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Impact of integrated use of bio and mineral nitrogen fertilizers on productivity and profitability of wheat (*Triticum aestivum* L.) under upper Egypt conditions

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Abstract

The effect of integrated use of mineral N fertilizer and biofertilizer (*Azotobacter* and/or *Azospirillum*) on grain and straw yields, harvest index and net profit of wheat was assessed. A field experiment was carried out during two years on a sandy soil. The recommended N (230 kg N ha^{-1}) and biofertilizer (*Azotobacter* and *Azospirillum*) were applied alone and in various combinations among them. A randomized complete block design, with three replications, was used in this study. Treatments significantly affected grain and straw yields, and harvest index. The highest values of such traits were obtained in treatment T_{11} (75% mineral N + biofertilizer with *Azotobacter* and *Azospirillum*). However, T_{12} (50% mineral N + biofertilizer with *Azotobacter* and *Azospirillum*) resulted also higher values for the above mentioned traits comparing with T_1 (100% mineral nitrogen and uninoculated) but the differences among the two treatments almost did not attain the statistical differences. In addition, T_{11} and T_{12} gave the maximum return and net profit per ha. From this study, it can be concluded that the biofertilizers (double-inoculation of *Azotobacter* and *Azospirillum*) of efficient strains could save 25 or 50 % of the recommended dose of mineral N.

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Introduction

The high cost of chemical nitrogenous fertilizers and the low purchasing power of most of the farmers restrict its use in proper amounts, hampering crop production. Besides, a substantial amount of the urea-N is lost through different mechanisms including ammonia volatilisation, denitrification and leaching losses, causing environmental pollution problems (De Datta and Buresh 1989, Choudhury and Kennedy, 2005).

The utilization of biological nitrogen fixation technology can decrease the use of urea-N, prevent the depletion of soil organic matter and reduce environmental pollution to a considerable extent (Choudhury and Kennedy 2004, Kennedy *et al.,* 2004). Also, Use of biofertilizers on Egyptian soils has decreased the pH, which had led to increased availability of trace elements that enhance plant growth. Bio-fertilizers are eco-friendly and have been proved to be effective and economical alternate of chemical fertilizers with lesser input of capital and energy (Hafeez *et al.,* 2002).

Nitrogen fixation potential of *Azotobacter* and *Azospirillum* are known. The organic matter rich soils promote the activities of these organisms (Lakshami *et al.,* 1972, Dobereiner and Day, 1975). Also, free-living nitrogen-fixing bacteria *eg Azotobacter chroococcum* and *Azospirillum lipoferum,* were found to have not only the ability to fix nitrogen but also the ability to release phytohormones similar to gibberellic acid and indole acetic acid, which could stimulate plant growth, absorption of nutrients, and photosynthesis (Fayez *et al.,* 1985).

Many authors have shown the positive effect inoculation of wheat with Azotobacter or/and *Azospirillum* (Tawfik and Gomaa 2005, Abbasdokht 2008, Badr *et al.,* 2009, Bahrani *et al.,* 2010). Tilak (1992) reported positive effects of double-inoculation of *Azotobacter* and *Azospirillum* on dry matter of maize and sorghum. Rai and Caur (1998) studied *Azotobacter* and *Azospirillum* and double-inoculation and alone inoculation effects on wheat growth and yield. Double-inoculation of *Azotobacter* and *Azospirillum* had positive effects on grain yield, biological yield and harvest index in various wheat genotypes.

Present study aims to evaluate the importance of bio-fertilization in the improvement growth, productivity and net profit of bread wheat crop as well as the expansion of bio-agriculture to reduce agriculture costs and environmental pollution via lowering mineral fertilizers application.

Materials and methods

Experimental site description

The field experiments were conducted at the Experimental Farm, Faculty of Agriculture, South Valley University (latitude 26°10′ N, longitude 32°43′ E, Altitude 79 m above sea level), Qena, Egypt during 2010-11 and 2011-12 seasons. The soil of the experimental site is sandy throughout its profile (73.7% coarse sand, 16.8% fine sand, 5.8% silt and 3.7% clay). Its pH value of 7.62, 1.75 EC (dSm^{-1}), 0.45% organic matter content, 0.25% total N, and available P and K of 7.42 and 170 ppm, respectively. The weather is very hot and dry from May to October where temperatures can reach up to 40 °C. On the other hand, the weather is usually warm during winter months and rainfall is rare.

