Effect of N Forms on Maize Yield and Leaf Components

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Effekt der Stickstoff-Formen bei Ertrag und Blattkomponenten von Mais

1. Introduction

In Turkey, fertilizers containing nitrogen are consumed the most. One reason is the deficiency of nitrogen in our soil and the other is the effect of this fertilizer on the growth of plants which is a visual event. The producer has insufficient knowledge in terms of both the amount of fertilizer necessary and the form of the fertilizer. The selection of the form of nitrogen in hydroponic medium which is employed in the agriculture system without soil in the undercover conditions using modern under cover techniques, becomes a problem. This study was employed to answer all these questions.

Our reason to use hydroponic medium was the difficulty of the stabilization of aminium nitrogen in soil conditions. The other reason is that corn is a monocotiledon test plant. Corn is consumed as bread and animal food in our country.

The nitrification of NH_4 was controlled with a nitrate inhibitor N-Serve. Since hydroponic medium has changed periodically, water culture was used. However, it is very difficult to control in soil.

XU et al. (1992) found the highest dry material formation in case of nitrate feding in their study with corn in water culture conditions.

MENGEL (1991) stated that there was a week development in several plants that were fed by NH_4 compared to those ones that were fed by NO_3 under water culture conditions with a possibility that they may be poisoned by NH_3. However, there are also some opposite results (BRETELER & SMITH, 1974; SAMATER et al., 1998)

The uptake rates of NH_4 carrying N fertilizers are relatively lower due to its adsorption to the binding sites in the soil. In this respect, IKEDA et al. (1962) state that C fixation of tomato and paddy roots fertilized by NH_4-N was three fold that of NO_3-N.

Similar situation was assessed in maize by 5 fold (CRAMER et al., 1993). KAFKAFI (1990), speculates that plants fertilized with NH_4 contained lower sugar in their roots. It is also reported that NO_3 uptake increases the negative charge of cytoplasm which stimulates the cation uptake (THIBAUD and GRIGNON, 1981; KIRKBY and KNIGHT, 1977). In plants that are supplied with NO_3 organic acids increase parallel

Zusammenfassung

Ein Wasser-Kultur-Versuch mit Mais wurde angelegt, um den Effekt verschiedener Stickstoffformen (Ammoniumsulfat, Kalziumnitrat; Harnstoff) beim Ertrag, Stickstoffgehalt, Gehalt an organischen Säuren und Zuckergehalt zu prüfen. Pflanzen, die Ammon-Stickstoff erhielten, hatten den geringsten Ertrag. In allen Varianten waren die gemessenen Gesamtstickstoffgehalte der Blätter beachtlich hoch. Galaktose war die vorherrschende Zuckerart aller Stickstoff-behandelten Pflanzen, Sucrose in der Kontrollgruppe. Dominierende organische Säuren waren Malate bei Pflanzen mit Ammonstickstoffzufuhr und Cis-Aconitate bei jenen, die Nitratstickstoff erhielten.

Schlagworte: N-Formen, Mais, Zucker, organische Säuren, Aminosäuren.

Summary

A water culture experiment was established with maize to test the effect of N forms [$(NH_4)_2SO_4$; $CaNO_3.4H_2O$; urea] on yield, nitrogen (%), organic acids and sugar fractions. Plants that received NH_4-N had the lowest yield. In all of the treatments total N (%) content of leaves were measured considerably high. β-galactose was the dominating sugar fraction of all of the N treated plants and sucrose of the control. Dominating organic acids were malate in NH_4-N receiving plants and cis-aconitate in NO_3-N treated ones.

Key words: N forms, maize, sugar, organic acid, amino acid.

to cations due to released OH during NO_3 reduction causing organic anion synthesis and malate formation. This is the main reason of enhanced organic acid content in the case of NO_3 fertilization.

2. Material and Methods

A water culture experiment was performed under greenhouse conditions where two maize seedlings were placed in 4.5 l pots full of nutrient solution. Table 1 shows the chemical composition of the solution.

