Effects of Different Forms of Nitrogen Application on Yield Response of Corn under Saline Conditions

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ABSTRACT

Soil salinity and sodicity alter nutrient availability for plant. The form of nutrition application can change plants respond to salinity stress. A field experiment was conducted to study the influence of nitrogen fertilizers in different forms on yield response of corn under saline conditions at the Islamic Azad University-Sabzevar Branch, Iran during 2010. The experiment design was randomized complete block with four replicates. Nitrogen fertilizers were added to soil at a uniform rate equivalent to 200 kg N ha\(^{-1}\) as urea, ammonium nitrate, ammonium sulfate, 50:50 mixtures of them and equal mixture of all three fertilizers, giving 7 treatments. A no-application of N treatment was included as control. Grain yield were increased significantly by the addition of ammonium nitrate compared to the other forms of N application. This experiment showed that N application as urea is not suitable at saline conditions and when applying urea to salt-affected soils combination with other fertilizers should be considered. The degree of application priority under saline conditions can be classified in order of increasing as alone or in combination was as follow: nitrate > ammonium sulfate > urea and combination form ammonium sulfate + ammonium nitrate > urea + ammonium nitrate > ammonium sulfate + urea, respectively.

Key words: Nitrogen fertilizers; Nutrient uptake efficiency; Corn; Salinity

Introduction

Soil salinity and sodicity are one of the main agricultural problems limiting plant growth and development in the world especially in arid and semiarid regions [11]. Osmotic effect, ionic imbalance, and specific ion toxicity are the main harmful salinity effects that can be inhibited plant growth and development [4]. Agricultural production in these soils to a large extent suffers from insufficient organic matter. It is well established that the growth inhibition and the adverse effects induced by salinity can be alleviated by proper fertilization and water management [4]. Investigations have found there is a positive correlation between soil salinity levels and nitrogen application. Therefore, excessive N application leads to soil salinization. Hence, proper rate and timing of N application are critical factors in saline soils.

Nitrogen has been recognized as an extremely essential nutrient for plant growth. Both ammonium-N (NO\(_3\)^-) and nitrate-N (NH\(_4\)^+) are readily taken up by plants. But NO\(_3\)^- is the preferred form in flooding or anaerobic conditions. Fageria [6] reported that plants supplied with equal proportions of NH\(_4\)^+ and NO\(_3\)^- grew as well as those supplied with any single

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amount of N form. The more or less favorable effect of \( \text{NH}_4^+ \) or \( \text{NO}_3^- \) in individual cases varies among species and is dependent on the concentration, as well as on the pH value, the buffer capacity, and the content of other nutrients in the medium. It has been claimed that \( \text{NH}_4^+ \) absorption is faster than \( \text{NO}_3^- \). The reason for such a differences between absorption rate can be due to more energy required to assimilate \( \text{NO}_3^- \) compared with \( \text{NH}_4^+ \) (20 ATP vs. 5 ATP), as well as oxygen demand to absorption of \( \text{NO}_3^- \).

Forms of N fertilizer varied widely and select the appropriate form of nitrogen should be of principal concern and depends up on various factors such as type of crop, soil status and rotation. In salt-affected soil, \( \text{NO}_3^- \) assimilation is low. There is no agreement that which type of N is the best form under saline conditions. Cations such as K, Ca and Mg decreased by increasing \( \text{NH}_4^+ \), while \( \text{NO}_3^- \) has incremental effect on these cations. It is believed that for most plant species, \( \text{NO}_3^- \) is preferred form of N under saline conditions, while a small number of plant prefer \( \text{NH}_4^+ \). Few workers have reported, however, mixtures of ammonium and nitrate at ratio of 50:50 resulted in consistently positive effects on greater grain and biological yields. These beneficial effects have been attributed to the antagonism effects of \( \text{NO}_3^- \) on Cl\(^-\) [3].

Irshad et al. [8] studied the influence of nitrogen and saline water on the growth and partitioning of mineral concentration in corn and reported that leaf, stem and root dry matter was significantly reduced by saline water. Saline water had significant effect on plant N concentration. Nitrogen application increased Na to K ratio, whereas ratios of Na to Ca and Na to Mg had greatest value in control. Their result indicated that interaction of saline water and nitrogen has mixed effects on the partitioning of mineral elements in corn. Response of sorghum plants to different sources and amounts of fertilizer at different levels of salinity also investigated. In sorghum, a study results showed that increasing salinity significantly decreased at 1% level of probability emergence, stem height, fresh and dry weight as well as leaf area index.

