5. SUMMARY

The aim of the present study was to investigate the response of barley plants to the added fertilizers under conditions of saline non-sodic, non-saline sodic and saline sodic soils. Three soils were collected from El - Kalubia, Al –Ismailia and El-Fayoum Governorates representing saline non sodic, non-saline sodic and saline sodic soils, respectively. Three pot experiments were conducted to study the effect of soil salinity and sodicity on the availability of applied macronutrients; one experiment was carried out for each of N, P and K fertilizers, to barley plants (*Hordum vulgare* cv. Giza 123). The design of each experiment was a randomized complete block – factorial involving two factors in three replicates.

The first experiment

This experiment was carried out to study the response to added fertilizer- N at rates of 0, 22.5, 45,0 and 90,0 mg N/kg soil (as NH_4NO_3, 33.5 % N). The obtained results could be summarized as follows:

A – Seed germination

1 – Germination rate

1 - Application of N fertilizer at a rate of 22.5 mg N/kg soil (R_1) resulted in a significant increase in germination rate of barley seeds in all of the three soils.

2 - Increasing N application rate from 22.5 mg N kg^{-1} soil (R_1) to 90 mg kg^{-1} soil (R_3) highly significantly decreased germination rate. The decrease was more pronounced in the saline non-sodic soil than in the non-saline sodic and saline sodic soils especially when N was applied at the medium rate of 45 mg N kg^{-1} soil (R_2).

3 - Increasing N application rate resulted in a non significant increase in germination percentage of barley seeds; the highest increase was obtained at the highest rate of N application (90 mg

N kg^{-1} soil). The highest increase in germination percentage was obtained by the non-saline sodic soil whereas the lowest was obtained by the saline none-sodic one.

It can be concluded that increasing N rate decreased the germination rate in all soils under study. However, the germination percentage increased in the non-saline sodic and the saline sodic soils, but decreased in the saline non-sodic one.

B. Plant growth:

Increasing N application rate caused a general increase in barley plants growth in all of the three soils; the highest increase was obtained on the saline non-sodic soil. The effect of N application at increasing rates on barley growth could be arrange in the increasingly order :

Saline non-sodic soil > non-saline sodic soil > saline sodic soil

1. Number of tillers

1 - increasing N application rate highly significantly increased the number of tillers of barley plants. The main effect of N application showed increases of 8.52 %, 38.31 %, and 39.46 % at rate R_1, R_2 and R_3, respectively.

2 - Increasing N rate highly significantly increased number of tillers of barley plants under saline conditions as compared with 0 N application and there was no significant difference between R_3 and R_2. However, under conditions of the non-saline sodic soil the increase was highly significant only at R_1 and R_3 and significant at R_2; under saline sodic conditions the interaction between the soil and N rate was no significant.

2- Number of spikes

1 - increasing N application rate increased the number of spikes The main effect of N application showed an increase by 12.17 %, 39.54 % and 63.87 % at R_1, R_2 and R_3, respectively.

2 - This pattern of increase occurred in the saline non-sodic soil; under conditions of the non-saline sodic soil, there was no significant difference among the three rates. Under conditions of the saline sodic soil there was no significant difference between R_1, R_2, and R_3 and the only rate which gave a significant increase in the number of spikes was R_3. Therefore, salinity combined with sodicity was of a marked effect on response of plants to N application.

3. Plant height:

1- Increasing N application rate highly significantly increased the height of barley shoots in all three soils. The main effect of N application showed increases of 14.56%, 23.83% and 25.52% at R_1, R_2, and R_3, respectively.

2- Under conditions of saline non-sodic soil there was no significant increase between R_1 and R_2 whereas a significant increase occurred between R_3 and R_2 and a highly significant increase occurred between R_3 and R_1.

3- Under conditions of the non-saline sodic soil there was a significant difference between R_1, R_2, but there was no significant difference between R_2 and R_3.

4- Under conditions of the saline sodic soil a highly significant increase occurred between R_1 and R_2; and R_1 and R_3, whereas no significant increase was occurred between R_2 and R_3.

C. - Dry weight

1- Straw yield

1 - Application of N resulted in a highly significant increase in straw yield. The increase in straw yield may be due to the increase in number of tillers and plant height. The main effect of N application showed increases of 11.69%, 25.34% and 30.55% at R_1, R_2 and R_3, respectively.

