

UDC: 633.43:631.559]:631.84
original scientific paper



Acta Agriculturae Serbica, Vol. XIII, 26 (2008) 105-114

Yield Components of Carrot as Affected by Nitrogen Fertilization

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Abstract: Throughout the growing seasons of 2005 and 2006, vegetation trials investigating two carrot genotypes (cv. *Nantes* and *Almaro F₁* hybrid) were set up to identify the effect of nitrogen on carrot productivity. The trial, established on an eutric vertisol, included four treatments involving increasing nitrogen application rates (0, 60, 120 and 180 kgN/ha). The research focused on monitoring the effect of nitrogen on individual root weight, total yield and marketable root yield. The application rate of 120 kgN/ha proved to be the most effective in enhancing individual root weight and producing the highest yields in the cultivar studied, the 60 kgN/ha rate showing the highest efficacy in the hybrid. The marketable root yield, as well as the proportion of high-quality roots in the total yield in both genotypes studied were found to be the highest at the lowest nitrogen rate (60kgN/ha) applied.

Key words: carrot, nitrogen rates, individual root weight, yield, marketable root.

Introduction

The carrot (*Daucus carota* L.) is an important vegetable crop widely used in the human diet. It is a source of vitamins and minerals, primarily of carotene, i.e. provitamin A, which is often lacking in the human diet. Owing to its pronounced nutritional and medicinal properties, it is used in food, pharmaceutical and cosmetics industries. Moreover, it provides all the nutrients essential for the nutrition of infants and young children. Being nitrophilous vegetable species, carrots demand fertilization as a major technological operation aimed at obtaining high-yield quality crops by

applying adequate nitrogen rates under specific environmental conditions (Dzamic and Stevanovic 2000).

Individual root weight is one of the most important yield components that is directly dependent on fertilization rates, as confirmed by the results obtained by Pavlovic *et al.* (2004). In his research on two carrot cultivars, Stanhill (1977) reported the root weight to range from 65.4 to 97.1 g and the root size, measured by weight, from being small (up to 60 g) to medium (from 60-150 g) or large (from 150-220 g). The average yield of carrot is directly dependent on individual root weight and determined by the cultivar used, agroenvironmental conditions, fertilization rates, primarily nitrogen ones and other factors. As reported by Zdravkovic (1988), the average yield ranges from 35.2-86.4 t/ha (cultivar) and 56.7-78.8 t/ha (hybrid), whereas Krasnic (1998) registered the yield of 42,375 kg/ha. In most investigations, the highest efficacy was produced by nitrogen application rates ranging from 80-120 kg/ha. The carrot root used in the human diet should meet specific market requirements in terms of morphological, production and technological traits, suggesting that the first-class, i.e. marketable root should account for more than 80% of the root yield (McCall and Moller 1999). Pavlovic and Jevdjovic (2002) explain that different deformities of a carrot root, root splitting and root rot, mostly inducing a lower proportion of marketable root, are due to excess moisture in the soil as well as to a sudden increase in soil moisture following soil moisture deficiency, suggesting the permanent need for a moderately moist soil. Furthermore, rising nitrogen rates lead to increased root splitting (Afsar *et al.* 2003).

Given the high nutritional quality of carrot and its role in the human diet, the objective of the present paper was to examine the effect of different nitrogen fertilization rates on the yield and yield components of two carrot genotypes.

Material and Methods

The experiment was conducted at the Village of Miokovci near Cacak, on eutric vertisol, in a randomized block design in three replications. The plot size was 6 m², the surface area of the trial being 78.5 m². In both research years, the trial involved topsoil preparation of the plot, which was followed by the incorporation of 1000 kg/ha NPK fertilizer (7:20:30) coupled with the soil insecticide Foxim at a prescribed concentration in each treatment, including the control one.

Thereafter, in both research years, carrot planting was performed in mid-April. Dense planting was employed at a spacing of 30x10 cm following the thinning procedure. Throughout the growing season, conventional crop management practices were used, the top dressing with KAN being applied at the intensive growth stage in the following treatments:

I treatment – the control Ø

II treatment - 60 kgN/ha

III treatment - 120 kgN/ha

IV treatment - 180 kgN/ha

The trial included two carrot genotypes: the cultivar *Nantes* and the *Almaro F₁* hybrid, both of the Nantes type, having a cylindrically shaped root intended for fresh consumption.

