Spinach Yield and its Nitrate Content as Affected by Salinity and Nitrogen and Potassium Fertilization

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ABSTRACT

Two field experiments were carried out to investigate the effect of salinity in irrigation water, N-and K-fertilizers on fresh yield, total nitrogen, nitrate, reduced sugar contents and actual and potential nitrate reductase activity in spinach (Spinacia oleracea L.).

Salinity reduced remarkably all above parameters except reduced sugar which thereby was increased. Nitrogen fertilization increased yield parabolcally, total nitrogen linearly, NO_3^- exponentially, potential and actual nitrate reductase activity slightly, but noticeably decreased reduced sugars. Splitting N-fertilizer improved fresh yield but was indifferent to NO_3^- and reducing sugars. Splitting K-fertilizer also improved the yield but decreased both NO_3^- and reducing sugar.

Significant first order interactions of the experimental parameters were discussed.

INTRODUCTION

Spinach (Spinacia oleracea L.) has a high nutritional value because of its high leaf content of iron and Vitamin A, Chaney and Ross (1966).

Nitrogen fertilization increases spinach yield (Aworh et al., 1980; Bradley et al., 1975 and Maga et al.,1976); its chlorophyll and nutrients contents (Greig et al., 1968 and Maynard, 1970), as well as nitrate accumulation in leaves (Aworh et al., 1980; Barker et al., 1971 and Steingrover et al., 1982).

Nitrate accumulation in spinach occurs mainly in plants' leaves, when uptake of this anion exceeds reduction (Maynard and Barker, 1972 and Schrader, 1978). This process is reported to vary with plant species, variety and plant part (Barker et al.,1971; Maynard et al., 1976 and Supramanya et al.,1980); with environmental conditions such as soil aeration, light intensity and temperature (Blom-Zandstra and Lampe, 1985 and Viets et al., 1971).

Part of the nitrate ingested by man may be converted to nitrite, causing methaemoglobinia (Walton,1951 and Wright and Davison, 1964). Far more, nitrite in man's blood might lead to the formation of nitrosamines, which are carcinogenic (Craddock, 1983 and Craven, 1989). So far, many conflicting reports have been made on lethal doses of nitrate-N and nitrite-N for adults and infants. Sollmann (1948) claimed that 5 g. nitrate per day is dangerous for adults; whereas, Smith and Simpson (1957) reported that, for an adult, the fatal dose of potassium nitrate is 15-30 g. and of sodium nitrate is 10 g. In infants the fatal dose is 0.35-0.4 g. of sodium nitrite.

High yielding cultivars with low nitrate content in leaves would be, therefore, the goal of concerned research work.

This study aimed to find out the effect of salinity and ammonical and potassium fertilizers on nitrate and reduced sugar contents in spinach leaves.

MATERIALS AND METHODS

This study was carried out at the Experimental Farm of Alexandria University, Abiess area; in two successive seasons: in the first seeds were sown on October 5,1989 and in the second seeds were sown on October 13,1990.

Field plots, 2 x 2 m each, were used for carrying out two experiments on spinach (cv. Savoy) response to mineral fertilization and salinity. The soil was a clay loam containing 9.3 % calcium carbonate, 0.92 % organic carbon and 0.12 % total nitrogen. Its pH was 8.1 and the EC of saturated paste extract was 1.43 dS/m.

The first experiment comprised 4 treatments of N-fertilization x 3 treatments of salinity in irrigation water, all randomized completely in three blocks. N-fertilizer treatments were 0, 30, 60 and 120 kg N/acre, added as ammonium nitrate. Salinity levels of irrigation water were 0.7, 4.7 and 7.8 dS/m and was designated as S_0, S_1 and S_2, respectively. The first water was the ordinary canal water (a branch from Abiess canal) and the other two waters were obtained by mixing canal water with drainage water (EC = 9 dS/m) in the proper ratios. Drainage water was obtained from Abiess drainage canal. Maximum values for total N and NO_3-N in drainage water were 53 and 11 ug/L, respectively. Salinity treatments were applied after 3 weeks of emergence. All plots received the same amount of K_2SO_4 at a rate of 30 Kg K/acre, which, together with N-fertilizer, were split equally in two additions: one before planting and the other two weeks after emergence. Phosphorus was applied at a rate of 15 kg P_2O_5/acre, as superphosphate, before planting.