2 - There was an interaction between N rate and soil type; under conditions of the saline non- sodic soil there was a significant difference in straw yield between R_0, R_1 and R_2 and no significant difference between R_2 and R_3.

3 - In the non-saline sodic soil there were significant differences between R_0 , R_2 and R_3 and no significant difference between R_2 and R_3.

4 - In the saline sodic soil there were no significant differences between the different rates of application; the only rate which gave a significant increase in straw yield as compared with R_0 is R_3 (90 mg N kg^{-1} soil).

2 - Grain yield

1. Grain yield increased with N application and the increase was highly significant. The increase in grain yield could be attributed to that the applied fertilizer-N increased plant tillering and hence number of spikes which in turn reflect on the grain yield. The main effect of N application showed increases by 23.17%, 25.44% and 54.01% at R_1, R_2 and R_3, respectively.
2. There was an interaction effect between the soil and applied N rate. Under conditions of the saline non-sodic and non-saline sodic soils there was no significant difference between R_1 and R_2 but a highly significant difference was occurred between R_2 and R_3.
3. In the saline sodic soil there was no significant difference between R_1 and R_2 or between R_2 and R_3 while a significant difference occurred between R_1 and R_3.

D. Nitrogen uptake by barley plants:

1. N-uptake by straw:

1 – There was a progressive increase in N – uptake with increasing N application rate. The main effect of N application showed

increases of 24.86%, 44.20%, and 56.91% at R_1, R_2 and R_3, respectively. The increase was highly significant.

2 - This pattern of response occurred in both the saline non-sodic and the non-saline sodic soils

3 - In the saline sodic soil there was a highly significant difference between R_2 and R_1, whereas, no significant difference was occurred between R_2 and R_3.

2 - N-uptake by grains

1. Application of N at increasing rate progressively increased N – uptake in grains; the increase highly significant; this may be owing to the role of N fertilizer in increasing photosynthetic area which resulted in increased photosynthetic gains
2. The main effect of N application showed increases of 20.27%, 38.29%, and 34.68% at R_1, R_2 and R_3, respectively.
3. The interaction effect between the soils and the added N rate showed a highly significant differences between R_1, R_2 and R_3. in all the three soils under consideration.

In conclusion the retarding effect of soil salinity, sodicity and salinity and sodicity on plant response to added fertilizer N could be arrange as follows

Saline sodic soil > non – saline sodic soil > saline non-sodic soil

The second experiment

This experiment was carried out to study the response of barley to added fertilizer P. Rates of added P were: 0, 7.5, 15.0 and 30.0 mg P/kg soil (as Ca-superphosphate material 15% P). The obtained results could be summarized as follows:

A - Seed germination

1 - Germination rate

1 - Application of P caused a highly significant decrease in germination rate particularly at high rates. Such a pattern of

response occurred in all of the three soils since no significant interaction occurred for this particular respect; the decrease was more pronounced in the saline non-sodic and the saline sodic soils. This indicates that sodicity has more hazardous effect on germination rate of barley seeds than salinity alone or salinity and sodicity together.

2 - The decrease in germination rate with increasing P application rate indicate that P fertilization decreases the hazardous effects of salinity and sodicity on barley seed germination. The effect of applied P on decreasing germination rate of barley seeds in the three soils could be arranged as follows:

Saline Sodic > saline non-sodic > non-saline sodic

2 - Germination percentage

Application P did not show a clear effect on germination percentage. However, it may be stated that P-application increased germination percentage slightly, particularly at the high rates of P.

B – Barley growth

1. Application of P caused a general increase in plant growth in all of the three soils, and the increase was more pronounced in the saline non-sodic soil than in the non-saline sodic or the saline sodic soil.
2. Application of P at increasing rates induced a higher growth of barley plants growing on saline soil than that of the plants growing on sodic and saline sodic ones; this effect could be arranged in the following increasing orde :

Saline non-sodic soil > non-saline sodic soil > saline sodic soil

1. Number of tillers:

1- Application of P at increasing rate was associated with increased number of tillers; but the increase was significant only at R_2. The

main effect of P application showed increases of 19.06%, 25.04%, and 14.57% at rate R_1, R_2 and R_3, respectively.