Carrots were harvested at the harvest maturity stage, 20 average roots being sampled for analysis of productive traits, including:

- individual root weight
- root yield
- yield of marketable root – by subtracting the weight of small deformed roots from the root yield, calculated as t/ha.

A three-factor analysis of variance was used to test the significance of differences between the calculated mean values for the factors studied. The significance was evaluated by F- test and LSD test at the 5% and 1% levels.

Results and Discussion

Of the climatic factors affecting the course of research, temperature and precipitation were the most prominent ones (Tab.1). Throughout the carrot growing season of 2005, the average monthly temperature (18.7°C), along with the favourable distribution and amount of precipitation, had a beneficial effect on yield and yield components of carrot. Throughout the growing season of 2006, the average monthly temperature remained unchanged from the previous year. Nevertheless, lower precipitation led to lower yields and affected the other parameters examined.

A comparison of the amount of precipitation during the growing seasons of the research years suggested the small rainfall (30 mm) during the intensive growth and development of the plants in May 2006, which adversely affected the initial root development, subsequently inducing lower yields as well. Furthermore, in July of the growing season, considerably lower precipitation (44.6 mm) was recorded as compared to the same period of the previous year (100 mm), which led to a decrease in yield and deterioration in productive traits of carrot in the stated year.

Tab. 1. An overview of temperatures and precipitation over 2005-2006

Month	Trait			
	Mean monthly temperatures (°C)		Precipitation (mm)	
	2005	2006	2005	2006
January	1.4	- 4.3	33.5	32.0
February	- 0.8	1.2	70.0	40.0
March	5.7	6.0	43.0	116.0
April	12.0	14.0	80.5	61.0
May	17.2	18.2	72.5	30.0
June	21.0	21.7	83.5	88.3
July	23.7	24.7	100.0	44.6
August	20.3	21.3	65.5	190.0
September	18.2	18.9	91.2	43.0
October	11.8	14.4	23.5	28.5
November	5.2	7.7	82.5	17.3
December	2.9	3.2	41.0	66.0
Average I - XII	11.6	12.3	787.0	757.0
IV - IX	18.7	19.8	493.0	457.0

Individual root weight is one of the most important yield components directly inducing high yields of carrot. The results on average yield given in tab. 2 and graph 1 show the positive effect on individual root weight as induced by the rising nitrogen rates used. The increase in individual root weight ranged from 3.6% (at 180 kgN/ha) to 7.4% (at 120 kgN/ha) in the cultivar Nantes, whereas in the Almaro F₁ hybrid the increase was registered only under the lowest nitrogen treatment (60 kgN/ha), being 7.2%. The average carrot root weight was 162.3 g and 123.9 g in the cultivar and hybrid, respectively, hence, according to root size classification, the root of the cultivar was categorized as large (>150 g), and that of the hybrid as medium (60-150 g), being the genetic characteristic of the hybrid.

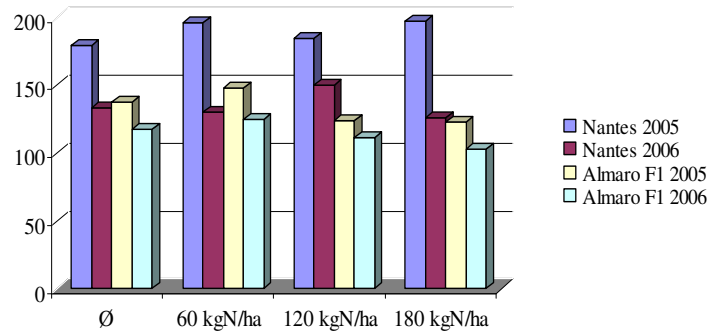
The effect of increasing nitrogen rates on root weight in both the cultivar and the hybrid did not exhibit any statistically significant differences. The differences were registered only in individual root weight in the hybrid between the application rates of 60 kgN/ha and 180 kgN/ha. The differences in root weight by the research year were found to be highly significant between the cultivar and the hybrid as well as in terms of the cultivation of the same cultivar/hybrid in both research years ($p < 0.01$), as induced by different weather conditions characterizing the study period.