Experimental treatments and design

The dose of nitrogen (230 kg N ha^{-1}) was manipulated at various levels in combination with different biofertilizers as per the treatment schedule. The different treatment combination as follows:

T_1- 100% mineral N (MN) and uninoculated, T_2- *Azotobacter* (AZB) alone, T_3- *Azospirillum* (AZS) alone, T_4- AZB + AZS, T_5- 75 % MN + AZB, T_6- 50 % MN + AZB, T_7- 25 % MN + AZB, T_8- 75 % MN + AZS, T_9- 50 % MN + AZS, T_{10}- 25 % MN + AZS, T_{11}- 75 % MN + AZB + AZS, T_{12}- 50 % MN + AZB + AZS, T_{13}- 25 % MN + AZB + AZS, T_{14}- Control (without nitrogen and uninoculated).

The seeds were inoculated by liquid culture of locally isolated strains of *Azotobacter chroococcum* and *Azospirillum lipoferum* (≈10^7 CFU/ml) which obtained from Biofertilizers Production Unit of Faculty of Agriculture, South Valley University. 1% of carboxy methyl cellulose (CMC) was added to the culture to increase its viscosity to gel form to act as adhesive biostabilizer, the addition of CMC was made just before using. The experiment was carried out in a randomized block design with three replications. Experimental unit measured 3.0 m in width and 4 m in length.

Cultural practices

Bread wheat (Giza 168 cv.) was sown on the 10^{th} of November in each season. P and K fertilizers were applied at a level of 36 and 50 kg ha^{-1}, respectively. Whole of phosphorus and potassium were applied basally before sowing in all treatments. The other cultural practices were carried out as recommended for the crop.

Measured traits

At harvest time, grain and straw yields were estimated at plot basis. Harvest index (%) of each plot was calculated by using the following formula:

$$Harvest\ Index\ (\%) = \frac{Grain\ \ yield}{Biolo\ gical\ \ yield}\ x\,100$$

For economic evaluation, the following figures were used: The price of one kilogram of nitrogen, phosphorus and potassium were 3.25, 6.25 and 3.00 L.E, respectively (Bank of Agricultural Credit and Development, Egypt). The price of biofertilizer (*Azotobacter* or *Azospirillum*) was 75 L.E. /ha. Other variable and fixed costs (land preparation, irrigation, harvesting, land rent, etc.), as well as total return, included price of grain (1962 L.E./ton) and straw (708 L.E./ton) yields were estimated from tables of Agricultural Statistics, Economic Affairs Sector (EAS), Ministry of Agriculture and Land Reclamation, Egypt.

Statistical analysis

The data were analyzed by analysis of variance (ANOVA) using MSTAT-C statistical software. Treatment means were compared using Duncan's multiple tests (Steel and Torrie, 1980). Since data followed the homogeneity test, pooling was carried out over the seasons and mean data are given.

Results and discussion

Grain and straw yields

The effects of studied treatments on the grain and straw yields were significant at 1 % level (Table 1). Means in Table 2 indicates that superiority of grain and straw yields were achieved by application of double-inoculation of *Azotobacter* and *Azospirillum* plus 75% mineral N (T_{11}) with a grain and straw yields of 5.046 and 6.470 tons ha^{-1}, respectively. Whereas, double-inoculation of *Azotobacter* and *Azospirillum* plus 50% mineral N (T_{12}) resulted higher value for the studied grain yield (4.684 t ha^{-1}) comparing with T_1 (4.486 t ha^{-1}) but the differences among the two treatments did not attain the statistical differences. Also, T_{12} treatment did not differ significantly with application with 100% mineral N (T_1) concerning the effect of straw yield as its values attained 6.059 and 6.058 t ha^{-1} for the two treatments, respectively.

Table 1. Analysis of variance of measured parameters.