The second experiment comprised 3 treatments of N-fertilizer x 2 treatments of K-fertilizer x 2 treatments of salinity in irrigation water x 3 replicates. Nitrogen treatments included zero addition (the control), 120 Kg N/acre which was split into two equal portions: one before planting and the other two weeks after emergence; and the same rate but was split into 3 equal portions: one before planting, the second two weeks after emergence and the third 3 weeks later. Nitrogen fertilizer used was $(NH_4)NO_3$. The potassium fertilizer treatments included the addition of 48 Kg K/acre (as K_2SO_4), all before planting and the addition of the same amount but after splitting into three equal portions: one before planting, the other two weeks after emergence and the third 3 weeks later. The salinity treatments included irrigation with canal water (EC = 0.70 dS/m), and irrigation with canal water mixed with drainage water to give final electric conductivity of 4.00 dS/m.

For both experiments just before flowering, 20 plants were taken at randum from each plot, weighed, washed with ice-cold distilled water. Then samples were directly frozen and kept at -30°C until analysis.

Nitrate was determined in oven-dried and ground plant leaves, without midribs, using the nitrate electrode, according to the procedures of Paul and Carlson (1968) as modified by Barker et al. (1971). Total nitrogen in leaves was determined by the Kjeldahl method according to Horwitz (1975).

Nitrate reductase activity (NRA) assay, both the actual and potential activity were carried out according to the method of Jones and Shread (1977) as modified by Blom-Zandstra and Lampe (1983).

Reducing sugars were determined according to Schaffer and Somogyi (1933).

Physical and Chemical soil analyses were carried out according to Black (1965).

RESULTS AND DISCUSSION

Statistical analysis reveal significant variation in spinach fresh yield and its content of total nitrogen, nitrates, reduced sugar and both actual and potential nitrate reductase activity in leaves due to salinity in irrigation water, N- and K-fertilizers, on general, and also due to interactions between these factors.

Salinity Effect: Increasing irrigation water salinity from 0.7 to 7.8 dS/m depressed fresh yield by 32.2 %, total nitrogen content by 15.5 %, nitrate content by 58.8 % and both actual and potential nitrate reductase activity by 34.5 and 35.6 %, respectively. Whereas, reduced sugar was raised by 69.8 % (Table 1).

It may be noticed that the reduction in both actual and potential nitrate reductase activities due to salinity was almost equal to the percent reduction in fresh yield. Also, the decrease in nitrate contents was close to the rise in reduced sugars. Thus a decrease in nitrate content must have been attended by a concomitant increase in reduced sugars to maintain the osmotic pressure in plant cells. Reduced sugars, hence, may play a role in osmo-regulation as well as nitrate (Alberda,1965; Barlow, 1983 and Mott and Steward, 1972) and that one compensates for the other under osmotic stress conditions (Veen and Kleinendorst, 1985).

Nitrogen-fertilizer Effect: The addition of N-fertilizer resulted on a significant increase in spinach fresh yield (Tables 1 and 2). Nevertheless, increasing the rate of N-fertilizer brout about a serious diminished yield return; being 94, 32 and 9 % for the first, second and third rate (Table 1). Also, giving the same amount of fertilizer in one dose was less effective than in three equal doses, 14 % difference (Table 2).

Total nitrogen content increased almost linearly with N-fertilizer additions (Table 1). It was somewhat greater

Table 1: The general effect of irrigation water salinity, N-fertilizer on Spinach fresh yield, total nitrogen, nitrate and reduced sugars contents and on the actual and potential nitrate reductase (NRA) activities in 1989 season.

