1st, 2nd year and in pooled data respectively, which was statistically on a par with green manuring alone *i.e.,* 5920 kg ha^{-1}, 6162 kg ha^{-1} and 6041 kg ha^{-1} during 1st, 2nd year and in pooled data respectively, over the rest of the treatments under test. The lowest yield was observed with the inorganic phosphorus applied through SSP application as found significantly inferior to other sources.

The percentage increase in grain yield with green manuring + PSB, green manuring and PSB over inorganic phosphorus alone through SSP was 23.7%, 21.9%, 15.5% during 1st year, 22.9%, 20.5, 15.1% during 2nd year and 23.3%, 21.2%, 15.3% in pooled data, respectively. A similar increase in grain yield was also reported by Ram *et al.* (2014) [14], Sarkar *et al*. (2014) [15], Thulasi *et al.* (2016) [16] and Roy *et al.* (2017) [10]. Higher grain yield was obtained with the application of 150% RDP followed by 100% and 50% RDP; however the differences were not significant.

Grain yield was not differed significantly at each level of phosphorus across main plot treatments (phosphorus sources) however, application of 50% RDP found significantly inferior with SSP as a source of phosphorus, compared to rest of the treatment combinations. Application of lower level of phosphorus (50% RDP) along with green manure or PSB found at par with that of grain yield obtained at 150% RDP through SSP during both the years of study as in pooled data (Table 4a).

Inorganic phosphorus source through SSP application at 50% RDP level found significantly inferior to other levels in increasing net return per rupee invested. However, when 50% RDP applied along with green manuring + PSB or green manuring alone or PSB alone found significantly higher return per rupee invested than 100% and 150% RDP application at the same level of phosphorus source (Table 4).

Net returns were significantly increased with green manuring + PSB (M_4) which was statistically at par with green manuring alone and significantly superior to inorganic P through SSP and soil application of PSB. In spite of the fact that yield obtained was higher with 150% RDP (S_3), an increase in net returns of sorghum was observed with 50% RDP (S_1) which might be attributed to the low cost of cultivation and comparable yield with that of S_3. The highest return per rupee invested were observed with the application of 50% RDP in sorghum which was statistically at par with 100% RDP and significantly superior to control (Table 4b, 4c).

Table 1: Plant height (cm) at different growth stages of rice as influenced by phosphorus management during *kharif* 2016-17, 2017-18 and pooled data

Treatments	2016-17				2017-18				Pooled data			
	30 DAT	**60 DAT**	**90 DAT**	**Maturity**	**30 DAT**	**60 DAT**	**90 DAT**	**Maturity**	**30 DAT**	**60 DAT**	**90 DAT**	**Maturity**
Source of phosphorus applied to rice												
M_1- Inorganic phosphorus	46.2	79.2	92.9	96.9	48.2	81.7	95.0	100.2	47.2	80.5	93.9	98.5
M_2- Green manuring	55.8	90.4	109.8	113.3	59.6	93.2	109.8	113.9	57.7	91.8	109.8	113.6
M_3- Soil application of PSB	51.3	85.2	101.8	105.6	54.2	87.3	103.2	106.7	52.8	86.3	102.5	106.2
M_4- Green manuring + PSB	56.9	90.6	112.1	115.8	60.2	94.8	111.6	114.2	58.6	92.7	111.9	115.0
SEm±	1.26	1.43	2.22	2.09	1.44	1.53	1.9	1.61	1.28	1.48	1.71	1.77
CD (p = 0.05)	4.3	4.9	7.6	7.2	5.0	5.2	6.5	5.5	4.4	5.1	5.9	6.1
CV (%)	7.2	5.0	6.4	5.8	7.8	5.1	5.4	4.4	7.0	5.0	4.9	4.9
Levels of phosphorus applied to rice												
S_1 - 50% RDP	51.4	84.7	100.1	105.3	54.1	87.8	102.3	107.4	52.7	86.3	101.2	106.3
S_2 - 100% RDP	52.5	86.9	104.3	107.8	54.9	89.5	105.4	108.3	53.6	88.2	104.8	108.1
S_3 - 150% RDP	54.1	87.5	108.0	110.5	57.7	90.4	106.9	110.6	55.9	89.0	107.5	110.5
SEm±	0.9	0.99	2.83	1.78	1.33	1.09	1.72	1.16	1.06	1.03	2.02	1.44
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	6.0	4.0	9.4	5.7	8.3	4.2	5.7	3.7	6.8	4.0	6.7	4.6
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Drymatter accumulation (kg ha^{-1}) at different growth stages of rice as influenced by phosphorus management during *kharif* 2016-17, 2017-18 and pooled data