2 -The interaction effect between P rate and soil salinity and sodicity indicate that under conditions of the saline non-sodic soils increasing P rate significantly increased number of tillers of barley plants at R_1 and R_3, and highly significantly increased at R_2. Also, there was a highly significant differences between R_2 and R_1 or between R_2 and R_3; the highest number of tillers under this conditions was obtained at R_2.

3 -Under conditions of non-saline sodic soil, the increase was significant only at R_1 and there is a significant difference between R_1 and R_2.

4 -Under saline sodic conditions there were no differences between the different P rates.

2 - Number of spikes

1 - Application of P increased the number of spikes, the increase was highly significant. The main effect of P application showed increases by 35.69%, 45.23% and 32.15% at R_1, R_2 and R_3, respectively.

2 - Such a pattern of increase occurred in the saline non-sodic and saline sodic soils.

3 - In the non-saline sodic soil there was no significant difference between R_1, R_2, and R_3, but a significant difference between R_1 and R_0 was found.

3 - Plant height

1 - Application of P increased the height of barley plants; the increase was highly significant only at R_2 and R_3. The main effect of P application showed increases of 10.53%, 24.55% and 37.42% at R_1, R_2, and R_3, respectively. This indicates that P application, particularly at high rates increased barley tolerance to salinity and sodicity conditions.

3 - Such a pattern of response occurred in the saline non- sodic.

4 - In the non - saline -sodic soil there was no significant difference between R_1, R_2 and R_3.

5 - In the saline sodic soil there was a significant difference between R_2 and R_1; and between R_1 and R_3 but no significant difference between R_2 and R_3 was found.

C. Dry weight:

1- Straw yield:

1 - Application of P resulted in an increase in straw yield. The increase was progressive with increasing P application rate and highly significant at all the three rates. The main effect of P application showed increases of 20.50%, 29.73% and 36.93% at R_1, R_2 and R_3, respectively.

2- This pattern of increase occurred particularly in the saline sodic soil. However, there was an interaction caused by the soil.

3 - In the saline non-sodic soil there was a significant difference between R_1 and R_2 and no significant difference was found between R_2 and R_3.

4 – In the non-saline sodic soil there was no significant difference in straw yield between R_1, R_2; and a lower yield at R_3 in comparison with R_1 indicating a more stimulating effect due to R_1 in particular.

2- Grain yield

1 - Grain yield was highly significantly increased with P application rate. The increase on average of the three soils was progressive with P rate application. The main effect of P application showed increases of 36.69%, 36.88% and 60.65% at R_1, R_2 and R_3, respectively.

3 - There was an interaction effect between the soil and applied P rate, in the saline non-sodic soil there was no significant

difference between R_1, R_2 and R_3, but a significant increase was obtained at any of them and the no-P treatment (R_0)

4 - In the non-saline sodic soil the increase progressed with increased P-application at R_1, then at R_3.

5 - In the saline sodic soil there was no significant difference between R_0 and R_1 or between R_1 and R_2 whereas a highly significant increase occurred at R_3.

The aforementioned results indicate the application of P fertilizer to barley plants increases its tolerance to salinity and sodicity especially when applied at a high rates.

D. Phosphorous uptake by barley plants:

1. P-uptake in straw

1 - Application of fertilizer- P resulted in an increase in P uptake. The main effect of P application showed increases of 34.68%, 48.34%, and 83.85% at R_1, R_2 and R_3, respectively.

2 - This pattern of response occurred particularly in the saline non-sodic.

3 - In the non- saline sodic soil, there was no significant difference between R_1 and R_2 and a highly significant difference between R_3 and R_2.

4 - Under conditions of the saline sodic soil the only rate which gave significant increase in P uptake was that of R_3.

2 - P-uptake in grains

1. There was a progressive increase in P uptake with increasing P application rate; the increase was highly significant. The main effect of P application showed increases of 44.00%, 58.86%, and 101.54% at R_1, R_2 and R_3, respectively.
2. Such a pattern of response occurred in the saline non-sodic soil and in the saline sodic soil; the increase was highly significant.

3. Under conditions of the non saline sodic soil there was no significant difference between R_1 and R_2; and R_3 showed significant increase over both R_1 and R_2, a highly significant difference occurred between R_3 and R_2.

