DOI: 10.17707/AgricultForest.61.1.15

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EFFECT OF SULFUR AND STABILIZED AMMONIUM NUTRITION ON NUTRIENT UPTAKE BY WHEAT IN CLAY AND CALCAREOUS SOILS

SUMMARY

A pot experiment was set up to study the effect of urea, $Ca(NO_3)_2$ and urea + nitrification inhibitor in the presence or absence of sulfur on the growth and nutrient uptake by wheat plant. Alluvial and calcareous soils were chosen for these experiments. Wheat seeds were sown and planted in 5 Kg soil packed in plastic pots at the rate of 15 seeds/pot. The plants were thinned 15 days after emergence to obtain ten seedlings per pot. Plant materials at three different growth stages were analyzed for their content of the different nutritional elements. At the end of the growing season plants were harvested (straw and grains) for analysis. Fe percentage and uptake generally increased with increasing S and N applications; the effect of S was more than that of N in that respect. Sulfur application to urea increased Fe concentration and its uptake compared to urea alone. Nitrification inhibitor increased Fe concentration in grains, which increased even more with sulfur addition. Iron content seemed to be affected by different N-forms, sulfur and by nitrification inhibitor treatment. Urea stimulated Fe content in wheat grains as compared with calcium nitrate. ES application was not effective in increasing Fe contents in wheat grains. Application of nitrification inhibitor increased Fe concentration in wheat grains. Urea + inhibitor had a predominant effect on N-uptake by wheat plant. Sulfur application resulted in an increase in N content as well as N-uptake in clay soil. Phosphorus absorption was positively influenced by the addition of nitrification inhibitor.

Keywords: nitrogen uptake, nitrification inhibitor, iron availability, sulfur.

INTRODUCTION

Plant roots acidify the root zone in response to ammonium (NH_4^+) nutrition and induce alkalinity in response to nitrate (NO_3^-) nutrition. Thus, the use of a nitrification inhibitor appears to be an essential condition whenever studying plant ammonium nutrition in soil (Zaccheo et al 2006). Metal availability in the soil can be manipulated by the proper ratio of NO_3^-/NH_4^+ used for plant fertilization by the effect of these N sources on soil pH (Selim et al., 1990).

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Paper presented at the 5th International Scientific Agricultural Symposium "AGROSYM 2014".
Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

Increasing the acidity of the rhizosphere through the oxidation of ES (SO_4^{--}) might contribute to the availability of certain nutrient elements and consequently their uptake by plants. Application of elemental sulfur may enhance the availability of Fe, which can be easily absorbed by plants, (Hitsuda et al 2005).

The well-known S fertilizers are: ammonium sulfate, single super phosphate and potassium sulfate. Gypsum, elemental sulfur (ES) and iron pyrites behave dual role as soil amendments as well as sulfur fertilizers. Among these sources; gypsum, elemental sulfur and single super phosphate containing calcium sulfate are good sources of sulfur for cultivated crops The acidification of soil with elemental S is a common agronomic practice, which can be used to mobilize metal captions in soil. Brown et al (1994) acidified a Cd- and Zn-contaminated soil with elemental S and observed that the accumulation of these metals by plants was greater than when the amendment was not used. Acidifying agents are also used to increase the availability of nutritional elements in the soil for plant uptake.

MATERIALS AND METHODS

A greenhouse experiment was conducted to study the effect of urea, $Ca(NO_3)_2$ and urea + nitrification inhibitor in the presence or absence of sulfur on the growth and nutrient uptake by wheat plant. Alluvial (clay soil; pH 8.0. EC 1.63 ds/m. $CaCO_3$ 3.48%) and calcareous (course loamy sand; pH 8.5, EC 1.0 ds/m. $CaCO_3$ 17.0%) soils were chosen for these experiments. Wheat seeds were sown and planted in 5 Kg soil (clay and calcareous) packed in plastic pots at the rate of 15 seeds/pot. The plants were thinned 15 days after emergence in order to obtain ten seedlings per pot. Nitrogen fertilization followed in the form of $Ca(NO_3)_2$, urea and urea + nitrification inhibitor at a rate of 1.5 g N per pot. Inhibitor (nitrapyrin) was applied in combination with urea at a rate of 0.1 % of added nitrogen. The same treatments were repeated with the addition of elemental sulfur (1.5 g/pot).

Plant materials at three different growth stages were analyzed for their content of the different nutritional elements. At the end of the growing season plants were harvested (straw and grains) for analysis. Total nitrogen, phosphorus, sulfur, and iron determinations were carried out according to standard procedures.

RESULTS AND DISCUSSION

The trend of the dry matter formation (g/pot) was followed over a period of 20 weeks starting from the time of fertilizer addition, in clay and calcareous soils as affected by the different nitrogen and sulfur treatments. After 40 and 70 days of germination, urea + inhibitor treatment gave the highest dry matter as compared with calcium nitrate and urea. The third growth stage (140 days of plantation) revealed that application of urea resulted in an increase of grain and straw yield as compared with calcium nitrate addition. Results revealed that still urea + inhib. + S was more effective compared to other treatments.

In calcareous soil, it was observed that application of urea gave a lower dry matter of wheat plant as compared with calcium nitrate particularly after 40 and 70 days of germination. Sulfur application with both calcium nitrate and urea resulted in slight increase in the dry matter yield of wheat compared with no sulfur treatments; this may be due to a rather limited effect of sulfur under these conditions.