The medium solution with pH 4.7 was weathered for 24 hours. This solution was changed once a week. The experiment continued 11 weeks until the tassel growth in corn. In this experiment, SG 304 was used as a corn type.

The layout of the experiment was randomized parcels with 4 replications and a control treatment. In order to reduce the nitrification of NH_4-N, 2 mg kg^{-1} of a nitrification inhibitor (N-Serve (2-chloro 6-trichlorometylprydin) was added to each pot (GORING, 1962).

Total nitrogen was determined by KJELDAHL (SCHALLER, 1993) method, using samples of the root stem the body leaves dried at 70 °C and ground. The samples of stem and leaves were burned with a HNO_3 + $HClO_4$ (4+1) mixture to determine the minor and major elements. The flame fotometer was used to analyze major elements, K, Ca, Na and the AAS (Atomic Absorbsion Spectrofotometer) was used to analyze micro elements, Mg, Fe, Zn, Mn, Cu. Phoshorus was determined colorimetricaly (KACAR, 1972). The sugar fractions in the samples of the stem and the leaf were determined by GC using N_2 as a carrier gas and FID detector (NEUBELLER and BUCHLOCH, 1975). The fraction of organic acid in the samples was determined by extracting with 0.2% H_3PO_4 mobile gas and with the help of C18 coloumn (SAATÇI, 1990).

The samples (stem and the leaf) were hydrolysed with 6N for 24 hours to analyze aminoacids. The amount of aminoacids in the hydrolized samples were measured by Biotronic LC 3000 amino acid analyser (EMIRO LU and MARQUARD, 1984).

Table 1: Chemical composition of the nutrient solution
Tabelle 1: Chemische Zusammensetzung der Nährstofflösung

Nutrients	Concentrations ($mgkg^{-1}$)	Forms
N	300	$(NH_4)_2SO_4$, $Ca(NO_3)_2.4H_20$, urea
P	100	KH_2PO_4
K	500	KH_2PO_4, K_2SO_4
Ca	400	$CaCl_2{\cdot}2H_2O$,$Ca(NO_3){\cdot}4H_2O$
Mg	50	$MgSO_4{\cdot}7H_2O$
Fe	20	FeEDTA
Zn	5	ZnEDTA
Mn	20	MnEDTA
Cu	1	$CuSO_4{\cdot}5H_2O$
B	0.5	H_3BO_3
Mo	0.25	$Na_2MoO_4{\cdot}2H_2O$

3. Results and Discussion

3.1 Effect of N forms on leaf, stem and root yield and on their Macro and microelement and Yield contents

Results showed that nitrogen forms were significantly (1 %) effective on the leaf, stem and root yield of maize (Figure 1, 2). Results also showed that NH_4-N form yielded lowest in agreement with some researchers (SERNA et al., 1992; GERENDAS et al., 1990). MENGEL (1991) states that NH_4 has a NH_3 toxic effect on the protoplasm.

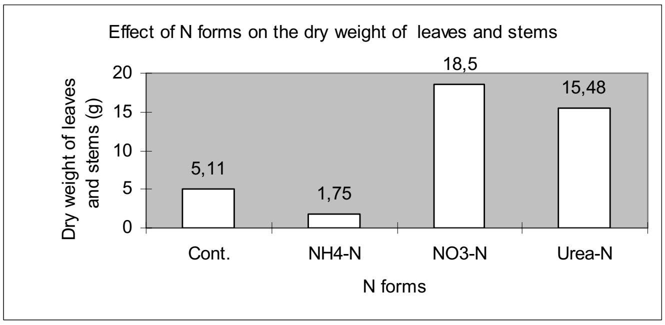


Figure 1: Effect of N forms on the dry weight of maize leaves and stems
Abbildung 1: Effekt der N-Form auf Trockengewichte von Blättern und Maiskolben

