Efficacy of co-inoculation of the *rhizobium* and *pseudomonas* in combination with chemical fertilizer on the productivity of rice under legume-based cropping system

Saraswoti Kandel¹*, Anil Pokhrel², Reena Sharma³, Kamana Rayamajhi⁴ and Suraj Chaudhary⁴

¹National Soil Science Research Centre, Khumaltar, Lalitpur, Nepal
²Ginger Research Program, Kapurkot, Salyan, Nepal
³National Potato Research Program, Nepal Agriculture Research Council (NARC), Khumaltar, Lalitpur, Nepal
⁴Central Department of Biotechnology, Tribhuvan University, Kritipur, Nepal
*Correspondence: kandelsaraswoti@gmail.com

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Abstract
The main production restriction in Nepal is a shortage of nitrogen and phosphorus-based fertilizers. In addition, the excessive use of chemical fertilizers to increase rice production alters the soils’ physicochemical and biological qualities. The effective application of biofertilizers obtained from beneficial microorganisms is on demand for increasing agriculture production as well as maintaining soil health sustainably. The experiment was conducted in a completely randomized block design (RCBD) with five treatments and four replications at Grain Legumes Research Program (GLRP), Khajura, Banke in order to find out the response of co-inoculation of *Rhizobium* and *Pseudomonas* in combination with different dose of recommended chemical fertilizers. The application of the co-inoculated *Rhizobium* and *Pseudomonas* at the dose of 800 g/ha along with the recommended N:P₂O₅:K₂O dose of 100:60:30 kg/ha was found to be best effective among all treatment combinations. The maximum panicle length, biological yield, grain yield and thousand grain weight were 27.75 cm, 6.55 t/ha, 6.083 t/ha, and 27.67 g, respectively. In this study, co-inoculation of *Rhizobium*, *Pseudomonas* and a full dose of prescribed chemical fertilizers improved panicle length, biological yield, grain yield and thousand grains weight considerably more than others.

Keywords: Biofertilizer, *Pseudomonas*, *Rhizobium*, rice, yield


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INTRODUCTION
The excessive use of chemical fertilizers for increasing rice production causes alterations in physico-chemical and biological properties of the soil. In such condition, the role of adequate population of beneficial microorganisms is essential in maintaining the soil health through
organic matter decomposition, toxin removal and cycling of C, N, P and S. So, there is recent increased interest in the application of the single and combined application of plant growth promoting rhizobacteria (PGPR) in the improvement of the productivity of rice. The rice crop which contributes as staple food to more than 50% of the world’s population, under monoculture and excessive fertilization becomes unfavourable for soil health as it releases up to 46% of N₂O in the environment (Winston et al., 2020).

In Nepal, the major production constraint is lacking enough nitrogen and phosphorus-based fertilizers. In such case, the role of nitrogen fixing, and phosphorus solubilizing bacteria is crucial. *Rhizobium* play significant role in nitrogen fixation through symbiotic relationship with nodules in legumes (Ohara, 2001). While phosphorus being most essential nutrient next to nitrogen plays role in crop growth, N₂ fixation and nodulation (Abel et al., 2002).

Though phosphorus is abundant in soil, it’s not readily available to crops. Specially, in case of mostly acidic soil just like in Nepal, the phosphorus is locked up in the form of iron and aluminium salt which are in insoluble phosphate form. That’s where the role of phosphate solubilizing bacteria lies, which can solubilize and transform insoluble phosphate into soluble form in the soil and make them available to the crops. *Pseudomonas* is one of them.

The inoculation of the soil microbes has proven to increase nutrients uptake capacity and water use efficiency. Among the plant growth promoting rhizobacteria, *Rhizobium* and *Pseudomonas* are the commonly utilized, whose efficacy depends on their survival in the soil, crop compatibility, their interaction ability, and overall environmental factors (Martinez et al., 2010). Their effects are direct in biofertilization through organic matter decomposition, stimulation of root growth and plant stress control while indirect in reducing the impact of diseases through production of phytohormones and improvement of nutrients availability (Egamberdieva et al., 2014).

