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Effect of Phosphate Solubilizing Bacteria on Yield of Transplanted Rice under Lateritic Belt of West Bengal, India

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A field experiment was conducted during *kharif* season 2014 at P.S.B. Agriculture farm, Visva-Bharati, Sriniketan West Bengal to study the effect of phosphate solubilizing bacteria on growth and productivity of transplanted rice laid out in RBD with three replications. The result revealed that at harvest, highest (1101.11 g) dry matter was accumulated with NPK+PSB which was statistically at par but 7.9%, 8.6%, 13.27% higher than NP_0K, NP_0K+PSB and NPK, respectively. NP_0K+PSB gave the highest (442.22) number of panicle m^{-2} which was significantly 40.70% and 37.68% higher over $N_0P_0K_0$+PSB and $N_0P_0K_0$, respectively. NPK+PSB proved best in influencing growth and productivity, which however at par with NP_0K, NPK, NP_0K+PSB, and NP_0K+PSB+RP except NP_0K+PSB+RP for dry matter at harvest. NPK+PSB recorded highest (₹ 52750/-) gross returns but NP_0K resulted maximum (₹ 19466/-) net returns.

Introduction

Rice is the most important crop in Asia as the main staple food and to those who depend on rice farming for their livelihoods. It is the world's leading food crop, cultivated over an area of about 166.8 mha with a production of 745.17 mt (FAOSTAT, 2013). India is the 2nd and largest producer of rice in the World after china. The present status of rice production in India is about 105.3 mt with an average productivity of 2.3 t ha^{-1} (IndiaStat, 2012), and it accounts for 45% of food grain production and provides employment of about 70% of the people in the rural areas, China produces 205.01 mt of rice from 30.39 million ha area with an average productivity of 6.72 t ha^{-1} (FAOSTAT, 2013), is more than a half total productivity of India. India's rice productivity (3.6 t ha^{-1}) is even far below the world average (4.5 t ha^{-1}) (FAOSTAT, 2013). Some of the important reasons for declining productivity of rice in India are poor soil fertility, imbalanced and indiscriminate use of inorganic fertilizers and that too with improper management practices. In order to achieve the desired yield potential from rice, balanced and sufficient input supply with appropriate management is a focus of research which needs an immediate attention.

Phosphorus is an essential nutrient required by rice (Yahya *et al.*, 1989; Kim *et al.*, 1998) and has a defined role in plant metabolisms such as root development, photosynthesis, nutrient transport within the plant, meiosis, phospholipid in cell walls, reproductive parts of plant (Rasipour *et al.*, 2007; Kianirad, 1995). Phosphorus deficiency can be removed with supplying phosphate to the soils but increasing phosphorus uptake and decreasing phosphorus fixation in soils is complicated and important. Rehman (2004) showed that available phosphorus inplants was affected by three factors: plant available phosphorus concentration in soil solution, the amount of exchangeable phosphorus and the amount of relative phosphorus uptake in soils.

Use of microorganisms as environment friendly biofertilizer helps to reduce the much expensive phosphatic fertilizers. Phosphatic biofertilizer could help to increase the availability of accumulated phosphate by solubilization efficiency of biological nitrogen fixation and increase availability of Fe, Zn etc., through production of plant growth promoting substances (Kucey *et al.*, 1989).Trials with PSB indicated yield increases in rice (Tiwari *et al.*, 1989), and other cereals (Afzal *et al.*, 2005; Ozturk *et al.*, 2003). Biological phosphate fertilizers containing beneficial bacteria and fungi increased phosphate solutions by increasing soil acidity or alkaline phosphatase enzyme, which can be absorbed by plants easily.

Soil chemical and biological characteristics improved by biofertilizer; moreover due to the use of low doses of chemical fertilizers, agricultural production will be free from contaminants (Habbasha *et al.*, 2007; Salimpour *et al.*, 2010). Several research groups have compared the effects of biological and chemical fertilization in the flooded rice system (Mathar *et al.*, 1981; Khadr *et al.*, 1985; Jeyaraman *et al.*, 1988) and reported that biofertilization could provide a better alternative for the extensive use of phosphate fertilizer in rice production.