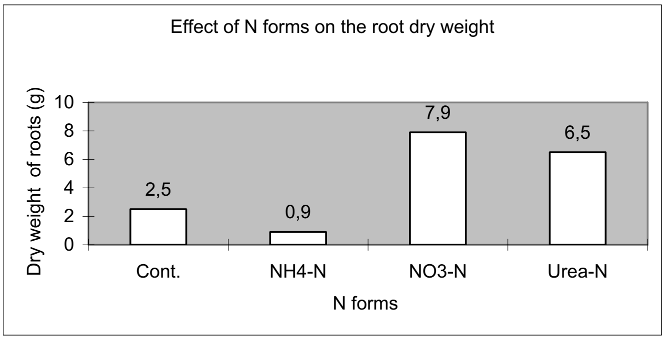


Figure 2: Effect of N forms on the dry weight of roots
Abbildung 2: Effekt der N-Form auf das Wurzeltrockengewicht

The N (%) content of the studied plant parts were not significantly affected by the tested N forms (Figure 3). However, compared to that of the control plant, other treated plants had considerably higher N contents similar to the results of EDIZDO AN (1997).

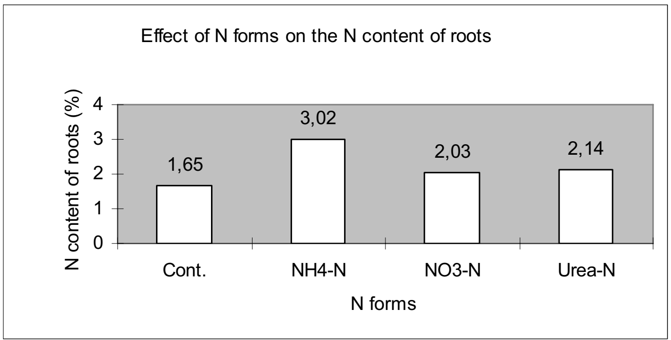


Figure 3: Effect of N forms on the N content of roots
Abbildung 3: Effekt der N-Formen auf Stickstoffgehalt der Wurzeln

It is shown that the fertilizers contain nitrogen affected the amount of Phosphorus in the leaf + stem significantly (Table 2). This is in accord with the findings of other researchers (COIC, 1964; BLAIR et al., 1970). The form of the fertilizer nitrogen affected the potassium level by 1% which is significant. The highest potassium amount in the leaf + stem was determined in the case of NH_4-N form. The lower amount in phosphorus and potassium nitrate is most probably due to the diletion effect of the formation of biomass in excess. There is no difference between the treatments with respect to the amounts of calcium element. In nitrate application, the high amount of Mg is due to synergistic effect of nitrate (MENGEL, 1991). Nitrogen increased the iron uptake which was highest in the form of NH_4 as a level of 1%. Similar study was done by GÜNEŞ and AKTAŞ (1991) with corn in water culture conditions. They found an increase in the total and active iron by application of nitrate. This is because of the lowest amount of iron determined in NO_3 form among the others. The highest zinc amount was found with the NO_3 form with 1 % significance level. This is most probably due to the interaction between iron and zinc (MARSCHNER, 1995). Manganese decreased compared to the blank with an application of nitrogen. This is because of the antagonistic effect of iron and zinc on manganese. Because of N applications, increase of Fe and Zn elements, is the result of their competition in respect to transportplaces. The highest copper uptake was observed with the NO_3 form. A positive relationship between the uptake of copper and the nitrate nitrogen is possible. While the copper level is low in the other forms of nitrogen, the high level of copper in case of nitrat nitrogen is probably due to the balance present between anions and cations.

3.2 Effect of N forms on the Quality Criteria of maize leaves and stem

No statistically significant effect of N forms on sugar contents were determined and the dominant sugar fraction was found β-Galactose in NH_4 fertilized plants (Table 3). In this regard, α-galactose, fructose and sucrose subsequently followed. In the case of urea-N form, the dominant sugar fractions were in the order of β-Galactose, sucrose, α-galactose and fructose in a similar study (HEHL, 1971). With 3 different crops from Graminacea family namely Lolium perenne, Arrhenatherum elatius, Phleum praetanse, glucose, fructose and saccharose were measured as the dominating sugars in the vegetative parts.

