RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
55 (4) 1259-1270, 2023
http://doi.org/10.54910/sabrao2023.55.4.19
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

ECONOMIC ANALYSIS AND EFFECT OF TRIPLE BACTERIAL AND MINERAL FERTILIZERS ON THE GROWTH AND YIELD TRAITS OF WHEAT

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SUMMARY

The conduct of a field trial in the 2021–2022 cropping season assessed the economic feasibility and effect of using locally produced microbial biofertilizers on the growth and yield traits of wheat (*Triticum aestivum* L.). The manures of *Providencia vermicola*, *Alcaligenes faecalis,* and *Raoultella planticola* served as sample treatments in the study. The research was in a randomized complete block design at the Agricultural Experiment and Research Station (31°20′19″N 45°17′20″E), College of Agriculture, Al-Muthanna University, Iraq. Microbial fertilizers were the first factor, with the second factor comprising two levels of mineral fertilizers, i.e., a) no chemical fertilizer and b) using half of the recommended chemical fertilizer, addressing the interactions between biofertilizers and chemical fertilizers, having a two-factor experiment. Field results showed that triple biofertilization consisting of *A. faecalis, R. planticola,* and *P. vermicola* proved superior based on grain yield and biomass using half of the recommended fertilizer (P7) (8.038 t ha^{-1} and 24.938 t ha^{-1}). In turn, the economic analysis results were consistent with the technical outcomes, as treatment P7 recorded the highest profit amounting to USD 483.625 ha^{-1}. In addition to recording the highest revenue per ha at the rate of 6.2477, treatment P7 for the level of fertilization F1 recorded the maximum level, amounting to about USD 144.284, 165,298.65, and 48,362.5 ha^{-1} for the criteria of the invested USD return, productive profitability, and added value, respectively.

Keywords: Wheat (*Triticum aestivum* L.), *Alcaligenes faecalis*, *Raoultella planticola***,** chemical fertilizers, growth and yield traits, economic return

Key findings: The results showed that the treatment P7 verified superior for biological and grain yield (24.938 Mg ha^{-1} and 8.038 Mg ha^{-1}, respectively). In turn, the economic results were consistent with the technical outcomes, with the treatment P7 recorded with the highest profit, amounting to USD 7157.6486 ha^{-1}, aside from having the highest yield per ha at a rate of 9.2466 Mg ha^{-1}. The F1 enrichment provided the maximum level for other criteria, reaching about USD 31. 60406, 24,464.21, and 7157.649 per Ha^{-1} for the investment return, productive profitability, and added value, respectively.

Citation: Blaw HH, Jassim SJ, Makki AA (2023). Economic analysis and effect of triple bacterial and mineral fertilizers on the growth and yield traits of wheat. *SABRAO J. Breed. Genet.* 55(4): 1259-1270. http://doi.org/10.54910/sabrao2023.55.4.19.

Communicating Editor: Dr. Osama Osman Atallah

Manuscript received: April 16, 2023; Accepted: July 14, 2023.

INTRODUCTION

In the agricultural sector, the high cost of production is one of the biggest obstacles to working with agronomic products, faced to compete with these products' importers and the dumping policies imposed by neighboring countries. Low prices of locally produced agricultural goods and high production costs cause losses to local farming communities and producers. Many need to stop production, reducing self-sufficiency and food security levels. Therefore, it is obligatory to investigate the costliest factors of production to find appropriate alternatives that guarantee reduction, thereby ensuring the economic viability of agricultural projects (Wise, 2004).

Mineral fertilizer costs come in second after fuel costs, and due to the lack of fuel alternatives, it has become necessary to find substitutes for chemical fertilizers (Al-Kaabi, 2011; Bome *et al*., 2022; Khan *et al*., 2023). Fertilizer prices have witnessed a significant enhancement due to a decline in the exchange rate of the Iraqi dinar by approximately 20%. As a decision of the Iraqi Government and the rise in global prices of fertilizers, chemical fertilizer prices have almost doubled due to the Russian-Ukrainian war. However, chemical fertilizer use is vital for increasing global food production because they provide fast food for plants to grow quickly and efficiently. However, many adverse effects occur, especially the excessive and unbalanced use of these fertilizers affecting the soil microbiology, among which defects in the soil's natural and biological systems negatively affect its natural fertility and have unfavorable impacts on groundwater and human health (Savci, 2012).