Chemical fertilizers are one ofthe major sources of providing phosphorus in plants, but environmental hazards caused by their overuses have led to an alarming threat. Phosphate solubilizing bacteria (PSB) are a group of beneficial bacteria capable hydrolysis of organic and inorganic phosphorus from insoluble compound. Till recent, a number of the PSB has been reported for solubilizing unavailable soil phosphorous into available form. However, Strain P_4 (*Burkholderia* sp.) has additive advantage over the other reported that it has no antagonism i.e. it lives in co-inoculation status with *Trichoderma viridi*, unlike other PSB. It has ability to solubilize rock phosphate, also produces siderophore (iron chelating substances) which can be used by the plant and as well as organism itself. Thus, it brings soil pathogens under iron stress condition. Moreover, P_4 strain also produces growth promoting substance like IAA. Keeping the above facts in view, the present investigation entitled Effect of Phosphate Solubilizing Bacteria on growth and Productivity of transplanted rice (*Oryza sativa* L.) has been planned with the following objectives: -i) To study the effect of PSB on growth and productivity of transplanted rice.ii) To study the economics of rice cultivation.

Materials and Methods

A field experiment was conducted during *kharif* season 2014 (July to October) at Palli Siksha Bhavana Agriculture farm, Visva-Bharati, Sriniketan West Bengal, the soil of the experimental plot was sandy loam in texture (Ultisol). The field is situated at about $23^0$39.823′ N latitude and $87^0$37.972′ E longitude with an average altitude of 60 m above the mean sea level. The location of experimental site is in the western part of West Bengal under sub humid red and lateritic agro-ecological zone. Normally the area received about 1000 mm rainfall during the *kharif* season (July to October). The minimum weekly temperature varied from 19.66^{0}C in October to 27.89^{0}C in July and the maximum temperature ranged from 29.90^{0}C in October to 35.51^{0}C in September during the cropping season. The relative humidity during cropping period varied from 79.14 to 90.0%. The long term average relative humidity also varied from 74.8 to 87.0%. This indicated that the relative humidity of the cropping season was almost normal of this area.

The soil of the experimental field had acidic in soil reaction of pH 5.65with low level of organic carbon 0.67% (Walkley and Black, 1934) and available nitrogen 157.93 kg ha^{-1} (Subbiah and Asija, 1956), but medium level of available phosphorus (Olsen *et al.*, 1954) and ammonium acetate exchangeable potassium (Hanway and Heidel, 1952).

Experimental treatments and design

The experiment was conducted in a completely randomize block design with three replication, consisting of seven treatment combination i.e. NP_0K, NP_0K + PSB, NP_0K+PSB+ROCK PHOSPHATE, NPK, NPK+PSB, $N_0P_0K_0$+PSB, $N_0P_0K_0$. Rice variety selected for the experiment was MTU 1010 and the species of phosphate solubilising bacteria was *Burkholderia* spp. strain P_4.

Characteristics of cultivar

Rice variety MTU 1010 was grown to study the effect of phosphate solubilising bacteria on growth and productivity during kharif season. The variety was released by Andhra Pradesh Rice Research Institute (APRRI), which is developed by cross-breeding of Krishnaveni with IR64. The variety is widely planted variety of India as well as world. It is a Semi dwarf with medium tillering green foliage, grain straw glumed, long slender, high yielding fine grain and resistant to blast and tolerant to BPH varieties. The duration of this variety ranges from 110-115 days. The grains are White, translucent in colour and are of superior quality with 23.0-25.0 g of its test weight. It can produce 73-74 q grains ha^{-1} in *kharif season* under good management practices.

