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Influence of some Alternative Nitrogen Sources and Regimes on Two Salad Cabbage Cultivars

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Abstract: Two-year trials were carried out on two salad cabbage cultivars [Glob Master (green white) and Ruby Perfection (red)] in new reclaimed sandy soil, to investigate the effect of three nitrogen fertilizer regimes (14, 17.5 and 21 g N/ m^2) and three nitrogen sources (ammonium sulphates "21.5% N', ammonium nitrate "33.5% N" and urea "46.5% N"), on vegetative growth, productivity, head quality parameters and nitrate accumulation. The results proved that cabbage heads of plants received ammonium sulphate treatments accumulated the lowest nitrate contents compared to the other nitrogen sources. The best results of productivity head weight were obtained with the medium levels of ammonium sulphate application with preference of the medium level as for low nitrate accumulation. Ammonium nitrate ranked the second nitrogen source, while urea was the latest one. The medium nitrogen fertilization level (17.5 g N/ m^2) seemed to be the optimum regime for cabbage under new reclaimed sandy soil condition.

Key words: Alternative nitrogen source, salad cabbage, vegetative growth and yield

INTRODUCTION

Cabbage is one of the most important leafy vegetables in Egypt, since its cultivation area was about 42942 Fadden (18036 ha) in 2005 year. Most of this area (11396 ha) was cultivated in the winter season, 3662 ha in summer season and 2977 ha in fall season. Recently, cabbage cultivation area in new reclaimed sandy soil regions is going to increase rapidly, it was about 1377 ha in 2005 year (Agric. Econ. Inst.,2006), and nitrogen fertilization strategy is the most confusion point for cabbage grower. The optimum N-form and application level must be found out to produce the higher yield and good head quality. Head compactness and its nitrate contents are the most important characters in concept of cabbage head quality. Moreover, the nitrate residues in cabbage and other leafy vegetables became one of the most critical issue. Since, the acceptable daily intake (ADI) of nitrate is between 0 and 3.65 mg kg-1 of body weight (WHO, 1995). According to this ADI, only 100 g of raw vegetables (with a NO_3 concentration of 2500 mg kg fw-1) accounts for an intake of 250 mg NO_3. Hence, if a 60-kg person consumes this amount alone, the ADI for NO_3 will be exceeded by 14% (Gonnella *et al.,* 2004). Nitrate upon reduction to nitrite can cause methaemoglobinaemia or act as precursor in the endogenous formation of carcinogenic nitrosamines. The leafy vegetables are the major vehicle for the entry of nitrate into the human system. About 87% of the total nitrate concentration in a normal diet is believed to be a direct result of vegetable intake (Prasad and Chetty, 2008).

This investigation was carried out to determine the optimum nitrogen fertilization strategy for summer cabbage cultivation in new reclaimed sandy soils, to produce the highest yield, best head quality, with acceptable NO_3 concentration.

MATERIALS AND METHODS

Two field experiments were carried out during the two successive seasons of 2006 and 2007 in sandy soil of new reclaimed area, National Research Center Experimental station at El-Bostan region, to investigate the response of two cabbage cultivars (Glob Master & Ruby Perfection) to three N- forms (ammonium sulphate 21.5% N, ammonium nitrate 33.5% N and urea 46.5% N)and three nitrogen application levels (14, 17.5 and 21 g N/ m2). Seed sowing was on December 1, transplants were set up in the field on January 18 in both

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growing seasons. During soil preparation, a mixture of 1 m3 of farm yard manure, 20 kg calcium super phosphate (15.5% P2O5), 5 kg potassium sulphate and 1.5 kg magnesium sulphate were applied per 200 m^2 of the soil, as basic fertilizers. In the middle of growing season, a mixture of 5 kg potassium sulphates and 1.5 kg magnesium sulphate were applied / 200 m2 of the soil, as top dressing near by the drippers. The amount of N- fertilizers was divided into six equal parts and applied as top dressing near the drippers every 15 days starting 10 days after transplanting. The eighteen treatments were adapted in split split plot design, with three replicates. The cultivars were placed in main plots, N-forms in sub plots and N-levels in sub subplots. After 90-110 days from transplanting, harvesting was carried out upon head maturity. At harvesting time, number and weight of outer non-wrapper leaves, as well as head weight, diameter and length were recorded. Moreover, nitrate content was determined by sap analysis with a NO_3 quick-test using the "Merckoquant" test strips as recommended by Alt and Full (1988), Szwonek (1988) and Hanafy *et al.* (1997). Also head shape index (length / diameter), net head percent (head weight / whole canopy weight X 100) , and head yield were calculated.

