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Economic evaluation of biological nitrogen fixation in flooded rice cultivation in subtropical lowlands

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Abstract

This study aimed to assess the economic viability of biological nitrogen fixation in flood rice cultivation in subtropical lowlands. A field experiment of seven treatments was carried out during the cropping seasons 2015/16, 2017/18, 2018/19 and 2019/20 at the Lowland Experimental Station of Embrapa, in Pelotas, RS, Brazil. The evaluated treatments were: (1) negative control (without N and inoculant); (2) positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant) (standard recommendation); (3) inoculant 1 (accessions CMM 174 + CMM 175 + CMM 179); (4) inoculant 2 (accessions CMM 176 + CMM 197 + CMM 205); (5) combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 1; (6) combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 2; and (7) commercial inoculant [*Azospirillum brasilense* (strains Ab-V5 and Ab-V6)]. A partial budget was used to compare evaluated treatments with the standard recommendation regarding nitrogen fertilisation. Inoculant 2 composed of bacterial accessions CMM 176 (*Rhizobium* sp.), CMM 197 (*Bacillus* sp.) and CMM 205 (*Aeromicrobium* sp.) combined with reduced mineral nitrogen fertilisation [90 kg N ha^{-1} (applied in top dressing)] demonstrates the best agroeconomic efficiency in the production of irrigated rice in subtropical lowlands with the cultivar BRS Pampa.

Keywords: partial budget, nitrogen, diazotrophic bacteria, inoculant, irrigated rice

1 Introduction

Rice (*Oryza sativa* L.) has a worldwide production of ~510 million metric tons of milled rice annually (FAO, 2022). Brazil produced 11.38 million metric tons of rough rice in 2021/22. This production is accomplished mainly in the states of Rio Grande do Sul (69 %), Santa Catarina (11 %) and Tocantins (7 %) (IBGE, 2022). In Rio Grande do Sul, 939,121 hectares were cultivated with irrigated rice in the 2021/22 crop, producing a total of 7.4 million tons of paddy rice, with an average yield of 7.90 metric tons per hectare (IBGE, 2022).

Nitrogen fertilisers count for Brazilian real (BRL) 400 to 700 ha^{-1} in irrigated rice production costs in Rio Grande do Sul, Brazil (CONAB, 2022; IRGA, 2022). In addition, it contributes to the emission of greenhouse gases (GHG) (Siqueira Neto *et al.*, 2011) and risks of environmental contamination, mainly water resources. Applying N fertiliser in rice production can also generate human health problems and environmental footprints (Arunrat *et al.*, 2022; Toolkiattiwong *et al.*, 2023). However, it is essential for the growth and production of rice (Fageria & Baligar, 2001). In a study carried out to assess the environmental impact of biological nitrogen fixation (BNF) technology on potential GHG emissions, Scivittaro *et al.* (2021) demonstrated that the partial replacement of mineral nitrogen fertilisation by the use of endophytic diazotrophic bacteria inoculant reduces N_2O emissions associated with the cultivation of irrigated rice, although it does not influence the global warming potential of the crop, given that this is predominantly composed of CH_4, whose emissions remained unchanged regardless of the management of nitrogen fertilisation.

Several studies have shown that using nitrogen-fixing bacteria contributes to the development of rice plants (Chaves *et al.*, 2016; Ferreira *et al.*, 2014; Santos *et al.*, 2015). The formulation of a peat inoculant, composed of the bacterial accessions 197 (*Bacillus* sp.) + 205 (*Aeromicrobium* sp.) + 176 (*Rhizobium* sp.), combined with reduced mineral

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nitrogen fertilisation [90 kg N ha^{-1} (applied in topdressing)], demonstrates agronomic efficiency regarding the grain yield of the BRS Pampa cultivar (Mattos *et al.*, 2020).

In another study carried out at the field level with flood-irrigated rice, Mattos *et al.* (2017) showed that using an inoculant containing *Azospirillum brasilense* can increase the yield of cultivars BRS Querência and BRS Pampa, allowing the reduction of mineral nitrogen fertilisation. An economic evaluation at the field level of this *Azospirillum brasilense*-based inoculant showed its profitability for rice farmers in Southern Brazil (Wander *et al.*, 2019). However, the existing literature is still mainly focused on demonstrating the agronomic feasibility of using the association of diazotrophic bacteria with irrigated rice. In this context, the present study aimed to assess the economic viability of biological nitrogen fixation in flooded rice cultivation in subtropical lowlands.

