Rice and wheat production in Pakistan with Effective Microorganisms

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Abstract. *There is a growing interest in the use of soil microbial inoculants as an alternative biological approach to a) improve soil quality, b) enhance the growth, yield and quality of crops, and c) reduce the inputs of chemical fertilizers and pesticides in agriculture worldwide. One such product that has received considerable attention, is Effective Microorganisms or EM; it consists of mixed cultures of beneficial microorganisms. A long-term field experiment was conducted at Faisalabad, Pakistan to determine the agronomic and economic merits of EM in a rice-wheat cropping system. Treatments were applied in a randomized complete block design that included: control (untreated); recommended chemical fertilizer (NPK); green manure (GM); farmyard manure (FYM); Effective Microorganisms (EM) alone; NPK + EM; GM + EM; and FYM + EM. Significantly higher grain and straw yields for both crops were obtained with NPK alone, with other treatments in the following order: NPK > GM > FYM > EM. However, when fertilizer and organic amendments were combined with EM, higher grain and straw yields were obtained for each crop following the same order, i.e., NPK+EM > GM+EM > FYM+EM. The GM+EM treatment produced grain and straw yields for each crop that approached those for NPK alone. In all cases, the grain and straw yields from EM alone were higher than the controls. With few exceptions, EM applied in combination with NPK, GM and FYM caused a significant increase in nutrient uptake by the grain and straw of each crop. The uptake of NPK by both crops was higher for EM alone than for the controls. A comparative economic analysis of the treatments showed a significantly higher net return due to EM. The average net profit from rice and wheat production using EM was \$44.90 ha^{-1} and \$62.35 ha^{-1}, respectively. The study indicates that EM can enhance maximum economic yields in a rice-wheat rotation and also improve soil productivity when applied with organic amendments.*

Introduction

Agriculture in Pakistan is largely an irrigated enterprise in which farmers, particularly smallholders and subsistence-type farmers, face major constraints that can adversely affect production levels. The yields of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Pakistan are generally low because of a steady decline in soil quality and productivity from uncontrolled degradative processes such as salinization, depletion of plant nutrients, loss of soil organic matter, excessive irrigation and waterlogging, soil fertility decline, and wind and water erosion. The situation has been exacerbated by farmers who have intensified their tillage and cropping practices without making the necessary inputs (e.g., fertilizers, organic manures and composts) to restore and/or maintain soil fertility and productivity.

According to the 1980 census of Pakistan, some 75% of the total 4.1 million farms in the country are less than 5 hectares. These small farms comprise 35% of the total farm area and 40% of the total cultivated area (Government of Pakistan, 1983). Currently, both farm size and the economic status of the small farmers are continuing to decline. The advent of the Green Revolution in the 1960s appeared to hold some promise for small farmers in overcoming their problems of poor soil quality and low productivity. However, it soon became evident that most small farmers could not afford the costly inputs (i.e., chemical fertilizers, pesticides, mechanization, high-yielding varieties, and credit) necessary for them to participate in the Green Revolution.

The agricultural soils of Pakistan are generally calcareous, with high pH and low organic matter content (usually less than 1%), and often have a high phosphorus-fixing capacity. Consequently, there are widespread deficiencies in available nitrogen and phosphorus. Some sandy soils are known to be deficient in potassium, while zinc and iron deficiencies have been identified in rice and fruit crops (Hussain and Muhammad, 1991; Hussain et al., 1995). While the judicious use of chemical fertilizers could correct these nutrient deficiencies and enhance the soil fertility status throughout the country, small and subsistence-level farmers consider such inputs to be too expensive. Consequently, the average N-P-K ratio of various chemical and organic fertilizers used by Pakistani farmers is about 1.0-0.3-0.02, and is considerably lower than the recommended ratio of 1.5-1.0-1.0 (Government of Pakistan, 1993).

Large farmers who practice conventional agriculture in Pakistan apply chemical fertilizers and pesticides in an effort to increase crop yields and improve crop quality. While such goals have often been achieved, the cost of these and other production inputs has made it difficult for

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many farmers to continue farming on a profitable basis. For example, according to recent estimates the average total production cost for wheat in Pakistan with optimum fertilization and management is \$237.47 ha^{-1} with an average net profit of \$14.10 ha^{-1}. The total production cost for rice with optimum inputs is \$299.76 ha^{-1} with a net loss of \$1.30 ha^{-1} (Ahmad et al., 1993). In view of these increasingly narrow profit margins for two such important crops, the Government of Pakistan has asked its scientists to explore effective and affordable alternatives to chemical-based practices that would enhance the long-term sustainability of agriculture. Such alternatives are also needed to avoid the adverse effects of chemical fertilizers and pesticides on environmental quality, human and animal health, and food safety and quality.