The high economic costs of inputs have prompted researchers to turn to biological fertilization due to their lowest outlays and being environmentally safe (Assistant, 2016). Biofertilizers provide some part of the essential nutrients for plant growth, such as nitrogen, phosphorus, and potassium, as well as the secretion of some hormones and acids that act as plant growth regulators, secreting some antibiotics, which helps to resist some endemic diseases in the soil and benefits the plant and its production by increasing the contents of proteins, essential amino acids, and vitamins (Bhardwaj *et al*., 2014). Furthermore, biofertilizers' use limits the large quantities of mineral fertilizers added to 50% of the complete requirement, which leads to obtaining a high-quality product and health security. It also helps reduce the dependency on chemical fertilizers added to crops, reducing expenses and increasing production (Kumar, 2010). The presented study reached this goal by evaluating the biofertilizer efficiency manufactured from local isolates of *P. vermicola*, *A. faecalis*, and *R. planticola* and using them singly, double, and triple, with 50% and 100% of the fertilizer recommendation, and their effects on growth and yield traits of wheat. The profit from biofertilizer use comes from knowing the total revenue and cost, then comparing it with the recommended fertilizer use outcomes.

MATERIALS AND METHODS

Preparing the bacterial inoculum

Bacterial isolates came from the laboratories of Badia Research Center, Samawa, Iraq, and Sawa Lake, Samawa, Iraq. The microbial biofertilizer isolated from Lake Sawa based on the bacterial isolates, viz., *Providencia vermicola*, *Alcaligenes faecalis,* and *Raoultella planticola* attained growth in nutrient broth for 48 h at 28 °C in an incubator (Somasegaran and Hoben, 1994). The total number of bacteria counted followed at the end of the incubation period. Inoculum densities were 0.75×10^6, 0.78×10^6, and 0.79×10^6 CFU, respectively. Later, the bio-inoculum, placed into the sterilized peat moss carrier in the heat preservation bag, received an injection of 100 ml of bacterial suspension under aseptic conditions, rubbing the bag to make the suspension, with the carrier evenly distributed and incubated again at 28 °C for 48 h. Bacterial inocula and their vectors resulted in bioavailable fertilizers for field trials.

Iraqi wheat cultivar Tammuz2 gained sterilization with a 1% sodium hypochlorite solution for 3 min and then washed with water for 30 min to remove the sterile solution. The seeds air-dried achieved inoculation with the bacteria carried on the carrier. Opening the bag and mixing the contents of moistened seeds with a 10% Arabic gum solution ensured the fertilizer adhered. The said process transpired away from sunlight and direct lighting, then left for 30 min to ensure that the biofertilizer stuck to the seeds evenly before sowing. As a control treatment, the Iraqi wheat cultivar seeds received no inoculation with the bacteria (Jassim, 2017).

Biological factors

The experiment involved two factors, with the first factor comprising biofertilizers, consisting of seven levels of inoculation with the bacteria coded as follows, i.e., without inoculation (P0), inoculation with *P. vermicola* (P1), *A. faecalis* (P2), *R. planticola* (P3), *P. vermicola* and *A. faecalis* (P4), *P. vermicola* and *R. planticola* (P5), *A. faecalis* and *R. planticola* (P6), and inoculation with three bacterial isolates (P7). The second factor included two levels of chemical fertilization, i.e., a) from urea (N - 46%), superphosphate fertilizer (P - 20%), potassium sulfate (K2O - 50%), without chemical fertilization (F0), and b) 50% of the recommended fertilizers (F1).

Factors of economic experience

The factors of economic importance were total costs, total revenue, and profits (Al-Shammari, 2010).

$$Production\ profit = profit \times 100$$

$$\text{Return on the invested dinar} = \frac{Total\ revenue}{Total\ costs}$$

$$\text{Value Added} = Total\ revenue - Variable\ costs$$

Crop husbandry

Field trials on Iraqi wheat cultivars ran in the cropping season 2021–2022. After plowing, soil leveling and adjusting preparation preceded sowing. The planting of Iraqi wheat cultivars was on 18 November 2021 in the field of Al-Bandar, Faculty of Agriculture, Al-Muthanna University, Iraq. Several soil samples taken and mixed into a composite sample represented the physical, chemical, and biological properties of the soil requirement for complete testing of the field (Table 1). The field division comprised three sectors, each containing 17 treatments (one plate) measuring 2 m × 2 m.