The effect of three forms of N, at a uniform rate equivalent to 100 kg N ha\(^-1\) namely: urea, nitrate-N, 50% urea + 50% nitrate-N (mixed-N) and no N application (control) on corn under saline and non-saline conditions was studied by Irshad et al. [9]. The biomass (shoot and root) of corn was significantly greater in mixed-N treatment than in single sources in saline condition, whereas it varied in the order of urea > mixed-N > nitrate-N > control in non-saline soil. Nitrogen use efficiency in non-saline soil improved by 15% compared with saline soil. Zhi-Wei et al. [14] showed that salinity had no effect on nitrogen content in the roots or shoots of corn, whereas it significantly reduces leaf area index, stem height, dry matter accumulation, root length and total N uptake. Shenker et al. [12] studied sweet corn response to combination of nitrogen levels and salinity stresses. At low salinities, the leaf N content, N uptake, and yield increased with increasing N fertilizer up to 45% of local N-fertilization recommendations. Azevedo Neto and Tabosa [2] evaluated the effect of different salinity levels on N, P and K nutrient efficiency in corn at seedlings stage. The salt stress reduced the N, P and K nutrient efficiency in both studied cultivars. Tolerant cultivar (Cv. P-305) had greater nutrient efficiency than sensitive cultivar (Cv. BR-5011) in high salinity conditions. Khalifa et al. [10] showed that the high concentrations of \( \text{NH}_4^+ \) reduced dry matter yield of corn in saline condition and \( \text{NO}_3^- \) was more effective in increasing total N content of plant tissues than the same concentration of \( \text{NH}_4^+ \). Concomitant using of \( \text{NH}_4^+ \) along with \( \text{NO}_3^- \) always induced higher yields and tissues N content than individual consumption of \( \text{NH}_4^+ \).

As an important macronutrient, N form may possibly influence growth and dry matter accumulation in corn under saline conditions. In the present experiment, we investigated the effects of N fertilizers in different forms on the growth and yield response of corn in salt-affected soil.

**Materials and Methods**

The experiment was conducted at agricultural research center of Islamic Azad University-Sabzevar Branch, Iran during 2010. In this study, a randomized complete block design with four replications was used. Treatments were N form (urea, ammonium nitrate, ammonium sulfate and mixed 50:50 and mixed equally with all three fertilizers). Each of fertilizers was applied based on soil tests and the need of corn (200 kg N ha\(^-1\)). Soil characteristics given in Table 3-1.

The treatments were laid out in 3*6 m plots. Crops were sown at a spacing of 0.60 m between rows and 0.20 m within rows. Seeds of crops were sown by hand. Sowing date was last week of June 2010. Preplant N fertilizer as ammonium nitrate (containing 34% N) and urea (containing 46% N) and ammonium sulfate (containing 21% N) were broadcasted manually and incorporated into the soil at planting. Nitrogen side-dress fertilizer was applied at seedling stage. Irrigation was done with saline water (Ec= 2.45 ds m\(^-1\)) in 10-day intervals according convention water scheme for corn in the region. The other fertilizers were applied based on soil analysis results. During the growth period all plots were weeded manually. No serious incidence of insect or disease was observed and no pesticide or fungicide was applied.
Table 1: Physicochemical characteristic of soil

<table>
<thead>
<tr>
<th>Clay</th>
<th>Silt</th>
<th>Sand</th>
<th>Soil acidity</th>
<th>EC ds.m⁻¹</th>
<th>N total *</th>
<th>Available phosphorus *</th>
<th>Potassium*</th>
<th>Boron*</th>
<th>Na*</th>
<th>Calcium*</th>
<th>Mg*</th>
<th>Organic matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>11</td>
<td>39</td>
<td>7.8</td>
<td>3.5</td>
<td>0.014</td>
<td>3.35</td>
<td>175</td>
<td>0.34</td>
<td>35</td>
<td>8.27</td>
<td>5.09</td>
<td>0.12</td>
</tr>
</tbody>
</table>

*Mg Kg⁻¹

At harvesting time one meter from the beginning and a half meter around each plot was removed as a marginal effect. The remaining area was harvested by hand. To evaluate yield components of corn including ear numbers per plant, grain numbers per ear, row numbers per ear, grain numbers and one-hundred grain weight, 10 plants were selected randomly from final harvest area.

Sodium and K were determined by flame-emission method (FP640, Shanghai Precision & Scientific Instrument Inc., Shanghai, China). Nitrogen content was analyzed using an Auto-Kjeldahl Unit (B-339, BuchiLabortechnik AG, Switzerland). Nitrogen use efficiency was calculated according;

\[ NUE = \frac{N_{a} - N_{b}}{N_{a}} \]

Where \(N_{a}\) and \(N_{b}\) represent absorbed N in grain for applied N plots and control, respectively and \(N_{a}\) is nitrogen application rate for each plot.