Tab. 2. Individual root weight (g)

Treatments	Cultivar/hybrid							
	Nantes				Almaro F ₁			
	2005	2006	Average	Index	2005	2006	Average	Index
Control	179.2	133.3	156.3	100	137.3	118.0	127.7	100
60 kgN/ha	196.3	130.1	163.2	104.4	148.3	125.5	136.9	107.2
120 kgN/ha	184.8	150.7	167.8	107.4	123.6	111.3	117.5	92.0
180 kgN/ha	197.4	126.6	162.0	103.6	123.0	102.7	112.9	88.4
Average	189.4	135.2	162.3		133.1	114.6	123.9	
test	Cultivar (A)	Treatment (B)	Year (C)	AB	AC	BC	ABC	
F	75.643	1.434	70.411	2.225	16.990	1.423	0.676	
p-level	0.000	0.251	0.000	0.104	0.000	0.254	0.573	
0.01	8.589	12.146	8.589	17.178	12.146	17.178	24.293	
LSD								
0.05	11.306	15.989	11.306	22.612	15.989	22.612	31.978	

Individual carrot root weight in both the cultivar and the hybrid was found to be slightly higher than reported by different authors. Zdravkovic (1988) showed that the highest average root weight in carrot hybrid was 115.7 g, whereas Pavlovic *et al.* (2004) reported a rising tendency as induced by increasing nitrogen rates, the individual root weight in the hybrid being 100.8 g, similarly with the results obtained by Furlanovic (1986).

The individual root weight obtained in the present research suggests that the trait examined was substantially affected not only by genetic predisposition but also by favourable soil and climate conditions, as registered in both research years at the site of research.



Graph 1. Individual root weight (g)

Root yield – The achieved carrot root yields given in Tab. 3 and Graph 2 show that the yield was directly dependent on nitrogen rates applied. Increasing nitrogen rates induced higher yields as compared to the control treatment in both the cultivar and the hybrid. The lowest and the highest average yields in the cultivar Nantes were achieved by the control treatment (44.2 t/ha) and the 120 kgN/ha rate (50.5 t/ha, being a 14.3% increase), respectively.

Tab. 3. Carrot root yield (t/ha)

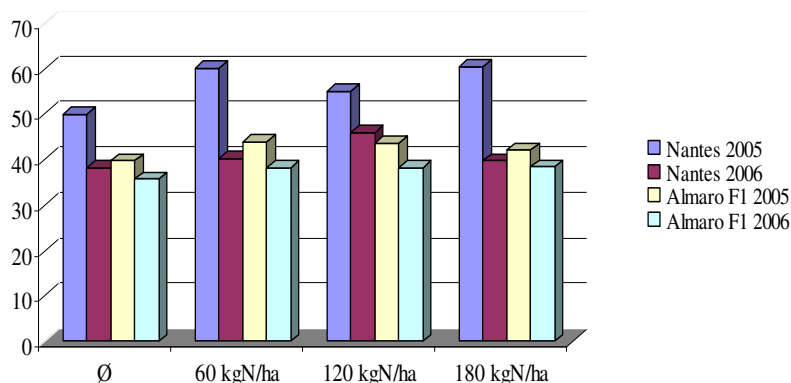
Treatments	Cultivar/hybrid							
	Nantes				Almaro F ₁			
	2005	2006	Average	Index	2005	2006	Average	Index
Control	50.0	38.3	44.2	100	39.7	35.7	37.7	100
60 kgN/ha	60.0	40.3	50.2	113.6	44.0	38.3	41.2	109.3
120 kgN/ha	55.0	46.0	50.5	114.3	43.7	38.3	41.0	108.8
180 kgN/ha	60.3	39.7	50.0	113.1	42.1	38.4	40.1	106.4
Average	56.3	41.1	48.7		42.4	37.7	40.0	
test	Cultivar (A)	Treatment (B)	Year (C)	AB	AC	BC	ABC	
F	42.873	2.934	57.145	0.294	16.199	1.142	1.281	
p-level	0.000	0.048	0.000	0.830	0.000	0.347	0.297	
0.01	2.616	3.699	2.616	5.231	3.699	5.231	7.398	
LSD								
0.05	3.443	4.869	3.443	6.886	4.869	6.886	9.738	

In the Almaro F₁ hybrid, the application rates of 60 kgN/ha and 120 kgN/ha produced almost identical average yields of the carrot root (41.2 t/ha and 41.0 t/ha, respectively), the lowest yield being registered in the control treatment (37.7 t/ha).