Briefly, the results pointed out β-galactose as the dominating and fructose as the least existing sugar fraction in NH_4, NO_3 and urea treatments and sucrose as the dominating in untreated control plants. MENGEL (1991), reports that sucrose in the leaves is transported to other plant parts to be utilized as an energy source of the metabolic processes. Galactose, on the other side, is involved in the formation of other oligo saccarides.

Table 2: Macro and microelement contents of leaf+stem of maize plant grown
Tabelle 2: Mikro- und Makronährstoffgehalt von Blättern und Stämmen der Maispflanzen

	%						ppm			
	N	P	K	Ca	Mg	Na	Fe	Zn	Mn	Cu
Control	1,56	0,62	4,97	0,57	0,22	0,03	81,0	38,40	149,3	11,00
NH_4-N	3,08	0,56	5,93	0,56	0,11	0,03	133,0	58,00	122,1	9,40
NO_3-N	2,63	0,36	4,63	0,50	0,21	0,02	102,2	79,50	127,4	12,10
UREA-N	2,81	0,39	3,76	0,45	0,14	0,01	126,3	49,60	102,8	9,90
LSD	n.s	0,10**	1,00**	n.s	0,02**	0,01*	18,84**	19,22**	12,33**	1,75**

Table 3: Sugar contents of maize leaves + stems
Tabelle 3: Zuckergehalt der Maisblätter und -stämme

	%				
	Fructose	α-Galactose	β-Galactose	Sucrose	Total
Control	0.058	0.083	0.104	0.203	0.448
NH_4-N	0.310	0.320	0.473	0.075	1.178
NO_3-N	0.108	0.222	0.320	0.285	0.935
UREA-N	0.040	0.337	0.515	0.470	1.362
LSD	n.s	n.s	n.s	n.s	n.s

Table 4: Organic acid contents of maize leaves + stems
Tabelle 4: Gehalt an organischen Säuren der Maisblätter und -stämme

	mg g^{-1} FW			
	Malate	Trans-aconit	Cis-aconit	Total
Control	46.13	13.16	16.47	75.76
NH_4-N	40.33	0.47	0.59	41.39
NO_3-N	14.95	34.00	42.54	91.49
UREA-N	25.34	5.68	7.11	38.13
LSD	n.s	8.65**	10.82**	n.s

Monosaccharates are by – products in young plants. Their level is low and they transform to the other products quickly. The form of sugar carried by succarose transform to the other sugar form polysaccharites in a very short time (EVANS and WILDES, 1971). Fructose, the sweetest sugar was found as highest with NH_4 applications whereas other monosaccharides and sucrose were highest at urea application. The lower sugar fractions in nitrate nitrogen is probably due to the intense carbon skeleton provided for the nitrogen compounds by the formation of more biomass with NO_3-nitrogen.

NH_4-N and urea treated maize plants contained malate in their leaves and stems as the dominating organic acids (Table 4). Malat is lowest in NO_3-nitrogen where the amount of product is also low. Malat is high in NO_3-N, urine, NH_4-N and control subsequently. Malat transforms to the trans and cis-aconitate easily (RICHTER, 1998). In NO_3-N application, malat transforms to the cis and trans-aconitata. The similar situation is also seen in case of urea in smaller amount. This is most probably due to the preparation of carbon skeleton of aminoacids and also the higher energy requirement of nitrogen uptake in nitrate form in the cells compare to the other forms (NAUHOLZ, 1989). In the case of NO_3-N treatments, cis-aconitate and trans-aconitata were measured in highest amounts (Figure 4, 5). GRIEB (1977), SCHERER (1978) and SCHERER and HÖFNER (1980) reported citrat, malate and aconitate as dominating organic acids of maize.