Phosphate Solubilizing Bacteria (PSB)

The phosphate solubilizing bacteria strain P_4 was isolated from the plant rhizospheric soil (soil type-red lateritic soil of Santiniketan) It was isolated on pikovskaya's agar plates containing insoluble tricalcium phosphate (TCP)as sole P source, and was selected on the basis of solubilizing zone produced by the strain. The isolated strain can produce more than 400µg/ml of soluble phosphate is PVK both (liquid medium) in the presence of TCP. It is also able to solubilize four different rock phosphates viz., Jordan rock phosphate, purulia rock phosphate, Udaipur rock phosphate, mussorie rock phosphate in appreciable amount. The isolated strain was also able to grow on nitrogen free Burk's medium which indicates its nitrogen fixing property. Though it is gram negative rod shaped bacteria it has no antagonism i.e. it release in co-inoculation status with *Trichoderma viridi*, unlike other Phosphate solubilizing bacteria.

Land preparation and fertilizer application

The main field was prepared by disk ploughing twice followed by puddling in standing water. The perfect leveling was done by using wet land leveler. After final land preparation, the land was left for 2 days to settle the soil. Then layout of plots was done with adequate number of bunds and channels to provide irrigation and draining channels for each treatment.

The fertilizer (urea for nitrogen, single super phosphate, rock phosphate, phosphate solubilising bacteria for phosphorous and murate of potash for potassium) was weighted separately as per the treatment combination. Required quantity of fertilizer was applied uniformly in the plots through broadcast method of application, PSB was inoculated with seedling's root for half an hour's as per treatments. Half dose of nitrogen as per treatments was applied in each plot before transplanting. The rest half nitrogen was top dressed in two splits- ¼th at active tillering and remaining at panicle initiation stage. And finally one month old seedlings were transplanted in the main field on 3rd Aug. 2014 with 2-3 seedlings per hill.

Studies on growth and yield attributes of rice

In each plot, five plants were randomly chosen to calculate plant height at 30, 60 and 90 DAT. The average height of these five plants was calculated for determining the average plant height in each treatment using a standard meter scale and was expressed in cm. The number of tillers per hill was recorded at 30, 60 and 90 DAT from randomly selected 5 hills in each plot and then number of tillers per unit area was estimated for each plot. Leaf area plant^{-1} was measured by leaf area meter (LICOR Model LI3100). Based on the leaf area plant^{-1}, the LAI was obtained by using the formula given by Johnson (1967).

$$LAI = \frac{\text{Leaf area plant}^{-1}}{\text{Land area occupied by individual plant}}$$

For dry matter accumulation destructive samples were taken at 30, 60, and 90 DAT from each plot. The plant were cut at the ground level and kept them separately in brown paper packet during sampling. The green leaves, stem were separated from each sample in each plot and dried in a hot oven at 60-80°C for 48 hours till constant weight were obtained. The dry weight of the plant (stem and leaves) for each plot was recorded with an electric digital balance for determining the dry matter accumulation (g/m^2).

The selected 10 panicles, which were used for panicle length measurement, were also used to record the weight of the panicles, mean panicle weight was computed, and number of grains per panicle was counted. The 1,000-filled grains, taken from sampled panicles, were first counted by and then weighed to compute the 1,000-grain weight.

Yields and harvest index of rice

Harvesting of rice was undertaken as soon as it attained the harvest maturity. The harvesting was done with sickles after leaving the border area. Net plots were demarcated at first from the portion of the plot kept for recording grain yield. Plants from the demarcated net plot area were harvested, tied in bundles and taken to the threshing floor for drying and threshing. The harvested plants were dried for 3-4 days to bring down the moisture content to around 14%. The sun dried grains obtained after threshing and cleaning from the harvested area of each plot were weighed for recording grain yield in each plot. The grain yield thus obtained was then converted into kg ha^{-1} for each plot. Straw yield was obtained by deducting the grain weight from the total weight. The economic yield (grain) per unit of biological yield i.e., grain and straw yield of the crop was determined by the following formula as suggested by Donald (1962).

$$H.\,I. = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

The economic yield indicates the seed yield, whereas the biological yield represents the total yield of above ground plant parts recorded in this experiment.

