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ASSESSING THE POLLUTION CAUSED BY EXCESSIVE NITROGEN FERTILIZATION

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ABSTRACT

A lyzimeter experiment was carried out to asses the most suitable form, rate and time of nitrogen fertilizer application and to follow up the potential pollution impact caused by excessive nitrogen fertilization. Corn (zeamaiz) (var. Giza 2) was cultivated and fertilized with ammonium sulfate (AS), urea (U), ammonium nitrate (AN) or ureaformaldehyde (UF)) at three rates of each (100,200,& 300 kg N/fed.), added either pre-planting or post-emergency**.**

Higher application rate of N fertilizer induced an increase in NO3-N concentration in the drainage water during the first 5 weeks which exceeds the permissible limits (>10mgN/L), where it was more pronounced by using fast release N fertilizers particularly at preplanting addition. Increasing N fertilization rate for all nitrogen forms used and application time increased foliage dry matter yield. However, delaying fertilization was most effective in increasing grain yield.

The efficiency of applied nitrogen was higher at the lowest application rate, however, efficiency of urea is less than that of other N sources. The efficiency of N was greater when it was applied post-emergency.

Increasing N application rate raised protein content, and soluble N (nitrate) which was higher than the permissible limit for human and animal consumption (>2mg NO3-N/ g dry weight) as well as decreased carbohydrate in the grain.

Nitrogen budget values were negative at post emergency application of the lowest N rate whatever its forms. Increasing N application rate raised N budget. The calculated N balance revealed that at the lowest rate of N fertilizer the highest proportion of N was taken up by corn crop, however, an increase in the application rate of N reduced its quantity utilized by the plants, and raised the amount remained in the soil to reach about 60% of N- inputs at the highest rate of application.

Finally, it could be concluded that the proper time of N fertilization was post-emergency and N rate must not exceed 200 kg N/fed for corn crop, where the higher rate can adversely reduce ground water quality and increase the risk of nitrate accumulation in plant tissue. The use of slow release N fertilizer could reduce the adverse effect of higher N application rates of other N- sources.

Key words: Nitrogen-fertilizers, corn-plants, pollution, nitrogen-budget, nitrogen-balance.

INTRODUCTION

Nitrogen is a major essential nutrient element and is required by plants in substantial quantities. It is most commonly the key limiting factor for crop production. Thus, on the average, considerably more N than any other element is supplied to crops as fertilizers and is removed from agricultural lands in harvested crops (Olson and Kurtz, 1982). However, excessive N applications are not only undesirable from an economic viewpoint since environmental and crop quality problems associated with excessive fertilizer N use are widely recognized (Keeney, 1982).

The proper use of N fertilizer includes the choice of fertilizer source as well as time and rate of N application to match the point of maximum uptake by the plant and reduce the negative effects of N fertilizers on the environment and lessen the ground water contamination.

With respect to the fertilizing values of various nitrogen sources, De Datta (1974) and Brady (1974) indicated that urea and ammonium sulfate fertilizers have shown to be satisfactory sources of nitrogen, while sulfur coated urea has proved in some cases to be superior than ordinary urea when both were applied as a basal treatment. However, Effat et al (1979) concluded that the highest dry weight of wheat plant, grown in clay soil, was obtained with ammonium nitrate treatment. Heggy et al (1987) reported that calcium nitrate was the best nitrogen sources for cereal crops, while, Genaidy et al (1991) and Omer (1996) illustrated that ammonium sulfate produced the highest yield of wheat, rice and cotton in both sandy and clay soils. Corn proved to be very responsive to nitrogen fertilization where, the grain yield increased gradually with increasing the rate of nitrogen. In this respect, Shalaby and Omar (1981) reported that corn grain yield, ear weight and plant height were increased with increasing N fertilization level. Hills et al (1983) reported that, the amount of N fertilizer for commercial corn yield was estimated to be 194 kg N/ha. However, Sidky (1984) and Genaidy et al (1987) reported that corn (var. Giza 2) produced the highest grain yield at level of N ranged from 93 to 120 KgN/fed. particularly as ammonium sulfate.

Many researches indicated that providing crops with too little N resulted in decreasing crop yield and poor economic returns, while providing them with too much N may result in the accumulation of mineral form of N (ammonia and nitrate) at the crop root zone which may be leached out from the soil causing contamination of ground and surface water supplies (Caporali et al, 1982 and Staver et al, 1989). Owens (1990) found that at high level of N fertilizer to maize plants grown in well drained lyzimeter, NO3-N concentration in percolate ranged from 15 to 40 mg/l which exceed the permissible limit of WHO (10 mg NO3-N /l).