Treatments	2016-17				2017-18				Pooled data			
	30 DAT	**60 DAT**	**90 DAT**	**Maturity**	**30 DAT**	**60 DAT**	**90 DAT**	**Maturity**	**30 DAT**	**60 DAT**	**90 DAT**	**Maturity**
Source of phosphorus applied to rice												
M_1- Inorganic phosphorus	1889	5179	9597	10835	1868	5213	9613	11214	1878	5196	9605	11025
M_2- Green manuring	2110	7143	10921	12680	2098	7092	11247	13018	2104	7118	11084	12849
M_3- Soil application of PSB	1998	6624	10264	11709	1983	6357	10390	12241	1991	6491	10327	11975
M_4- Green manuring + PSB	2175	7271	11035	13165	2148	7130	11541	13476	2161	7201	11288	13320
SEm±	31.3	105.7	188.5	218.6	31.0	206.6	193.3	218.3	31.2	151.0	190.7	218.5
CD (p = 0.05)	109	366	652	757	107	715	669	756	108	523	660	756
CV (%)	4.6	4.8	5.4	5.4	4.7	9.6	5.5	5.2	4.6	7.0	5.4	5.3
Levels of phosphorus applied to rice												
S_1 - 50% RDP	1985	6325	10259	11783	1966	6304	10324	12141	1976	6314	10299	11962
S_2 - 100% RDP	2038	6655	10302	11916	2020	6335	10839	12274	2029	6495	10571	12095
S_3 - 150% RDP	2106	6684	10802	12591	2087	6706	10932	13047	2097	6695	10858	12819
SEm±	41.4	107.2	184.8	291.1	41.2	142.0	180.1	291.1	41.3	75.7	182.3	282.0
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	7.0	5.7	6.1	8.3	7.1	7.6	5.8	8.0	7.0	4.0	6.0	8.1
Interaction	NS	**S**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2a: Interaction between sources and levels of phosphorus on drymatter accumulation (kg ha^{-1}) at 60 DAT of rice as influenced by phosphorus management during 2016-17

Source of phosphorus applied to rice	Levels of Phosphorus applied to rice			Mean
	S_1 - 50% RDP	**S_2 - 100% RDP**	**S_3 - 150% RDP**	
M_1- Inorganic phosphorus	4321	5594	5622	5179
M_2- Green manuring	7110	7125	7195	7143
M_3- Soil application of PSB	6613	6625	6635	6624
M_4- Green manuring + PSB	7257	7275	7283	7272
Mean	6325	6655	6684	
	SEm±	**CD (p = 0.05)**	**CV (%)**	
Source of phosphorus applied to rice (M)	105.7	366	4.8	
Levels of phosphorus applied to rice (S)	107.2	NS	5.7	
Interaction				
M*S	214.5	643		
S*M	204.5	639		

Table 3: Number of panicles m^{-2}, total number of grains panicle^{-1} and filled grains panicle^{-1} of rice as influenced by phosphorus management during *kharif* 2016-17, 2017-18 and pooled data

Treatments	2016-17			2017-18			Pooled data		
	No. of panicles m^{-2}	Total No. of grains panicle^{-1}	Filled grains panicle^{-1}	No. of panicles m^{-2}	Total No. of grains panicle^{-1}	Filled grains panicle^{-1}	No. of panicles m^{-2}	Total No. of grains panicle^{-1}	Filled grains panicle^{-1}
Source of phosphorus applied to rice									
M_1- Inorganic phosphorus	374	180	162	381	185	167	377	182	164
M_2- Green manuring	437	213	184	442	219	191	439	216	187
M_3- Soil application of PSB	417	204	172	412	203	175	414	204	174
M_4- Green manuring + PSB	443	223	192	445	226	203	444	225	198
SEm±	5.6	2.8	3.0	7.5	3.2	3.2	6.1	2.7	3.1
CD (p = 0.05)	20	10	10	26	11	11	21	10	11
CV (%)	4.0	4.1	5.1	5.4	4.6	5.3	4.4	4.0	5.2
Levels of phosphorus applied to rice									
S_1 - 50% RDP	399	200	174	398	204	180	399	202	177
S_2 - 100% RDP	422	204	177	427	206	183	425	205	180
S_3 - 150% RDP	430	211	181	434	214	189	432	212	185
SEm±	10.7	3.2	2.5	12.2	3.7	2.8	11.2	2.8	2.4
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.9	5.3	5.0	10.1	6.2	5.2	9.3	4.8	4.6
Interaction	NS	**S**	NS	NS	NS	NS	NS	NS	NS