Statistical analysis

All the replicated data obtained from the experiment were statistically analysed using the F-testas per the procedure given by Gomez and Gomez (1984). Least significant difference (LSD) values at P = 0.05 were used to determine the significance of differences between treatment means.

Economics

To calculate the cost of cultivation, gross return, net return and return per rupee invested of different treatments, the cost of various inputs like seeds, fertilizers, herbicides and all other inputs including labour charges were estimated as per price of the items in the local market. The value of products like grain and straw was also calculated on the basis of available price at the local market.

Results and Discussion

Growth attributes

Plant height (cm)

At 30 DAT, the maximum plant height (65.87 cm) was recorded with NP_0K which was significantly higher than NPK, NPK+PSB, $N_0P_0K_0$+PSB, and $N_0P_0K_0$. On the other hand, NP_0K+PSB gave next tallest plant height (63.07 cm) and found statistically at par with all the treatments except $N_0P_0K_0$+PSB and $N_0P_0K_0$ (Table 1).

At 60 DAT also, tallest (112.35 cm) plant height was recorded from the same treatment i.e., NP_0K which was significantly higher among all the treatment except NP_0K+PSB. NP_0K+PSB also exhibited taller (63.07 cm) plants significantly higher than NPK+PSB, $N_0P_0K_0$+PSB and $N_0P_0K_0$. At harvest also, maximum plant height (112.37 cm) was obtained from NP_0K which was significantly higher than the NP_0K+PSB+RP, NPK+PSB, $N_0P_0K_0$+PSB, $N_0P_0K_0$. Beside that NP_0K+PSB gave next tallest plant height (109.90 cm) and found statistically at par with all the treatments except $N_0P_0K_0$+PSB and $N_0P_0K_0$.

Number of tillers m^{-2}

The effect of treatments on total number of tillers m^{-2} at 30 DAT, 60 DAT and at harvest was significantly affected by all the treatments (Table 2).

At 30 DAT, highest 528.89 tiller m^{-2} was observed with the treatment NP_0K+PSB which was statistically at par with all the treatments except $N_0P_0K_0$+PSB, and $N_0P_0K_0$. NPK+PSB gave the next best results after NP_0K+PSB, which was significantly higher than $N_0P_0K_0$+PSB, and $N_0P_0K_0$.

At 60 DAT also, NP_0K+PSB recorded significantly more number (448.89) of tillers over $N_0P_0K_0$+PSB, and $N_0P_0K_0$, respectively. Next best treatment NPK+PSB also resulted significantly higher (435.56) tillers m^{-2} than $N_0P_0K_0$+PSB and N_0P_0K, respectively.

At harvest, NP_0K+PSB proved significantly better in producing tillers over $N_0P_0K_0$+PSB, and $N_0P_0K_0$, respectively. Almost similar trend was observed with NPK+PSB.

Leaf area index

At 30 DAT, highest (2.11) LAI was recorded from NPK+PSB, which was statistically at par with NP_0K and NPK, NPK+PSB is 51.18% and 49.28% significantly higher over $N_0P_0K_0$ and $N_0P_0K_0$+PSB (Table 3).

At 60 DAT also, NPK+PSB gave the highest (7.02) LAI that was significantly higher than all treatments except NP_0K (6.84), and NPK+PSB significantly higher than rest all treatments.

At harvest, highest (4.25) LAI was noticed from NPK+PSB, which was significantly higher over all the treatment except NP_0K; beside it was 28.47% and 32.5% significantly higher over $N_0P_0K_0$+PSB and $N_0P_0K_0$.

Dry matter accumulation (g m^{-2})

A significant response was obtained from different effect of treatments towards dry matter accumulation at 30 DAT, 60 DAT, and at harvest. At 30 DAT, The maximum (286.11 g) dry matter accumulation was noticed with treatment NPK, which was significantly higher over NP_0K, NP_0K+PSB+RP, $N_0P_0K_0$+PSB, and $N_0P_0K_0$ (Table 4).