Data collected were subjected to the analysis of variance (ANOVA). Test of significance of the treatment difference was done on a basis of a t–test. The significant differences between treatments were compared with the critical difference at 5% and 1% level of probability.

Results:

Analysis of variance showed that nitrogen form had significant effect on economic and biological yields \((p<0.01, \text{Table2})\). The effects of N Form on economic yield is illustrated in Fig. 1. Ammonium had more effect on yield compared with other forms of N, although there was no significant difference between ammonium nitrate and ammonium sulfate, but nitrogen as urea could not produce desirable yield. Orthogonal comparisons showed that use of mixture fertilization had more effect on yield than single form of N. Among combination form of N, 50:50 combination of ammonium nitrate: ammonium sulfate had greatest economic yield. The greatest biological yield was observed at combination of three forms of N (Fig 2). The lowest biological yield was achieved in control treatment. There are no difference among urea and combination of urea along with ammonium sulfate and ammonium nitrate. Biological yield had less sensitive to N form than economic yield.

Yield Components:

Analysis of variance showed that nitrogen source had significant effect on row numbers (ear⁻¹), grain numbers (row⁻¹), grain numbers (ear⁻¹) and one-thousand grain weight at 1% level of probability, while sodium was not affected by nitrogen form and the type of fertilizer had significant effect on potassium and nitrogen efficiency at 5% level of probability (Table2).

The highest row numbers (ear⁻¹) were observed in ammonium nitrate form, which had no significance difference with ammonium sulfate and 50:50 combination of ammonium nitrate and ammonium sulfate. The less significance difference among treatment in row numbers (ear⁻¹) may be due to sensitivity to amount of nitrogen than nitrogen form. As shown in table 3 maximum grain numbers (row⁻¹) was achieved in plant receiving nitrogen in ammonium nitrate form and minimum grain numbers (row⁻¹) was observed in control treatment. There was no significant difference between nitrogen supply as ammonium sulfate and ammonium nitrate whereas combination of these cannot produce desirable grain numbers (row⁻¹). Grain numbers (ear⁻¹) that multiply of row numbers (ear⁻¹) and grain numbers (row⁻¹) had similar trend to nitrogen form as rows per was and the highest grain numbers (ear⁻¹) were observed in ammonium nitrate or ammonium sulfate than other nitrogen sources.

Control had the lowest grain weight and fertilization with ammonium nitrate had the highest grain weight. Fewer statistical differences among treatments for grain weight compared with other yield’s components were due to compensation by other components. In other words, no significant difference in the treatments of urea and a combination of different sources due to low grain numbers (row⁻¹) and row numbers (ear⁻¹) that caused each individual grain receive more assimilate. Therefore, one-thousand grain weight increased. The least potassium concentration was observed at combination of urea and ammonium nitrate whereas the highest potassium concentration was obtained in ammonium sulfate form. Maximum nitrogen use efficiency (NUE) was observed when plate feed by ammonium nitrate that had significant difference with the consumption of fertilizers as urea or urea + sulfate form (Table 3). The least potassium concentration was observed at combination of urea and ammonium nitrate whereas the highest potassium concentration was obtained as ammonium sulfate. Maximum NUE was obtained when plate feed by ammonium nitrate that had significant difference with the consumption of fertilizers as urea or urea + sulfate form (Table 3).
Table 2: Analysis of variance of yield and yield components of corn.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Economic yield</th>
<th>Biological yield</th>
<th>Rows per ear</th>
<th>Seed row</th>
<th>Kernel in ear</th>
<th>Kernel weight</th>
<th>Potassium</th>
<th>Nitrogen uptake efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>ns</td>
<td>ns</td>
<td>0</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>**</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Orthogonal comparison</td>
<td>**</td>
<td>**</td>
<td>ns</td>
<td>0</td>
<td>**</td>
<td>ns</td>
<td>0</td>
<td>**</td>
</tr>
</tbody>
</table>

Coefficient of variation 16.52 13.62 16.20 13.58 9.35 15.82 3.5 8.32

ns not significant; (*) and (**) represent significant difference over control at P < 0.05 and P < 0.01, respectively.