The purpose of this study was to highlight the excessive use of nitrogen fertilizers and its impact on drainage water quality. It may focus on commonly used sources of N fertilizers (ammonium sulfate, urea and ammonium nitrate) compared to slow release N-one (ureaformaldehyde).

The proper management techniques to improve their efficiency and safeguard the environment will also be discussed.

MATERIALS AND METHODS

A lyzimeter trial (dimensions of 1x1x1m.) situated in a natural greenhouse at Agric. Res. Center, Giza-Egypt, was carried out during the summer season of 1999, using corn (Zea Mays L,cv Giza 2). The used soil was clayey in texture, having organic matter content 1.63 %, total nitrogen

0.098 %, the available forms of N,P, & K nutrients were found to be 45, 11.6 & 470 ppm in respective order, pH 8.5 (in 1: 2.5 soil- water suspension) and total soluble salts 0.16 %; according to the standard methods outlined by Chapman & Pratt (1961) and Jackson (1973).

The tested nitrogen fertilizers were: ammonium-sulphate (AS), ammonium -nitrate (AN) and Urea (U) as a fast N-fertilizers. Ureaformaldhyde (UF) as a slowrelease N-one, containing 41.27 % N and had an activity index about 66.35 % and water soluble N of 29.23 %.

Three rates of each of N-sources, i.e. equivalent to 100, 200 and 300 Kg N/ fed., were used compared with the control, given either pre-planting or post-emergency. All lyzimeters were subjected to common agricultural practices, with a basal application of 20 kg P2 O5 as calcium superphosphate (15 % P_2O_5) and 24 kg K_2O as potassium-sulphate (48 % K_2O) per fed. adeed befor cultivation, and using Nile fresh-water (EC = 0.41 mmhos / cm. & SAR = 0.80) for irrigation.

The leachate of each treatment was collected weekly. At expiry of growth season, plant and soil were sampled. Dry weight of foliage, cob and grain; ratio of grain to stover; total-N (Chapman & Pratt, 1961) and protein content of grain; soluble-N, using auto analyzer TM II; and grain carbohydrate content (Smith et al., 1956) were determined. Nitrate-N in both leachates and soil were estimated according to Jackson (1973).

RESULTS AND DISCUSSION

I-The effect of time, form and rate of N application on drainage water contamination:

Supplying crops with adequate N is vital to ensuring food supplies. However, providing crops with too much N may be results in the accumulation of nitrate and ammonia within the crop root zone, which may leach out form the soil causing contamination to drainage water.

The data presented in Figure 1 revealed that the concentration of nitrate in the leachate, and its distribution pattern throughout the growing season were affected by the time of nitrogen application, as well as its form and rate.

Concerning the effect of application time, it was noticed that early application of N fertilizer induced an increase in NO3-N concentration in the drainage water during the first five weeks of the growing season to be greatly higher than the WHO limits (10 mg N/l), and increased the total amount of NO3-N leached out during the whole growth season as it was indicated in fig2. However, delaying the application of N fertilization till the initial of rapid growth phase (post-emergency) minimize the concentration of NO3-N in the leachate and at the same time declined the total amount of NO3-N lost by leaching during the whole growth period. This could be attributed to that, post-emergency application coincides with the initial of rapid phase of plant growth and in turn the maximum of N requirements, thus declined N-losses through leaching while applying fertilizer early, most of it would be leached beyond the root zone before it could be used by the plant. In this respect,

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Olson and Kurtz (1982) found that, when N fertilizer was applied before or at planting, the potential for loss is greater than when it is delayed until near the time of crop need.

It could be noticed also that using slow release N- fertilizer (ureaformaldehyde) (UF) minimize the risk of drainage water contamination with NO3-N even at higher application rate (300 kg N/fed.). While appreciable amount of applied fast release N- sources was lost by leaching, particularly at early application of higher rates (200 and 300 kgN/fed.) with superiority of AN forms, causing a great contamination to drainage water, compared to the other two traditional N sources AS & U. This finding was in agreement with those obtained by several workers (Owens et al, 1992 and Gabris & Rakovsha, 1994).

II- Nature of plant responses to applied nitrogen:

Plant response to N fertilization may occur as dry matter yield as well as grain yield and quality.