Factor	Fresh yield g/plant	Total N % of DM	NO_3^- g/100g leaves	Reduced sugars mg/g DM	NRA umol NO_2^-/g FW/hr. actual	NRA umol NO_2^-/g FW/hr. potential
Salinity dS/m						
0.70	55.7	4.34	0.743	62.2	0.93	1.28
4.70	44.4	4.13	0.364	86.0	0.86	1.11
7.80	37.8	3.67	0.302	105.1	0.60	0.84
L S $D_{0.05}$	2.25	0.235	0.156	1.66	0.017	0.025
N-fert. Kg N/acre						
0	22.1	3.53	0.172	98.8	0.55	0.91
30	42.9	3.92	0.324	89.3	0.57	1.10
60	56.8	4.21	0.514	83.7	0.59	1.13
120	62.2	4.53	0.868	69.2	0.61	1.15
L S $D_{0.05}$	2.59	0.27	0.181	1.92	0.019	0.029

with split than with single N-application (Table 2).

Nitrate contents increased, rather with acceleration, with N-fertilizer applications (though ammonium salt), being 2, 3 and 5 times that of the control treatment (Table 1). Splitting the fertilizer application showed the same effect as single application in this respect (Table 2).

Reduced sugar contents decreased steadily with every increase in N-fertilizer rate, being 23 to 30 % less than that of the control with 120 Kg N treatment (Tables 1 and 2).

Both actual and potential nitrate reductase activities increased, but very slightly, with the increase in N-fertilizer rate of application.

Summarizing, with respect particularly to the effect of N-fertilizer on yield and NO_3^- content, it may be concluded that 30 Kg N/acre resulted in doubling both yield and its NO_3^- content. Further additions of N-fertilizer resulted in lesser gain in yield associated with higher NO_3^- contents.

Potassium-fertilizer Effect: Table 2 shows that splitting the 48 Kg K/acre was more effective with respect to fresh yield and somewhat to total nitrogen contents, but decreased noticeably nitrate and reduced sugar contents.

Interactions' Effects: Salinity x N-fertilizer interaction effect on fresh yield, NO_3^- and reduced sugar contents and actual and potential NRA proved to be significant. However, this interaction effect on fresh yield, NO_3^- and reduced sugar contents were of somewhat measurable magnitude as shown in Fig. 1. Results shown in Fig. 1-A indicate that higher rate of N-fertilizer application was more effective on the yield at higher than at lower salinity levels. This would refer to a probable ameliorative effect as was observed with other crops (Soliman et al., 1986). The same interaction effect on NO_3^- content in leaves (Fig. 1-B) was found to be contrary to that on yield. With higher salinity, nitrate contents decreased relatively more at the higher than at the lower rate