The experiment, laid out in a randomized complete block design (RCBD), had a factorial arrangement, with the total number of transactions reaching 51 treatments. Two batches comprised fertilization. Adding fertilizers at half of the recommended fertilization and the complete recommended dose of each nitrogen fertilizer (in the form of urea, N - 46%), with the first at planting and the second at elongation, having the recommended fertilization at 160 kg N ha^{-1}. Phosphorus fertilizer application was also in batches as superphosphate fertilizer (P - 20%) in cultivation, with the recommended fertilizer dose at 100 kg P ha^{-1}. As potassium sulfate (K2O - 50%) during potassium application was also in batches, with the recommended fertilizer dose at 100 kg K ha^{-1}. Crop harvesting was at the maturity stage on 26 April 2022. All data analysis per RCBD design with split-plot arrangement used the Genstat program (Oehlent, 2010). Using the least significant difference (LSD) test also aided in comparing and separating means.

Table 1. Effect of biofertilizer and mineral fertilizer levels on plant height (cm) in wheat.

Bacterial inoculum B	Chemical fertilizer (kg ha^{-1}) F		Average (cm)
	FO	F1	
Comparison	90.49	104.33	97.41
P. vermicola	100.33	99.99	100.16
A. faecalis	100.77	86.66	93.715
R. planticola	105.11	108.44	106.775
P. vermicola & *A. faecalis*	105.88	100.88	103.38
P. vermicola & *R. planticola*	105.10	81.16	93.13
A. faecalis & *R. planticola*	99.99	103.88	101.935
P. vermicola, *A. faecalis,* & *R. planticola*	94.77	97.99	96.38
Average (cm)	100.305	97.916	
F100%			106.21
$LSD_{0.05}$	B = 7.881, F = 3.940, BF = 11.145		

RESULTS AND DISCUSSION

Plant height

The results revealed that adding biofertilizers and the bacterial isolate *R. planticola* (P3) had increased plant height (106.775 cm) compared with bacterial treatments P4, P6, and P1 (103.38, 101.935, and 100.16 cm, respectively) (Table 1). It might be due to its effectiveness in growth regulators, including indole acetic acid and gibberellins, which affect cell division and elongation. Through these mechanisms, the formation of proteinaceous matter increases, positively reflected in the plant height (Hasan, 2002; Jat and Shaktwat, 2003). However, the least plant height showed for treatment P2 (93.715 cm). Results also indicated that two fertilizer treatments (FO and F1) confirmed nonsignificant differences in plant height. On the other hand, with biofertilization and chemical fertilization (P3 × F1), the highest plant height was 108.44 cm, which was 2.056% higher than the 106.21 cm obtained with the recommended complete fertilization. It is attributable to the activity of bacteria and their growth in bio-composts, where half of the composting recommendations exist, and the mineral fertilizers can provide the necessary nutrients for the thriving of organisms, leading to increased colony size, which positively boosts the crucial activities of composting organisms (Seneviratne *et al*., 2011).

Chlorophyll index

Adding biological inoculum affected the chlorophyll index of wheat plants positively compared with the control treatment (Table 2). The biofertilization treatments (P6, P5, P2, and P4) resulted significantly better than the control treatment, with recorded spit-out rates of chlorophyll (30.93, 30.77, 30.685, and 29.575 SPAD, respectively), while the mean of the control treatment was 22.95 SPAD. The reason can refer to the role of microorganisms in promoting root growth and increasing the surface area of the absorption zone, which in turn, increases the rate of water and nutrient uptake, thereby having the ability to increase the number of leaves, the surface area of leaves, and eventually, the chlorophyll content in plants. The production of enzymes that aid in pigment formation and the availability of bacteria to isolate nutrients plants need, such as, nitrogen, phosphorus, and other macro- and micro-elements, increased chlorophyll content. This result agrees with Bonkowski *et al*. (2000) and Al-Rajab (2005), who confirmed the effect of microbial interactions in the root zone and their impacts on plant growth.

