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AN ECONOMIC IMPROVEMENT PRACTICE ON NATURAL RANGELANDS: PLANT GROWTH PROMOTING BACTERIA

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ABSTRACT

The main objective of agricultural applications using intensive chemical fertilizers is to guarantee high yield and quality. But these applications are costly and cause environmental problems. For these reasons, there has recently been increased interest in environmental friendly, sustainable and organic farming practices. In this study was to evaluate and compare the cost of different microbial bio-fertilizers, commercial organic fertilizer and chemical fertilizer treatments, applied on rangeland in Erzurum, Turkey. A total of 22 different applications were evaluated for the economic analysis of plant nutrient applications from different sources in natural rangeland conditions in Erzurum province. As an alternative for chemical and commercial organic fertilizer applications, only the subjects that 5 different bacteria replaced with reduced fertilizer doses. As a result of the study, half-dose nitrogen + *Pseudomonas fluorescens* T26 treatment and half-dose nitrogen + half dose Phosphorus + *Paenibacillus polymyxa* TV-12E can be recommended in terms of economical. In rangelands, bacterial applications will provide yield increase, and also protects the underground water and soil resources against nitrate pollution.

KEYWORDS:
Nutrient management, PGPR, Rangelands, Turkey

INTRODUCTION

Fertilizers can be classified into organic and inorganic fertilizer categories. Organic fertilizers are produced through natural processes while inorganic fertilizers are produced through chemical processes using natural sources, by chemically altered.

In agriculture, fertilizers are chemical compounds applied to promote plant growth, but using of excess fertilizers leads to nitrate accumulation in the soil and excess nitrate ions mix into groundwater due to not absorbed by soil and plants. The specific level of this ions in the groundwater can cause serious environmental and health problems. For these reasons, it is recommended to use bio-fertilizer and organic fertilizer instead of chemical fertilizer in the absence of nutrients in the soil and to prevent high cost and environmental pollution with these applications.

Unlike cultivable lands, rangeland areas are mainly used for animal grazing and grazing is the most effective and economic improvement practice provided that proper management principles. But under some conditions, in addition to appropriate grazing management practices, other additional improving practices are necessary to increase yield [1, 2]. Fertilizer application especially nitrogen fertilization may be effective on yield increasing of rangelands. Phosphorus is another important nutrient for rangeland vegetation. But nitrogen and phosphorus fertilizer production cost may be too high and using too much nitrogen fertilizer may cause environmental pollution.

The use of bio-fertilizers, which contain beneficial microorganisms instead of synthetic chemicals, to helps maintain the environmental health and soil fertility while improve plant growth [3]. Many bacterial species have been studied during the years and many species have been identified that are useful for plant growth, yield and product quality. They have been called 'plant growth promoting rhizobacteria (PGPR)' including the strains in the general *Acinetobacter*, *Alcaligenes*, *Arthrobacter*, *Azospirillium*, *Azotobacter*, *Bacillus*, *Beijerinckia*, *Burkholderia*, *Enterobacter*, *Erwinia*, *Flavobacterium*, *Rhizobium* and *Serratia* [4, 5]. PGPBs enhances plant growth through various mechanisms like nitrogen cycling through nitrification, denitrification, fixation, mineralization and increasing solubilization of phosphate [6]. In some previous studies, it was found that PGPR could stimulate growth and increase yield in plum [7], sour cherry [8], cauliflower [9], lettuce [10], cabbage [11, 12], saffron [13], mountain tea [14].

This study was carried out in Erzurum province, and it is one of the important animal production centers with wide meadows and rangeland areas, and 6.7% of total meadow areas, 10.3% of total rangeland areas of Turkey are located in Erzurum [15]. In this region, an increase of the yield and quality of pasture has crucial important due to livestock activities is mainly based on rangelands.

The aim of this study was to evaluate and compare the cost of different PGPBs, commercial organic fertilizer and chemical fertilizer treatments, applied on rangeland in Erzurum, Turkey.

MATERIALS AND METHODS

Bacterial strains used in this study. PGPBs strains (*Pseudomonas fluorescens* T26, *Pantoea agglomerans* 16B, *Paenibacillus polymyxa* TV-12E, *Bacillus cereus* TV-30D and *Bacillus megaterium* TV-3D) used in this study were obtained from the culture collection unit in the Department of Plant Protection, Faculty of Agriculture at Atatürk University, Erzurum, Turkey. These non-pathogenic bacterial strains had been isolated from the rhizosphere and phyllosphere *of* wild and traditionally cultivated plants growing in the Eastern Anatolia region of Turkey [16, 17]. The list of the bacterial isolates and their origin is presented in Table 1.