2 Materials and methods

Field trials were carried out in 2015/16, 2017/18, 2018/19 and 2019/20 harvests at the Experimental Station Terras Baixas (ETB) of Embrapa Temperate Climate (Latitude: 31° 52' 00" S; Longitude: 52° 21' 24" W), in the municipality of Capão do Leão, RS, Brazil. The soil is classified as Haplic Planosol. The local climate is classified as subtropical (Cfa - Köppen) (Wrege *et al.*, 2012), with average annual precipitation and temperature of 1,367 mm and 17.8 °C, respectively (Estação Agroclimatológica de Pelotas, 2017). More details are available in Mattos *et al.* (2020). The irrigated rice cultivar used was BRS Pampa. The accessions used in the study are preserved in the Collection of Multifunctional Microorganisms of Temperate Climate (CMMCT) (SisGen Registry: A9D4105), with the code CMM.

The tested treatments were as follows:

1. negative control (without N and inoculant);
2. positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant) (standard recommendation);
3. inoculant 1 (accessions CMM 174 + CMM 175 + CMM 179);
4. inoculant 2 (accessions CMM 176 + CMM 197 + CMM 205);
5. combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 1;
6. combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 2;
7. commercial inoculant [*Azospirillum brasilense* (strains Ab-V5 and Ab-V6)].

Since only the nitrogen-related management changed among treatments, a partial budgeting analysis was used to compare all treatments with farmers' standards (treatment 2). Thus, following the approach described in Wander (2001), partial budget analysis was done to identify if an alternative nitrogen fertilisation strategy (treatments 1 and 3 to 7) increases, maintains, or decreases the farmers' net income. Partial budget was implemented using Microsoft Excel-Sheet, using the structure mentioned in Table 1.

Table 1: *Partial budget structure.*

Question (proposed change): Should we replace treatment 2 with treatment 1 (and 3 to 7)?			
Positive effects (PE)	*Value*	*Negative effects (NE)*	*Value*
Additional income		Reduced income	
Reduced costs		Additional costs	
Sum of PE		Sum of NE	
Change in net income: Sum of PE – Sum of NE			

Source: Own preparation based on Wander (2001).

The yields of each treatment in the four analysed cropping seasons (Mattos *et al.*, 2020) considered in this analysis are represented in Table 2.

Table 2: *Paddy rice yields (kg ha^{-1}) obtained by treatments 1 to 7 in cropping seasons 2015/16, 2017/18, 2018/19 and 2019/20 in Pelotas, RS, Brazil.*

*T**	*2015/16*	*2017/18*	*2018/19*	*2019/20*	Average
1	8,109	9,413	7,357	6,278	7,789
2	13,112	12,479	10,066	9,162	11,205
3	7,194	10,675	7,702	8,055	8,407
4	9,745	10,544	8,300	9,607	9,549
5	12,565	11,032	8,772	9,974	10,586
6	13,095	12,103	9,685	10,738	11,405
7	8,926	8,650	7,092	8,852	8,380

* T = treatment: 1. negative control (without N and inoculant);
2. positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant) (standard recommendation);
3. inoculant 1 (accessions CMM 174 + CMM 175 + CMM 179);
4. inoculant 2 (accessions CMM 176 + CMM 197 + CMM 205);
5. combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 1;
6. combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 2;
7. commercial inoculant [*Azospirillum brasilense* (strains Ab-V5 and Ab-V6)].

The prices considered for the economic analysis included:

- Rice (BRL 50 kg bag^{-1}, in Pelotas-RS, Brazil, in March (main harvest month), with data from https://www.agrolink.com.br/cotacoes/graos/arroz;

- Urea (BRL kg^{-1}, October (main month of sowing), with data from https://indexmundi.com, at an exchange rate of October 15 in each cropping year (USD 1.00 = ?):
  - Oct 15, 2015: BRL 3.84;
  - Oct 15, 2017: BRL 3.15;
  - Oct 15, 2018: BRL 3.72;
  - Oct 15, 2019: BRL 4.15.
- Commercial inoculant AzoTotal (150 mL 50 kg seeds-1; 90 kg seeds ha^{-1}; 3 bottles 100 mL ha^{-1}; BRL 10.00 per bottle of 100 mL = BRL 30.00 ha^{-1});
- For the yet non-commercial inoculants 1 and 2, the same price of commercial inoculant AzoTotal was considered.

3 Results

In determining the economic viability of treatments 1 and 3 to 7, the partial budgeting technique was used, which measures the changes generated by each practice (treatment) about the standard recommendation for using nitrogen fertilisation (treatment 2). Negative values written in red mean a reduction in net income per hectare. Positive values represent an increase in farmers' net income.