No significant differences emerged between the two fertilizer treatments (FO and F1) on the chlorophyll index. However, the bilateral interaction of biofertilizer and chemical fertilizer (F × P) showed a significant increase in chlorophyll content. The proportion of complete fertilization was 24.745% with a

Table 2. Effect of bio- and mineral fertilizers on the chlorophyll index (SPAD) of wheat.

Bacterial inoculum B	Chemical fertilizer kg.H^{-1} F		Average (SPAD)
	FO	F1	
Comparison	21.29	24.61	22.95
P. vermicola	28.07	27.92	27.995
A. faecalis	27.99	33.38	30.685
R. planticola	23.71	27.79	25.75
P. vermicola & A. faecalis	28.28	30.87	29.575
P. vermicola & *R. planticola*	30.02	31.52	30.77
A. faecalis & *R. planticola*	30.88	30.98	30.93
P. vermicola, *A. faecalis,* & *R. planticola*	30.68	27.15	28.915
Average (SPAD)	27.615	29.276	
F100%			25.12
$LSD_{0.05}$	B= 6.310, F= 3.155, BF= 8.924		

chlorophyll index of 25.12 SPAD, while the lowest value of chlorophyll in the overlapping treatment (P0 × F0) was 21.29 SPAD. It might be because adding appropriate nitrogen and biofertilizer promotes the increased secretion of growth regulators that promote root growth, resulting in enhanced root absorption capacity and increased nitrate, phosphate, and potassium uptake, boosting plant growth. Development and division of plant cells and their entry into the synthesis of proteins, amino acids, and organic bases participate in forming chlorophyll and cytochrome compounds, which play a vital role in the photosynthesis and respiration processes (Bandara *et al*., 2006; Akbari *et al*., 2011).

Grain yield

Results enunciated that the highest grain yield resulted in biological fertilizer treatment P7 (7.788 Mg ha^{-1}), and the yield increase rate was 47.689% compared with the control treatment P0 (4.074 Mg ha^{-1}) (Table 3). The second best was treatment P5 (7.214 Mg ha^{-1}), which showed a nonsignificant difference with treatment P7. It might be due to the biofertilizer application, which provided some nutrients that directly affect the plant growth contributing to the progression. Improvement in the efficiency of plant life processes increases the progress of plant roots and vegetative systems, enhancing the total chlorophyll content, which makes the plants more dynamic in absorbing nutrients and transporting them to their storage places in the plant body. The results also showed the effect of chemical fertilizers on the grain yield of wheat plants, and the F1 treatment was superior (6.76975 Mg ha^{-1}) over the F0 level (5.849 Mg ha^{-1}), with the F1 showing an increase of 13.604% in grain yield compared with the F0 treatment. This superiority results from a direct correlation between chlorophyll content and grain yield (Mohammed *et al*., 2021).

Biological yield

On the effect of biofertilizer on the biological yield of wheat, treatment P5 showed superior with a recorded biological harvest of 22.063 Mg ha^{-1}, having an increased rate of 32.579% compared with the control treatment P0 (14.875 Mg ha^{-1}) (Table 4). Treatments P3 and P7 followed P5, with 21.729 Mg ha^{-1} and 21.073 Mg ha^{-1}, respectively. Inoculation of food crops with biofertilizer may denote a positive effect on improving biological yield, in which crop growth and grain production increase. Biofertilizers are vital in increasing the supply of nutrients, including nitrogen, which helped enhance vegetative growth, branch number, and flag leaf area, increasing biomass. The augmentation in biological yield can also refer to a positive correlation between

Table 3. Effect of bio- and mineral fertilizers on grain yield (Mg ha^{-1}) of wheat.

Bacterial inoculum B	Chemical fertilizer $kg.ha^{-1}$ F		Average (Mg ha^{-1})
	FO	F1	
Comparison	3.194	4.953	4.074
P. vermicola	5.512	7.266	6.389
A. faecalis	4.873	5.832	5.353
R. planticola	5.933	7.114	6.524
P. vermicola & *A. faecalis*	6.488	6.636	6.562
P. vermicola & *R. planticola*	6.724	7.704	7.214
A. faecalis & *R. planticola*	6.528	6.615	6.572
P. vermicola, *A. faecalis,* & *R. planticola*	7.537	8.038	7.788
Average (Mg ha^{-1})	5.849	6.770	
F100%			7.216
$LSD_{0.05}$	B= 0.7930, F= 0.3965 , BF= 1.1214		

Table 4. Effect of bio- and mineral fertilizers on the biological yield (Mg ha^{-1}) of wheat.