One such alternative to conventional agricultural practices in Pakistan is the use of a microbial inoculant known as Effective Microorganisms (EM) within the context of nature farming and organic farming systems. The concept of EM was developed by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan. EM consists of mixed cultures of naturally-occurring, beneficial microorganisms applied as inoculants to increase the microbial diversity of soils and plants which, in turn, can improve soil quality and the growth, yield, and quality of crops (Higa and Wididana, 1991a; Higa and Parr, 1994). EM predominantly contains selected species of lactic acid bacteria, yeasts, actinomycetes, photosynthetic bacteria, and other types of organisms. All of these organisms are mutually compatible and can coexist in liquid cultures for extended periods (Higa, 1991).

EM is not a substitute for good management practices. It is, however, an added dimension for optimizing our best soil and crop management practices such as crop rotations, use of organic amendments, conservation tillage, recycling of crop residues and animal manures, and biocontrol of pests. When used properly, EM has been shown to enhance the beneficial effects of these practices on crop growth and yield (Arakawa, 1991; Higa and Kinjo, 1991; Higa and Wididana, 1991a,b; Hussain et al., 1993; Panchaban, 1991; Higa and Parr, 1994; Minami and Higa, 1994). A number of beneficial effects of EM have been cited by these and other researchers including: a) increased decomposition of organic amendments and release of plant available nutrients; b) increased nutrient availability in the rhizosphere of plants; c) increased seed germination, emergence and seedling growth; d) increased biocontrol of plant diseases and pathogens through antagonism and antibiosis; e) increased plant growth from microbially-sythesized hormones (e.g., auxins) and growth factors; f) detoxification of residual phytotoxic substances; and g) increased production of antioxidants that suppress the adverse effects of free radicals in plant metabolism.

Extensive field trials in Pakistan on nature farming using EM technology began in 1989. Results have shown that EM has consistently increased crop yields while allowing some farmers to reduce their inputs of chemical fertilizers (Hussain et al., 1993). The present study was conducted to determine the effects of chemical fertilizer green manure, and farmyard manure applied singly or in combination with EM on crop growth, yield and net returns in a rice-wheat cropping system in Pakistan.

Materials and Methods

A three-year study was begun in 1990 to determine the agronomic and economic effects of EM in a rice-wheat rotation compared with the inputs that many farmers would normally make including chemical fertilizer (N-P-K), green manure (GM) and farmyard manure (FYM). The soil was a sandy clay loam (pH, 7.8; total N, 0.04%; available P, 7.7 mg/kg; available K, 85.4 mg/kg; CEC, 9.2 $cmol^{(+)}$/kg; organic matter, 0.55%). The following treatments were applied to 4 x 4 m plots using a randomized complete block design with three replications:

T1 = Control (untreated, no amendments)

T2 = Chemical fertilizers (N-P-K, 120-90-60 kg ha^{-1})

T3 = Green manure (GM, 10 t ha^{-1})

T4 = Farmyard manure (FYM, 20 t ha^{-1})

T5 = Effective Microorganisms (EM, 10 liters ha^{-1})

T6 = NPK + EM

T7 = GM + EM

T8 = FYM + EM

The green manure crop (*Sesbania aculeata*) was grown each year *in situ* on the respective plots for 35 days and incorporated in the soil prior to transplanting rice (cv. KS-282) as a summer crop (May to September). After the rice was harvested, wheat (cv. PAK-81) was grown as a winter crop (October to April). An earlier paper by Hussain et al. (1995) reported that *S. aculeata* grown in this way will produce about 90 kg ha^{-1} of total N, most of which would become available during the year and would supply at least half of the N required by either crop. The green manure crop was applied at 10 t ha^{-1} (dry weight basis). Farmyard manure had an N-P-K ratio of 1-1-1 and was applied each year to respective plots at 20 t ha^{-1} (dry weight basis) which provided about 200 kg ha^{-1} of total N, with only 40 to 50 percent becoming available the first crop year. Chemical fertilizer was applied each year at the indicated N-P-K rates.