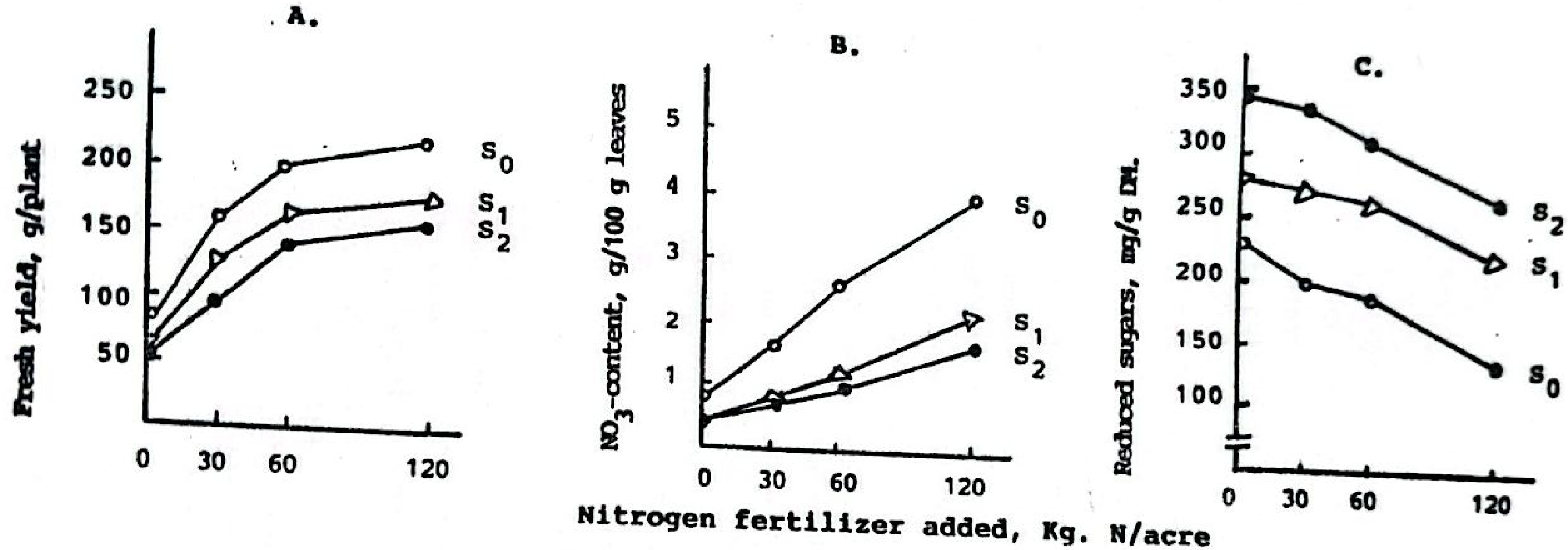

Fig. 1 : The interactive effect of irrigation water salinity and nitrogen fertilization on spinach fresh yield (A), nitrate content (B) and reduced sugar content (C) in leaves. S_0, S_1 and S_2 stand for the electric conductivity of irrigation water (EC_i), i.e. 0.7, 4.7 and 7.8 dS/m respectively.

of N-fertilizer application. In other words, with higher salinity (EC_i=7.8 dS/m) a higher rate of N-fertilizer dressing tended to raise yield but to lower the NO_3^- content, relatively. This is quite comprehensible as most of the uptaken nitrogen nitrogen by plant would then be assimilated in yield production. Interaction effect on reduced sugar contents (fig. 1-C) shows that at higher application of N-fertilizer reduced sugar content was more depressed at lower than at higher salinity level. Reduced sugar contents are negatively correlated to nitrate contents in leaves (r = -0.85). Under osmotic stress conditions, Veen and Kleinendorst (1985) reported a similar relation between nitrate and reduced sugars.

Salinity x N-fertilizer effect on actual and potential nitrate reductase activity showed that both activities increased relatively more at lower than at higher salinity levels as N-fertilizer addition was increased. This effect, however, was of very small magnitude that worths no presentation.

Salinity x K-fertilizer interaction effect on both NO_3^- and reduced sugar contents proved also to be significant. Reduced sugar content increased more appreciably by splitting K-fertilizer application at lower salinity level (EC_i=0.7 dS/m) than at higher salinity (EC_i= 4.0 dS/m), Table 3-A. Respective mean values were from 55.1 to62.3 % and from 81.8 to 83.6 %. Nitrate contents decreased more at lower than at higher salinity levels by splitting the fertilizer addition (Table 3-A). Parallel values were from 1.02 to 0.75 % and from 0.62 to 0.61 %, respectively.

N-fertilizer x K-fertilizer interaction effect was also found significant on NO_3^- and reduced sugar contents (Table 3-B). Nitrate contents did not differ when K-fertilizer was split in the zero N-fertilized plots, being 0.25 and 0.26 g per 100 g leaves. However, in the 120 Kg N/acre fertilized plots, whether N was split or not, nitrates increased greater in the one-dose K-fertilized plots than in the split three-

Table 2: The general effect of irrigation water salinity, nitrogen and potassium fertilizers on fresh yield and total nitrogen, nitrate and reduced sugar contents in spinach plants. in 1990 season.

