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Effect of *In-situ* green manuring, Bio-fertilizer (PSB) and inorganic fertilizer (SSP) on yield attributes and yield of rice in rice-groundnut sequence

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Abstract
A field experiment was conducted during *Kharif* 2016-17 and 2017-18 on loamy sands of soil at Agricultural College Farm, Bapatla to study the effect of *In-situ* green manuring, Bio-fertilizer (PSB) and inorganic fertilizer (SSP) on yield attributes and yield of Rice. The treatments consisted of four sources of phosphorus as main plots $S_{1:}$ Inorganic fertilizer phosphorus through SSP, $S_{2:}$ Green manuring *in-situ* with dhaincha @ 25 kg seed ha^{-1}, $S_{3:}$ Biofertilizer (PSB) @ 750 ml ha^{-1}, $S_{4:}$ Green manuring *in-situ* with dhaincha @ 25 kg seed ha^{-1} + Biofertilizer (PSB) @ 750 ml ha^{-1} and three levels of phosphorus $L_{1:}$ 50% recommended dose of P, $L_{2:}$ 100 % recommended dose of P and $L_{3:}$ 150% recommended dose of P**.** In *kharif* rice was laid out in split plot design with three replications. Results of the experiment showed that application of *in-situ* green manuring + PSB along with inorganic phosphorus through SSP showed superior performance in terms of yield attributes like panicle length, panicle weight, test weight, number of panicles m^{-2}, total number of grains panicle^{-1}, number of filled grains panicle $^{-1}$ and yield and over alone application of inorganic fertilizer phosphorus through SSP. Among the levels of phosphorus 150 % RDP showed higher yield attributes like panicle length, panicle weight, test weight, number of panicles m^{-2}, total number of grains panicle^{-1} and number of filled grains panicle^{-1} and yield and over 50 *%* RDP and however it was on par with 100 % RDP.

Keywords: Yield attributes, Yield, in-situ green manuring, Phosphorus management and Rice

Introduction
Rice (*Oryza sativa* L.) is one of the most important cereal crop. In India, rice ranks first among all the crops occupying 43.95 m ha area and production of 106.54 mt with an average productivity of 2424 kg/ha (CMIE, 2017-18) [6].

Among the fertilizer elements, Phosphorus is an essential nutrient and no one of the plant can produce better yield if it suffers from P deficiency. It is involved in the supply and transfer of energy for all biochemical processes in plants and hence, it is called as the "energy currency of living cells". It stimulates early root growth and development, encourages more active tillering, drymatter accumulation and promotes early flowering, maturity and good grain development. Further, optimum response to added nitrogen could be obtained only when adequate amount of P is supplied. Therefore, availability of P from soils to the plant is for getting higher yields. Plants utilize less amounts of phosphate fertilizers that are applied and the remaining portion is converted in to insoluble complexes in the soil. Slow mobility of applied phosphorus and its marked fixation results in low crop recoveries in the order of 20-25%. Phosphate solubilizing bacteria (PSB) solubilize insoluble phosphorus and increase its availability phosphorus in the soil and inturn the overall phosphate use efficiency. Green manures represent a promising approach to maintain sustainable nutrient supply for crop growth. The P in green manure could potentially be delivered to the soil in a form which is readily available to plants and soil microorganisms. The present study was, therefore, designed to find out the response of rice to sources and levels of phosphorus with regard to yield attributes and yield of rice.

Material and Methods
The experiment was conducted at the Agricultural College Farm, Bapatla. Initial soil sample showed that the experimental soil was loamy sand in texture, pH of the soil was 7.6, 7.8 (slightly alkaline in reaction), organic carbon was 0.42, 0.43 % (low), available nitrogen was