II-1.Effect of N on yield component:

It was noticed from the data presented in table 1 that foliage dry matter yield was increased with increasing N- application rate for all studied N- forms and application times. Whereas cob and grain yields were decreased by increasing the added rate of fast release N- fertilizers (AS,U and AN) particularly when applied early (preplanting). These results indicated that, delaying fertilization was most effective, where the applied N will be available throughout the period of grain formation without being used earlier for vigorous foliage production. This was confirmed by the decrease in the grain/stover ratio obtained by early N fertilization compared to that of post-emergency. This was in accordance with Olson and Kurtz(1982). On the other hand, increasing rate of slow release N- fertilizer (UF) promotes yield formation to be higher than that obtained by any rate of fast release fertilizers, where the highest grain yield (230 g/plant) was obtained by pre-planting application of 300 Kg N/fed. as UF. This could be attributed to that UF provides a more permanent source of available N corresponds to the requirements of the plant during the whole growth period (Mengel and Kirkby, 1979).

II-2.Nitrogen efficiency:

A good measurement of N-efficiency is the amount of extra dry matter produced for each unit added of fertilizer nutrient. The values of the calculated N-efficiency (table 2) reflect that for grain yield the efficiency of applied N was higher at the lowest application rate whatever its form and time of application. However, each extra increase in fertilization rate reduced greatly the increment of dry matter accumulation in the grain per each fertilization unit to be negative at the two higher rates of traditional fertilizers (200 and 300 kg N/fed.) which means that extra fertilization restricts yield formation instead of promoting it. On the other hand, efficiency of fertilizer N was greater when it was applied at the most rapid rate of N-uptake by the plant.

Table (1): The effect of various nitrogen forms, rates and time of application on Maize yield component

Application time		Pre-planting				Post – emergency			
N- source	N-rate Kg/fed.	Dry weight (g/plant)			Grains/ stover	Dry weight (g/plant)			Grains/ Stover
		Foliage	Cob	Grain		Foliage	Cob	Grain	
Control	0	84	30	30	0.35	---	---	---	---
A.S.	100	150	34	180	1.20	136	34	200	1.47
	200	200	32	160	0.80	170	31	170	1.00
	300	270	30	119	0.44	200	28	150	0.75
U	100	160	38	170	1.06	140	40	190	1.35
	200	210	30	150	0.70	160	31	160	1.00
	300	290	30	100	0.34	210	31	130	0.62
A.N.	100	155	36	175	1.10	130	38	190	1.46
	200	200	32	150	0.75	180	33	175	.097
	300	270	32	110	0.40	200	29	140	0.70
UF	100	120	35	150	1.25	110	39	140	1.27
	200	180	42	200	1.10	150	45	180	1.20
	300	200	40	230	1.15	180	43	200	1.10

Table (2): The effect of various nitrogen forms, rates and time of application on nitrogen efficiency for grains and foliage

Application time	Pre-planting				Post-emergency			
N- rate (kg/fed.)	For grains							
	AS	U	AN	UF	AS	U	AN	UF
100	6.25	5.83	6.04	5.00	7.08	6.66	6.66	4.58
200	-0.83	-0.83	-1.04	2.08	-1.25	-1.25	-.062	1.66
300	-1.70	-2.08	-1.66	1.25	-.083	-1.25	-1.45	0.83
	For foliage							
100	2.75	3.16	2.95	1.50	2.16	2.33	1.91	1.08
200	2.08	2.08	1.87	2.50	1.41	0.83	2.50	1.66
300	2.90	3.33	2.92	0.83	1.25	2.08	0.83	1.25

Concerning N sources, it was noticed that efficiency of urea is less than that of other N fertilizers under study.

II-3. Effect of N on grain quality:

The predominant positive impact of N fertilizer on crop quality is in its enhancement of the total N content of crops. However, excess N tends to result in the accumulation of NO3-N in plant, which may be toxic to man and livestock if ingested in large amounts.

II-3-1. N fertilizer and grain protein content:

The data presented in Fig.3 revealed that increasing rate of N above those that give maximum grain yield (100kg/fed) induced a further increase in protein content of the grains. Thus, when higher rates of N depressed crop yield, a negative relation between grain yield and its protein content was observed. This relation was also demonstrated by Goh and Haynes(1984).

The obtained data exhibit no appreciable differences between various fast release N fertilizers (AS, U and AN) concerning their effect on protein content in the grain. However in the case of UF fertilization there was

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a positive relation between N application rate and both grain yield and its protein contents.