Sarma & Saikia (2014) reported that *Pseudomonas aeruginosa* strain has improved the growth of *Vigna radiata* (mung beans) plants under drought conditions. Ahmad et al., (2013) and Naved et al., (2014) reported that the stomatal conductance (water vapor exiting through the stomata leaf) of plant leaf was higher in PGPR inoculated plants than non-PGPR inoculated ones under drought conditions. The finding from both studies proves that PGPR-inoculated plants tend to improve the water-use efficiency of plants.

The deficiencies of several nutrients like nitrogen, phosphorus, sulfur, iron, zinc, boron, and molybdenum have been reported to reduce nodulation in legumes (FAO, 1982). And such deficiencies are prevalent more in acidic soils like Nepal, whereas the combined inoculation of *Rhizobium* with mineral fertilizer has been reported to increase the nodulation and yield in soybean, lentil, and chickpea (Bhattarai & Maskey, 1987). To find out the best combination of PGPRs with mineral-based fertilizers for the increment of rice grain yield, this experiment was conducted. The specific objective of this study was to evaluate the effect of co-inoculation of *Rhizobium* and *Pseudomonas* along with a recommended dose of chemical fertilizer for increasing rice productivity under a legume-based cropping system.
MATERIALS AND METHODS

Experimental site
The experiment was conducted at the research field of the Grain Legumes Research Program (GLRP), Khajura, Banke, Nepal (28° 06' 45" N latitude, 81° 35" 58' E longitude, and 182 masl) from July 2018 to November 2020. The soil type of experimental plots was found to be sandy loam.

Experimental design and treatments
The field experiment was conducted in GLRP, Khajura, Banke, Lumbini Province during the summer season of three consecutive years, 2018, 2019 and 2020. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications and five treatments. The total area of experimental plot was 240 m$^2$ with each plot of 12 m$^2$ (4 m × 3 m). The treatment detailed was given as below:

T1: Control
T2: Inoculation with Rhizobium and Pseudomonas (800 g/ha)
T3: Fertilization with full dose of recommended N:P$_2$O$_5$:K$_2$O (100:60:30 kg/ha)
T4: Inoculation with Rhizobium and Pseudomonas (800 g/ha) + full dose of recommended N:P$_2$O$_5$:K$_2$O (100:60:30 kg/ha)
T5: Inoculation with Rhizobium and Pseudomonas (800 g/ha) + half dose of recommended N:P$_2$O$_5$:K$_2$O (100:60:30 kg/ha)

Climatic condition of the study area
During the study period of June to November the study area received 1144 mm (2018), 1737.6 mm (2019) and 58.7 mm (2020) rainfall, where the November was the coolest month. The mean minimum temperature, maximum temperature, rainfall and relative humidity of the study area are presented in Table 1.