226, 230 kg ha^{-1} (low), available phosphorus was 18, 20 kg ha^{-1} (low) and available potassium was 483, 521 kg ha^{-1} (high) during 2016-17 and 2017-18 respectively. The treatments consisted of four sources of phosphorus $S_{1:}$ Inorganic fertilizer phosphorus through SSP, $S_{2:}$ Green manuring *in-situ* with dhaincha @ 25 kg seed ha^{-1}, $S_{3:}$ Biofertilizer (PSB) @ 750 ml ha^{-1}, $S_{4:}$ Green manuring *in-situ* with dhaincha @ 25 kg seed ha^{-1} + Biofertilizer (PSB) @ 750 ml ha^{-1} as main plots and three levels of phosphorus $L_{1:}$ 50% Recommended dose of P, $L_{2:}$ 100% Recommended dose of P and $L_{3:}$ 150% Recommended dose of P as subplots. The *Kharif* rice experiment was laid out in a split plot design and the treatments with three replications. A very popular variety, BPT 5204 (Samba Mahsuri) was used for the study. The field was ploughed two times by a tractor drawn cultivator, followed by a rotovator to obtain required tilth. Later the field was divided into the required number of main plots as per the field layout. The seed of dhaincha was broadcasted in the main plots namely S_2 (Green manuring *in situ* @ 25 kg ha^{-1}) and S_4 (Green manuring *in situ* + biofertilizer (PSB) @ 750 ml ha^{-1}) for all the three replications as per the layout plans and the seeds were covered by dragging a spike toothed harrow. These main plots were divided into sub plots after incorporation of green manure by making strong bunds and before transplanting of rice crop irrigation was given for better decomposition during both the years of experimentation.

A common dose of nitrogen at 120 kg ha^{-1} was applied in the form of urea in three splits, half at basal, one fourth at active tillering and remaining at panicle initiation stage. A common dose of 40 kg K_2O ha^{-1} was applied as basal just before transplanting through muriate of potash by taking the plot size into consideration. Phosphorus in the form of single super phosphate was applied basal as per the treatments.

Results and Discussion

Grain Yield (kg ha^{-1})

Grain yield was significantly influenced by sources and levels of phosphorus and their interaction too during both years of study and pooled data of study. The data pertaining to the grain yield of rice are presented in Table 1. The grain yield of various treatments was higher during the second year (2017-18) of study than that of the first year (2016-17). However the influence of different treatments was almost consistent in the both years of study and pooled data as well.

During both the years significantly higher yields were recorded with the treatment that received in combination with inorganic fertilizer through SSP and *in-situ* green manuring + biofertilizer (PSB) *i.e.* 5656 kg ha^{-1}, 5896 kg ha^{-1} and 5776 kg ha^{-1} during 1st, 2nd years and pooled data respectively, which was statistically on a par with *in-situ* green manuring treatment (5520, 5730 and 5625 kg ha^{-1}) during 1st and 2nd years and pooled data respectively but proved significantly superior to alone inorganic fertilizer through SSP (4620, 4649, 4635 kg ha^{-1}) and biofertilizer (PSB) alone treatment (5179, 5329 and 5254 kg ha^{-1}) under test.

Total drymatter accumulation might have reflected on the economic yield in view of the fact that vegetative part of the plant serves as the source, where as the spikelets are serve as sink. Accumulation of drymatter during the vegetative growth stage and its distribution to yield attributes during reproductive stage through a process of translocation from source to sink and finally determines the economic yield of the crop.

Present study results showed that *in-situ* green manuring + biofertilizer (PSB) with inorganic fertilizer through SSP significantly influenced the grain yield of rice. Application of *in-situ* green manuring + biofertilizer (PSB) along with fertilizer was found to be superior in realizing maximum grain yield. It might be due to the fact that green manure biomass is a potential source of major nutrients for lowland rice and showed significant improvement in growth, yield, net returns, soil moisture retension, organic carbon and nutrient status of soil and reduction in bulk density of plough layer (Jyothi and Nallaiah (2015) [15] and Siva Jyothi *et al*., 2013, 2015) [29, 30]**.** The yield increase may be due to increase in growth attributes like drymatter production and yield attributes like panicle length, total number of grains, more number of filled grains per panicle. Similar findings were also reported by Arivukkarasu and Kathiresan (2007) [1] and Deshpande and Devasenapathy (2010) [8]. Green manure + Biofertilizer (PSB) promotes improvement in leaf photosynthetic rate, biomass production and sink formation, which increased the grain yield of rice. Besides P solubilisation activity, PSB liberates growth harmone (IAA) that might have influenced on root growth and yield. The extensive root system might have increased nutrient uptake from the surroundings which boosted plant biomass and subsequently more grain yield of rice. These results were alike with the findings of Panhwar *et al*. (2010) [21].

However, the lowest grain yield was recorded with inorganic fertilizer through SSP (4620 kg ha^{-1}, 4649 kg ha^{-1} and 4635 kg ha^{-1}during 1st, 2nd year and pooled data of study).This might be due to phosphorus fixation in soil and lowest growth parameter like drymatter production and yield attributes like panicle length, total number of grains, more number of filled grains per panicle with SSP treatment.