The data presented in Fig.3 revealed a reverse relation between carbohydrate and protein content in maize grain, where carbohydrate content was decreased by increasing N fertilizer application rate. This could be attributed to the fact that plant expends at many steps of N metabolism, a large amount of the energy it receives primarily in the course of photosynthetic phosphorylation and oxidative degradation of carbohydrate. In addition to that, during vigorous N-uptake most of carbon fixed in photosynthesis is spent in the biosynthesis of various protein compounds rather than carbohydrates.

II-3-2 Nitrate accumulation:

The accumulation of nitrate in plant parts is a natural phenomenon that occurs when the uptake of NO_3-N by the roots exceeds its reduction and subsequent assimilation within the plant. The amount, source and timing of N application all govern the effect of N fertilizer on NO_3-N accumulation.

The data presented in Fig. 4 revealed a direct relation between NO_3-N accumulation in the grains and N application rates for all N-sources and application time. At higher N application rate, NO3-N concentration in the plant tissue reached 3.16, 3.27, 3.45 and 2.39 mg NO3-N/ g plant fresh weight for preplanting application of AS , U, AN and UF respectively while the corresponding values for post emergency application were 3.7, 3.77, 3.65 and 2.4 respectively which exceeds the permissible limit for animal and human consumption (2 mg NO3-N/ g dry weight as cited by Mengel and Kirkby, 1979). However, Urea and AS fertilizers resulted in less accumulation of NO3 than AN fertilizer at each application rate. Moreover, the use of slow release N- fertilizer (UF) induced a further reduction in NO_3-N accumulation in the plant compared to all fast release N- ones. This could be attributed to the high available N release from the traditional fertilizers (AS,U and AN) which increasing the rate of N-uptake by plant than its assimilation rate (particularly at the higher fertilization rate) which results the accumulation of N-soluble form in the plant tissue. Pechova and Preugar (1985), Etman(1993) and El Mallah *et al.* (1998) obtained similar findings.

III-Nitrogen budget:

The nitrogen budget is important in evaluating the rule of nitrogen fertilization in the nitrate contamination of soils and ground water, and for more precise determination of the nitrogen doses to be applied under specific soil conditions.

The full N budget contains all the N transformation processes, inputs and outputs. The inputs are the applied fertilizers and available form of N in the soil, atmospheric deposition …. etc; while the main outputs are removal with harvested yield, leaching denitrification, and volatilization….. etc. There are also some internal processes as mineralization-immobilization.

N-budget presented in table (3) was calculated using the following equation:

N-Budget = - (Ni-No)+ Nf –Nnitrate

Where:
Ni =the amount of nitrogen taken up by the crop of certain treatment
No = the amount of nitrogen taken up by the crop of the control treatment
Nf = amount of N fertilizer given in the selected treatment
Nnitrate = the amount of nitrate-N in the soil

It could be noticed from this table that at lower fertilization rate (100 kg N/fed.) N-budget are negative in the case of post-emergency application of AS, U , AN or UF while at the higher application rate (200 kg N/fed.) the negative value of N-budget was obtained in the case of UF fertilization only. The negative N-budget means that the crop took more nitrogen from other soil resources such as the organic –N in soil. All other N fertilization treatments have a positive N-budget, which increased by increasing N fertilization rate. The positive N-budget means that the excess amount of N application either transferred to immobilized form biologically, or leached in the drainage water or lost by volatilization.

Table (3): Nitrogen budget as affected by various nitrogen fertilizer treatments

Application time	Pre-planting				Post-emergency			
N-rate (Kg/fed.)	AS	U	AN	UF	AS	U	AN	UF
100	3.46	3.65	2.66	-2.27	-4.00	-1.87	-3.89	1.10
200	9.90	11.74	8.67	-.077	2.64	2.13	2.03	2.79
300	17.28	18.66	15.02	1.828	3.39	5.16	7.43	7.75

VI-Nitrogen balance:

To investigate more adequately the nitrogen balance of different fertilizer treatments, all inputs and outputs parameters must be taken into consideration, for this purpose the following equation was used:

N balance = N input – N output
= (Initial soil N + amount of N given in the fertilizer) – (N uptake by crops + N leached + available N in the soil at harvest time).

The calculated N balance illustrated that, increasing nitrogen application rate whatever its form induced an increase in nitrogen balance which was higher in the case of pre-planting application compared to that of post-emergency. N- balance for slow release fertilizer was higher than that of fast release one at each application rate and time. The increase in nitrogen balance value indicated that this amount of nitrogen was either migrated down the root zone, or immobilized by microorganisms in the soil or lost by volatilization.