Effective microorganisms were applied in a formulation designated as EM 4. The stock solution of mixed cultures of beneficial microorganisms (mainly lactic acid bacteria, yeasts, actinomycetes and photosynthetic bacteria) was prepared by the International Nature Farming Research Center, Atami, Japan. EM stock solution was diluted 1:1,000 or 1:2,000 (EM:water) and spray-applied to the soil or crop of respective plots at each irrigation event, i.e., four and eight irrigations for wheat and rice, respectively. Consequently, EM 4 was applied to respective plots for both crops at a total rate of 10 liters ha^{-1} of stock solution. Both crops were irrigated with canal water; all other agronomic practices were applied equally for each treatment. Application rates for inputs in treatments 6-8 were the same as for treatments 2-5.

Crop growth and yield were recorded throughout the three-year study; soil, grain and straw samples were collected at each harvest for N, P, and K analysis. The data were analyzed statistically using the analysis of variance method of Steel and Torrie (1986); means were compared using Duncan's Multiple Range Test (Duncan, 1961). Crop yield (grain and straw) and nutrient uptake data are the means of three

Table 1. Effect of Chemical Fertilizer, Organic Amendments, and Effective Microorganisms (EM) on Grain and Straw Yield of Paddy Rice.

TREATMENTS	CROP YIELD	
	RICE GRAIN	RICE STRAW
	($t\ ha^{-1}$)	
Control (untreated)	2.13 e	3.27 d
Chemical Fertilizer (NPK)	4.77 a	7.28 a
Green Manure (GM)	3.80 c	5.17 bc
Farmyard Manure (FYM)	3.49 c	4.90 bc
Effective Microorganisms (EM)	2.52 d	3.99 cd
NPK + EM	4.96 a	7.77 a
GM + EM	4.19 b	6.06 ab
FYM + EM	3.81 c	5.50 bc

Control treatment did not receive NPK, organic amendments, or EM. Treatment means in a column sharing common letters are not significantly different at the 5% probability level. Values are the means of three years data.

Table 2. Effect of Chemical Fertilizer, Organic Amendments, and Effective Microorganisms (EM) on Grain and Straw Yield of Wheat.

TREATMENTS	CROP YIELD	
	WHEAT GRAIN	WHEAT STRAW
	($t\ ha^{-1}$)	
Control (untreated)	1.59 d	2.99 g
Chemical Fertilizer (NPK)	3.94 a	5.33 ab
Green Manure (GM)	2.73 c	4.25 de
Farmyard Manure (FYM)	2.41 c	3.83 ef
Effective Microorganisms (EM)	1.99 d	3.34 fg
NPK + EM	4.18 a	5.73 a
GM + EM	3.22 b	4.98 bc
FYM + EM	2.81 c	4.51 cd

Control treatment did not receive NPK, organic amendments, or EM. Treatment means in a column sharing common letters are not significantly different at the 5% probability level. Values are the means of three years data.

crop years (1990-92) with three replications per treatment per year.

Results and Discussion

Grain and straw yields

The effects of chemical fertilizer (NPK), green manure (GM), farmyard manure (FYM), and Effective Microorganisms (EM) on the grain and straw yield of paddy rice and wheat are reported in Tables 1 and 2, respectively. In studies of crop response to various organic amendments and biofertilizers, a chemical fertilizer treatment with NPK applied at recommended rates is often included as a "fertilized control" for comparison. Thus, it is not surprising that the grain and straw yields for both crops were significantly higher with NPK than with the other treatments because of the rapid response to readily available nutrients.

When the treatments were applied singly, the grain and straw yields of both crops followed the order of: NPK > GM > FYM > EM > control (no EM). However, when the microbial inoculant (EM) was applied in combination with other treatments, the grain and straw yields of both crops increased, some significantly, over the individual treatments and in the same order: NPK+EM > GM+EM > FYM+EM. Grain and straw yields with EM alone, though lower than the other treatments applied singly, were all higher (in the case of rice grain, significantly higher) than the controls (no amendments applied).