A comparison of the root yields between the cultivar and the hybrid suggests that the average yield in the cultivar was 8.7 t/ha higher than that in the Almaro hybrid, being also due to higher individual root weight in the cultivar.

An analysis of Tab. 3 reveals statistically significant differences ($p < 0.01$) between the research years, as expectable from the more favourable weather conditions in the 2005 carrot growing season. Namely, the distribution and the amount of precipitation throughout the growing season of 2005 were more favourable

for plant growth and development, resulting in the higher average yield in both the cultivar and the hybrid as compared to the second year of study. The average yield in the cultivar in the first and second years was 56.3 t/ha and 41.1 t/ha, the yield in the hybrid being 42.4 t/ha and 37.7 t/ha, respectively.



Graph 2. Root yield of carrot (t/ha)

The research results suggest that the application rates of 60 kgN/ha and 120 kgN/ha gave satisfactory results and that further increases in nitrogen rates did not induce substantial increases in individual root weight and root yield in either the cultivar or the hybrid, as consistent with the results obtained by Markovic *et al.* (1992) showing that nitrogen rates exceeding 100 kg/ha did not induce any major yield increases. Similar results were reported by Wiebe (1987) who achieved the highest carrot yield by nitrogen fertilization at the rate of 80-140 kg/ha. Additionally, according to Galeev *et al.* (1980), the highest yields and superior quality of carrot were produced by the 80 kgN/ha fertilization rate. Similar results were obtained by Ilin *et al.* (2004) suggesting that the highest average yield over a three-year period resulted from the application of 100 kg/ha of each of the three nutrients (NPK).

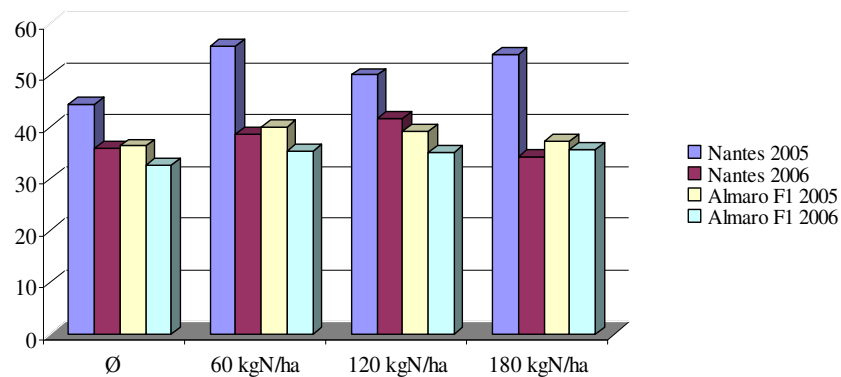
Similarly with the results of the present research, Krasnic, T. (1998) reported that the highest yield of the studied carrot cultivar, i.e. 42.375 kg/ha, was produced by the application of 100 kgN/ha.

Marketable root yield is a significant yield parameter in terms of market requirements, being made up of high-quality roots. The higher its proportion in the total yield, the higher the production profitability. The average marketable root yield obtained in the research was 44.4 t/ha in the cultivar and 36.5 t/ha in the hybrid, the difference expressing statistical significance. As with the overall yield, higher marketable root yields were produced in 2005 than in 2006, being due to more favourable climate conditions.

Tab. 4. Marketable root yield (t/ha)

Treatments	Cultivar/hybrid							
	Nantes				Almaro F ₁			
	2005	2006	Average	Index	2005	2006	Average	Index
Control	44.5	36.0	40.3	100	36.3	32.7	34.5	100
60 kgN/ha	55.7	38.7	47.2	117.1	40.0	35.3	37.7	109.3
120 kgN/ha	50.0	41.7	45.8	113.7	39.3	35.0	37.2	107.8
180 kgN/ha	54.0	34.3	44.2	109.7	37.3	35.6	36.5	105.8
Average	51.0	37.7	44.4		38.2	34.7	36.5	
test	Cultivar (A)	Treatment (B)	Year (C)	AB	AC	BC	ABC	
F	39.312	3.008	45.050	0.420	15.121	1.095	1.720	
p-level	0.000	0.045	0.000	0.740	0.000	0.365	0.182	
0.01	2.476	3.502	2.476	4.952	3.502	4.952	7.003	
LSD								
0.05	3.259	4.609	3.259	6.519	4.609	6.519	9.219	