Application procedure of bacterial bioformulation. Application of the bacterial bioformulation was performed using the spraying method. Approximately, 0.2 g of sucrose (10 mg/ml) was added to each clear spray bottle containing 500 ml of the bacterial bioformulation ($1x10^7$ CFU/ml). After shaking, the suspension was sprayed on plants. Additional applications were done at 15 days after first application.

Research area and treatments. This study was carried out on rangeland in 37S 0677633E-4420815N and 37S 0677625E-4420790 N with 2010 m altitude in Erzurum, Turkey, during the years 2011-2014, for 4 years period. This pasture has been grazed intensively for many years. The study area was delineated and fenced in the year 2010 to protect animal grazing. In this study, total 22 treatments were applied (Table 2). Fertilizers used were ammonium nitrate (33.5 percent nitrogen), triple superphosphate (44 percent available P_2O_5). The experiment was designed in a randomized complete block design, replicated three times. The size of treatment plots was 6 m^2 and total plots number were 66. There was three meters distance between blocks, and 2 meters between plots to prevent the transitions of the treatments each other.

Economic Analysis. Partial budgeting and marginal analysis were used to determine the superiority of the between treatments. Strategies for

TABLE 1
Bacterial strains used in this study, their host isolated, nitrogen fixation and phosphate-solubilizing activity

Bacterial strain	Sources	N_2-fixation	P-solubilization
Pantoea agglomerans 16B	*Thymus* sp.	+	+
Bacillus megaterium TV-3D	*Secale* sp.	+	+
Pseudomonas flourescens T26	Wild raspberries	S^+	+
Paenibacillus polymyxa TV-12E	Wheat	S^+	+
Bacillus cereus TV-30D	Wild beet	+	-

S+: strong positive reaction, +: positive reaction, -: negative reaction

TABLE 2
The treated chemical fertilizers, commercial organic fertilizer and PGPB lists

Treatments	Material Use (unit / da)				
	Nitrogen (kg/da)	Phosphorus (kg/da)	Bacterium Lt/da		Commercial organic fertilizer (lt/da)
T_1	--	--	--	--	--
T_2	10	5	--	--	--
T_3	10	--	--	--	--
T_4	--	5	--	--	--
T_5	--	--	*Pseudomonas fluorescens* T26	0.2	--
T_6	--	--	*Pantoea agglomerans* 16B	0.2	--
T_7	--	--	*Paenibacillus polymyxa* TV 12E	0.2	--
T_8	--	--	*Bacillus cereus* TV-30D	0.2	--
T_9	--	--	*Bacillus megatherium* TV-3D	0.2	--
T_{10}	--	--	--	--	0.3
T_{11}	5	--	*Pseudomonas fluorescens* T26	0.2	--
T_{12}	5	--	*Pantoea agglomerans* 16B	0.2	--
T_{13}	5	--	*Paenibacillus polymyxa* TV-12E	0.2	--
T_{14}	5	--	*Bacillus cereus* TV-30D	0.2	--
T_{15}	5	--	*Bacillus megatherium* TV-3D	0.2	--
T_{16}	5	--	--	--	0.3
T_{17}	5	2.5	*Pseudomonas fluorescens* T26	0.2	--
T_{18}	5	2.5	*Pantoea agglomerans* 16B	0.2	--
T_{19}	5	2.5	*Paenibacillus polymyxa* TV-12E	0.2	--
T_{20}	5	2.5	*Bacillus cereus* TV-30D	0.2	--
T_{21}	5	2.5	*Bacillus megatherium* TV-3D	0.2	--
T_{22}	5	2.5	--	--	0.3

economic analysis were embraced from Cimmyt [18]. The method of the partial budget was used to calculate the costs and benefits of numerous alternative treatments. In the Partial Budget Analysis (PBA), the application differences between the study subjects were considered as variable and the other costs were regarded as constant among the treatments (ceteris paribus). These costs are named Total Variable Costs (TVC) which is subtracted from Gross Return to give Net Return. Gross return is the product of yield and the price per unit of output. Costs of fertilization in the trial subjects and the value of the product obtained after the application were calculated based on the market prices in 2017.

Benefit-cost ratio calculated for each treatment by the following formula:

$$BCR = Net\ return\ /Expenditure$$

Marginal analysis in PBA is the comparison of the change in TVCs with a change in Net return. This comparison reveals the change in benefits associated with a using technology. Marginal Rate of Return (MRR) is calculated in the study. MRR is the ratio of the marginal net return to marginal cost. The marginal net return is the difference between the net return' of two consecutive treatments while the difference between the TVCs is the marginal cost.