Data were subjected to the statistical combined analysis of ANOVA, and the means were compared according to Duncan multiple range test Alpha=0.05, as reported by Gomez and Gomez (1984). All statistical analyses were performed with SAS computer software. The combined analysis of the two years of this investigation, was conducted since the results took the same trend in both two investigation years.

RESULTS AND DISCUSSION

Vegetative Growth:

Data in Table (1) and Appendix (1) show the combined analysis of two investigated years of cabbage cultivars, nitrogen forms, rates and their interaction, effects on cabbage vegetative growth parameters,i.e.,whole canopy weight and non wrapper leaf number and weight.

Data revealed that Glob Master plants had a vigorous growth than those of Ruby Perfection. The differences between two cultivars were significant at probability less than 0.01. Also, cabbage plants which fertilized with ammonium sulphate recorded the greatest values of growth parameters than those received ammonium nitrate or urea forms. Also, the application of highest nitrogen level (21 g N / m^2) statistically increased cabbage plant growth followed by the medium level (17.5 g N / m^2) meanwhile, the lowest rate (14 g N / m2) gave the lowest growth parameter values.

As for the combined statistical analysis of the data, results also, indicated that the interactions among cabbage cultivars, nitrogen rates and forms were significant. In other words, the investigated factors had dependent effect on cabbage vegetative growth character. These results were true all over the growing seasons.Application of 21 g N / m^2 Ammonium sulphate for Glob Master plants was the best treatment.

Yield Parameters:

The effects of cabbage cultivars, nitrogen forms, rates and their interaction on yield parameters are shown as combined analysis in Table (1) and Appendix (1).

Glob Master plants recorded higher net head weight, net head percent and net yield than those of Ruby Perfection. The differences between the two cultivars were very high significant at probability less than 0.01. As for the nitrogen form effects, plants fertilized by ammonium sulphate recorded the highest net head weight, net head percent and net yield / m^2 than those received ammonium nitrate or urea form. The differences among nitrogen forms were significant at probability of 0.001.

Concerning the effects of nitrogen application rates on cabbage yield, application of the highest rate of nitrogen resulted in very high statistical increases of cabbage net head weight, net head percent and net yield / m^2, since it recorded the greatest values, followed by medium rate while, the lowest rate gave the lowest values.

The combined statistical analysis of data indicated that the interaction between cultivars and nitrogen forms was often significant. The interaction between cultivars and nitrogen rates was significant. The interactions among cabbage cultivars, nitrogen rates and nitrogen forms were significant. Glob Master plants which receive ammonium sulphate at the highest level gave the highest valuesof net head weight and yield.

Similar results were reported by Meena and Paliwal (2003), who found that all growth and yield parameters were increased with increasing N levels (100, 125 and 150 kg/ha). Moreover, Sharma *et al.* (2005) reported that nitrogen application increased the number and weight of non-wrapper leaves per plant, head length and width, gross and net head weight per plant and yield. Moreover, these results matched well with those of Choudhary and Choudhary (2005), whom investigated the effect of different N levels (100, 150, 200 and 250 kg N/ha) on the growth, yield and quality of cabbage. They stated that cabbage vegetative growth prameters "plant height, plant spread and number of outer leaves per plant" increased considerably with increasing N rates.

Table 1: The influence of cultivars, nitrogen forms and rates on cabbage vegetative growth and yield parameters.