Cis aconitate was found highest in the NO_3-N treated plants and statistically compared with the other N forms this organic acid significantly (1%) differed from the others. The cis-aconitate content of NH_4-N and urea-N treated plants contained the least trans-aconitate even lower than the control. In this regard, EDIZDOĞAN (1997) notified cis-aconitate as the dominating organic acid in this studies.

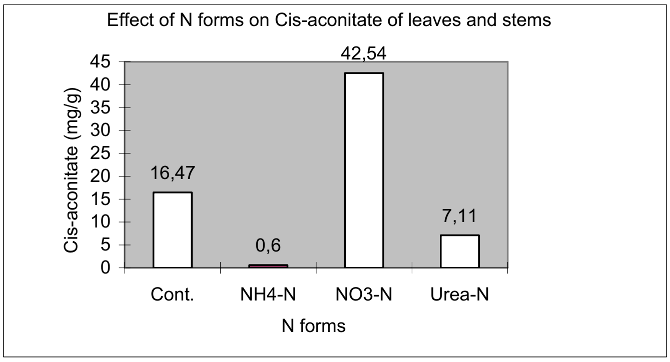


Figure 4: Effect of N forms on cis-aconitate content of leaves + stems
Abbildung 4: Effekt der N-Formen auf den Cis-Aconitat-Gehalt von Blättern und Stämmen

Results related to total amount of organic acids showed that NO_3-N treated plants had the higher concentrations in agreement with the reports of BERGMANN (1988).

In general, Glutamine, asparagines and alanine type of aminoacids are dominant in plants which belong to Gram-

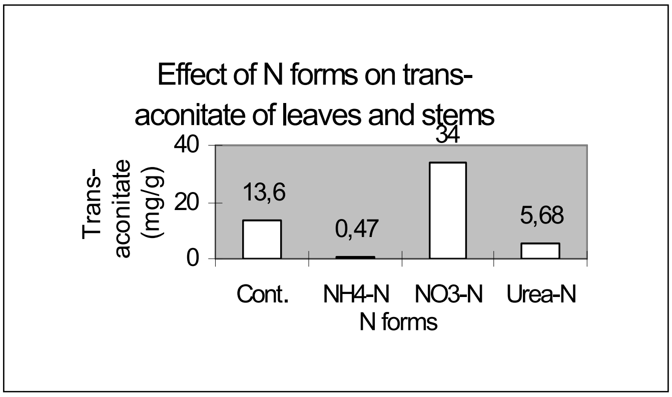
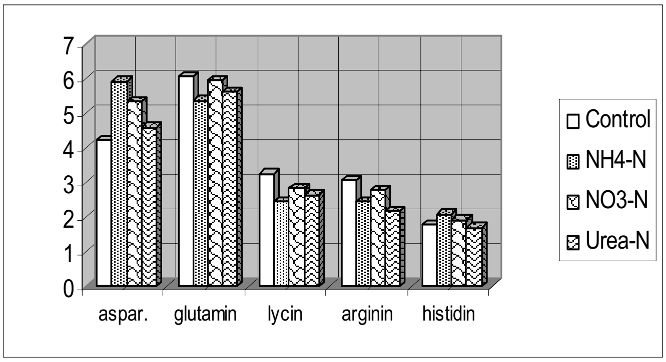


Figure 5: Effect of N forms on trans-aconitate content of leaves + stems

Abbildung 5: Effekt der N-Formen auf den Trans-Aconitat-Gehalt von Blättern und Stämmen

nie family (Figure 6, 7, 8) (MENGEL, 1991). The highest aminoacid was found in threonin, glycin, alanin, valin, isoleusin, leusin and tyrosin in NO_3-nitrogen.prolin in urea, asparagin and histidin in NH_4-nitrogen application was higher. In several studies conducted, it was determined