Table 3a: Interaction between sources and levels of phosphorus on total number of grains panicle^{-1} of rice as influenced by phosphorus management during 2016-17

Source of phosphorus applied to rice	Levels of Phosphorus applied to rice			Mean
	S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP	
M_1- Inorganic phosphorus	160	176	203	180
M_2- Green manuring	212	213	214	213
M_3- Soil application of PSB	203	204	204	204
M_4- Green manuring + PSB	223	223	224	223
Mean	200	205	211	
	SEm±	**CD (p = 0.05)**	**CV (%)**	
Source of phosphorus applied to rice (M)	2.8	10	4.1	
Levels of phosphorus applied to rice (S)	3.2	NS	5.3	
Interaction				
M*S	6.5	19		
S*M	6.1	18		

Table 4: Grain yield (kg ha^{-1}), net returns and return per rupee invested of rice as influenced by phosphorus management during *kharif* 2016-17, 2017-18 and pooled data

Treatments	2016-17			2017-18			Pooled data		
	Grain yield	Net returns	Return per rupee invested	Grain yield	Net returns	Return per rupee invested	Grain yield	Net returns	Return per rupee invested
Source of phosphorus applied to rice									
M_1- Inorganic phosphorus	4623	32094	0.73	4896	40048	0.90	4759	36071	0.82
M_2- Green manuring	5920	51434	1.17	6162	59932	1.35	6041	55683	1.26
M_3- Soil application of PSB	5477	44549	1.02	5767	53444	1.21	5622	48996	1.11
M_4- Green manuring + PSB	6059	52844	1.18	6352	62294	1.38	6206	57569	1.28
SEm±	99.5	1439.3	0.04	134.1	2055.3	0.04	108.4	1610.2	0.04
CD (p = 0.05)	344	4981	0.13	464	7113	0.16	375	5572	0.13
CV (%)	5.4	9.5	10.8	6.9	11.4	11.0	5.7	9.7	10.0
Levels of phosphorus applied to rice									
S_1 - 50% RDP	5273	46507	1.17	5555	55033	1.38	5414	50770	1.28
S_2 - 100% RDP	5593	45317	0.99	5817	53229	1.16	5705	49273	1.08
S_3 - 150% RDP	5693	43866	0.90	6010	53527	1.10	5852	48696	1.00
SEm±	126.9	1950.2	0.05	119.9	1873.0	0.04	134.2	1053.8	0.03
CD (p = 0.05)	NS	NS	0.14	NS	NS	0.12	NS	NS	0.08
CV (%)	8.0	14.4	15.8	7.2	12.0	11.1	4.1	7.4	7.8
Interaction	**S**	NS	**S**	**S**	**S**	**S**	**S**	S	S

Table 4a: Interaction between sources and levels of phosphorus on grain yield (kg ha^{-1}) of rice as influenced by phosphorus management during 2016-17, 2017-18 and pooled data