Treatment	Whole canopy weight (g)	Non-wrapper leaves		Net head weight (g)	Net head percent % (W/W)	Net head yield (Kg/m^2)
		Number	Weight (g)			
			Cultivars "*cv*"			
Glob Master	2777.00^a	13.63^b	721.11^a	1992.93^a	72.91^a	21.654^a
Ruby Perfection	1633.56^b	15.11^a	603.96^b	1029.59^b	62.60^b	10.983^b
			Nitrogen forms "*NF*"			
Ammonium sulphates	2388.72^a	15.06^a	725.39^a	1663.33^a	68.74^a	17.743^a
Ammonium nitrate	2174.44^b	13.56^b	687.22^a	1487.22^b	60.92^b	15.864^b
Urea	2052.67^c	14.50^b	575.00^b	1383.22^c	67.59^b	15.347^c
			Application rates "*AR*"			
14 g N/ m2	1895.33^c	13.56^b	618.72^b	1276.61^c	65.76^c	13.618^c
17.5 g N/ m2	2224.44^b	14.78^a	668.89^{ab}	1555.56^b	68.00^b	16.593^b
21 g N/ m2	2496.06^a	14.78^a	700.00^a	1701.61^a	69.50^a	18.744^a
			Significance levels			
Cultivars	***	***	***	***	***	***
Nitrogen Form	***	**	***	***	***	***
Application Rate	***	**	NS	***	***	***

NS= significant at 5 % *= significant at 5 % **= significant at 1% ***= significant at < than 1%

Table 2: The influence of cabbage cultivars, nitrogen forms and rates on head diameter, length , head shape index and NO_3 content.

Treatment	Head Diameter (cm)	Head Length (cm)	Head Shape Index	NO_3 content mg/ Kg
		Cultivars "CV"		
Glob Master	19.59^a	11.20^b	0.57^b	1216.42^b
Ruby perfection	10.40^b	12.99^a	1.25^a	1424.44^a
		Nitrogen Forms "*NF*"		
Ammonium Sulphates	15.59^a	12.20^a	0.89^b	1043.40^c
Ammonium Nitrate	14.80^b	12.05^a	0.92^a	1658.90^a
Urea	14.59^b	12.04^a	0.94^a	1258.99^b
		Application Rates "*AR*"		
14 g N/ m2	14.48^b	11.85^b	0.94^a	712.31^c
17.5 g N/ m2	14.57^b	11.73^b	0.91^{ab}	1305.18^b
21 g N/ m2	15.94^a	12.72^a	0.90^b	1943.80^a
		Significance levels		
Cultivars	***	***	***	***
Nitrogen Form	***	Ns	**	***
Application Rate	***	***	0	***

NS= significant at 5 % *= significant at 5 % **= significant at 1% ***= significant at < than 1%

Cabbage Head Quality:

The effected of cultivars, nitrogen forms, rates and their interaction on head diameter, length, shape index and compactness are shown in Table (2) and Appendix (1).

The data revealed that Glob Master head recorded higher value of head diameter and compactness index, than those of Ruby Perfection. Meanwhile, the heads of Ruby Perfection higher had head length and shape index than those of Glob Master cultivar. The differences between two cultivars were very high significant for all head quality parameters.

As for nitrogen forms, plants received ammonium sulphate recorded the highest head diameter, length and compactness than those received ammonium nitrate or urea form. However, application of urea highly significantly increased cabbage head shape index in comparison with other nitrogen forms. The influences of nitrogen forms on head diameter and compactness index were very highly significant. However, there were no significant effect for nitrogen forms on head length.

Application of the highest nitrogen rate recorded the highest values of head diameter and length, compared to medium or lowest rates. Meanwhile, the lowest nitrogen application rate resulted in the highest head shape index value, followed by the medium rate and the highest rate. The differences among nitrogen levels were very highly significant for head diameter, length but was significant at only 5% probability for head shape index.

These results matched well with those of Choudhary and Choudhary(2005), Gupta and Samnotra (2004) who studied the effect of nitrogen levels and bio-fertilizers and reported that, the application of 90 kg N + *Azospirillum* resulted in the greatest head diameter,head weight and yield.

Nitrate Contents:

The effects of cultivars, nitrogen forms, rates and their interaction on nitrate content of cabbage plants are shown in Table (2) and Appendix (1).

Appendix 1: The influence of interaction among cultivars, nitrogen forms and rates on cabbage vegetative growth, yield parameters, head quality and nitrate contents.