This treatment though statistically at par but recorded 15.45%, 23.33% higher dry matter over NPK+PSB and NP_0K+PSB, respectively. On the other hand NPK+PSB statistically at par with all the treatment except $N_0P_0K_0$.

At 60 DAT, highest (935.22 g) dry matter accumulation was taken place with NPK+PSB which was significantly 22.86%, 26.2%, and 39.13% higher than $N_0P_0K_0$+PSB, NP_0K+PSB+RP and $N_0P_0K_0$, respectively. Next highest (829.18 g) dry matter was recorded highest with NP_0K that was significantly higher than NP_0K+PSB, NP_0K+PSB+RP, $N_0P_0K_0$+PSB, respectively.

At harvest, highest (1101.11 g) dry matter was accumulated with NPK+PSB which was statistically at par but 7.9%, 8.6%, 13.27% higher than NP_0K, NP_0K+PSB and NPK, respectively.

The same treatment however, 19.7%, 22.89%, and 33% was higher than $N_0P_0K_0$+PSB, NP_0K+PSB+RP, and $N_0P_0K_0$, respectively. NP_0K was revealed statistically at par with all the treatments except $N_0P_0K_0$ which resulted 38.5% more dry matter accumulation than $N_OP_0K_0$.

Yield attributing characters

Total number of panicle m^{-2}

The recorded data revealed that total number of panicle m^{-2} are significantly influenced by the treatments, NP_0K+PSB gave the highest (442.22) number of panicle m^{-2} which was significantly 40.70% and 37.68% higher over $N_0P_0K_0$+PSB and $N_0P_0K_0$, respectively. This treatment was statistically at par with rest of the treatments. On the other hand, NPK+PSB also gave highest (426.67) number of panicle m^{-2} next to NP_0K+PSB, that was significantly higher than NP_0K+PSB and $N_0P_0K_0$ (Table 5).

Total number of grain panicle^{-1}

There was no significant difference between the treatments on this yield attributing character.

However, the maximum number of grain (130.93) was counted in (NPK) which is followed by NPK+PSB 129.80.

Number of filled grain panicle^{-1}

The data pertaining to the effect of treatment on the number of filled grain panicle^{-1} found no significant differences.

However, NPK gave the maximum (109.13) number of filled grain panicle^{-1} followed by the treatment NP_0K and NPK+PSB i.e.107.7 and 105.73.

Panicle length (cm)

The panicle length of rice was significantly influenced by the treatment. It revealed that the highest panicle length (25.46 cm) was noticed from NPK and NPK+PSB, which were statistically at par with all the treatments except $N_0P_0K_0$+PSB, and $N_0P_0K_0$.

Table.1 Effect of treatments on plant height

Treatments	Plant height (cm)		
	30 DAT	60 DAT	Harvest
NP_0K	65.87	112.35	112.37
NP_0K + PSB	63.07	110.27	109.90
NP_0K + PSB + RP	62.99	106.59	106.75
NPK	59.85	107.65	107.91
NPK + PSB	60.54	105.61	105.89
$N_0P_0K_0$ + PSB	54.83	96.41	96.13
$N_0P_0K_0$	53.60	95.66	96.37
SEm±	1.497	1.329	1.728
CD (p=0.05)	4.613	4.096	5.325
CV (p=0.05)	4.314	2.194	2.849

Table.2 Effect of treatments on tillers m^{-2}

Treatments	Tillers m^{-2}		
	30 DAT	60 DAT	Harvest
NP_0K	464.44	364.44	362.22
NP_0K + PSB	528.89	448.89	442.22
NP_0K + PSB + RP	502.22	404.44	404.44
NPK	453.33	368.89	366.67
NPK + PSB	524.44	435.56	426.67
$N_0P_0K_0$ + PSB	326.67	266.67	262.22
$N_0P_0K_0$	362.22	300	275.56
SEm±	42.156	28.004	26.136
CD (p=0.05)	129.89	86.290	80.535
CV (p=0.05)	16.163	13.115	12.476