Among the levels of phosphorus, 150 % RDP recorded highest grain yield (5425, 5583 and 5504 kg ha^{-1}) over 50 % RDP (5024, 5164 and 5094 kg ha^{-1}) it was remained on a par with 100 % RDP (5283, 5456 and 5369 kg ha^{-1}) during first, second and pooled data of study. This might be due to adequate supply of P in soil might have favoured efficient use of P in turn brought higher grain yield. These results are in close conformity with the findings obtained by Rao (2003) [26], Dutta and Gogoi (2009) [9] and Ramesh Babu *et al.* (2013) [25].

Number of Panicles m^{-2}

Data on number of panicles m^{-2} are presented in (Table 2) of rice, which was significantly affected by different sources and levels of phosphorus but not their interaction during both the years and pooled data.

The maximum number of panicles (340, 357 and 349 m^{-2}) were recorded during 2016-17, 2017-18 and pooled data respectively, with the combined application of *in-situ* green manuring and PSB which was significantly superior to alone biofertilizer (PSB) (310, 322, 316 m^{-2}) and inorganic fertilizer through SSP (278, 288, 283 m^{-2}) but was however, comparable with *in-situ* green manuring (335, 350, 343 m^{-2}) during 2016-17, 2017-18 and pooled data respectively.

Incorporation of *in-situ* green manuring and soil application of PSB recorded continuous supply and solubilization of adequate phosphorus might have helped in faster cell division and enlargement and lead to increased number of panicles m^{-2}. Increase in yield attributes of rice might be due to more residual effect of biological N-fixed in the root nodules of previous green manuring crop. These results are in accordance with the findings of Bastia (2002) [3], Meena and Shivay (2010) [19] and Panhawar *et al*. (2011).

The lowest number of panicles m^{-2} was recorded in the treatment, inorganic fertilizer through SSP (278, 288 and 283) during first, second year and pooled data due to fixed form of phosphorus in soil and less translocation of nutrients to the plant.

Among the phosphorus levels, 150 % RDP recorded significantly higher number of panicles m^{-2} (329) over 50 % RDP (296) and it was on a par with 100 % RDP (322). Similar trends were observed during second year and pooled data. Similar findings were reported by some other researchers like Masthan Reddy *et al*. (2005) [18] and Chaudary and Thakur (2007) [7].

Panicle Length (cm)

A significant difference in length of the panicle (Table 2) was observed among the sources and levels of phosphorus but not their interaction, which was followed the same trend as in the case of panicles m^{-2} during the two consecutive years and pooled data of study. Among the phosphorus sources, *in-situ* green manuring + PSB recorded significantly higher panicle length (16.9 cm) and was closely followed by the treatment, *in-situ* green manuring (16.1 cm) which was significantly superior to biofertilizer (PSB) (15.5 cm) and inorganic fertilizer through SSP (14.5 cm). Similar trend was observed during both the years and pooled data.

Application of *in-situ* green manuring + PSB recorded significantly highest panicle length which might be owing to higher availability of nutrients and modifying soil environment for better retention of nutrient and water during critical crop growth stages. The results are in conformity with the findings of Mandal *et al*. (2004) [16] and Gaur (2006) [11].

The lowest panicle length was recorded in the treatment, inorganic fertilizer through SSP (14.5, 15.1 and 14.8 cm) during first, second year and pooled data due to insoluble form of phosphorus in soil and less available nutrients to the plant and hence, finally shortest length of panicles was recorded.

Among the phosphorus levels, 150 % RDP recorded the highest panicle length (16.5 cm) over 50 % RDP (15 cm) and it was on a par with 100 % RDP (15.7 cm). Similar trend was observed during second year and pooled data. These results are in accordance with the findings of Bhanuprakash *et al*. (2013) and Bekele Anbessa Fayisa and Getahun Dereje Welbira (2016) [4].

Table 1: Grain yield (kg ha^{-1}) of *Kharif* rice as influenced by phosphorus management practices

Treatments	2016-17	2017-18	Pooled data
Source of phosphorus			
S_1- Inorganic phosphorus	4620	4649	4635
S_2- Green manuring	5520	5730	5625
S_3- Soil application of PSB	5179	5329	5254
S_4- Green manuring + PSB	5656	5896	5776
S.Em±	73.14	79.45	75.81
CD (p = 0.05)	253.1	274.9	262.3
CV (%)	4.2	4.4	4.3
Levels of phosphorus			
L_1- 50% RDP	5024	5164	5094
L_2- 100% RDP	5283	5456	5369
L_3- 150% RDP	5425	5583	5504
S.Em±	55.92	70.28	57.21
CD (p = 0.05)	167.7	210.7	171.5
CV (%)	3.7	4.5	3.7
Interaction	s	S	S