If a rice farmer replaced treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 1 [negative control (without N and inoculant)], his net income would be reduced in BRL 2,583.40 per hectare (Table 3).

Table 3: *Changes in farmers' net income (BRL ha^{-1}) due to changing treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 1 [negative control (without N and inoculant)], 2015/16, 2017/18, 2018/19 and 2019/20 crops, in Pelotas, RS, Brazil.*

Positive effects (PE) (BRL ha^{-1})						Negative effects (NE) (BRL ha^{-1})					
+ effects	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*	*- effects*	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*
Additional income	-	-	-	-	-	Reduced income*	4,125.47	2,140.07	2,164.49	2,855.74	2,821.44
Reduced costs†	209.92	212.10	267.84	262.28	238.04	Additional costs	-	-	-	-	-
Sum of PE	209.92	212.10	267.84	262.28	238.04	Sum of NE	4,125.47	2,140.07	2,164.49	2,855.74	2,821.44
Change in 4-crops-average net income = Sum of PE – Sum of NE								−2,583.40			

* Rice yield reduction. † Reduction in urea use (120 kg N = 266.67 kg urea). Source: Research results.

Table 4: *Changes in farmers' net income (BRL ha^{-1}) due to changing treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 3 [inoculant 1 (accessions CMM 174 + CMM 175 + CMM 179)], 2015/16, 2017/18, 2018/19 and 2019/20 crops, in Pelotas, RS, Brazil.*

Positive effects (PE) (BRL ha^{-1})						Negative effects (NE) (BRL ha^{-1})					
+ effects	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*	*- effects*	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*
Additional income	-	-	-	-	-	Reduced income*	4,879.98	1,259.19	1,888.84	1,096.15	2,281.04
Reduced costs†	209.92	212.10	267.84	262.28	238.04	Additional costs‡	30.00	30.00	30.00	30.00	30.00
Sum of PE	209.92	212.10	267.84	262.28	238.04	Sum of NE	4,909.98	1,289.19	1,918.84	1,126.15	2,311.04
Change in 4-crops-average net income = Sum of PE – Sum of NE								−2,073.00			

* Rice yield reduction. † Reduction in urea use (120 kg N = 266.67 kg urea). ‡ Inoculant 1 (3 bottles of 100 mL; 1.5 bottle 50 kg^{-1} of seeds). Source: Research results.

Table 5: *Changes in farmers' net income (BRL ha^{-1}) due to changing treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 4 [inoculant 2 (accessions CMM 176 + CMM 197 + CMM 205)], 2015/16, 2017/18, 2018/19 and 2019/20 crops, in Pelotas, RS, Brazil.*

Positive effects (PE) (BRL ha^{-1})						Negative effects (NE) (BRL ha^{-1})					
+ effects	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*	*- effects*	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*
Additional income*	-	-	-	440.64	110.16	Reduced income†	2,776.43	1,350.63	1,411.03	-	1,846.03
Reduced costs‡	209.92	212.10	267.84	262.28	238.04	Additional costs§	30.00	30.00	30.00	30.00	30.00
Sum of PE	209.92	212.10	267.84	702.92	348.20	Sum of NE	2,806.43	1,380.63	1,441.03	30.00	1,876.03
Change in 4-crops-average net income = Sum of PE – Sum of NE								−1,527.83			

* Rice yield increase.† Rice yield reduction. ‡ Reduction in urea use (120 kg N = 266.67 kg urea). § Inoculant 2 (3 bottles of 100 mL; 1.5 bottle 50 kg^{-1} of seeds).
Source: Research results.

Table 6: *Changes in farmers' net income (BRL ha^{-1}) due to changing treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 5 [combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 1], 2015/16, 2017/18, 2018/19 and 2019/20 crops, in Pelotas, RS, Brazil.*

Positive effects (PE) (BRL ha^{-1})						Negative effects (NE) (BRL ha^{-1})					
+ effects	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*	*- effects*	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*
Additional income*	-	-	-	804.04	201.01	Reduced income†	451.06	1,010.01	1,033.91	-	831.66
Reduced costs‡	52.48	53.03	66.96	65.57	59.51	Additional costs§	30.00	30.00	30.00	30.00	30.00
Sum of PE	52.48	53.03	66.96	869.62	260.52	Sum of NE	481.06	1,040.01	1,063.91	30.00	861.66
Change in 4-crops-average net income = Sum of PE – Sum of NE								−601.13			

* Rice yield increase.† Rice yield reduction. ‡ Reduction in urea use (30 kg N = 66.67 kg urea). § Inoculant 1 (3 bottles of 100 mL; 1.5 bottle 50 kg^{-1} of seeds). Source: Research results.