<table>
<thead>
<tr>
<th>Month</th>
<th>2018 Min Temp (°C)</th>
<th>2018 Max Temp (°C)</th>
<th>2018 Rainfall (mm)</th>
<th>2018 Relative humidity (%)</th>
<th>2019 Min Temp (°C)</th>
<th>2019 Max Temp (°C)</th>
<th>2019 Rainfall (mm)</th>
<th>2019 Relative humidity (%)</th>
<th>2020 Min Temp (°C)</th>
<th>2020 Max Temp (°C)</th>
<th>2020 Rainfall (mm)</th>
<th>2020 Relative humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>25.9</td>
<td>34.8</td>
<td>580.9</td>
<td>87.3</td>
<td>26.0</td>
<td>35.1</td>
<td>590.9</td>
<td>77.5</td>
<td>26.5</td>
<td>35.2</td>
<td>15.6</td>
<td>26.5</td>
</tr>
<tr>
<td>July</td>
<td>26.6</td>
<td>32.8</td>
<td>392.8</td>
<td>85.7</td>
<td>26.5</td>
<td>33.5</td>
<td>534.9</td>
<td>91.9</td>
<td>28.3</td>
<td>33.6</td>
<td>16.8</td>
<td>28.3</td>
</tr>
<tr>
<td>August</td>
<td>26.3</td>
<td>33.5</td>
<td>170.4</td>
<td>84.6</td>
<td>26.9</td>
<td>34.8</td>
<td>193.7</td>
<td>84.7</td>
<td>29.3</td>
<td>34.1</td>
<td>15.6</td>
<td>29.3</td>
</tr>
<tr>
<td>September</td>
<td>22.6</td>
<td>33.1</td>
<td>0</td>
<td>80.2</td>
<td>25.6</td>
<td>33.1</td>
<td>418.1</td>
<td>88.4</td>
<td>28.1</td>
<td>34.2</td>
<td>10.7</td>
<td>28.1</td>
</tr>
<tr>
<td>October</td>
<td>13.9</td>
<td>30.4</td>
<td>0</td>
<td>93.3</td>
<td>20.6</td>
<td>31.4</td>
<td>0</td>
<td>89.9</td>
<td>20.7</td>
<td>31.5</td>
<td>0</td>
<td>20.7</td>
</tr>
<tr>
<td>November</td>
<td>10.5</td>
<td>25.7</td>
<td>0</td>
<td>87.3</td>
<td>15.5</td>
<td>28.8</td>
<td>0</td>
<td>50.3</td>
<td>15.3</td>
<td>25.9</td>
<td>0</td>
<td>15.3</td>
</tr>
</tbody>
</table>

Field operations
The rice variety Ramdhan was transplanted in the same plot of row to row and plant to plant spacing of 20 cm × 20 cm during the 2nd week of July. In rice, fertilizers were applied @ 100:60:30 kg N:P$_2$O$_5$:K$_2$O per ha. The full dose of P$_2$O$_5$ and K$_2$O, and half dose of N were applied at the time of transplanting and other remaining dose of N was applied at 30 days after transplanting, and the remaining cultural practices like weeding and irrigation were adopted as per needed. Initially planted mungbean was harvested and the biomass was incorporated into the same plot.
Data collection and statistical analysis
All the data on yield and yield attributing parameters like plant height, tillers per meter square, panicle length, biological yield, grain yield and thousand grains weight were analyzed statistically by using MS Excel and GenStat at probability level $p \leq 0.05$.

RESULTS AND DISCUSSION
Effect of bio and chemical fertilizers on the agronomic character of rice (2018)
Table 2 shows the impact of chemical fertilizers, biofertilizer, and mixture of biofertilizer and chemical fertilizers on the agronomic features of rice plants during the study year of 2018. The treatment with the prescribed dose of $N:P_2O_5:K_2O$ performed significantly better than all other treatments for most agronomic characteristics measured. With treatment T3 (the recommended dose of $N:P_2O_5:K_2O$), the average plant height (29.25 cm), average panicle length (29.25 cm), thousand grain weight (21.75 g) and tiller per meter square (273) were the highest among the others. Mixture of recommended dose of $N:P_2O_5:K_2O$ and biofertilizer ($Pseudomonas$ and $Rhizobium$), treatment T4 had the maximum biological yield and grain yield of 6.75 t/ha and 6.2 t/ha, respectively (Table 2). The control treatment performed poorly in every measure evaluated.

Table 2. Treatment effects on yield and yield attributing parameters of rice during 2018