RESULTS AND DISCUSSION

The cost, efficiency and income items for the experiment treatments are given in Table 3. Depending on the amount of used material, the amount of costs can vary. The subject of T_2, used the full doses of chemical fertilizers, had the most costly material with 54.21 TL / da. The subject T_{22} (half doses of N and P plus commercial organic fertilizer), with 49.605 TL / da cost, had secondly material cost in terms of the amount of the cost. These two subjects were followed by the subject T_{16} (half doses of nitrogen plus commercial organic fertilizer). Except for control treatment (was made no application) T_5, T_6, T_7, T_8, and T_9 were the most advantageous subjects in terms of application cost.

When evaluated in terms of hay yield, the subject T_{19}, applied half-dose nitrogen, half-dose phosphorus plus bacteria had the highest yield with 328.9 kg/da. After the subject T_{19} subject T_{20}, T_{21}, T_{17}, applied half dose chemical fertilizers plus different bacteria had a higher yield than that of the other subjects. The yields of these subjects were 312.7 kg, 310.4 kg and 309.9 kg/da respectively. The lowest dry yields were T_{10} (187.5 kg/da), T_6 (190 kg/da) and T_4 (193.1 kg/da). It can be said that the reason of the highest yields, obtained from the subjects that applied reduced by 50% of the chemical fertilization doses replaced by bacteria may be related with increasing effects of the bacteria on the productivity or the increasing of the efficiency of chemical fertilizers or made by bacteria in the soil and in the plant. Previous studies have shown that the microbial fertilizers increase the nutrient activity in plants [19-22].

It was stated that the substitution of bacterium to a certain amount of chemical fertilizer may increase the yields in different plants in the previous out studies. Hernández and Chailloux [23] found that bacterial substitution to reduced by 25% of chemical fertilizer application had higher yields than full chemical fertilizer application. Riggs, Chelius [24] indicated that application of bacteria in corn plants significantly increased plant growth and yield. Rashedul, Madhaiyan [25] reported that using of bacterial as an alternative to chemical fertilizer has positive effects on seed germination, plant height and grain yield in many plants produced in field and greenhouse conditions. Rosas, Avanzini [26] found that the using of bacteria more increased grain yield, harvest index and protein content than lower doses of fertilizer in wheat. In crop production, a number of studies have been carried out that demonstrated the positive effects of bacterial use on yield and other parameters [6, 27-31].

In terms of gross income, subjects with the highest value were T_{19} (296 TL / da), T_{20} (281.4 TL / da) and T_{21} (279.4 TL / da). As a natural result of productivity, the subject ranking in gross income results was the same as the yield order. Net income is one of the criteria that can most obviously show the economic advantages and disadvantages between the applications. Similar to gross income results the subjects that applied half-dose nitrogen, half-dose phosphorus plus bacteria had the highest net income. The highest net income was in T_{19} with 264.2 TL / da. T_{19} was followed by T_{20} (249.5 TL / da) and T_{21} (247.5 TL/da). The lowest net income was T_{10} (146.2 TL / da), T_4 (155.9 TL / da) and T_6 (166.2 TL /da). Similarly, Gurdeep and Reddy [32] found that phosphate-solubilizing bacterial applications had higher net income than chemical fertilizers in corn and wheat production.

The benefit-cost ratio is used to express proportionally the generated income to the costs in any production or investment activity. In other words, it represents net income per unit of cost. In this study, T_9, T_7 and T_8 were the most advantageous subjects in terms of cost-benefit ratio, while the subjects T_{22}, T_2 and T_{16} were the least advantageous. Jilani, Akram [33], found that the highest yields were chemical fertilization in corn plant, but they expressed that organic and biocompatible fertilizers had a higher income and cost-benefit ratio due to the lower costs. Mishra, Prasad [34], in pea production, they evaluated the chemical fertilizers and different doses of bacteria and obtained the highest gross and net income from bacteria application.

When the evaluated the trial subjects, the main subject identified was the T_1 comparative basis.

There is no calculation dealing with net income for T_1, but only income obtained as a result of enclosure to animal grazing. In enclosed rangeland, when compared to no application treatment each additional nutrient element may economically feasible treatment, depend on providing an economical benefit or not. The subjects T_4, T_5, T_6, T_7, T_8, T_{10}, T_{14}, T_{16}, and T_{22}, were eliminated and not evaluated by marginal analysis, due to not provided economical benefit, and occurred an economical loss.

Comparison of applications in terms of marginal revenue ratio (MRR), it is important to understand how additional doses of the application will affect net income. The MRR percent rate refers to the change (increase or decrease) in the net income for an increase in cost by 100 units depending on the additional treatment.