Bacterial inoculum B	Chemical fertilizer $kg.ha^{-1}$ F		Average (Mg ha^{-1})
	FO	F1	
Comparison	14.583	15.167	14.875
P. vermicola	15.383	24.792	20.088
A. faecalis	14.583	17.5	16.042
R. planticola	21.583	21.875	21.729
P. vermicola & *A. faecalis*	16.33	19.542	17.936
P. vermicola & *R. planticola*	22.458	21.667	22.063
A. faecalis & *R. planticola*	16.042	16.042	16.042
P. vermicola, *A. faecalis,* & *R. planticola*	17.208	24.938	21.073
Average (Mg ha^{-1})	17.271	20.190	
F100%			16.625
LSD(0.05)	B= 3.852 , F= 1.926 , BF= 5.447		

plant height and biological yield (Farhood *et al*., 2022; Al-Fatlawi et al., 2023). These results were in analogy with the past findings concerning the evaluation of the capacity of phosphate-solubilizing bacteria and fungi on different forms of phosphorus in liquid culture (Turan *et al*., 2006, Schoebitz *et al*., 2013; Al-Bahrani, 2015).

Mineral fertilizers cause a significant effect on biological yield, and the second fertilization level, F1, provided the highest natural harvest (20.190 Mg ha^{-1}), exceeding the F0 level with a significant difference. It could be due to the increased concentration of macronutrients in the soil, positively affecting nutrient uptake. Results showed that the interaction treatment between P7 × F1 (24.938 Mg ha^{-1}) outperformed all other treatments with a 33.335% increase over recommended fertilization treatment, followed by the interaction of P3 × F1 (24.792 Mg ha^{-1}). However, the exchange of P0 × F0 appeared with the lowest biological yield (14.583 Mg ha^{-1}). Biofertilizers added to half doses of mineral fertilizers promote plant growth through multiple mechanisms, including enhanced auxin regulation and increased nutrient availability in the soil, promoting plant growth (Hettiarachchi *et al*., 2014).

Production costs

Cost is one of the critical determinants of the success of any project, and therefore, accurate cost calculation is the first step in assessing project profitability (Birkhaeuser *et al*., 1991). Fixed costs for the growing season include land rent, which may be approximately USD 600 per ha. For family businesses, this amount may be up to USD 300 (Table 5). This cost includes all the transactions and fertilizer levels (F0-F5). Variable costs include all the production requirements from field preparation to sale (Tawfiq, 2001), which are equal for all transactions except the cost of selling crops. According to the number of marketed crops, the marketing costs of all treatments and fertilization levels calculation followed details available in Table 3, as shown in Table 6.

Cost of producing straw

One hay bale of 14 kg costs USD 0.34. Table 7 shows the calculation to identify the number of hay and the amount of straw per ha.

The cost of the vital inoculum

The vital inoculum costs about USD 33.78 for the PCR test and USD 3.38 for each isolate. Table 8 shows the essential inoculum costs for each treatment, with the highest price recorded for the P7 treatment at the F1 level and half of the recommended compost.

Table 5. Total fixed costs for transaction and fertilization levels (USD ha^{--1}).

Inoculum	Land gain (USD ha^{-1})	Family business (USD ha^{-1})	TFC
Comparison	0.68	0.34	1.02
P. vermicola	0.68	0.34	1.02
A. faecalis	0.68	0.34	1.02
R. planticola	0.68	0.34	1.02
P. vermicola & *A. faecalis*	0.68	0.34	1.02
P. vermicola & *R. planticola*	0.68	0.34	1.02
A. faecalis & *R. planticola*	0.68	0.34	1.02
P. vermicola, *A. faecalis,* & *R. planticola*	0.68	0.34	1.02

Table 6. Marketing cost of grain yield.