Table 3: Effects of different forms of nitrogen on Rows per ear, Kernel per Rows, Kernel in ear, Kernel weight, Potassium and Nitrogen uptake efficiency.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rows per ear</th>
<th>Kernel per Rows</th>
<th>Kernel in ear</th>
<th>Kernel weight (gr)</th>
<th>Potassium (mg.g⁻¹)</th>
<th>Nitrogen uptake efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium sulfate</td>
<td>16 ab</td>
<td>50 ab</td>
<td>798 b</td>
<td>302.71 a</td>
<td>4.75 a</td>
<td>17 ab</td>
</tr>
<tr>
<td>Urea</td>
<td>10 d</td>
<td>34 d</td>
<td>536 f</td>
<td>209.61 bc</td>
<td>4.53 b</td>
<td>15.5 b</td>
</tr>
<tr>
<td>A. nitrate + Urea</td>
<td>12 dc</td>
<td>42 c</td>
<td>510 de</td>
<td>236.86 abc</td>
<td>4.22 c</td>
<td>16.25 ab</td>
</tr>
<tr>
<td>Urea + A. nitrate + A. sulfate</td>
<td>14 bc</td>
<td>46 bc</td>
<td>640 dc</td>
<td>258.11 ab</td>
<td>4.56 ab</td>
<td>16.35 ab</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>18 a</td>
<td>54 a</td>
<td>972 a</td>
<td>309.06 a</td>
<td>4.68 ab</td>
<td>17.5 a</td>
</tr>
<tr>
<td>A. nitrate + A. sulfate</td>
<td>16 ab</td>
<td>48 b</td>
<td>766 bc</td>
<td>285.81 ab</td>
<td>4.6 ab</td>
<td>16.75 ab</td>
</tr>
<tr>
<td>Urea + A. sulfate</td>
<td>12 dc</td>
<td>32 d</td>
<td>386 fe</td>
<td>226.06 abc</td>
<td>4.44 bc</td>
<td>15.75 b</td>
</tr>
<tr>
<td>Control</td>
<td>6 e</td>
<td>15 e</td>
<td>102 e</td>
<td>163.2 c</td>
<td>4.25 e</td>
<td>-</td>
</tr>
</tbody>
</table>

Values followed by the same letter within the same columns do not differ significantly at P = 5% according to DMRT.

FIG. 1: Effects of different forms of nitrogen on Economic yield.

FIG. 2: Effects of different forms of nitrogen on Economic yield.

Discussion:

Nitrogen source had significant effect on yield and yield components of corn. It seems that corn prefer ammonium uptake under salinity conditions. No significant difference between ammonium nitrate and ammonium sulfate on yield may be due to the ammonium sulfate had sulfur in its structure that has...
provided sulfur as essential nutrient. Also, in saline soil high pH decreased availability and absorption of other essential elements for growth. Addition of sulfate in soil reduces pH, decreasing of pH increased availability of other elements. Faramarzi et al. [7] also showed that nitrogen as ammonium nitrate was better than urea for corn growth. In this study, yield reduction was due to loss nitrogen from soil and leaching nitrogen due to irrigation. In cotton has also been reported that nitrogen can reduce the effects of salinity on the plan [4]. On sugar beet has also been reported that the impact of nitrate or ammonium form of nitrogen on root fresh weight was different. In saline conditions use of nitrogen as nitrate form reduced fresh weight, while in normal conditions this form increased root fresh weight of sugar beets. Both in saline conditions and normal conditions, however, ammonium nitrogen form increased fresh weight of sugar beet [13]. Number of rows per ear and kernel per ear was the most important components in corn that was affect by nitrogen form in saline condition. That this indicates that nitrogen plays an important role in determining the number of rows is in the ear. In the urea treatment was also observed that providing nitrogen increased the number of rows per ear. Increasing of kernel per ear may be due to increasing of ear length or increasing of rows per ear also. In Faramarzi et al. [7] study the number of rows per ear was not influenced by type of nitrogen source, although the amount of nitrogen fertilizer affected row number per ear. Alizadeh et al. [1] reported that kernel per ear is dependent on availability or accumulation of nitrogen in different organs.

Moreover, time and amount of N grains can also affect the kernel per ear.

It is reported that chlorine ions in saline soils had antagonistic effects on nitrate uptake therefore appears reduction of kernel per ear in urea treatment was due to antagonistic effects of Cl-. Orthogonal comparison among treatment showed that the combined consumption of fertilizer (urea + ammonium nitrate, ammonium sulfate + ammonium nitrate + ammonium sulfate + urea) more beat than single form (ammonium nitrate, ammonium sulfate and urea).

Greater amount of potassium in ammonium sulfate treatments may be due to the exchange element of SO₄²⁻ and K⁺ in the root environment. When pH decreased beside root, ore potassium entered in root so increased value of this element in the shoot. On the other hand, in the other sources of nitrogen competition between elements had negative effects on potassium uptake so the amount of potassium absorbed has been less than ammonium sulfate form. Esmaili et al. [5] in sorghum showed that increasing salinity levels increases potassium percentage in dry matter. Potassium percentage in dry matter when plant received nitrogen urea was more than ammonium nitrate. Higher NUE for ammonium nitrate also seems due to prepare both form of nitrate or ammonium that allowed plant absorbs more nitrogen. High NUE in saline condition when urea was used indicated that this form of nitrogen in not suitable. Combination of different form of nitrogen may be appropriate than single form.

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References