Factors	Fresh yield g/plant	Total N % of DM	NO_3^- g/100g leaves	Reduced sugars mg/g DM
Salinity dS/m				
0.70	64.98	4.69	0.887	58.70
4.00	58.20	4.52	0.616	82.00
$L\ S\ D_{0.01}$	3.07	0.08	0.014	1.42
Nitrogen Kg N/acre				
0	28.63	3.69	0.252	112.20
3 x 40	83.17	5.23	1.033	86.60
120	72.97	4.89	0.969	85.30
$L\ S\ D_{0.01}$	3.76	0.09	0.017	1.74
Potassium				
3 x 16	63.52	4.68	0.687	68.50
48	59.67	4.53	0.816	73.00
$L\ S\ D_{0.01}$	3.07	0.08	0.014	1.42

Table 3: Interaction effects on nitrate and reducing sugar contents in leaves of spinach plants. Potassium fertilizer was added at a rate of 48 kg. K/acre in one dose (K_1) or the same amount after splitting into three equal doses (K_3).

A. Salinity of irrigation water and K-fertilization rates

Salinity dS/m	Potassium fertilization rates, Kg. K/acre			
	K_1	K_3	K_1	K_3
	NO_3^-, g/100 g leaves		Reduced sugars, mg / g DM	
0.70	1.02	0.75	55.1	62.3
4.00	0.62	0.61	81.8	83.6

B. Nitrogen fertilizer and potassium fertilizer

Nitrogen fertilizer Kg. N/acre	Potassium fertilization rates, Kg. K/acre			
	K_1	K_3	K_1	K_3
	NO_3^-, g/100 g leaves		Reduced sugars, mg / g DM	
0	0.26	0.25	82.15	84.2
120	1.07	0.87	61.65	68.20
3 x 40	1.13	0.94	61.55	66.45

dose K-fertilized plots, being 1.2 and 89 %, respectively. The situation with reduced sugar contents was contrary to NO_3^- behavior. In the N-fertilized plots sugar content declined greater in the one-dose than in the 3-dose-K-fertilized plots, being from 68.20 to 61.65 % and from 66.45 to 61.55 %, respectively.

From the presented data, two issues may be envisaged for commercial growers and practical applications. Firstly, potassium salts, either sulfate or chloride, could be broadcast at a very low rate before the last irrigation of spinach crop. This is to reduce high NO_3^- content and, thereby, to improve the quality of the yield. Secondly, although small losses in spinach yield under low saline conditions ($EC_i < 4.0$ dS/m), it is still economical to produce a crop with good quality, i.e. with low nitrate content under this range of salinity in irrigation water. However, precautions must be taken over to prevent any gradual accumulation of salts in soil profile.

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تأثير ملوحة ماء الري التسميد الازوتي والبوتاسي محصول السبانخ ومحتواها من النترات

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الملخص العربي

اجريت تجربتان حقليتان خلال موسمى ١٩٨٩ ، ١٩٩٠ لدراسة تأثير ملوحة ماء الري والتسميد الازوتي والبوتاسي على محصول السبانخ ومحتواها من النتروجين الكلى والنترات والسكريات المختزلة وأيضا نشاط أنزيم Nitrate reductase activity (NRA)

وأظهرت النتائج أن ملوحة ماء الري لها تأثير واضح فى أختزال كمية المحصول ومحتواه من النتروجين الكلى والنترات وأيضا نشاط (NRA) بينما محتوى أوراق السبانخ من السكريات المختزلة ازداد طرديا مع زيادة ملوحة ماء الري المستخدمة. التسميد الازوتي أدى الى زيادة المحصول الخضرى ومحتواه من النتروجين الكلى والنترات ونشاط أنزيم (NRA) ولكنه قلل السكريات المختزلة.

وقد وجد أن اضافة السماد الازوتي على دفعات أثناء نمو المحصول ساعد على تحسين المحصول الخضرى ولكنه لم يؤثر فى محتوى الاوراق من النترات أو السكريات المختزلة بينما اضافة السماد البوتاسي على دفعات أدى ذلك الى تحسين فى المحصول الخضرى مع نقص محتوى الاوراق من النترات والسكريات المختزلة . وقد تم ايجاد ومناقشة التداخل بين تلك العوامل .