In terms of marginal income, the subject T_{11} was the most advantageous subject. For the additional 100 liras cost, T_{11} made 285.5 TL, T_{19} 266.4 and T_{20} 220.3 TL net income, while the least advantageous subjects were T_{13}, T_{12} and T_2, respectively

If a general evaluation will be made of this study, carried out in the pasture conditions in Erzurum province; it has been determined that phosphorus application alone, bacterial application alone (except *Bacillus megatherium* TV-3D), commercial organic fertilizer application alone, half nitrogen + commercial organic fertilizer application, half nitrogen + half phosphorous + commercial organic fertilizer applications were not economical, the yield, obtained from enclosure treatment was higher than that of these treatments. Where as, in rangelands, it is not recommended to apply any of the subjects T_4, T_5, T_6, T_7, T_8, T_{10}, T_{14}, T_{16}, and T_{22}.

According to the results of this study, Nitrogen alone, nitrogen + phosphorus, nitrogen + bacteria, and nitrogen + phosphor + bacteria applications were economically profitable between the treatments more profitable ones than in T_1 for the recommendation of any treatment was made based on net income and marginal income ratio. The treatment having highest net income can be suggested, if the investor has not any capital constraints for the resource utilization, that is, if there is enough capital to use the resources at the optimum level. If the investor's resource use is limited, the subject that the resource utilization is the most economically efficient, that is, the marginal income ratio is the highest will be suggested. In terms of net income, the subject T_{19} (5 kg/da N + 2.5 kg/da P + *Paenibacillus polymyxa* TV-12E) was the most advantageous subject with 269,2 TL; while in terms of marginal income ratio, the most advantageous subject was the subject T_{11} (5 kg/da N + *Pseudomonas fluorescens* T26) with 285.5%.

CONCLUSION

In this study, 22 different issues were evaluated for the economic analysis of plant nutrient applications from different sources in natural rangeland conditions in Erzurum province. As an alternative for chemical and commercial organic fertilizer applications, only the subjects that 5 different bacteria replaced to reduced fertilizer doses. As a result

TABLE 3
Average dry matter yield and economical analysis results

Treatments	Average Dry Yield (kg/da)	Costs that vary (Marginal Costs) (TL/da)	Yield	Gross Benefits (TL/da)	Net Benefits (TL/da)	Marginal Net Benefits (TL/da)	BCR	MRR %
T_1 (Base)	199.2	0	199.2	179.3	179.3	--	--	--
T_2	271.6	54.21	271.6	244.4	190.2	10.9	3.51	20.1
T_3	256.7	36.36	256.7	231.0	194.7	15.4	5.35	42.3
T_4	193.1	17.85	193.1	173.8	155.9	-23.4	8.74	-131.1
T_5	193.5	4.76	193.5	174.1	169.4	-9.9	35.58	-208.9
T_6	190.0	4.76	190.0	171.0	166.2	-13.1	34.92	-274.7
T_7	194.2	4.76	194.2	174.8	170.1	-9.3	35.73	-194.5
T_8	194.3	4.76	194.3	174.9	170.1	-9.2	35.73	-193.8
T_9	211.9	4.76	211.9	190.7	186.0	6.7	39.07	139.7
T_{10}	187.5	22.5	187.5	168.7	146.2	-33.1	6.50	-147.0
T_{11}	297.4	22.94	297.4	267.7	244.8	65.4	10.67	285.3
T_{12}	226.8	22.94	226.8	204.1	181.1	1.8	7.90	8.0
T_{13}	226.6	22.94	226.6	204.0	181.0	1.7	7.89	7.5
T_{14}	213.1	22.94	213.1	191.8	168.8	-10.5	7.36	-45.7
T_{15}	248.4	22.94	248.4	223.6	200.6	21.3	8.75	92.9
T_{16}	236.9	40.68	236.9	213.2	172.5	-6.8	4.24	-16.7
T_{17}	309.9	31.87	309.9	278.9	247.0	67.7	7.75	212.5
T_{18}	251.3	31.87	251.3	226.2	194.3	15.0	6.10	47.1
T_{19}	328.9	31.87	328.9	296.0	264.2	84.8	8.29	266.3
T_{20}	312.7	31.87	312.7	281.4	249.5	70.2	7.83	220.4
T_{21}	310.4	31.87	310.4	279.4	247.5	68.2	7.77	214.1
T_{22}	247.5	49.605	247.5	222.7	173.1	-6.2	3.49	-12.5

of the study, half-dose nitrogen + *Pseudomonas fluorescens* T26 treatment and half-dose nitrogen + half dose Phosphorus + *Paenibacillus polymyxa* TV-12E can be recommended in terms of economical. In rangelands, bacterial applications will provide yield increase, and also protects the underground water and soil resources against nitrate pollution.

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