<table>
<thead>
<tr>
<th>Treatments</th>
<th>PH (cm)</th>
<th>TPM</th>
<th>PL (cm)</th>
<th>BY (t/ha)</th>
<th>GY (t/ha)</th>
<th>TGW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>27.25b</td>
<td>251.50b</td>
<td>27.25b</td>
<td>4.50c</td>
<td>5.12d</td>
<td>20b</td>
</tr>
<tr>
<td>T2</td>
<td>27.75ab</td>
<td>259.7ab</td>
<td>27.75ab</td>
<td>5.57b</td>
<td>5.36cd</td>
<td>20b</td>
</tr>
<tr>
<td>T3</td>
<td>29.25a</td>
<td>273.0a</td>
<td>29.25a</td>
<td>5.95b</td>
<td>5.72b</td>
<td>21.75a</td>
</tr>
<tr>
<td>T4</td>
<td>26.75b</td>
<td>256.2b</td>
<td>26.75b</td>
<td>6.75a</td>
<td>6.2a</td>
<td>20.75b</td>
</tr>
<tr>
<td>T5</td>
<td>26.50b</td>
<td>254.5b</td>
<td>26.50b</td>
<td>5.50b</td>
<td>5.53bc</td>
<td>20.25b</td>
</tr>
<tr>
<td>SE</td>
<td>0.84</td>
<td>6.55</td>
<td>0.84</td>
<td>0.25</td>
<td>0.13</td>
<td>0.41</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>1.83</td>
<td>14.27</td>
<td>1.83</td>
<td>0.55</td>
<td>0.28</td>
<td>0.90</td>
</tr>
<tr>
<td>CV (%)</td>
<td>4.33</td>
<td>3.58</td>
<td>4.33</td>
<td>3.64</td>
<td>3.23</td>
<td>2.84</td>
</tr>
</tbody>
</table>

$PH=$ Plant height, $TPM=$ Tillers per meter square, $PL=$ Panicle length, $BY=$ Biological yield, $GY=$ Grain yield, $TGW=$ Thousand grains weight, $CV=$ coefficient of variation, $SEM=$ Standard Error of Mean, $SE=$ Standard Error, $LSD=$ Least Significant Difference.

There was a significant effect of chemical fertilizer, biofertilizer, and the mixture of biofertilizer and chemical fertilizer, on the agronomic properties of rice plants. Our experiment treatment with a combination of chemical fertilizers and biofertilizers ($Rhizobium$ and $Pseudomonas$) yielded the tallest plants. $Rhizobium$ species are known to produce phytohormones such as Indole acetic acid (IAA), and gibberellins, along with nitrogen fixation, which may have contributed to plant height increase (Nadarajah, 2017). $Pseudomonas$ has been discovered to be an excellent phosphate solubilizer with biocontrol abilities (Beneduzi et al., 2012). The use of biofertilizers is known to increase macronutrient and micronutrient absorption (Nadarajah, 2017). Nguyen et al., (2022) reported the importance of the co-inoculation of specific microbes in soil quality maintenance and plant growth. Biofertilizer inoculation has been shown to improve plant N uptake and enhance several physiological aspects of plant performance. One theory is that the biofertilizer stimulates root growth, increasing the uptake of indigenous N from the soil. Second, greater root development may reduce N fertilizer losses, and biological N fixation may be a third approach (Sharma et al., 2010).
Effect of bio and chemical fertilizers on the agronomic character of rice (2019)
In the study year 2019, the treatment including a combination of recommended N:P₂O₅:K₂O doses and biofertilizer (Pseudomonas and Rhizobium), treatment T4 beat all other treatments in all agronomic aspects except for tiller per meter square which are shown in Table 3. The average plant height, panicle length, biological yield, grain yield, and thousand grain weight were 24.75 cm, 29.25 cm, 7.78 t/ha, 7.20 t/ha, and 37 g respectively. It was followed by the recommended N:P₂O₅:K₂O dose (T3), with an average panicle length of 27 cm, biological production of 6.78 t/ha, grain yield of 6.28 t/ha, and thousand grain weights of 35 g. The control treatment performed poorly in all research parameters except for number of tiller per meter square (326.5).

Table 3. Treatment effects on yield and yield attributing parameters of rice during 2019