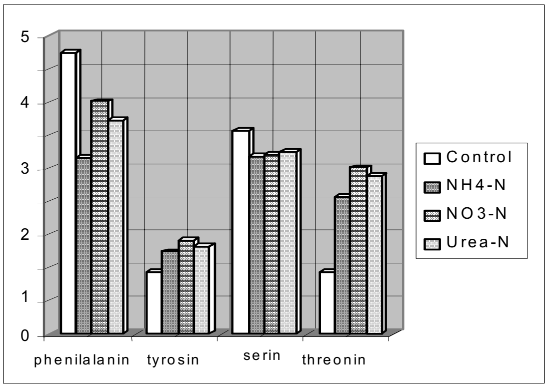


Figure 6: Neutral, aromatic and hydroxiaminoacids in the leaf + body samples of corn that is grown

Abbildung 6: Neutrale, aromatische und Hydroxie-Aminosäuren in Blatt- und Stammstichproben

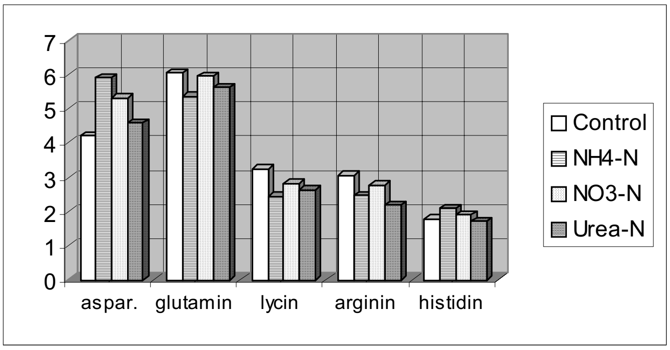


Figure 7: Acidic and basic aminoacids in the leaf + body samples of corn that is grown

Abbildung 7: Säure und basische Aminosäuren in Blatt- und Stammstichproben

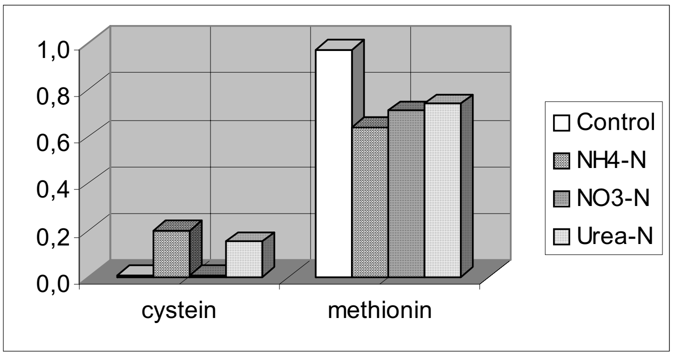


Figure 8: Aminoacids which contain sulphur, in the leaf + body samples of corn that is grown

Abbildung 8: Schwefelhaltige Aminosäuren in Blatt- und Stammstichproben

that NO_3-nitrogen increases the amount of aminoacid (SCHULZ et al., 1980; SCHRADER et al., 1972). In a study with corn in water culture conditions, it was determined that the glycine and aspartat increased the most in NO_3-N and NH_4-N applications respectively. BARKER and BRADFIELD (1963) also setted that the amount of aspartat increased in the leaf of corn in water culture conditions by NH_4-N application.

4. Conclusion

In this study, the following conclusions were found:

- Nitrogen applications (300 ppm) and N forms affected the maize leaf + stem and root biomass yield significantly. The highest canopy and root yield resulted with nitrate and urea treatments.
- Leaf + stem and root yields of the ammonium treatments

were found lower than in the control. Result proved that ammonium-nitrogen was toxic under water culture conditions.

- Results related to sugar fractions of leaf+stem proved the dominancy of β-Galactose and the presence of α-Galactose, Fructose and Saccarose.
- Malate and aconyte (cis and trans) organic acids were determined in leaf + stem parts of the maize plants. The highest aconyte content and the lowest malate were measured in nitrate forms of the nitrogen treatments.
- Although the amount of aminoacids were higher in compare to control, it has no statistical importance.

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References

BARKER, A. V. and R. BRADFIELD (1963): Effect of potassium and nitrogen on free amino acid content of corn plants. Agron. J. 55, 465–470.