Table.3 Effect of treatments on leaf area index

Treatments	Leaf area index		
	30 DAT	60 DAT	Harvest
NP_0K	2.00	6.84	4.07
NP_0K + PSB	1.85	6.57	3.75
NP_0K + PSB + RP	1.63	6.56	3.45
NPK	1.96	6.70	3.87
NPK + PSB	2.11	7.02	4.25
$N_0P_0K_0$ + PSB	1.07	5.23	3.04
$N_0P_0K_0$	1.03	5.01	2.87
SEm±	0.037	0.060	0.060
CD (p=0.05)	0.114	0.186	0.184
CV (p=0.05)	3.864	1.66	2.876

Table.4 Effect of treatments on dry matter accumulation

Treatments detail	Dry wt. (gram m^{-2})		
	30 DAT	60 DAT	Harvest
NP_0K	203.61	829.18	930.60
NP_0K + PSB	219.34	825.33	923.56
NP_0K + PSB + RP	207.35	689.59	779.57
NPK	286.11	786.83	876.81
NPK + PSB	241.89	935.22	1011.01
$N_0P_0K_0$ + PSB	188.43	721.49	811.47
$N_0P_0K_0$	125.62	569.25	671.44
SEm±	23.226	58.652	57.297
CD (p=0.05)	71.56	180.726	176.551
CV (p=0.05)	19.126	13.274	11.569

Table.5 Effect of treatments on yield attributing characters

Treatments	Number of panicle m^{-2}	Total number of grain panicle $^{-1}$	Number of filled grain panicle $^{-1}$	Panicle length (cm)	Test wt. (g)
NP_0K	362.22	127.53	107.07	24.90	23.78
NP_0K+ PSB	442.22	120.47	99.33	25.27	23.75
NP_0K+ PSB +RP	404.44	118.33	99.53	25.06	24.34
NPK	366.67	130.93	109.13	25.46	25.87
NPK+PSB	426.67	129.80	105.73	25.46	23.88
$N_0P_0K_0$+PSB	262.22	107.60	91.47	22.63	24.66
$N_0P_0K_0$	275.56	93	78.53	21.86	24.15
SEm±	26.136	8.709	7.614	0.694	0.660
CD (p=0.05)	80.53	NS	NS	2.14	NS
CV (p=0.05)	12.476	12.75	13.365	4.93	4.700

Table.6 Effect of treatments on biological yield and harvest index

Treatments	Grain yield kg $^{ha-1}$	Straw yield kg $^{ha-1}$	Harvest index
NP_0K	4166.67	5353.33	0.44
NP_0K+PSB	4106.67	5896.67	0.41
NP_0K+PSB+RP	4036.67	6670.00	0.39
NPK	4143.33	6633.33	0.39
NPK+PSB	4226.6	6256.67	0.41
$N_0P_0K_0$+PSB	2963.33	3058.33	0.51
$N_0P_0K_0$	2686.67	3103.33	0.46
SEm±	168.646	695.717	0.035
CD (p=0.05)	519.65	2143.72	NS
CV (p=0.05)	7.765	22.815	14.24

Table.7 Effect of treatments on gross returns, and net returns in transplanted rice

Treatments	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})
NP_0K	51186.67	19466.67
NP_0K + PSB	51070.00	19300.00
NP_0K + PSB + RP	51073.33	18053.33
NPK	52210.00	18090.00
NPK + PSB	52750.00	18580.00
$N_0P_0K_0$ + PSB	35655.00	6095.00
N_0P_0K	32656	3146.67
SEm±	2055.119	2055.119
CD (*p*=0.05)	6332	6332.451
CV (*p*=0.05)	7.629	24.254

Test weight

No significant response was found from the effect of treatments on test weight However highest (25.87 g) test weight was recorded with NPK, followed by $N_0P_0K_0$+PSB.

