SUMMARY

5. SUMMARY

The current study aimed at evaluating cyanobacteria soil based inoculum (SBI) and *Azolla* as biological nitrogen sources, studying their effects on rice and subsequent wheat plants as compared with synthetic nitrogen fertilizer (urea), monitoring the changes in soil N and P after using them, and testing the efficiency of Fe and/ or Zn-enriched *Azolla* in supplying Fe and Zn to plants.

To achieve these aims a clay soil was collected from Moshtohor, Kalubia and two pot experiments were executed using rice plants, one for cynobactria and the other for *Azolla* each alone or combined with urea. The same pots were reseeded with wheat as a subsequent crop without addition of biofertilizer or urea. Also, two pot experiments were conducted using maize plants to test the efficiency of Fe and /or Zn-inriched *Azolla* as Fe and Zn sources.

The treatments of the executed experiments:

1-Rice experiments:

a- Cynobacteria (SBI) and urea:

1. Control. 2. SBI-1 (200 g fed^{-1} equals 0.2 mg/kg^{-1}) 3. SBI-2 (1.5 kg fed^{-1} equals 1.5 mg/kg^{-1}) 4. SBI –3 (3 kg fed^{-1} equals 3 mg/kg^{-1}) 5. Urea-1 (30 kg N fed^{-1} equals 30 mg/kg^{-1}) 6. Urea-2 (60 kg N fed^{-1} equals 60 mg/kg^{-1}) 7. SBI-1 + Urea-1 8. SBI-1 + urea-2 9. SBI-2 + Urea-1 10. SBI-2 + Urea-2 11. SBI-3 + Urea-1 12. SBI-3 + Urea-2

b- *Azolla* and urea:

1. Control 2. Azol-1 (30 kg N fed^{-1} equals 30 mg/kg^{-1}) 3. Azol-2 (60 kg N fed^{-1} equals 60 mg/kg^{-1}) 4. Urea-1 (30 kg N fed^{-1} equals 30 mg/kg^{-1}) 5. Urea-2 (60 kg N fed^{-1} equals mg/kg^{-1}) 6. Azol-1 + Urea-1 7.Azol-1 + Urea-2 8. Azol-2 +Urea-1 9. Azol-2 + Urea-2

2-Wheat experiments:

Wheat grains were sown after rice harvesting and did not receive any N, SBI and *Azolla* treatments. The aim is to assess the residual effect caused by the treatments given to the preceding rice plant.

3- Maiz experiments:

a-Iron experiment:

1. Control
2. Fe EDTA (5% Fe) at a rate of 5 mg kg^{-1}.
3. Fe EDDHA (6% Fe) at a rate of 10 mg kg^{-1}.
4. $FeSO_4$ (56 % Fe) at a rate of 20 mg kg^{-1}.
5. *Azolla*-Fe_1 (8.6 % Fe) at a rate of 5 mg kg^{-1}.
6. *Azolla*-Fe_2 (8.6 % Fe) at a rate of 10 mg kg^{-1}.
7. *Azolla*-Fe_3 (8.6 % Fe) at a rate of 20 mg kg^{-1}.

b-Zinc experiment:

1. Control
2. Zn EDDHA (17.7 % Zn) at a rate of 5 mg kg^{-1}.
3. $ZnSO_4.7H_2O_2$ (22.6 % Zn) at a rate of 20 mg kg^{-1}.

4. *Azolla*-Zn_1 (5.27 % Zn) at a rate of 5 mg kg^{-1}.

5. *Azolla*-Zn_2 (5.27 % Zn) at a rate of 10 mg kg^{-1}.

6. *Azolla*-Zn_3 (5.27 % Zn) at a rate of 20 mg kg^{-1}.

The results obtained could be summarized as follows:

1-Rice and wheat experiments:

a-Cynobacteria (SBI):

Using the third level of cyanobacteria alone (SBI-3) significantly increased both rice straw and grain yields. Increasing N rate from 30 to 60 kg N fed^{-1} was accompanied with a significant increase of dry matter yield (119 % for straw and 105% for grain).