Absorption of nitrogen by wheat plant was influenced by applied treatments along the growing season. In the first growing stage (40 days after germination) N- concentration in young plants ranged between 3.2 - 2.7 % for urea + inhibitor and calcium nitrate treatment respectively, this indicates more response to ammonium than to nitrate in such young plants. Calculation of the N-amount taken up by plants revealed that the addition of nitrification inhibitor when added along with urea contributed to an increase in N- uptake by about 44%, 38% and 48% compared to urea without nitrification inhibitor after 40, 70 and 140 days of germination, respectively (Tables 1 and 2). Martinez et al (2013) concluded that addition of the nitrification inhibitor to ammonium sulphate in drip irrigated adult citrus trees, increased fertilizer-N uptake, and fruit yield. N loss through leaching was markedly reduced as a consequence of the diminished nitrification rate. Therefore, the use of the nitrification inhibitor enabled a more efficient utilization of the fertilizer-N.

Table 1. Nitrogen content (%) and uptake (mg/pot) at different growth stages of wheat plants as affected by different treatments in clay soil

Treatments	Time in days after germination					
	40 day		70 days		140 days	
	N%	N-uptake	N%	N-uptake	N%	N-uptake
Control	1.5	170	1.2	276	1.2	463
$Ca(NO_3)_2$	2.7	388	2.1	5.4	1.8	928
$Ca(NO_3)_2$+ S	3.1	577	2.1	631	2.1	1281
Urea	2.7	435	2.0	502	2.0	1139
Urea + S	3.6	516	1.9	541	2.1	1514
Urea + inhib.	3.2	625	2.2	743	2.2	1570
Urea+S+ inhib.	3.0	648	2.2	698	2.5	1984

Table 2. Nitrogen content (%) and uptake (mg/pot) at different growth stages of wheat plants as affected by different treatments in calcareous soil

Treatments	Time in days after germination					
	40 day		70 days		140 days	
	N%	N-uptake	N%	N-uptake	N%	N-uptake
Control	1.3	122	0.96	140	0.9	257
$Ca(NO_3)_2$	2.2	275	1.6	315	1.9	616
$Ca(NO_3)_2$ + S	2.5	350	1.8	365	2.2	770
Urea	2.9	324	1.9	353	2.1	703
Urea + S	2.3	305	1.9	376	1.9	703
Urea + inhib.	2.4	384	2.0	418	2.2	798
Urea+S+ inhib.	2.4	482	2.1	510	2.1	868

Results indicated an increase in the concentration and uptake of iron with added nitrogen (either in the form of NO_3^- or NH_4^+) and sulfur compared with control.

Sulfur application to urea increased Fe concentration and its uptake compared to urea alone. Nitrification inhibitor increased Fe concentration, which was further, increased with sulfur addition.

Soliman et al. (1992) found that, without S application, plant contents of Fe, Mn, Zn were unaffected by different N-sources. Iron and Phosphorus concentrations and uptake generally increased with S and N applications. The effect of S on these parameters was greater than that of N. The uptake of iron, sulfur and other nutrients by wheat grains are presented in Table 3. Iron content seemed to be affected by different N-sources, sulfur and nitrification inhibitor treatments. Data revealed that added urea stimulated the Fe content in wheat grains as compared with calcium nitrate in both clay and calcareous soils.

Table 3. Nutrient uptake (mg/pot) by wheat grains as affected by different treatments in clay and calcareous soils

Treatments	N		P		S		Fe	
	Clay	calcar.	Clay	calcar.	Clay	calcar.	Clay	calcar.
Control	323	148	48.5	32.8	115	110	1.54	0.37
$Ca(NO_3)_2$	611	377	53.2	39.2	168	119	1.87	0.44
$Ca(NO_3)_2$ + S	782	487	97.2	48.7	284	139	1.87	0.49
Urea	629	397	87.3	47.7	223	156	2.62	0.72
Urea + S	690	407	78.5	48.9	309	196	2.71	0.41
Urea + inhib.	850	508	102.5	65.8	275	226	3.20	0.59
Urea+S+inhib.	1036	543	112.0	73.7	364	252	3.30	1.01
L.S.D.	52.1	20.17	3.41	2.74	42.30	7.00	0.028	0.011

Sulfur application was not effective in increasing the Fe contents in wheat grains. Application of nitrification inhibitor increased Fe concentration in wheat grains. Application of elemental sulfur resulted in an increase in S concentration.

Sulfur content in grains was found to increase successively and significantly with the application of nitrogen and sulfur. The interaction of both elements was found to have a significant effect on grains sulfur content. Increased sulfur content has been ascribed to increased available sulfate content in the soil. Application of N increased Fe - concentration and its uptake by grain yield of wheat. Application of elemental sulfur may enhance the availability of iron which can be easily absorbed by plants. Increasing the acidity of the rhizosphere through the oxidation products of elemental sulfur might contribute to the availability of certain nutrient elements and consequently their uptake by plants.

CONCLUSIONS

Application of urea was superior for increasing N- concentration in straw. However, elemental sulfur and nitrification inhibitor had little effect, whereas urea stimulated N- accumulation by wheat straw. It was noticed that nitrification inhibitor resulted in an increased N-uptake. Addition of elemental sulfur was more effective when combined with calcium nitrate than with urea alone. In addition, calcium nitrate and urea increased P-uptake by about 16.8% and 78.9% compared with the control, respectively.

Sulfur addition seemed to play a positive role for improving N-uptake in wheat grains. Urea treatments increased P-concentration and P-uptake in wheat grains. It was observed that N-addition might enhance the P-concentration in the grains of wheat. Urea treatment increased P-concentration as compared with calcium nitrate with or without sulfur. Urea treatment increased the N-content in grains as compared with calcium nitrate. Nitrification inhibitor seemed not to play an important role in increasing P-concentration in the grains but increased the total P-uptake. Sulfur concentration and uptake showed no clear trend as nitrogen and phosphorus. Sulfur application was not effective in increasing the Fe contents in wheat grains. The positive effect of nitrification inhibitor on increasing Fe uptake in wheat grains was more evident in clay soil.

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