The higher yields of grain and straw for both crops, when EM was applied in combination with the organic amendments, can be attributed largely to the activity of the introduced beneficial microorganisms which enhanced the decomposition of GM and FYM and the release of available nutrients for plant uptake. However, the fact that EM also increased grain and straw yields when applied with chemical fertilizer (i.e., NPK+EM) suggests that EM may have induced other mechanisms that exert positive effects on crop growth and yield (Higa and Wididana, 1991a,b; Parr et al., 1994). Nevertheless, it is noteworthy that the GM+EM treatment resulted in yields of both rice and wheat that approached those obtained with NPK alone. Others have reported similar results on the beneficial interaction of EM and organic amendments in soils and cropping systems (Higa and Kinjo, 1991; Karim et al., 1992; Ibrahim et al., 1993; Chowdhury et al., 1994; and Myint, 1994).

Nutrient uptake

The effect of chemical fertilizer (NPK), green manure (GM), farmyard manure (FYM), and Effective Microorganisms (EM) on nitrogen, phosphorus, and potassium uptake by grain and straw of paddy rice is reported in Tables 3, 4, and 5, respectively. The wheat data for uptake of these three macronutrients is not reported here because of its similarity to the rice data both in treatment order and magnitude. In most cases, nutrient uptake by rice grain and straw was significantly higher than the control whether treatments were applied singly or in combination with EM. The uptake of NPK by rice grain and straw for treatments applied singly followed the order of: NPK > GM >

Table 3. Effect of Chemical Fertilizer, Organic Amendments, and Effective Microorganisms (EM) on Nitrogen Uptake by Grain and Straw of Paddy Rice.

TREATMENTS	N UPTAKE	
	RICE GRAIN	RICE STRAW
	(kg ha^{-1})	
Control (untreated)	20.8 g	19.9 f
Chemical Fertilizer (NPK)	62.2 b	43.0 b
Green Manure (GM)	44.9 d	28.3 de
Farmyard Manure (FYM)	39.9 e	24.4 e
Effective Microorganisms (EM)	26.8 f	17.6 f
NPK + EM	68.8 a	49.5 a
GM + EM	53.3 c	36.0 c
FYM + EM	44.7 d	31.5 d

Control treatment did not receive NPK, organic amendments, or EM. Treatment means in a column sharing common letters are not significantly different at the 5% probability level. Values are the means of three years data.

Table 4. Effect of Chemical Fertilizer, Organic Amendments, and Effective Microorganisms (EM) on Phosphorus Uptake by Grain and Straw of Paddy Rice.

TREATMENTS	P UPTAKE	
	RICE GRAIN	RICE STRAW
	(kg ha^{-1})	
Control (untreated)	3.0 f	1.0 g
Chemical Fertilizer (NPK)	10.2 b	3.4 b
Green Manure (GM)	7.2 d	2.1 d
Farmyard Manure (FYM)	6.2 e	1.8 e
Effective Microorganisms (EM)	3.7 f	1.4 f
NPK + EM	11.6 a	3.9 a
GM + EM	8.4 c	2.7 c
FYM + EM	7.2 d	2.2 d

Control treatment did not receive NPK, organic amendments, or EM. Treatment means in a column sharing common letters are not significantly different at the 5% probability level. Values are the means of three years data.

FYM > EM > control. However, when chemical fertilizer and the two organic amendments were applied in combination with EM, the uptake of NPK by grain and straw increased significantly in the order of NPK+EM > GM+EM > FYM+EM.

As with the yield data (Tables 1 and 2), a partial explanation for the increased nutrient uptake with EM applied with GM and FYM may be the result of a higher level of microbial activity which enhanced organic matter decomposition and the release of plant available nutrients. Since EM also increased nutrient uptake from the NPK treatment, there may have been other EM-induced modes-of-action that favorably affected plant growth (Higa and Wididana, 1991a,b; Parr et al., 1994). Hussain et al. (1994) reported that the significant effect of EM applied with organic amendments was not limited to the release of plant nutrients through microbial activity, but that the increased plant nutrient availability prevented deficiencies at critical stages of seedling growth.