Source of variance	d.f	Grain yield /ha	Straw yield /ha	Harvest index
Year (Y)	1	0.238	0.323	0.0082
Rep./Y(Ea)	6	0.167	0.218	0.0551
Treatment (T)	13	4.518**	6.594**	0.176**
Y x T	13	0.020	0.161	0.041
Error (Eb)	78	0.102	0.167	0.039

** significant at P < 0.01 level

Table 2. Effect of integrated use of bio and mineral nitrogen fertilizers on wheat productivity and harvest index (data over two seasons).

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
T_1- 100% mineral N (MN)	4.486 b	6.058 b	42.5 ab
T_2- *Azotobacter* (AZB)	3.043 f	4.422 e	40.7 ce
T_3- *Azospirillum* (AZS)	3.362 e	4.829 d	41.0 bc
T_4- AZB + AZS	3.708cd	5.411 c	40.7 ce
T_5- 75 % MN + AZB	4.422 b	6.059 b	42.2 ab
T_6- 50 % MN + AZB	3.870 c	5.575 c	41.0 bc
T_7- 25 % MN + AZB	3.385de	4.977 d	40.5 ce
T_8- 75 % MN + AZS	4.521b	6.060 b	42.7 ab
T_9- 50 % MN + AZS	3.877 c	5.647 c	40.7 ce
T_{10}- 25 % MN + AZS	3.481de	5.000 d	41.0 bc
T_{11}- 75 % MN + AZB + AZS	5.046 a	6.470 a	43.8 a
T_{12}- 50 % MN + AZB + AZS	4.684 b	6.059 b	43.6 a
T_{13}- 25 % MN + AZB + AZS	3.955 c	5.557 c	41.6 b
T_{14}- Control (without N)	2.724 g	4.015 f	40.4 e

The same letters within columns means not significant differences at 5% level.

Application of T_{11} had significantly higher grain and straw yields by 12.5 and 6.8 % relative to T_1 and by 85.2 and 61.1%, respectively relative to T_{14}. Also, T_{12} had significantly higher grain and straw yields by 71.9 and 50.9%, respectively relative to T_{14}. Also it is showed in Table 2 that *Azospirillum* is more effective than *Azotobacter* on grain yield due to more role of *Azospirillum* in up taking nitrogen produced by biological fixing by *Azospirillum* bacteria that finally will cause to more grain yield of plant. The lower values of grain and straw yields (2.724 and 4.015 t ha^{-1}, respectively) were obtained from T_{14} (without nitrogen and uninoculated). It is evident from the data in Table 2 that combined application of mineral and biofertilizers were favorable in enhancing yield than using mineral or biofertilizer alone.

In the present study, application of strains of bacteria *Azotobacter chrocooccum* and *Azosprillium lipoferum* plus 75% mineral N (T_{11}) shot up the grain yield by 85.2 and 12.5% over the control (T_{14}) and 100% mineral nitrogen (T_1), respectively. Also, application of these strains plus 50% mineral N (T_{12}) increased grain yield by 71.9% over T_{14} and did not significant with T_1 (Table 2). Such increase in yields (grain and straw) and harvest index, due to application of T_{11} or T_{12}, might be due to the role of biofertilizer (*Azotobacter* and *Azospirillum*) in enhancing soil biological activity, which improved nutrient mobilization from organic and chemical sources. Also, the biofertilizer plays a significant role in regulating the dynamics of organic matter decomposition and the availability of plant nutrients and in increasing nitrogen fixer. These results are in concordance with most similar previous studies (Radwan and Hussein 1996, Sharief *et al.,* 1998, Elsayed *et al.,* 2005, El-Garhi *et al.,* 2007, Badr *et al.,* 2009, Bahrani *et al.,* 2010).

Harvest index

Variance analyzing of harvest index, data showed that harvest index was significant influenced by various studied treatments at 1% probability level (Table 1). Application of T_{11} resulted highest value of harvest index (43.8%) and it was followed by T_{12} (43.6%), T_8 (42.7%), T_1 (42.5%) and T_5 (42.2%) without any differences significant among them (Table 2). While, the lower value of harvest index (40.4%) was obtained from T_{14}.