Source of phosphorus applied to rice	Levels of Phosphorus applied to rice (2016-17)			Mean	Levels of Phosphorus applied to rice (2017-18)			Mean	Levels of Phosphorus applied to rice (Pooled data)			Mean
	S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP		S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP		S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP	
M_1- Inorganic phosphorus	3661	4926	5282	4623	4019	4980	5689	4896	3840	4953	5485	4759
M_2- Green manuring	5910	5912	5937	5920	6151	6164	6170	6162	6031	6038	6054	6041
M_3- Soil application of PSB	5470	5470	5491	5477	5764	5766	5771	5767	5617	5618	5631	5622
M_4- Green manuring + PSB	6052	6062	6063	6059	6286	6358	6412	6352	6169	6210	6237	6206
Mean	5273	5593	5693		5555	5817	6010		5414	5705	5852	
	SEm±	**CD (p = 0.05)**	**CV (%)**		**SEm±**	**CD (p = 0.05)**	**CV (%)**		**SEm±**	**CD (p = 0.05)**	**CV (%)**	
Source of phosphorus applied to rice (M)	99.5	344	5.4		134.1	464	6.9		108.4	375	5.7	
Levels of phosphorus applied to rice (S)	126.9	NS	8.0		119.9	NS	7.2		134.2	NS	4.1	
Interaction												
M*S	253.8	761			239.7	719			235.5	706		
S*M	229.9	709			237.2	746			214.9	769		

Table 4b: Interaction between sources and levels of phosphorus on net return (Rs. ha^{-1}) of rice as influenced by phosphorus management during 2017-18 and pooled data

Source of phosphorus applied to rice	Levels of Phosphorus applied to rice (2017-18)			Mean	Levels of Phosphorus applied to rice (Pooled data)			Mean
	S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP		S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP	
M_1- Inorganic phosphorus	30962	40232	48951	40048	26724	37942	43547	36071
M_2- Green manuring	64644	58873	56280	59932	60463	54583	52002	55683
M_3- Soil application of PSB	58403	52409	49520	53444	53950	47926	45113	48996
M_4- Green manuring + PSB	66122	61402	59356	62294	61943	56642	54122	57569
Mean	55033	53229	53527		50770	49273	48696	
	SEm±	**CD (p = 0.05)**	**CV (%)**		**SEm±**	**CD (p = 0.05)**	**CV (%)**	
Source of phosphorus applied to rice (M)	2055.3	7113	11.4		1610.2	5572	9.7	
Levels of phosphorus applied to rice (S)	1873.0	NS	12.0		1053.8	NS	7.4	
Interaction								
M*S	3745.9	11231			2107.6	6319		
S*M	3685.0	11578			2356.7	7574		

Table 4c: Interaction between sources and levels of phosphorus on return per rupee invested (Rs. ha^{-1}) of rice as influenced by phosphorus management during 2016-17, 2017-18 and pooled data

Source of phosphorus applied to rice	Levels of Phosphorus applied to rice (2016-17)			Mean	Levels of Phosphorus applied to rice (2017-18)			Mean	Levels of Phosphorus applied to rice (Pooled data)			Mean
	S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP		S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP		S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP	
M_1- Inorganic phosphorus	0.58	0.80	0.80	0.73	0.80	0.90	1.02	0.90	0.69	0.85	0.91	0.82
M_2- Green manuring	1.42	1.10	0.98	1.17	1.63	1.29	1.15	1.35	1.52	1.19	1.07	1.26
M_3- Soil application of PSB	1.26	0.96	0.84	1.02	1.47	1.15	1.02	1.21	1.37	1.05	0.93	1.11
M_4- Green manuring + PSB	1.43	1.12	0.99	1.18	1.63	1.32	1.19	1.38	1.53	1.22	1.09	1.28
Mean	1.17	0.99	0.90		1.38	1.16	1.10		1.28	1.08	1.00	
	SEm±	**CD (p = 0.05)**	**CV (%)**		**SEm±**	**CD (p = 0.05)**	**CV (%)**		**SEm±**	**CD (p = 0.05)**	**CV (%)**	
Source of phosphorus applied to rice (M)	0.04	0.13	10.8		0.04	0.16	11.0		0.04	0.13	10.0	
Levels of phosphorus applied to rice (S)	0.05	0.14	15.8		0.04	0.12	11.1		0.03	0.08	7.8	
Interaction												
M*S	0.09	0.28			0.08	0.23			0.05	0.15		
S*M	0.08	0.26			0.07	0.25			0.06	0.18		

Conclusion

Use of excess phosphatic fertilizers does not result in significant marginal increase in the yield besides it results in increasing the cost of cultivation and creating adverse effects on other nutrients. Hence, it can be concluded that the judicious use of phosphorus fertilizers, saves cost of cultivation and also saves the soil from the ill effects that result due to imbalance of nutrients.

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