Soil nutrient status

The effects of chemical fertilizer, green manure, farmyard manure, and Effective Microorganisms on soil nutrient concentrations after three years of a rice-wheat rotation are reported in Table 6. All treatments showed significant increases in the soil NPK levels over the control. The highest residual soil nutrient levels resulted from the application of chemical fertilizer. Where treatments were applied singly, the nutrient concentrations followed the order of: NPK > GM > FYM > EM. However, in most cases, when EM was applied in combination with chemical fertilizer and the two organic amendments, soil nutrient concentrations increased significantly in the same order as the single treatments. Others have also reported that EM applied to soils in association with organic amendments (crop residues, green manures, animal manures, composts, etc.) promoted the release of plant available nutrients from these materials that resulted in higher soil nutrient concentrations (Higa and Wididana, 1991a; Lin, 1994; Lee, 1994; Sharifuddin et al., 1994).

The beneficial effects of EM are generally enhanced by the concurrent application of organic amendments because most of the microorganisms that comprise EM are heterotrophs and, thus, require organic substances as sources of carbon and energy for their growth and metabolism. Providing organic amendments ensures the optimum growth and activity of EM cultures and, concomitantly, the decomposition of organic amendments and release of plant nutrients (Higa and Parr, 1994).

Economic considerations

In view of the increased grain and straw yields in this study for both rice and wheat from the use of EM, the obvious question is whether its use in this cropping system is profitable. The costs, income, and net profit from using EM for rice and wheat production, with various treatments applied singly and in combination with EM, are reported in Tables 7 and 8, respectively. The greatest costs were associated with chemical fertilizer applied with and

Table 5. Effect of Chemical Fertilizer, Organic Amendments, and Effective Microorganisms (EM) on Potassium Uptake by Grain and Straw of Paddy Rice.

TREATMENTS	K UPTAKE	
	RICE GRAIN	RICE STRAW
	(kg ha^{-1})	
Control (no EM)	3.4 g	42.3 g
Chemical Fertilizer (NPK)	10.3 b	114.3 b
Green Manure (GM)	7.5 d	75.9 e
Farmyard Manure (FYM)	6.5 e	70.6 e
Effective Microorganisms (EM)	4.4 f	53.6 f
NPK + EM	12.2 a	127.7 a
GM + EM	9.0 c	93.9 c
FYM + EM	7.7 d	84.6 d

Control treatment did not receive NPK, organic amendments, or EM. Treatment means in a column sharing common letters are not significantly different at the 5% probability level. Values are the means of three years data.

Table 6. Effect of Chemical Fertilizer, Organic Amendments, and Effective Microorganisms (EM) on Soil Nutrient Concentrations After Three Years of a Rice-Wheat Rotation.

TREATMENTS	SOIL NUTRIENT CONCENTRATIONS		
	N	P	K
	(%)	(mg kg^{-1})	
Control (untreated)	0.04 e	6.2 g	80.2 f
NPK	0.07 b	7.8 b	120.5 b
GM	0.06 c	7.3 e	100.2 d
FYM	0.06 c	7.3 e	103.2 cd
EM	0.05 d	6.9 f	88.7 e
NPK + EM	0.08 a	8.2 a	135.8 a
GM + EM	0.07 b	7.5 d	103.2 cd
FYM + EM	0.06 c	7.6 c	107.3 c

Control treatment did not receive NPK, organic amendments, or EM. Treatment means in a column sharing common letters are not significantly different at the 5% probability level.

without EM. These treatments also produced the highest gross and net income. All of the amended treatments had a higher net income than the controls. The net income for treatments applied singly to both crops followed the order of : NPK > GM > FYM > EM. However, the net income was increased significantly when EM was applied in combination with chemical fertilizer and the two organic amendments, and followed the order of: NPK+EM > GM+EM > FYM+EM. Interestingly, the net income from GM+EM approached that obtained with NPK alone.

The net profit from application of EM was obtained as the difference in net income between treatments applied singly (no EM) and the corresponding treatments applied with EM. These differences are shown as net profit from EM for rice production in Table 7 and wheat production in Table 8. The highest net profit due to EM for both rice and wheat was obtained with the GM +EM treatment. Moreover, the net profit from EM alone was higher for both crops than from NPK + EM, mainly because of the high cost of chemical fertilizer.

These results should be of considerable interest to a) poor, subsistence-level farmers who cannot afford the cost of chemical fertilizers, and particularly in some developing countries where subsidies once available to facilitate their purchase no longer exist; and b) affluent, large-scale farmers who wish to reduce their dependence on chemical inputs to achieve a more sustainable agriculture and environment. The mean net profit from the use of EM in rice and wheat production over the three years of this study was $44.90 and $62.35 per hectare, respectively, as reported in Tables 7 and 8.