<table>
<thead>
<tr>
<th>Treatments</th>
<th>PH (cm)</th>
<th>TPM (t/ha)</th>
<th>PL (cm)</th>
<th>BY (t/ha)</th>
<th>GY (t/ha)</th>
<th>TGW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>24.50</td>
<td>326.50</td>
<td>21.75c</td>
<td>5.62c</td>
<td>5.15d</td>
<td>21.0c</td>
</tr>
<tr>
<td>T2</td>
<td>23.25</td>
<td>289.25</td>
<td>22.5c</td>
<td>6.22bc</td>
<td>5.65cd</td>
<td>22.0c</td>
</tr>
<tr>
<td>T3</td>
<td>24.25</td>
<td>285.25</td>
<td>27b</td>
<td>6.78b</td>
<td>6.28d</td>
<td>35.0a</td>
</tr>
<tr>
<td>T4</td>
<td>24.75</td>
<td>276.25</td>
<td>29.25a</td>
<td>7.78a</td>
<td>7.20a</td>
<td>37.0a</td>
</tr>
<tr>
<td>T5</td>
<td>23.00</td>
<td>316.00</td>
<td>23.25c</td>
<td>6.47b</td>
<td>5.88bc</td>
<td>29.5b</td>
</tr>
<tr>
<td>SE</td>
<td>0.82</td>
<td>44.49</td>
<td>0.69</td>
<td>0.38</td>
<td>0.27</td>
<td>1.49</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>ns</td>
<td>ns</td>
<td>1.50</td>
<td>0.83</td>
<td>0.6</td>
<td>3.24</td>
</tr>
<tr>
<td>CV (%)</td>
<td>4.87</td>
<td>21.70</td>
<td>3.96</td>
<td>8.28</td>
<td>6.56</td>
<td>7.29</td>
</tr>
</tbody>
</table>

**Note:** PH= Plant height, TPM= Tillers per meter square, PL= Panicle length, BY= Biological yield, GY= Grain yield, TGW= Thousand grains weight, CV= coefficient of variation, SEM= Standard Error of Mean, SE= Standard Error, LSD= Least Significant Difference.

The use of chemical fertilizers and biofertilizers increased the number of grains per panicle, biological yield, and 1000-grain weight of rice. This could be attributed to an increase in nutritional availability. According to Maurya et al., (2021), increasing the N level resulted in a considerable increase in grain yield. Singh et al., (2015) reported that biofertilizer inoculation improved rice grain yield. This is also supported by Biswas et al., (2000) who concluded that the rice straw, as well as grain yield, increased due to increased nitrogen uptake by rhizobial inoculation. The increase in yield caused by biofertilizer inoculates may not be attributable entirely to N fixation or phosphate solubilization, but also to various additional causes such as the release of growth-stimulating compounds, the control of plant pathogens, and the proliferation of beneficial organisms (Mathews et al., 2006). The effect of biofertilizer in conjunction with inorganic fertilizer on rice yield, when grown alone or in combination with other crops such as soybean and Vigna radiata, is well documented (Sawar 2005; Wu et al., 2005). Maintaining appropriate N supply from soil and fertilizer at key growth phases is a critical factor for yield. The capacity of microorganisms to maintain nitrogen supply throughout the vegetative and reproductive growth of the plants can be attributed to the better production of a mixture of chemical fertilizer and biofertilizer (Asif et al., 1999; Kropff et al., 1993).

Effect of bio and chemical fertilizers on agronomic character of rice (2020)
During the study year 2020, the mixture of recommended doses of N:P₂O₅:K₂O and biofertilizers (T4) had the maximum average plant height (102.25 cm), average panicle length (27.25 cm), grain yield (4.85 t/ha) and thousand grains weight (5.25 g) which is shown in Table 4. The study parameter biological yield was maximum (6.80 t/ha) with recommended dose of N:P₂O₅:K₂O (T3) followed by mixture of biofertilizer and recommended dose of
N:P₂O₅:K₂O (T4) at 5.12 t/ha. When compared to all other treatments, the control treatment performed poorly.

The use of biofertilizers in conjunction with chemical fertilizers resulted in a significant increase in biological yield. The administration of the recommended dose of N:P₂O₅:K₂O in combination with *Pseudomonas* and *Rhizobium* resulted in higher biological yield, while the control resulted in the lowest yield. The increased biological output could be related to the amount of nitrogen accessible through biofertilizers along with N:P₂O₅:K₂O applied. Nitrogen is known to enhance tillering, improve leaf length and width, which increases dry matter and is responsible for an increase in biological yield (Khnda and Dixit, 1995). Gopalswamy et al., (1989) also reported that soil application of biofertilizers boosted rice biological yield.