BENNETT, W. F., J. PESK and J. J. HANWAY (1964): Effect of Nitrate and Ammonium on Growth of Corn in Nutrient Solution Sand Culture. Agronomy Journal 56 (3), 342–345.

BERGMANN, W. (1988): Ernährungsstörungen bei Kulturpflanzen. Veb. Gustav Fischer Verlag. Jena.

BRETELER, H. and A. L. SMITH (1974): Effect of ammonium nutrition on uptake and metabolism of nitrate in wheat. Neth. J. Agric. Sci. 22, 73–81.

BLAIR, J., M. H. MILLER and W. A. MITCHELL (1970): Nitrate and ammonium as Sources of Nitrogen for corn and their influence on the uptake of other ions. Agronomy journal 4, 530–532.

COIC, Y. (1964): Sur le determinisme del'absorbtion des cations mineraux par les genres et especes vegetales: Influence de la localisation du metabolisme de l'azote. Academic d'Agriculture de France. Extrait du proles-verbal dela scance du Juin, 925–932.

CRAMER, M. D., O. A. M. LEWIS and S. H. LIPS (1993): Anorganic carbon fixation and metabolism in maize roots as affected by nitrate and ammonium nutrition. Physiol. Plant 89, 632–639.

EVANS and WILDES (1971): Potassium and Its Role in Enzyme Activation. Proc. 8th Collog. int. Potash Inst. Bern, pp. 13–39.

EMIROĞLU, Ş. H. and R. MARQUARD (1984): Ertragleistung und Qualitätseigenschaften türkischer Erdnuss-Selektion im Vergleich mit internationalen Sorten. Fette. Seifen. Anstrichmittel 86 (3), 103–107.

EDIZDOĞAN ÖZDÖLEKLER, S. (1997): Değişik Seviyelerde Uygulanan Azotlu Gübrenin Silaj Olarak De erlendirilecek Mısır Bitkisinin Kimi Organik Asit ve Amino Asit Fraksiyonlarına Etkisi. E. Ü. Fen Bilimleri Enst. Toprak ABD. (Yüksek Lisans Tezi).

GERENDAS, J., R. G. RATCLIFFE and B. SATTELMACHER (1990): 31 P nuclear magnetic resonance evidence for differences in intracellular pH in the roots of maize seedling grown with nitrate or ammonium. J. Plant Physiol. 83, 399–407.

GRIEB, R. (1977): Einfluss von Fe und Mo auf den Gehalt an organischen und anorganischen Ionen in Mais und Sonnenblumen Pflanzen unterschiedlicher Chloroseanfälligkeit. Inaugural Dissertation, Justus-Liebig-Universität Gießen.

GORING, C. A. I. (1962): Control of Nitrification by 2-chloro-6-(Trichlorometyl) Pyridine. Soil Science 93 (3), 211–218.

GÜNEŞ, A. and M. AKTAŞ (1991): Mısır bitkisinde demir noksanlığının giderilmesinde nitrifikasyon inhibasyonunun etkisi.Toprak Ilmi Derneği, XI Bilimsel Toplantı Tebliğleri, 481–494, Antalya.

HAUNOLD, E. and J. ZVARA (1976): Translocation of N-15 labelled fertilizers in soil columns. Vortr. Agrochemicals in soil. Jerusalem.

HEHL, G. (1971): Der Einfluss der Ernährung und des physiologischen Alters auf den Kohlenhydratgehalt sowie die einzelnen Kohlenhydratfraktionen bei einigen Gramineen und Leguminosen. Dissertation. Justus-Liebig-Universität.Gießen.

IKEDA, M., K. MIZOGUCHI and T. YAMAKAWA (1962): Stimulation dark carbon fixation in rice and tomato roots by application of ammonium nitrogen. Soil Sci. Plant. Nutr. (Tokyo) 38, 315–322.

KACAR, B. (1972): Bitki ve Toprağın Kimyasal Analizleri II.Bitki Analizleri. A. Ü. Ziraat Fakıyayınları. 453. Uyg. K›lavuzu, 155.