Cultivate "*CV*"	N-Forms "*NF*"	N-Rates "*AR*"	Canopy weight (g)	Non-Wrapper Leaves		Net Head weight (g)	Net Head percent % (W/W)	Net Head yield (Kg/m^2)	Head Diameter (cm)	Head Length (cm)	Head Shape Index	NO_3 content mg/ Kg
				Number	weight (g)							
Globe Master	Ammonium Sulphate	Low	2540.67^{de}	14.33^{bcd}	796.67 ^{b}	1800.00 ^{bc}	69.30 ^{d}	19.201 ^{f}	19.93 ^{bc}	10.63^{gh}	0.54^{e}	621.86^{i}
		Medium	3060.00^{b}	17.00^{ab}	800.00 ^{b}	2260.00 ^{a}	73.86 ^{bc}	24.107 ^{c}	20.17 ^{b}	11.40^{efg}	0.57 ^{de}	948.99 ^{j}
		High	3400.00^{a}	14.00^{cd}	953.33^{a}	2446.67 ^{a}	71.96 ^{c}	26.099 ^{a}	21.17 ^{a}	12.20^{cde}	0.58^{de}	1233.14 ^{h}
	Ammonium Nitrate	Low	2160.00^{f}	13.33^{cde}	706.67^{bcd}	1453.33 $^{c\ d}$	67.28 ^{e}	15.503 ^{g}	17.93 ^{e}	10.13^{h}	0.57^{de}	696.50^{l}
		Medium	2583.33^{de}	12.67^{de}	680.00^{bcdef}	1903.33 ^{b}	73.69 ^{bc}	20.303 ^{e}	18.13 ^{e}	9.97 ^{h}	0.55^{de}	1501.55 ^{e}
		High	3130.00^{b}	13.67^{cde}	743.33 ^{bc}	2386.67 ^{a}	76.26 ^{a}	25.459 ^{b}	20.50 $^{a\ b}$	10.84^{fgh}	0.53^{e}	2504.14 ^{b}
	Urea	Low	2546.33^{e}	12.67^{de}	640.00 ^{bcdef}	1906.33 ^{b}	74.87 ^{ab}	20.335 ^{e}	19.13 $^{c\ d}$	11.60^{defg}	0.61^{de}	639.86^{l}
		Medium	2870.00^{c}	13.67^{cde}	670.00 ^{bcdef}	2200.00 ^{a}	76.65 ^{a}	23.467 ^{d}	18.67 $^{d\ e}$	11.53^{efg}	0.62^{d}	1192.17 ^{h}
		High	2646.67^{d}	11.33^{e}	500.00 ^{f}	1580.00 $^{c\ d}$	72.29 ^{c}	20.410 ^{e}	20.67 $^{a\ b}$	12.50^{cd}	0.61^{de}	1609.59 ^{e}
Ruby perfection	Ammonium Sulphate	Low	1442.33^{i}	14.00^{cde}	489.00 ^{f}	953.33^{hij}	66.06 ^{f}	10.169 ^{k}	10.67 ^{g}	12.70^{bc}	1.20^{c}	631.39^{l}
		Medium	1736.67^{h}	15.00^{bcd}	616.67 ^{bcdef}	1120.00^{ghi}	64.49	11.947 ^{i}	10.50 $^{f\ g}$	12.73^{bc}	1.22^{bc}	1087.70 ^{i}
		High	2096.67^{f}	16.00^{bc}	696.67 ^{bcde}	1400.00^{cdf}	66.78 ^{e}	14.934 ^{g}	11.10 ^{f}	13.55^{ab}	1.22^{bc}	1737.36 ^{d}
	Ammonium Nitrate	Low	1470.00^{i}	13.67^{cde}	566.67^{bcdef}	903.33^{ij}	61.45 ^{gh}	9.636 ^{k}	10.07 $^{f\ g}$	14.28^{a}	1.42^{a}	900.27 ^{j}
		Medium	1756.67^{h}	13.33^{cde}	696.67 ^{bcde}	1060.00^{ghi}	60.35 ^{hi}	11.307 ^{j}	11.10 ^{f}	13.50^{ab}	1.20^{c}	1716.35 ^{d}
		High	1946.67^{g}	14.67^{bcd}	730.00 ^{bc}	1216.67^{efg}	62.51 ^{g}	12.978 ^{h}	11.07 ^{f}	13.60^{ab}	1.23^{bc}	2634.58 ^{a}
	Urea	Low	1156.67^{k}	13.33^{cde}	513.33 ^{def}	643.33^{k}	55.61	6.862^{m}	9.13	11.73^{def}	1.29^{b}	784.02 ^{k}
		Medium	1340.00 ^{j}	17.00^{ab}	550.00 ^{cdef}	790.00 $^{j\ k}$	58.96 ^{i}	8.427^{l}	8.83	11.23^{efg}	1.27^{bc}	1384.31 ^{g}
		High	1756.33^{h}	19.00^{a}	576.67 ^{cdef}	1179.67 $^{f\ g\ h}$	67.18 ^{e}	12.584 ^{h}	11.13 ^{f}	13.62^{ab}	1.22^{bc}	1943.98 ^{c}
	Cv x NF		***	***	***	Ns	***	***	***	***	**	Ns
	Cv x AR		***	***	Ns	0	***	***	0	Ns	0	***
	NF x AR		***	Ns	Ns	***	0	***	**	0	**	***
	Cv x NF x AR		***	Ns	Ns	***	***	***	0	Ns	Ns	***