Biological yield

Grain yield

The highest grain yield (4226.6 kg ha^{-1}) was recorded with treatment NPK+PSB which is significantly higher (29.88%) than $N_0P_0K_0$+PSB, 36.43% higher than $N_0P_0K_0$, respectively (Table 6).

NP_0K proved best after NPK+PSB which proved significantly higher 28.8% $N_0P_0K_0$+PSB and 36.9% with $N_0P_0K_0$.

Straw yield

The maximum straw yield (6670 kg ha^{-1}) was recorded from NP_0K+PSB+RP. This treatment was significantly 54.14% and 53.47% higher over the $N_0P_0K_0$+PSB and $N_0P_0K_0$, respectively; and statistically at par with all the rest of the treatments. NPK resulted (6633.33 kg ha^{-1}) which was significantly 53.91% and 53.21% higher over $N_0P_0K_0$+PSB and $N_0P_0K_0$, respectively.

Gross returns and net returns

It indicates that gross returns and net returns are significantly influenced by the treatments. NPK+PSB resulted the highest gross returns (₹ 52750/-) which was significantly 32.4% and 38.09 % higher over $N_0P_0K_0$+PSB, and $N_0P_0K_0$, respectively. However, highest net return (₹ 19466/-) was recorded from NP_0K which was 68% and 83.8 higher over $N_0P_0K_0$+PSB, and $N_0P_0K_0$ (Table 7).

At 30 DAT, the maximum plant height (65.87 cm) was recorded with NP_0K which was significantly higher than NPK, NPK+PSB, $N_0P_0K_0$+PSB, and $N_0P_0K_0$. At 60 DAT also, tallest (112.35 cm) plant height was recorded from the same treatment but at par with only NP_0K+PSB. At harvest also, maximum plant height (112.37 cm) was obtained from NP0K which was significantly higher than the NP_0K+PSB+RP, NPK+PSB, $N_0P_0K_0$+PSB, $N_0P_0K_0$. This might be due to P availability increased in the flooded soil because of the reduction of ferric phosphate to more soluble ferrous form and hydrolysis of phosphate compound. These findings were in accordance with Fageria and Baligar, 2001 and Fageria *et al.*, (2007).

At 30 DAT, highest 528.89 tiller m-2 was observed with the treatment NP_0K+PSB.

NPK+PSB gave the next best results after NP_0K+PSB. At 60 DAT also, NP_0K+PSB recorded significantly more number (448.89) of tillers over $N_0P_0K_0$+PSB. At harvest, NP_0K+PSB again proved significantly better in producing tillers over $N_0P_0K_0$+PSB, and $N_0P_0K_0$, respectively. Almost similar trend was observed with NPK+PSB. This might be due to the positive effect of PSB inoculation which results higher amount of soluble P uptake in soil solution increased P uptake in plant, and resulted higher plant biomass and positive effect on plant growth attributes. This line was with the findings of (Panhwar *et al.*, 2011; Ravikumar *et al.*, 2013; Singh and Sirvastava, 2010).

At 30 DAT, highest (2.11) LAI was recorded from NPK+PSB. At 60 DAT also NPK+PSB gave the highest (7.02) LAI that was significantly higher than all treatments except NP_0K (6.84) and At harvest, highest (4.25) LAI was noticed from NPK+PSB, which was significantly higher over all the treatment except NP_0K. The LAI was found to increase from 30 DAT, to 60 DAT, followed by decreased at harvest. The increase in leaves as well as tiller bearing habit helped to increase LAI, from 30-60 DAT. However due to death in older leaves as well as ineffective tillers in the subsequent stage, LAI had been found to decrease. This might be due to more availability of nutrients because PSB inoculation significantly increased leaf chlorophyll β-carotenoid, increased N, P, K and increased content of organic acids from the soil. *Burkholderia* spp. also produce siderophore iron chelating substances which results more availability of micro nutrients like Fe. These findings were in accordance with (Panhwar *et al.*, 2011; Hossian *et al.*, *2008;* Ravikumar *et al.*, 2013; Tamgale, 2006).