Inoculum	Production F0	Production F1	Marketing F0	Marketing F1
Comparison	3.194	4.953	21.58	33.47
P. vermicola	5.512	7.266	37.24	49.09
A. faecalis	4.873	5.832	32.93	39.41
R. planticola	5.933	7.114	40.09	48.07
P. vermicola & *A. faecalis*	6.488	6.636	43.84	44.84
P. vermicola & *R. planticola*	6.724	7.704	45.43	52.05
A. faecalis & *R. planticola*	6.528	6.615	44.11	44.70
P. vermicola, *A. faecalis,* & *R. planticola*	7.537	8.038	50.93	54.31
Average	5.849	6.7697	39.52	45.74

Table 7. Amount of straw per ha.

Inoculum	Biofertilizer levels	Amount of straw (ton ha^{-1}) 1	Number of clicks (ha^{-1}) 2	Cost of producing straw bales (ha^{-1}) 3
Comparison	F0	11.3890	813.5000	274.83
P. vermicola	F1	10.2140	729.5714	246.48
A. faecalis	F0	9.8710	705.0714	238.20
R. planticola	F1	17.5260	1251.8571	422.92
P. vermicola & *A. faecalis*	F0	9.7100	693.5714	234.31
P. vermicola & *R. planticola*	F1	11.6680	833.4286	281.56
A. faecalis & *R. planticola*	F0	15.6500	1117.8571	377.65
	F1	14.7610	1054.3571	356.20
Comparison	F0	9.8420	703.0000	237.5
P. vermicola	F1	12.9060	921.8571	311.44
A. faecalis	F0	15.7340	1123.8571	379.68
R. planticola	F1	13.9630	997.3571	336.945
P. vermicola & *A. faecalis*	F0	9.5140	679.5714	229.58
P. vermicola & *R. planticola*	F1	9.4270	673.3571	227.49
A. faecalis & *R. planticola*	F0	9.6710	690.7857	233.37
	F1	16.9000	1207.1429	407.82
Average	F0	11.4223	815.8786	275.63
	F1	13.4207	958.6214	323.86

$$1 - \mathit{The\ amount\ of\ hay\ kg\ /\ hectare} = \mathit{the\ amount\ of\ biological\ yield} - \mathit{the\ amount\ of\ grain\ yield}$$

$$2 - \mathit{Number\ of\ hays\ /\ hectare} = \mathit{amount\ of\ hay\ kg\ /\ hectare} \div 14\ (\mathit{average\ weight\ of\ hay})$$

$$3 - \mathit{The\ cost\ of\ hay\ production\ /\ dinar} = \mathit{amount\ of\ hay\ /\ 14\ kg} \times (500\ \mathit{dinars})$$

Table 8. The cost of isolating and identifying the vital inoculum for each treatment and fertilizer level.

Inoculum	PCR costs	Diagnostic costs	Total cost of a bioinoculum
Comparison	0	0	0
P. vermicola	33.78	3.38	37.17
A. faecalis	33.78	3.38	37.17
R. planticola	33.78	3.38	37.17
P. vermicola & *A. faecalis*	67.57	6.76	74.32
P. vermicola & *R. planticola*	67.57	6.76	74.32
A. faecalis & *R. planticola*	67.57	6.76	74.32
P. vermicola, *A. faecalis* & *R. planticola*	101.35	10.14	111.49

Total variable costs

Table 9 shows the variable cost items for fertilization levels for all transactions, including land preparation, seeding, irrigation, fertilization, control, harvesting, marketing, and pressing straw (Hussein, 2010). Among the fertilization levels of F0, the cost of treatment P0 was the lowest, while treatment P5 was the highest (USD 1067.00 ha^{-1}.), followed by treatment P3 (USD 1195.98 ha^{-1}). At the F1 level of fertilization, the maximum cost recorded was for treatment P7 (USD 1411.46 ha^{-1}), followed by treatment P6 (USD 1184.35 ha^{-1}) (Table 9). The inoculum's treatment P0 has the lowest cost (USD 1117.79 ha^{-1}). Total costs are the costs for each treatment and each level of fertilizer used, including fixed and variable costs, with calculations based on Tables 5–9 through the following equation (Al-Ruwais. 2009) (Table 10):

$$TC = TFC + TVC$$

Table 9. Items of variable costs for study transactions for fertilizer recommendation F0.