KAFKAFI, U. (1990): Root temperature, concentration and the ratio NO_3, NH_4 effect on plant development. J. Plant Nutr. 13, 1291–1306.

KIRKBY, E. A. and A. H. KNIGHT (1977): The influence of the level of nitrate nutritionon on uptake and assimilation, organic acid accumulation and cation-anion balance in whole tomato plants. 60: 349–353.

MARSCHNER, H. (1995): Mineral Nutrition of Higher Plants. Second Edition. Academic Press. London.

MENGEL, K. (1991): Ernährung und Stoffwechsel der Pflanze. Gustav Fischer Verlag. Stuttgart.

NAUHOLZ, E. (1989): Photoreduktion von Fe im Zusammenhang mit dem Metabolismus organischer Säuren. Dissertation, FB 19 Universität Gießen.

NEUBELLER, J. and G. BUCHLOCH (1975): Zuckerbestimmung in Gartenbauprodukten im Hinblick auf die Qualitätsbildung. Mitteilungen Rebe und Wein Obstbau und Früchteverwertung. Klosterneuburg 25.

RICHTER, G. (1998): Stoffwechselphysiologie der Pflanzen. Thieme.

SAMATER, A. H., O. VAN-CLEEMPUT and T. ERTEBO (1998): Influence of the presence of nitrite and nitrate in soil on maize biomass production, nitrogen immobilization and nitrogen recovery. Biology and fertility of Soils 27 (2), 211–218.

SAATÇI, N. (1990): Die Wirkung neuer Fe Dünger auf Chlorose bei Weinreben (*Vitis vinifera* L.). Dissertation. Justus-Liebig-Universität. Gießen.

SCHALLER, K. (1993): Praktikum zur Bodenkunde und Pflanzenernährung. Band 2, Geisenheimer Berichte.

SCHRADER, L. E., D. DOMSKA, P. E. JUNG JR. and L. A. PETERSON (1972): Uptake and Assimilation of Ammonium-N and Nitrate and their ınfluence on the Growth of Corn (*Zea mays* L.) Agronomy journal 64.

SCHERER, H. W. (1978): Einfluss von Fe und Mn auf den Gehalt an Mineralstoffen und Organischen Säuren in Mais- und Sonnenblumenpflanzen. Dissertation. Justus-Liebig-Universität, Gießen.

SCHERER, H. W. and W. HÖFNER (1980): Einfluss von Fe- und Mn-Mangel auf den Kationen- und Anionengehalt von Mais und Sonnenblumen. Z. Pflanzenernährung und Bodenkunde 143, 26–37.

SCHULZ, E., H. J. OSLAGE and L. ANGELOWA (1980): Nutritive value of maize protein in new hybrides plant research and Development, volume II, Institute of Animal Nutrition, Federal Agricultural Research Centre, Braunschweig-Völkenrode, Germany.

SERNA, M. D. and R. BORRAS (1992): The influence of nitrogen concentration and ammonium/nitrate ratio on N-uptake, mineral composition and yield of citrus.Plant and Soil 147, 13–23.

THIBAUD, J. B. and C. GRIGNON (1981): Mechanism of nitrate uptake in corn roots. Plant. Sci. Lett. 22, 279–289.

TURAN, C. and B. YÜRÜR (1978): değişik azot taşıyıcılar ile mısır bitkisi kökünün iyon alınımı arasındaki ilişkiler. Ankara Üniv. Zıraat Fak. yıllığı, Cilt: 28. Ankara.

XU, Q. F., C. L. TSAI and C. Y. TSAI (1992): Interaction of potassium with the form and amount of nitrogen nutrition on growth and nitrogen uptake of maize. Journal of Plant Nutrition 15, 23–33.

ZAMYATINA, V. B. (1971): Nitrogen balance studies using N-labelled Fertilizers (based on nitrogen-15 studies in the USSR). In: Nitrogen-15 in soil-plant studies, 33–45. IAEA, Vienna.

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