Table 2: Number of panicles m^{-2} and panicle length (cm) of *Kharif* rice as influenced by phosphorus management practices

Treatments	Number of Paniclesm^{-2}			Panicle length (cm)		
	2016-17	2017-18	Pooled data	2016-17	2017-18	Pooled data
Source of phosphorus						
S_1- Inorganic phosphorus	278	288	283	14.5	15.1	14.8
S_2- Green manuring	335	350	343	16.1	18.8	17.4
S_3- Soil application of PSB	310	322	316	15.5	16.8	16.2
S_4- Green manuring + PSB	340	357	349	16.9	19.6	18.3
S.Em±	10.24	9.77	9.98	0.23	0.48	0.26
CD (p = 0.05)	35.4	34.0	34.5	0.8	1.7	0.9
CV (%)	9.7	8.9	9.3	4.4	8.2	4.6
Levels of phosphorus						
L_1- 50% RDP	296	310	303	15.0	17.0	16.0
L_2- 100% RDP	322	335	329	15.7	17.5	16.6
L_3- 150% RDP	329	343	336	16.5	18.3	17.4
SEm±	9.01	9.01	9.01	0.22	0.27	0.24
CD (P=0.05)	27.0	27.0	27.0	0.7	0.8	0.7
CV (%)	9.9	9.5	9.7	4.9	5.3	5.0
Interaction	NS	NS	NS	NS	NS	NS

Total Number of Grains Panicle^{-1}

Total number of grains panicle^{-1} presented in (Table 3) was significantly influenced by sources and levels of phosphorus but not their interaction which was followed the similar trend as in the case of panicles m^{-2} during the two consecutive years and pooled data of study.

Significantly higher number of grains panicle^{-1} was recorded with the treatment, *in-situ* green manuring + PSB (191) which was remained statistically on a par with *in-situ* green manuring (180) but proved significantly superior to the rest of the treatments. Similar trend was followed during second year and pooled data of experimentation. Higher number of total grains panicle^{-1} recorded with the treatment, green manuring + PSB might be due to better nutrient availability with decompositionof green manure and carbondioxide produced in the rhizosphere by the microorganisms has been reported to be involved in increased P availability to plants which might be the reason for increase in tiller number m^{-2} in the present study. Similarly, higher number of productive tillers m^{-2} and filled grains per panicle by inoculation with PSB was also reported by Ramesh Babu *et al*. (2009) [24] and Islam *et al*. (2015) [13].

The lowest number of grains panicle^{-1} was observed in the treatments, inorganic fertilizer through SSP and biofertilizer (PSB) during both years and pooled data of study.

With regard to levels of phosphorus, 150 % RDP (181 grains panicle^{-1}) recorded significantly higher total number of grains per panicle over 50 % RDP (161 grains panicle^{-1}) and it was found on a par with 100 % RDP (171 grains panicle^{-1}) in first year. Similar trend was observed during second year and pooled data. This might be due to treatment with higher P levels noticed higher p concentration and higher P uptake of plant thereby increase the number of grains in the form of sink. These results are in accordance with the findings of Dwivedi *et al*. (2006) [10] and Shahzado Noonari *et al*. (2016) [28].

Table 3: Total number of grains panicle^{-1} of *Kharif* rice as influenced by phosphorus management practices

Treatments	2016-17	2017-18	Pooled data
Source of phosphorus			
S_1- Inorganic phosphorus	148	152	150
S_2- Green manuring	180	191	186
S_3- Soil application of PSB	164	170	167
S_4- Green manuring + PSB	191	203	197
S.Em±	3.54	3.35	3.43
CD (p = 0.05)	12.2	11.6	11.9
CV (%)	6.2	5.6	5.9
Levels of phosphorus			
L_1- 50% RDP	161	168	164
L_2- 100% RDP	171	180	175
L_3- 150% RDP	181	189	185
S.Em±	4.02	4.21	4.09
CD (p = 0.05)	12.1	12.6	12.3
CV (%)	8.2	8.1	8.1
Interaction	NS	NS	NS

Number of Filled Grains Panicle^{-1}

Data on number of filled grains panicle^{-1} are represented in (Table 4) was significantly affected by different sources and levels of phosphorus but not their interaction during both the years and pooled data of study.