The most effective treatment on straw and grain yields of rice plants was SBI-3 + urea-1 as it increased straw yield by 161 % and grain yield by 175.4 % followed by SBI-3 + urea-2 (for straw) and SBI-2 + urea-2 (for grain).

Inoculation with SBI at the tested three rates failed to increase straw yield of wheat significantly over that of the control. However, using SBI alone significantly increased wheat grain yield. Using urea at the two tested rates succeeded to increase wheat straw yield significantly over the control treatment.

Combining SBI and urea increased plant height of rice plants, and the increase was significant with the most effective treatment of (SBI-3 +urea-1).

In case of rice, it is valuable to ensure that the most effective treatment among the studied treatments on 1000-grain weight was (SBI-3 + urea –2).

Inoculation of rice with 3 kg fed^{-1} cyanobacteria inoculum (SBI-3) gave 6.56 % of protein in grains, which was significantly higher than that of the control treatment (3.30 %). The highest protein parentage value (7.24) was for the treatment of SBI-3 + urea-1.

The treatment of (SBI-3 + urea-1) gave the highest total N-uptake by rice plants which was comparable to that achieved with using (urea-2). The highest value of total N-uptake by wheat (350 mg N pot^{-1}) was achieved with the (SBI-3 + urea-1) treatment.

Doubling the urea N rate resulted in one of the highest P uptake value (285 mg P pot^{-1}). The highest amounts of P uptake by rice (296 mg P pot^{-1}) and wheat (171 mg P pot^{-1}) were recorded with treatment of (SBI-3 + urea-1).

Cyanobacteria inoculation and urea application significantly increased total nitrogen in soil after rice harvesting. The highest total nitrogen amount (1100 mg N kg^{-1}) was accompanied with the (SBI-3 + urea-1) treatment.

It was observed that when urea was applied along with cyanobacteria, the amount of total-N was higher than when urea was applied alone. The highest total-N value of 800 mg N pot^{-1} was due to (SBI-3 + urea-1) treatment.

Total phosphorus was insignificantly increased when rice plants were supplied with urea and / or SBI either alone or in combination. The highest total phosphorus in soil after rice and wheat cultivation was recorded with the treatment of (SBI-3 +urea-1).

Values of the tested parameters indicate that the most effective treatment was (SBI-3 + urea-1). This means that we can reduce the amount of mineral N could be reduced to one half with using cyanobacteria (SBI).

b-*Azolla*:

Straw yield of rice was increased by 163% and grain yield increased by 119% with using *Azolla* at 30 and 60 kg N fed^{-1} (Azola-1 + urea-2), respectively. Application of urea-1 and urea-2 rates increased straw yield by 111 and 194 %, respectively.

Grain yield of rice was increased by 125 and 251 % with urea-1 and urea-2, respectively. The highest straw and grain yields of 77.35 and 55.70 g pot^{-1} were due to the treatment of (Azol-1 + Urea-1), respectively. The residual effect produced by the application of *Azolla* and urea increased wheat straw yield by 58.6 to 83.4 %. The highest straw and grain yields of wheat were attained with the (Azol-1 + urea-1) treatment.

The highest plant height of rice (115.64 cm) was accompanied with the treatment of (Azol-1 + Urea-1). *Azolla* application alone significantly increased plant height of wheat and produced the tallest plants which were better compared with urea alone.

The highest value of 1000- grain weight of rice was recorded with the (Azol-1+ Urea-1) treatment. In case of wheat plants, applying *Azolla* alone or urea alone produced the heaviest 1000-grain weight. However, those treated with combined treatments (*Azolla* + urea) produced less weights except those received (Azol-1 + urea-I) treatment.

The highest protein percentage in rice grains (6.52) was due to the treatment of (Azol-1 + urea-1). Protein content in wheat grains was insignificantly increased with both *Azolla* and urea, which were previously applied to the preceding rice plants.