The thousand grains weight varied significantly between the controls, N:P₂O₅:K₂O fertilizer, and N:P₂O₅:K₂O plus biofertilizer. N:P₂O₅:K₂O plus biofertilizer produced the greatest thousand grains weight, followed by recommended N:P₂O₅:K₂O fertilizer alone. A higher thousand grains weight of seeds were observed as fertility levels increased (Venkateswarlu & Singh, 1980).

### Table 4. Treatment effects on yield and yield attributing parameters of rice during 2020

<table>
<thead>
<tr>
<th>Treatments</th>
<th>PH (cm)</th>
<th>TPM</th>
<th>PL (cm)</th>
<th>BY (t/ha)</th>
<th>GY (t/ha)</th>
<th>TGW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>97.25a</td>
<td>279.50</td>
<td>18.75d</td>
<td>3.95cd</td>
<td>3.33b</td>
<td>20.25c</td>
</tr>
<tr>
<td>T2</td>
<td>94.75ab</td>
<td>271.25</td>
<td>21.0c</td>
<td>4.53bc</td>
<td>3.88b</td>
<td>22.0b</td>
</tr>
<tr>
<td>T3</td>
<td>98.75a</td>
<td>277.00</td>
<td>23.0b</td>
<td>6.80a</td>
<td>4.70a</td>
<td>24.0a</td>
</tr>
<tr>
<td>T4</td>
<td>102.25a</td>
<td>267.00</td>
<td>27.25a</td>
<td>5.12b</td>
<td>4.85a</td>
<td>25.25a</td>
</tr>
<tr>
<td>T5</td>
<td>88.75b</td>
<td>249.75</td>
<td>23.25b</td>
<td>3.62d</td>
<td>3.58b</td>
<td>21.75bc</td>
</tr>
<tr>
<td>SE</td>
<td>3.74</td>
<td>18.91</td>
<td>0.74</td>
<td>0.38</td>
<td>0.32</td>
<td>0.74</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>8.15</td>
<td>ns</td>
<td>1.62</td>
<td>0.70</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>5.50</td>
<td>9.95</td>
<td>4.65</td>
<td>11.80</td>
<td>11.31</td>
<td>4.65</td>
</tr>
</tbody>
</table>

*PH= Plant height, TPM= Tillers per meter square, PL= Panicle length, BY= Biological yield, GY= Grain yield, TGW= Thousand grains weight, CV= coefficient of variation, SEM= Standard Error of Mean, SE= Standard Error, LSD= Least Significant Difference.*

**Combined mean separated values of all study parameter of all three study years**

There was no significant difference in parameters: average plant height and numbers of tillers per meter square among the different treatment combinations however there was year wise variation in plant height and tillers per meter square. The grand mean of average plant height in first, second and third year was 90.95 cm, 23.95 cm, 96.35 cm, respectively. The parameters like panicle length, biological yield, grain yield and thousand grain weight are significantly different among all treatment combinations in all three years. The maximum panicle length, 27.75 cm was found in the combination of *Rhizobium, Pseudomonas* and full dose of N:P₂O₅:K₂O followed by 26.42 cm in the application of recommended dose of N:P₂O₅:K₂O only. Similar results were obtained in biological yield i.e., maximum biological yield, 6.55 t/ha was found in the combination of *Rhizobium, Pseudomonas* and full dose of N:P₂O₅:K₂O followed by 6.26 t/ha in the application of recommended dose of N:P₂O₅:K₂O only. Similarly, the grain yield (6.083 t/ha) as well as thousand grains weight (27.67 g) was highest in the combination of *Rhizobium, Pseudomonas* and full dose of N:P₂O₅:K₂O.

The application of the combination of *Rhizobium, Pseudomonas* and full dose of N:P₂O₅:K₂O was found significantly higher in all parameters under consideration as compared to all
treatment combinations. Next the full recommended dose of \(\text{N:P}_2\text{O}_5\text{K}_2\) fertilizers was found to have significant effect over panicle length, biological yield and thousand grain weights. However, the co-inoculation of \textit{Rhizobium} and \textit{Pseudomonas} only and also in combination with half dose of \(\text{N:P}_2\text{O}_5\text{K}_2\) were also found to be better responsive than the control condition.