Maximum number of filled grains panicle^{-1}was recorded with the treatment, *in-situ* green manuring + PSB (151) which was closely followed with the treatment, *in-situ* green manuring(144) but proved significantly superior to inorganic fertilizer through SSP (119) and biofertilizer (PSB) (130) during first year. Similar trend was followed during second year and pooled data of the trail.

Significantly higher number of filled grains panicle^{-1} recorded with the treatment, *in-situ* green manuring + PSB might be due to slow release of nutrients due to decomposition of green manure and PSB with additional release of N released after mineralization by microbes and increase phosphorus availability in soil led to better matching between nutrient demand by crops and its supply by soil. So, produced more carbohydrates and protein and ultimately to drymatter accumulation and hence favourable effect on more number of filled grains panicle^{-1}. These results are in close conformity with the findings of Yogesh *et al*. (2013) [31] and Meena *et al*. (2015) [20].

Among the levels of phosphorus, 150 % RDP (147) recorded significantly higher number of filled grains panicle^{-1} over 50 % RDP (127) and it was on a par with 100 % RDP (139). Similar trend was also observed during second year and pooled data. Increased phosphorus application could be attributed better nutrient availability more in these treatments than other treatments, which in turn, might have helped in faster cell division and enlargement. Further it might be also due to more number of tillers and higher drymatter accumulation. Similar results were also reported by Bandhyopadhyay and Puste (2002) [2] and Prasad *et al*. (2002) [23].

Table 4: Number of filled grains panicle^{-1} of *Kharif* rice as influenced by phosphorus management practices

Treatments	2016-17	2017-18	Pooled data
Source of phosphorus			
S_1 - Inorganic phosphorus	119	124	121
S_2- Green manuring	144	155	150
S_3 - Soil application of PSB	130	140	135
S_4- Green manuring + PSB	151	164	157
S.Em±	3.48	3.33	3.37
CD (p = 0.05)	12.0	11.5	11.7
CV (%)	7.6	6.8	7.1
Levels of phosphorus			
L_1 - 50% RDP	127	136	132
L_2 - 100% RDP	139	148	143
L_3 - 150% RDP	147	156	152
S.Em±	4.09	4.46	4.26
CD (p = 0.05)	12.2	13.4	12.8
CV (%)	10.3	10.5	10.4
Interaction	NS	NS	NS

Test Weight (g /1000 grains)

Test weight (g/1000 grains) are presented in (Table 5) which revealed that sources of phosphorus were found to be significantly differed during second year but not their levels and their interaction during both the years and pooled data of study.

During second the year of study, significantly higher test weight was recorded with the treatment that received *in-situ* green manuring + PSB (17.2 g) which was statistically on a par with *in-situ* green manuring treatment (16.6 g) but proved significantly superior to the rest of the treatments. The higher test weight recorded with the combined application of organics and inorganics may be attributed to steady supply of nutrients and which enhanced drymatter production and translocation of photosyntates to sink (grain) resulted in bold seeds which in turn increased the test weight as reported by Jha *et al*. (2004) [14] and Sai saravan *et al*. (2016) [27].

However, the lowest 1000-grain weight was recorded with inorganic fertilizer through SSP (16.4 g) and biofertilizer

(PSB) (16.4 g) during second year of study.

There was no significant difference observed with the levels of phosphorus on test weight of rice during both the years and pooled data of study. These results are in close conformity with the findings Masthan *et al.* (1999) [17] and Hasanuzzaman *et al*. (2011) [12].

Table 5: Test weight (g/1000 grains) of *kharif* rice as influenced by phosphorus management practices

Treatments	2016-17	2017-18	Pooled data
Source of phosphorus			
S_1 - Inorganic phosphorus	15.7	16.4	16.0
S_2- Green manuring	16.0	16.6	16.3
S_3 - Soil application of PSB	15.7	16.4	16.0
S_4- Green manuring + PSB	16.5	17.2	16.8
S.Em±	0.29	0.25	0.27
CD (p = 0.05)	NS	0.7	NS
CV (%)	5.4	4.6	4.9
Levels of phosphorus			
L_1 - 50% RDP	15.9	16.5	16.2
L_2 - 100% RDP	15.7	16.4	16.1
L_3 - 150% RDP	16.3	17.0	16.6
S.Em±	0.26	0.22	0.24
CD (p = 0.05)	NS	NS	NS
CV (%)	5.6	4.6	5.1
Interaction	NS	NS	NS

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