Urea fertilization and *Azolla* inoculation applied to rice either alone or in combination significantly raised N-uptake by rice straw and grains. The most effective treatment on total N content in rice was (Azol-1 + urea-1). Also, in the subsequent crop of wheat, the highest value of total N-uptake (460 mg pot^{-1}) was due to the residual effect of the (Azol-1+urea-1) treatment.

The effectiveness of the studied treatments on total P uptake by straw and grain of rice could be arranged in the flowing order: (Azol-1 + urea-1) > (Azol-2 + urea-2) > (urea-2) > (Azol-1 + urea-2) > (Azol-2 + urea-1) > (Azol-2) > (urea-1) > (Azol-1). The highest P-uptake value (150 mg P pot^{-1}) was attained due the residual effect of (Azol-1+ urea-1) treatment.

All the treatments that contained *Azolla* and urea significantly increased total nitrogen in soil after rice than those which contained urea or *Azolla* alone. This was true in case of rice and wheat. The most effective treatment was (Azol-1 + urea-1).

No significant increase was observed in the total soil phosphorus after rice due to using urea and *Azolla* either alone or in combination. However, after wheat, the highest total P amount (850 mg P kg^{-1}) was due to the residual effect of(Azol-1 +urea-1).

All treatments significantly increased the amounts of available P, the highest available P amounted to 8.70 and 8.02 mg P kg^{-1} with (Azol-1 + urea-1) treatment after rice and wheat, respectively.

Azolla can be beneficial to many target crops other than rice, for instance it is beneficial to wheat when applied in a rotating rice-wheat cropping system

The most effective treatment was (Azol-1 + urea-1) when applied directly to rice or indirectly to the second crop wheat. This means that using biofertilizer can reduce the needed mineral fertilizer to one half and enhance the subsequent crop.

2- Maize experiments:

a-Iron experiment:

Iron forms significantly increased shoots dry yield of plants. The highest yield of shoots (19.20 g pot^{-1}) among treatments receiving Fe was attained with Azol-Fe_1 and the lowest one 15.87 g pot^{-1} was attained by inorganic Fe source treatment (Fe SO_4). Iron forms significantly increased roots dry weight over the control treatment although FeEDTA and $FeSO_4$ treatments showed increases which were not significant.

The highest yield of roots (14.03 g pot^{-1}) was due to Azol-Fe_2 treatment and the lowest one (7.17 g pot^{-1}) was achieved with Fe EDTA.

The highest Fe concentration in shoots (1066.70 mg kg^{-1}) was obtained with Azol- Fe_1 treatment. However, iron concentration in corn roots increased significantly except for the treatment of Azol- Fe_1. The highest iron concentration in roots was associated with Fe EDDHA treatment.

Iron sources increased significantly Fe-uptake by shoots. The highest Fe-uptake by shoots (20.44 mg pot^{-1}) was recorded with Azol- Fe_1. On the other hand, Fe-uptake by roots recorded the highest (18.37 mg pot^{-1}) with the Fe EDDHA treatment.

b-Zinc experiment:

The highest shoot dry weight value (17.30 g pot^{-1}) was obtained with Azol-Zn_2 treatment (organic zinc form).

Inorganic and organic zinc forms significantly increased zinc concentration in shoots. The highest concentration of zinc in shoots (853.33 mg kg^{-1}) was due to Azol- Zn_3 treatment.

Zinc forms significantly increased zinc concentration in roots over the control treatment (23.00 mg kg^{-1}). The highest zinc concentration value in roots (336.70 mg kg^{-1}) was achieved with $ZnSO_4$ treatment.

Zinc treatments significantly increased Zn-uptake by both shoots and roots. The highest value of zinc uptake by shoots (13.63 mg $pot^{-1)}$ was achieved with Azol-Zn_3 treatment.

The results obtained indicate that *Azolla* enriched with iron and / or zinc could be considered as equivalent and effective source of iron or zinc to those of chelated sources. Iron-enriched *Azolla* was equivalent to the highly expensive iron chelates like Fe-EDTA and Fe-EDDHA.