Table 7: *Changes in farmers' net income (BRL ha^{-1}) due to changing treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 6 [combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 2], 2015/16, 2017/18, 2018/19 and 2019/20 crops, in Pelotas, RS, Brazil.*

Positive effects (PE) (BRL ha^{-1})						Negative effects (NE) (BRL ha^{-1})					
+ effects	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*	*- effects*	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*
Additional income*	-	-	-	1,560.56	390.14	Reduced income†	14.02	262.45	304.42	-	193.63
Reduced costs‡	52.48	53.03	66.96	65.57	59.51	Additional costs§	30.00	30.00	30.00	30.00	30.00
Sum of PE	52.48	53.03	66.96	1,626.13	449.65	Sum of NE	44.02	292.45	334.42	30.00	223.63
Change in 4-crops-average net income = Sum of PE – Sum of NE								226.02			

* Rice yield increase.† Rice yield reduction. ‡ Reduction in urea use (30 kg N = 66.67 kg urea). § Inoculant 2 (3 bottles of 100 mL; 1.5 bottle 50 kg^{-1} of seeds). Source: Research results.

If a rice farmer would replace treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 3 [inoculant 1 (accessions CMM 174 + CMM 175 + CMM 179)], his net income would be reduced in BRL 2,073.00 per hectare (Table 4).

If a rice farmer would replace treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 4 [inoculant 2 (accessions CMM 176 + CMM 197 + CMM 205)], his net income would be reduced in BRL 1,527.83 per hectare (Table 5).

If a rice farmer would replace treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 5 [combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 1], his net income would be reduced in BRL 601.13 per hectare (Table 6).

If a rice farmer would replace treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 6 [combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 2], his net income would be increased in BRL 226.02 per hectare (Table 7).

Table 8: *Changes in farmers' net income (BRL ha^{-1}) due to changing treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 7 [commercial inoculant with* Azospirillum brasilense *(strains Ab-V5 and Ab-V6)], 2015/16, 2017/18, 2018/19 and 2019/20 crops, in Pelotas, RS, Brazil.*

Positive effects (PE) (BRL ha^{-1})						Negative effects (NE) (BRL ha^{-1})					
+ effects	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*	*- effects*	*2015/16*	*2017/18*	*2018/19*	*2019/20*	*4-crop average*
Additional income	-	-	-	-	-	Reduced income*	3,451.78	2,672.64	2,376.23	306.96	2,201.90
Reduced costs†	209.92	212.10	267.84	262.28	238.04	Additional costs‡	30.00	30.00	30.00	30.00	30.00
Sum of PE	209.92	212.10	267.84	262.28	238.04	Sum of NE	3,481.78	2,702.64	2,406.23	336.96	2,231.90
Change in 4-crops-average net income = Sum of PE – Sum of NE								−1,993.86			

* Rice yield reduction. † Reduction in urea use (120 kg N = 266.67 kg urea). ‡ Commercial inoculant AzoTotal [*Azospirillum brasilense* (strains Ab-V5 and Ab-V6) 3 bottles of 100 mL; 1.5 bottle 50 kg^{-1} of seeds. Source: Research results.

Finally, if a rice farmer would replace treatment 2 [positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant); standard recommendation] with treatment 7 [commercial inoculant with *Azospirillum brasilense* (strains Ab-V5 and Ab-V6)], his net income would be reduced in BRL 1,993.86 per hectare (Table 8).

Table 9: *Change in rice growers' net income per hectare of paddy rice (BRL ha^{-1}) due to inoculation with bacterial consortia. Data from the four crops. Embrapa Temperate Climate, Pelotas, RS, Brazil.*

T*	2015/16	2017/18	2018/19	2019/20	Average
1	−3,915.55	−1,927.97	−1,896.65	−2,593.45	−2,583.40
2	-	-	-	-	-
3	−4,700.06	−1,077.09	−1,650.99	−863.87	−2,073.00
4	−2,596.51	−1,168.53	−1,173.19	672.92	−1,527.83
5	−428.57	−986.98	−996.94	839.62	−601.13
6	8.46	−239.42	−267.46	1,596.13	226.02
7	−3,271.85	−2,490.54	−2,138.38	−74.68	−1,993.86

* T = treatment: 1. negative control (without N and inoculant);
2. positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant) (standard recommendation);
3. inoculant 1 (accessions CMM 174 + CMM 175 + CMM 179);
4. inoculant 2 (accessions CMM 176 + CMM 197 + CMM 205);
5. combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 1;
6. combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 2;
7. commercial inoculant [*Azospirillum brasilense* (strains Ab-V5 and Ab-V6)].