NS= significant at 5 % *= significant at 5 % **= significant at 1% ***= significant at < than 1%

Concerning the cultivar effects, data showed that Ruby Perfection plants recorded higher value of NO_3 content than those of Glob Master. The differences between two cultivars were significant at probability of 0.001.

As for nitrogen forms, the results indicated that the cabbage plants received ammonium nitrate recorded the highest NO_3 value, followed by urea treatment and then ammonium sulphate. The differences among nitrogen forms were also very highly significant (at probability of 0.001).

Looking at the N application rate effects on nitrate content, it was clear to notice that increasing nitrogen application rate resulted in raising up nitrate accumulation in cabbage head, the highest NO_3 content was obtained when the highest application rate was used, meanwhile the lowest value was recorded with the lowest application rate. The nitrogen application rate effects on nitrate contents was very highly significant. The interactions indicated also that the lowest NO_3 values were obtained by the application of low N levels, regardless of N form .

Similar results were reported by Grigorov *et al.* (2005) who reported that the best head quality was obtained with the highest fertilizer rate. They also added that nitrate content in all variants was within the allowable concentration. Also, Turan and Sevml (2005) studied the effects of different nitrogen (N) sources and levels on NO_3 content in cabbage and reported that nitrate content of plants increased with the increasing N application, especially with nitrate fertilizer. Ammonium sulphate application at 250 kg N ha-1 was the most suitable fertilizer application rate for plant quality according to lower risk yields of plants (2650 g plant-1) for human nutrition. Moreover, Al-Moshileh *et al,* (2004) investigated the effects of different nitrogen sources " potassium nitrate, calcium nitrate, urea and chicken manure" at the level of 100 Kg N / ha, on yield and nitrate accumulation in lettuce and cabbage plants. They found that the use of NO_3 fertilizers in growing vegetable production resulted in an accumulation of NO_3 in the plants when uptake exceeds assimilation, meanwhile the lowest values for NO_3 were achieved with urea followed by chicken manure fertilizer treatment. In addition, Abdel-Alim (2005) investigated the nitrogen fertilization rates in Egypt, using the application rates of 50, 80, 100 and 120 kg N /fed "fed =4200 m^2". It was reported that to get an economic cabbage yield with allowable nitrate content concentration, cabbage plants must be supplied with nitrogen at 80 kg N / fed. (About 19 g N / m^2).

Conclusion:

It could be concluded that the optimum nitrogen fertilization strategy under the new reclaimed sandy soil for green white head cabbage *cv,* Glob Master and red cabbage, Ruby Perfection, is the application of 21 g N/ m2 (210 kg / ha or 88-90 kg / fed), in the form of ammonium sulphate or 17.5 g N/ m2 as urea, since those treatments gave an economic net yield with good head quality and allowable nitrate content concentration in the produced head, in comparison with all investigated nitrogen fertilization strategies.

Further investigation should be carried out to investigate the possibility of using mixed inorganic nitrogen sources as well as mineral and organic N sources in combination with bio-fertilizers in propose of producing economic yield, better quality and lower NO_3 contents.

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