Inoculum	Chemical fertilization levels	Cost of straw production	Cost of marketing	Cost of a bioinoculum	Fees for preparing the land until harvest	Chemical fertilizer	Total TVC
Comparison	F0	274.83	21.58	0	567.57	0.0000	863.98
P. vermicola	F1	246.48	33.47	0	567.57	270.27	1117.79
A. faecalis	F0	238.20	37.24	37.17	567.57	0.0000	880.18
R. planticola	F1	422.92	49.09	37.17	567.57	270.27	1347.02
P. vermicola & *A.*	F0	234.31	32.93	37.17	567.57	0.0000	871.98
faecalis	F1	281.56	39.41	37.17	567.57	270.27	1195.98
P. vermicola & *R. planticola*							
A. faecalis & *R.*	F0	377.65	40.09	37.17	567.57	0.0000	1022.48
planticola	F1	356.20	48.07	37.17	567.57	270.27	1279.28
Comparison	F0	237.5	43.84	74.32	567.57	0.0000	923.23
P. vermicola	F1	311.44	44.84	74.32	567.57	270.27	1268.44
A. faecalis	F0	379.68	45.43	74.32	567.57	0.0000	1067.00
R. planticola	F1	336.945	52.05	74.32	567.57	270.27	1301.155
P. vermicola & *A.*	F0	229.58	44.11	74.32	567.57	0.0000	915.58
faecalis	F1	227.49	44.70	74.32	567.57	270.27	1184.35
P. vermicola & *R. planticola*							
A. faecalis & *R.*	F0	233.37	50.93	111.49	567.57	0.0000	963.36
planticola	F1	407.82	54.31	111.49	567.57	270.27	1411.46
Average		275.63 323.86					

Table 10. Total costs TC hundred (USD ha^{-1}).

Inoculum	TC / F0	TC / F1
Comparison	2131.29	1877.49
P. vermicola	2360.53	1893.69
A. faecalis	2209.48	1885.48
R. planticola	2292.78	2035.99
P. vermicola & *A. faecalis*	2281.95	1936.74
P. vermicola & *R. planticola*	2314.68	2080.52
A. faecalis & *R. planticola*	2197.86	1929.10
P. vermicola, *A. faecalis,* & *R. planticola*	2424.97	1976.87

Total revenue

All the revenue received from the production process is total revenue (Al-Shammari, 2010). Its calculation consists of multiplying the production quantity/ton by the price of a ton, equivalent to USD 574,324. The income from by-products from the sale of straw computation has the price of one mill multiplied by the number of mills, i.e., USD 1.35. The total earnings from wheat and the income from straw constitute the total income, as shown in Table 11. Transaction P7 recorded the highest revenue from food crops, as fertilization levels F1 and F0 reached approximately USD 461,640 ha^{-1} and 432,870 ha^{-1}, respectively. Transaction P1 at fertilization level F1 recorded the maximum possible income from straw at two fertilization levels totaling USD 169,170 ha^{-1}, with second place was P7 at fertilization level F1, amounting to USD 163,130 ha^{-}. The total income reached the utmost level when fertilizing F1 level treatment P7 because it reached about USD 624,770, whereas the lowest gains came from the two degrees of

Table 11. Total Revenue (USD).

Inoculum	Fertilization levels	Proceeds revenue (Hundred USD ha^{-1})	Revenue (straw) (Hundred USD ha^{-1})	Total revenue (Hundred USD ha^{-1})
Comparison	F0	1.8344	1.0993	2.9337
P. vermicola	F1	2.8447	0.9859	3.8306
A. faecalis	F0	3.1657	95280.	4.1185
R. planticola	F1	4.1730	1.6917	5.8647
P. vermicola & *A. faecalis*	F0	2.7987	0.9372	3.7359
P. vermicola & *R. planticola*	F1	3.3495	1.1263	4.4758
A. faecalis & *R. planticola*	F0	3.4075	1.5107	4.9182
	F1	4.0857	1.4248	5.5105
Comparison	F0	3.7262	0.950	4.6762
P. vermicola	F1	3.8112	1.2457	5.0569
A. faecalis	F0	3.8618	1.5187	5.3805
R. planticola	F1	4.4246	1.3478	5.7724
P. vermicola & *A. faecalis*	F0	3.7492	0.9183	4.6675
P. vermicola & *R. planticola*	F1	3.7992	0.9090	4.7082
A. faecalis & *R. planticola*	F0	4.3287	0.9335	5.2622
	F1	4.6164	1.6313	6.2477
Average	F0	3.3593	1.1026	4.4619
	F1	3.8880	1.2954	5.1834