The third experiment

This experiment was carried out to study the response to added fertilizer K. Rates of K were 0. 12, 24, and 48 mg K/kg soil (as K_2SO_4, 43% K). The obtained results could be summarized as follows:

A. Seed germination:

1. Germination rate:

1 - Results show that K application caused a highly significant decrease in germination rate. This occurred in all soils since there was no significant interaction between soils on K application.

2 - The main effect of K application showed a decreases of 14.41%, 16.51% and 29.59% due to application of R_1, R_2 and R_3, respectively. The decrease in germination rate with increasing K application rate indicate that K fertilization alleviates the hazardous effects of salinity and sodicity on barley seed germination and hence decreases the number of days required for germination.

3 - The effect of applied K on decreasing germination rate of barley seeds in the three soils could be arranged as follows:

Saline non -sodic > saline sodic > non-saline sodic

2 - Germination percentage

1. Application of K resulted in an insignificant decrease ranging between 0 to 5.75% ,in germination percentage of barley seeds. This slight decrease occurred with all soils.

2. It could be concluded that K application rate caused a slight insignificant decrease in the germination rate in all of the three soils and that the rate of K caused no difference. .

B – Barley growth

1. Application of K caused an increase in plant growth in all of the three soils and the increase was more pronounced in the saline non-sodic soil than in the non-saline sodic and saline sodic ones.
2. Plant growth at a given rate of K was highest in plants grown on the saline non-sodic soil and lowest in these grown on the saline sodic soil.

1. Number of tillers:

1 - Application of K rate slightly increased the number of tillers of barley plants grown on the three soils. The main effect of K application showed increases in the number of tillers by 14.79%, 22.61%, and 28.64% by applying K at rates of R_1, R_2 and R_3, respectively.

2 - The highest number of tillers was obtained in the saline non-sodic soil whereas the lowest was obtained in the saline sodic one.

2 - Number of spikes

1. Application of K insignificantly increased the number of spikes. The main values of increases due to K application were 29.5%, 36.6% and 26.0% at R_1, R_2 and R_3, respectively.
2. The highest number of spikes was obtained in the saline non-sodic soil whereas the lowest was obtained in the saline sodic one.

3 - Plant height

1. Results reveal that increasing K application rate increased the height of barley plants; the increase was progressive with increasing K rate of application but it was insignificant.

2. The main effect of K application showed increases of 5.47%, 13.41% and 20.27% at R_1, R_2, and R_3, respectively.

C. Dry weight:

1. Straw yield:

1. Application of K resulted in an increase in straw yield. The increase was highly significant at R_1 and R_2, and insignificant at R_3. The main effect of K application showed increases of 11.26%, 30.77% and 32.93% at R_1, R_2 and R_3, respectively.
2. There was an interaction effect caused by the soil; in the saline non-sodic soil and the non-saline sodic each increase in K application was accompanied with an associated increase in straw yield.
3. Under conditions of the saline non-sodic soil the significant increase occurred only at R_3, This result indicate that application of K at a high rate has a simulative effect on barley tolerance to salinity combined with sodicity.

2 - Grain yield

1. Grain yield was highly significantly increased with K application. The main effect of K application showed increases by 37.1%, 6.66% and 58.9% at R_1, R_2 and R_3, respectively.
2. There was a significant interaction effect between the soil and K application: in the saline non-sodic soil as well as the non-saline sodic soil, the increase in K rate was accompanied by an increase in grain yield. In the saline sodic soil, only R_2 which gave a significant increase.

D. Potassium uptake by barley plants:

1. K-uptake in straw:

1. Results indicate that application of K resulted in an increase in K uptake; the increase was significant up to R_2. The increase of R_3 over R_2 was not significant. This pattern of response occurred in

all of the three soils since no significant interaction occurred for this particular respect.

2. The main effect of K application showed increases of 26.8%, 53.9%, and 62.2% at R_1, R_2 and R_3, respectively.

2 - K-uptake in grains

1. There was an increase in K-uptake by barley grains, due to K application; the increase was highly significant.
2. The main effect of K application showed increases of 40.7%, 51.3%, and 67.7% at R_1, R_2 and R_3, respectively.
3. The decrease in K-uptake by barley straw and grains under conditions of the saline sodic soil could be attributed to the low dry matter yield obtained under such conditions. Also, it may be attributed to an antagonistic effect of sodium on potassium uptake and hence the increasing presence of excess sodium ions in the root medium may affects adversely the availability of potassium to plants.