Representing all output items (N-uptaked by the crop, total amount of N leached and the total amount of N remained in the soil as available N) as a percentage of the summation of nitrogen in the soil at each fertilization level (Figs. 5, 6 and 7) revealed that, at the lowest fertilization rate of traditional sources of N (AS, U and AN) the highest proportion of N-input was taken up by the plant, which was true for the tow application time. However, increasing application rate of N decreased the proportion taken up by the plant where, at the highest application rates (200 and 300 kg N/fed.) the highest proportion of the applied N remained in the surface soil layer in the

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form of available N. This reveals that a heavy dressing of nitrogen fertilizer was less benefit to plants, and a high proportion of it remained in the soil, thus increasing the possibility of polluting the environment.

CONCLUSION

Finally, it could be concluded that optimum fertilization rate for maize lays between 100 and 200 kg N/fed., where excessive application of N fertilizer whatever its forms, can adversely impact ground water quality, in addition to the risk of nitrate accumulation in plant tissue. The proper time of application was post-emergency which corresponded to the requirement of the plant. Using slow release N- fertilizer can minimize the risk of using highest N application rate.

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تقييم التلوث المتسبب عن الإسراف فى استخدام الأسمدة النيتروجينية

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أجريت تجربة الأحواض الأسمنتية (1×1×1م) تحت الظروف الطبيعية للصوبة بمركز البحوث الزراعية بالجيزة بالموسم الصيفي لعام 1999م باستخدام تربة طينية ونباتات الذرة الشامية (صنف جيزة 2) وذلك لتقييم تأثير مصادر مختلفة من السماد النيتروجين (نترات الأمونيوم وكبريتات الأمونيوم واليوريا واليوريا فورمالدهيد) عند معدلات تكافؤ (100،200،300 كجم نيتروجين / فدان) أضيفت إما قبل الزراعة أو بعد ظهور البادرات ولتتبع تلوث مياه الصرف بالنيتروجين ولتحديد المصدر والمعدل والوقت الأمثل للتسميد بها.

وقد أوضحت النتائج أن المعدل الأعلى للسماد أدى إلى زيادة تلوث مياه الصرف بالنيتروجين خلال الأسابيع الخمس الأولى للإضافة حيث زاد عن الحدود المسموح بها وهى (الحد المسموح أقل من 10 مجم / لتر) وكان ذلك أكثر وضوحا باستخدام الأسمدة الآزوتية سريعة التحلل عند إضافتها قبل الزراعة.

زاد محصول المادة الجافة (للعلف) بزيادة معدل وقت التسميد فى جميع مصادر النيتروجين المختبرة وكان تأخير التسميد أكثر فاعلية فى زيادة محصول الحبوب ودلت النتائج على أن كفاءة الأسمدة المستخدمة كانت أعلى عند إضافتها بأدنى معدل بعد ظهور البادرة وأن اليوريا كانت أقل كفاءة عن غيرها.

زاد محتوى الحبوب من البروتين والنيتروجين الذائب (النترات) والذى كان أعلى عن الحد المسموح به للإنسان أو الحيوان (الحد المسموح به أقل من 2 مجم نيتروجين نتراتى / جم وزن جاف) وقلت الكربوهيدرات بزيادة معدل إضافة النيتروجين السمادى. وكانت الاستفادة الكلية للنبات من الأزوت المضاف عند التسميد فى مرحلة ما بعد ظهور البادرة بأدنى معدل أزوت سالبة وذلك بغض النظر عن المصدر الأزوتى المضاف وقد زادت هذه الاستفادة بزيادة معدل التسميد الأزوتى تحت الدراسة.

وأشارت نتائج الميزان النيتروجيني المحسوب إلى انه عند المستوى الأدنى للإضافة فان الجزء الأكبر من النيتروجين السمادى يمتص بواسطة النبات بينما زيادة معدلات التسميد أدت إلى نقص كمية النيتروجين المستخدم بالنبات وزيادة الكمية المتبقية منه بالتربة لتصل إلى حوالى 60% من النيتروجين المضاف عند أعلى مستوى للتسميد النيتروجيني تحت الدراسة.

ومن هذه الدراسة يمكن التوصية بأن الوقت المناسب لإضافة الأسمدة النيتروجينية هو ما بعد ظهور البادرات وأن معدل الإضافة لا يزيد عن 200كجم نيتروجين / فدان للذرة حيث أن المعدل الأعلى عن ذلك يؤدى إلى خفض جودة المياه الجوفية والى خطر تراكم النترات فى أنسجة النبات وأن استخدام أسمدة النيتروجين بطيئة الذوبان قد يقلل من التأثير الضار لمعدلات التسميد النيتروجيني العالية.