The results showed that utilizing biofertilizer can reduce the amount of recommended inorganic fertilizer, with benefits on growth and production comparable to using recommended fertilizer alone. Now, that the ecosystem is suffering from enormous inorganic fertilizer overloads that are damaging to soil health and sustainable productivity. This study and other previous research suggest that biofertilizer, as an ecologically friendly resource, provides a feasible alternative not only for maintaining high yield but also for safeguarding and conserving the environment. Furthermore, a continuing search for biofertilizers and environmentally acceptable crop production system should be undertaken.

Table 5. Effect of co-inoculation of rhizobium and pseudomonas with chemical fertilizers in yield and yield parameters of rice

<table>
<thead>
<tr>
<th>SN</th>
<th>Treatments</th>
<th>PH (cm)</th>
<th>TPM</th>
<th>PL (cm)</th>
<th>BY (t/ha)</th>
<th>GY (t/ha)</th>
<th>TGW (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T1</td>
<td>71.25a</td>
<td>285.8a</td>
<td>22.58c</td>
<td>4.69c</td>
<td>4.53c</td>
<td>20.42c</td>
</tr>
<tr>
<td>2</td>
<td>T2</td>
<td>70.50a</td>
<td>273.4a</td>
<td>23.75ab</td>
<td>5.44b</td>
<td>4.94c</td>
<td>21.33c</td>
</tr>
<tr>
<td>3</td>
<td>T3</td>
<td>71.58a</td>
<td>278.4a</td>
<td>26.42a</td>
<td>6.26a</td>
<td>5.56b</td>
<td>26.92a</td>
</tr>
<tr>
<td>4</td>
<td>T4</td>
<td>71.92a</td>
<td>266.5a</td>
<td>27.75a</td>
<td>6.5a</td>
<td>6.083a</td>
<td>27.67a</td>
</tr>
<tr>
<td>5</td>
<td>T5</td>
<td>66.83a</td>
<td>273.4a</td>
<td>24.33b</td>
<td>5.2ab</td>
<td>4.992c</td>
<td>23.83b</td>
</tr>
</tbody>
</table>

GM Year 1 90.95 259 27.50 5.65 5.575 20.55
GM Year 2 23.95 298.6 24.75 6.57 6.03 28.90
GM Year 3 96.35 268.9 22.65 4.66 4.065 22.65

F test Treatment 0.097 0.88 <.001 <.001 <.001 <.001
F test Year <.001 0.025 <.001 <.001 <.001 <.001
F test Treatment x Year Interaction 0.208 0.858 <.001 0.004 0.18 <.001

SEM 0.450 1.428 13.29 0.364 0.154 0.1182
LSD (0.05) 1.284 4.075 37.92 1.039 0.4396 0.337
CV (%) 1.3 7.0 16.7 5.1 9.5 7.8

\(PH=\) Plant height, \(TPM=\) Tillers per meter square, \(PL=\) Panicle length, \(BY=\) Biological yield, \(GY=\) Grain yield, \(TGW=\) Thousand grains weight, \(CV=\) coefficient of variation, \(SEM=\) Standard Error of Mean, \(SE=\) Standard Error, \(LSD=\) Least Significant Difference.

**CONCLUSION**

The panicle length, biological yield, grain yield and thousand grain weight increased significantly with the co-inoculation of \textit{Rhizobium} and \textit{Pseudomonas} along with full dose of chemical fertilizers in the experiment. Neither the application of full recommended dose of chemical fertilizers nor the combination of half dose chemical fertilizers with co-inoculation of \textit{Rhizobium} and \textit{Pseudomonas} gave better results in terms of grain yield. So, the combination of \textit{Rhizobium}, \textit{Pseudomonas} and full dose of chemical fertilizers was found to be superior among all treatments in the experiment.

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Authors’ Contributions
All authors listed have made a substantial, direct and intellectual contribution to the experimentation, data recording, and analysis and manuscript preparation.

Conflicts of Interest
The authors have no relevant financial or non-financial interests to disclose.

REFERENCES