At 30 DAT, The maximum (286.11 g) dry matter accumulation was noticed with treatment NPK. At 60 DAT, highest (935.22 g) dry matter accumulation was taken place with NPK+PSB which was significantly 22.86%, 26.2%, and 39.13% higher than $N_0P_0K_0$+PSB, NP_0K+PSB+RP and $N_0P_0K_0$, respectively. At harvest, highest (1101.11 g) dry matter was accumulated with NPK+PSB which was statistically at par but 7.9%, 8.6%, 13.27% higher than NP_0K, NP_0K+PSB and NPK, respectively. Investigation done by Banerjee *et al.*, 2009; Panhwar *et al.*, 2011; Ravikumar *et al.*, 2013; Tamgale; 2006 found that inoculation of PSB not only increased availability of NPK but also enhance micronutrients availability. However, *Burkholderia* spp. produce siderophore iron chelating substances which result positive effect on dry matter accumulation.

In case of yield attributing character it is noticed that, most of the character are not found significantly influenced by the treatments except number of panicle $m^{-2}$and Panicle length (cm). But however, inoculation of PSB with other inorganic nutrients positively influenced the yield attributing characters as it solubilize nutrients and make more available to plants (Alam *et al.*, 2008; Panhwar *et al.*, 2013; Sapsirisopa *et al.*, 2009; Ferreira *et al.*, 2012; Banerjee *et al.*, 2009; Hossain *et al.*, *2008*;).

The highest grain yield (4226.6 kg ha^{-1}) was recorded with treatment NPK+PSB which is significantly higher (29.88%) than $N_0P_0K_0$+PSB, 36.43% higher than $N_0P_0K_0$, respectively. NP_0K proved best after NPK+PSB which proved significantly higher 28.8% $N_0P_0K_0$+PSB and 36.9% with $N_0P_0K_0$.Singh and Sirvastawa (2010) found application of PSB along with full dose of NPK fertilizer is necessary to increased yield. PSB increased grain protein by 5-7% which resulted higher grain yield (Kar *et al.*, 2009; Tripathy *et al.*, 2009). Sharma *et al.*, (2003) reported that application of PSB along with

35 kg P fertilizer increased grain yield by 10-17%. Estrada *et al.*, (2013) found inoculation of *Herbaspirillum* strain and *Burkholderia* spp. increased rice grain yield from 33-47% with TCP and 18-44% with TSS, respectively.

The result revealed that use of PSB performed statistically at par with the treatments where phosphorus was not applied, this revealed the supply of native soil phosphorus to the plant. In flooded soil, availability of P increased because of the reduction of ferric phosphate to more soluble ferrous forms and the hydrolysis of phosphate compound (Fageria and Baligar, 2001; and Fageria, 2007).

The maximum straw yield (6670 kg ha-1) was recorded from NP_0K+PSB+RP.

This treatment was significantly 54.14% and 53.47% higher over $N_0P_0K_0$+PSB and $N_0P_0K_0$, respectively; Banerjee *et al.*, 2009 reported that application of PSB along with rock phosphate increased straw yield of *kharif* rice.

NPK+PSB resulted the highest gross returns (₹ 52750/-) which was significantly 32.4% and 38.09 % higher over $N_0P_0K_0$+PSB, and $N_0P_0K_0$, respectively. However, highest net return (₹ 19466/-) was recorded from NP_0K which was 68% and 83.8 higher over $N_0P_0K_0$+PSB, and $N_0P_0K_0$. Yadav *et al.*, (*2008*, 2009, 2013) and Kaushik *et al.*, 2004 revealed that application of PSB along with organic source of nutrients as well as inorganic source of nutrients gave highest gross monetary returns.

NPK+PSB proved best in influencing growth and productivity, which however at par with NP_0K, NPK, NP_0K+PSB, and NP_0K+PSB+RP except NP_0K+PSB+RP for dry matter at harvest. NPK+PSB recorded highest gross returns but NP_0K resulted maximum net returns.

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