Conclusions

Effective Microorganisms or EM is a microbial inoculant consisting of mixed cultures of naturally-occurring beneficial microorganisms, which has been studied extensively in countries of the Asia-Pacific Region. Research has shown that EM can improve soil quality; increase the growth, yield, and quality of crops; and provide plant protection against diseases and pathogens. Results of a three-year study in Pakistan show that EM applied in combination with chemical fertilizer, green manure, and farmyard manure significantly increased the yields and nutrient uptake of rice and wheat, compared with these treatments applied singly. The net income over costs and net profit from EM were considerably higher due to the application of this microbial inoculant. These results indicate that EM applied together with good quality organic amendments is cost-effective, and may allow farmers to substantially reduce their inputs of chemical fertilizer while maintaining maximum economic yields and net profits.

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Table 7. Cost, Income, and Net Profit from Effective Microorganisms (EM) for Rice Production with Various Treatments Applied Singly and in Combination with EM.

TREATMENTS	COSTS	INCOME GROSS	INCOME NET	PROFIT NET (EM)
	($ha^{-1})			
Control (untreated)	—	376.90	376.90	
NPK	111.00	843.80	732.80	
GM	33.40	668.00	634.60	
FYM	33.40	614.50	581.10	
EM	13.40	446.70	433.30	56.40
NPK + EM	124.40	878.80	754.40	21.60
GM + EM	46.80	739.00	692.20	57.60
FYM + EM	46.80	671.90	625.10	44.00
			MEAN	$44.90

Values are the means of three years data.

Chemical fertilizer applied at:

120 kg N ha^{-1} (unit cost, \$0.34 kg^{-1}) = \$40.80

90 kg P ha^{-1} (unit cost, \$0.56 kg^{-1}) = \$50.40

60 kg K ha^{-1} (unit cost, \$0.33 kg^{-1}) = \$19.80

TOTAL = $111.00

Green manure applied at 10 t ha^{-1}.

Cost of seed, rotovating, sowing — \$33.40 ha^{-1}.

Farmyard manure applied at 20 t ha^{-1} (unit cost, \$1.67 t^{-1}).

Effective Microorganisms applied to rice (1:2,000 dilution) at each of 8 irrigations; total application rate of 10 liters ha^{-1} of EM stock solution (unit cost, $1.67 per application).

Market price of grain and straw:

Rice grain — \$167.70 t^{-1}

Rice straw — \$ 6.70 t^{-1}

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Table 8. Cost, Income, and Net Profit from Effective Microorganisms (EM) for Wheat Production with Various Treatments Applied Singly and in Combination with EM.

TREATMENTS	COSTS	INCOME GROSS	INCOME NET	PROFIT NET (EM)
	($ha^{-1})			
Control (untreated)	—	311.60	311.60	
NPK	111.00	703.00	592.00	
GM	33.40	505.60	472.20	
FYM	33.40	448.90	415.50	
EM	6.70	376.60	369.90	58.30
NPK + EM	117.70	748.40	630.70	38.70
GM + EM	40.10	595.30	555.20	83.00
FYM + EM	40.10	525.00	484.90	69.40
			MEAN	$62.35

Values are the means of three years data.

Chemical fertilizer applied at:

120 kg N ha^{-1} (unit cost, \$0.34 kg^{-1}) = \$40.80

90 kg P ha^{-1} (unit cost, \$0.56 kg^{-1}) = \$50.40

60 kg N ha^{-1} (unit cost, \$0.33 kg^{-1}) = \$19.80

TOTAL = \$111.00

Green manure applied at 10 t ha^{-1}.

Cost of seed, rotovating, sowing — \$33.40 ha^{-1}.

Farmyard manure applied at 20 t ha^{-1} (unit cost, \$1.67 t^{-1}).

Effective Microorganisms applied to wheat (1:1,000 dilution) at each of 4 irrigations; total application rate of 10 liters ha^{-1} of EM stock solution (unit cost, \$1.67 per application).

Market price of grain and straw:

Wheat grain — \$133.40 t^{-1}

Wheat straw — \$ 33.30 t^{-1}

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