Table 9 shows the consolidated results of the changes in the farmers' net income that each practice (treatment) would generate per hectare of flood-irrigated rice in each crop as well as in 4-crop-average if it were adopted instead of the standard recommendation for the use of nitrogen fertiliser (Treatment 2).

Table 10 shows a ranking of all seven treatments, considering the 4-crops-average changes in farmers' net income. From the results shown, it is easy to realise that only treatment 6 [combination of reduced N-fertiliser doses (90 kg N ha^{-1}) and inoculant 2] performed better than the standard recommendation regarding nitrogen fertilisation.

4 Discussion

From an agronomic point of view, our results are in line with those obtained by Kandel *et al.* (2022) combining N fertilisation with coinoculation of *Rhizobium* and *Pseudomonas*, as well as Amutha *et al.* (2009) combining microorganisms. The agronomic results represent the confirmation of what Saha *et al.* (2017) described as harmonising the ecosystem and providing economic gains, and an expansion of crops using co-inoculation in agriculture (Santos *et al.*, 2019).

As recommended by Wander (2001), it is important to mention that the results of partial budgeting should not be considered in absolute terms but as a change (plus or minus) in farmers' net income if the practice (treatment) had been adopted instead of the standard recommendation (treatment 2, in this case). Compared with the standard nitrogen fertilisation recommendation (treatment 2), from the economic point of view, treatments 1 (negative control), 3 (inoculant 1) and 7 (*Azospirilum brasiliense*) were not efficient in any of the analysed cropping years. Treatments 4 (inoculant 2) and 5 (90 kg N ha^{-1} + inoculant 1) were efficient only in the 2019/20 cropping year. The best economic result was observed in treatment 6 (90 kg N ha^{-1} + inoculant 2). This treatment was more efficient in the years 2015/16 and 2019/20, in addition to being more advantageous in the average of 4 harvests.

Table 10: *Change in rice growers' net income per hectare of paddy rice (BRL ha^{-1}) due to inoculation with bacterial consortia. Data from the four crops. Embrapa Temperate Climate, Pelotas, RS, Brazil.*

Treatment	*Average change in net income (BRL ha^{-1})*	*Rank*
6	226.02	1
2	-	2
5	−601.13	3
4	−1,527.83	4
7	−1,993.86	5
3	−2,073.00	6
1	−2,583.40	7

1. negative control (without N and inoculant);
2. positive control with recommended N-fertilisation (120 kg N ha^{-1}, without inoculant) (standard recommendation);
3. inoculant 1 (accessions CMM 174 + CMM 175 + CMM 179);
4. inoculant 2 (accessions CMM 176 + CMM 197 + CMM 205);
5. combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 1;
6. combination of reduced N-fertiliser doses (90 kg N ha^{-1}) + inoculant 2;
7. commercial inoculant [*Azospirillum brasilense* (strains Ab-V5 and Ab-V6)].

Treatment 6 (90 kg N ha^{-1} + inoculant 2) economically performed better than the commercial inoculant (treatment 7), which has been evaluated by Wander *et al.* (2019) at the field level. Therefore, there is a market potential for new inoculants based on the combination of the bacterial accessions CMM 197 (*Bacillus* sp.), CMM 205 (*Aeromicrobium* sp.) and CMM 176 (*Rhizobium* sp.), tested here as Inoculant 2, in combination with a reduced N-fertiliser rate of 90 kg N per hectare.

The main contribution of this study is adding an economic perspective to the agronomic results. Thus, treatment 6, which combines 90 kg N ha^{-1} with a combination of microorganisms is not only superior from an agronomic perspective but also generates economic gains for the rice farmer.

5 Conclusion

A potential formulation of an inoculant composed of bacterial accessions CMM 197 (*Bacillus* sp.) + CMM 205 (*Aeromicrobium* sp.) + CMM 176 (*Rhizobium* sp.) (= Inoculant 2) combined with reduced mineral nitrogen fertilisation [90 kg N ha^{-1} (applied in top dressing)] (= treatment 6 of this study) demonstrates agroeconomic efficiency in irrigated rice production with the BRS Pampa cultivar.

Conflict of interest

The authors have no conflict of interest related to the content of this paper.

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