T_{11} gave the highest value of harvest index percentage comparing with other treatments. Thus it is indicated that using biofertilizers caused to increasing harvest index due to effect on dry weight and allocating more photosynthetic matters to grain. The *Azotobacter* and *Azosprillium* association helps the crop improvement also by excretion of ammonia in the presence of root exudates that enhances and regulates the nutrient uptake by plants (Narula *et al.,* 1993, Narula and Yadav, 1989). In controlled field trials in Iran, Khavazi *et al.,* (2005) found that yield improvements of more than 20% have been observed for wheat as a result of application of *Azotobacter* and *Azospirillum* inoculums.

Table 3. Some economics of wheat productivity per ha at various fertilization treatments (data over two seasons).

Treatments	Total costs (L.E*/ha)	Return (L.E/ha)		Total return (L.E/ha)	Net profit (L.E/ha)	Return-cost ratio
		Grain	Straw			
T_1- 100% mineral N (MN)	8490	8802	4289	13091	4601	1.542
T_2- Azotobacter (AZB)	7718	5872	3107	8980	1262	1.163
T_3- *Azospirillum* (AZS)	7708	6596	3419	10015	2307	1.299
T_4- AZB + AZS	7768	7275	3831	11106	3338	1.430
T_5- 75 % MN + AZB	8351	8676	4290	12966	4615	1.553
T_6- 50 % MN + AZB	8141	7593	3947	11540	3399	1.418
T_7- 25 % MN + AZB	7946	6641	3524	10165	2219	1.279
T_8- 75 % MN + AZS	8341	8870	4290	13161	4820	1.578
T_9- 50 % MN + AZS	8131	7607	3998	11605	3474	1.427
T_{10}- 25 % MN + AZS	7936	6830	3540	10370	2434	1.307
T_{11}- 75 % MN + AZB + AZS	8356	9900	4581	14481	6125	1.733
T_{12}- 50 % MN + AZB + AZS	8161	9190	4290	13480	5319	1.652
T_{13}- 25 % MN + AZB + AZS	7951	7760	3934	11694	3743	1.471
T_{14}- Control (without N)	7571	5344	2843	8187	616	1.081

1 L.E. (One Egyptian pound) = $ 0.164

Economic evaluation

It is noticed from the results in Table 3 that the maximum return and net profit per ha of 14481 and 6125 L.E., respectively, were obtained in the treatment of T_{11} (75% mineral N + biofertilizer with *Azotobacter* and *Azospirillum*), followed by T_{12} (50% mineral N + biofertilizer with *Azotobacter* and *Azospirillum*) of 13480 and 5319 L.E, respectively. The return and net profit per ha were minimum (8187 and 616 L.E. /ha, respectively) in the T_{14} treatment (control). The highest value of return-cost ratio (1.733) was obtained by the application of T_{11}, followed by T_{12} (1.652), while the lowest (1.081) was obtained from T_{14}.

Highest return and net profit values observed in the T_{11} or T_{12} treatments can be attributed to the increases in grain and straw yields produced per unit area under these treatments (Table 2). In addition, these treatments saved 25 or 50% from applied of mineral nitrogen which leads to reduce variable costs of these treatments. These results are in agreement with those reported by Jen-Hshuan, (2006) reported that microbial inoculants could be used as an economic input to increase crop productivity and fertilizer doses might be lowered. Also, Abd El-Lattief, (2008) found that application of one-half dose from recommended mineral fertilizers + 14 tons FYM /ha + biofertilizer (3.0 kg microbien /ha) gave the highest return and net profit values per ha.

In the present experiment, the interaction effect of fertilization and year was not significant for yield attributes traits and grain yield as well as harvest index (Table 1). Such results indicated that fertilization treatments showed similar effects from season to season.

Conclusion

In conclusion, the use of biofertilizers became inescapable to minimize the environmental pollution, caused by the chemical ones, and to improve the yield quality of various crops needed at the time being. Although 25 or 50 % of mineral N was replaced by biofertilizers (double-inoculation of *Azotobacter* and *Azospirillum*), the yield as well as return and net profit values per ha of wheat increased compared to that obtained with the recommended dose of mineral nitrogen. Finally, the biofertilizers of efficient strains could save 25 or 50 % of the recommended dose of mineral nitrogen.

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