1- $$Revenue\ of\ grain\ yield\ =\ amount\ of\ yield\ / \times\ 850\ thousand\ dinars$$

$$Revenue\ of\ grain\ yield\ =\ amount\ of\ yield\ / \times\ 850\ thousand\ dinars$$

2- $$Hay\ revenue\ =\ number\ of\ hays \times 2000\ dinars$$

$$Hay\ revenue\ =\ number\ of\ hays \times 2000\ dinars$$

$$Total\ revenue\ =\ grain\ revenue\ +\ hay\ revenue$$

3- $$Total\ revenue\ =\ grain\ revenue\ +\ hay\ revenue$$

treatment P0 fertilizer. Meanwhile, the highest income of fertilization level F0 resulted in treatment P7, with the H-1 income of about USD 526,220.

Economic efficiency criteria

One of the principal indicators in evaluating the performance of projects is the calculation of profits, profitability of production, the return of the invested dinar (dollar), and the added value, according to the following equations (Al-Ezzi, 1989):

$$Productive\ profitability\ =\ profit\ \times\ 100$$

$$Return\ on\ investment\ in\ dinars\ =\ total\ income\ /\ total\ costs$$

$$Value\ added\ =\ total\ revenue\ -\ variable\ costs.$$

Treatment P7 showed superiority over all economic efficiency indicators at the semi-recommended level of fertilizer F1 (Table 12). The net profit was about USD 483,625 ha^{-1}, with P1 ranking second and the same fertilization level gained a profit of USD 451,770 ha^{-1}. For fertilization level F0, the most profitable was P5, reaching about USD 6383.9 ha^{-1}, followed by transaction P3 (USD 3895.63 ha^{-1}). The treatment P7 at fertilization level F1, recorded the highest measure among all the treatments and achieved the return-on-investment dinars, production profitability, and value-added of approximately USD 1.44284, 165.29865, and 483.625 ha^{-1}, respectively. These results were consistent with those for grain and biological yield, confirming the achievement of technical and price efficiencies, and thus economic efficiency.

Table 12. Economic efficiency criteria for all treatments and fertilizer recommendation levels.

Inoculum	Compost recommendation	Standards of economic efficiency (in USD)			
		Net profit	Return of investments	Productivity profitability	Value added
Comparison	F0	206.97	0.93006	65.61601	206.97
P. vermicola	F1	271.28	1.378.54	97.62702	271.28
A. faecalis	F0	323.83	1.17886	92.69189	323.83
R. planticola	F1	451.77	2.09256	161.19392	451.77
P. vermicola & *A. faecalis*	F0	286.40	1.14248	87.58243	286.40
P. vermicola & *R. planticola*	F1	327.98	1.60391	117.53311	327.98
A. faecalis & *R. planticola*	F0	389.56	1.44935	114.80338	389.56
	F1	423.13	1.82876	140.42162	423.13
Comparison	F0	375.30	1.38461	111.12432	375.30
P. vermicola	F1	378.85	1.76423	132.17095	378.85
A. faecalis	F0	431.35	1.57061	125.91419	431.35
R. planticola	F1	447.12	1.87465	145.20811	447.12
P. vermicola & *A. faecalis*	F0	375.19	1.434.90	115.34324	375.19
P. vermicola & *R. planticola*	F1	352.48	1.64939	123.45676	352.48
A. faecalis & *R. planticola*	F0	429.88	1.46621	119.77905	429.88
	F1	483.625	1.44284	165.29865	483.625

CONCLUSIONS

Implementing a triple bacterial inoculum, combined with a reduced fertilizer recommendation, created a more conducive environment for the cultivation and productivity of wheat. Consequently, this approach yielded favorable economic outcomes by reducing agricultural expenses and increasing revenues. Hence, it is imperative to conduct further research exploring alternative fertilization strategies. This research should prioritize investigating the economic implications of fertilizer usage and its environmental and health impacts. Additionally, efforts should focus on raising awareness regarding utilizing biological fertilization methods.

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