The total yield and yield of high-quality roots are dependent not only on cultivar traits, climate and edaphic conditions but also on the rates, date of application and forms of mineral fertilizers used (Afsar *et al.* 2003). The incorporation of nitrate fertilizers enhances the abundance of foliar mass and yield, also however adversely affecting the plant by causing root splitting and plant lodging, thereby inducing pathogen attacks and, therefore, yield losses and quality deterioration, as confirmed by the present study, as well. In all the studied treatments, the hybrid showed greater uniformity of marketable root yield as compared to the cultivar, the trait itself being a genetic characteristic of the hybrid.



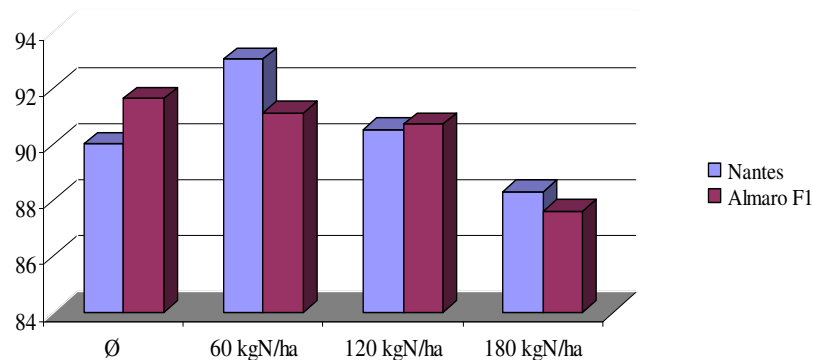
Graph 3.- Marketable root yield (t/ha)

The proportion of the marketable root yield in the total carrot root yield is presented in Tab. 5.

Tab. 5. Proportion of marketable roots (%)

Treatments	Cultivar/hybrid					
	Nantes			Almaro F ₁		
	Average yield (t/ha)	Average yield of marketable root (t/ha)	% of high-quality roots	Average yield (t/ha)	Average yield of marketable root (t/ha)	% of high-quality roots
Control	44.2	40.3	91.2	37.7	34.5	91.5
60 kgN/ha	50.2	47.2	94	41.2	37.7	91.5
120 kgN/ha	50.5	45.8	90.7	41.0	37.2	90.7
180 kgN/ha	50	44.2	88.4	40.1	35.9	89.5
Average	46	44.4		40	36.5	

The analysis of the effect of increasing nitrogen rates on the proportion of high-quality marketable roots of fresh carrot (Tab. 5, graph 4) showed that the lowest nitrogen rate (60 kgN/ha) in both the cultivar and the hybrid gave the highest proportion of high-quality roots (94% and 91.5%, respectively). The stated results suggested that nitrogen rates exceeding 60 kg/ha did not induce quality improvements in carrot root associated with the proportion of marketable roots in the total root yield. However, irrespective of the decline in the percentage of marketable carrot root in the total yield, the proportion of high-quality roots remained consistently high as the nitrogen rates increased, ranging from 88.4-90.7% in the cultivar and from 89.5-91.5% in the hybrid.



Graph 4.- Proportion of marketable roots (%)

The results of the present research are consistent with the results obtained by Mc Call and Moller (1999) who reported that high-quality roots accounted for more than 80% of the total root yield. The above results are close to those given by Afsar *et al.* (2003) who determined that nitrogen rate increases induced both yield increases and deformities such as root splitting. Root harvest delay leads to elevated risks of diseases, pests and root deformities, causing lower yields of high-quality marketable roots (Suojala 1999).

Conclusion

The objective of the present research and the two-year results on the effect of different nitrogen rates on the production traits of carrot suggest the following:

- The fertilization rates of 120 kgN/ha and 60 kgN/ha were the most effective in enhancing individual root weight in the cultivar and the hybrid, respectively.
- The highest root yield in the cultivar and the hybrid was produced by the fertilization rates of 120 kgN/ha and 60 kgN/ha, respectively. Furthermore, considerably higher yields in both the cultivar and the hybrid were obtained throughout the growing season of 2005 characterized by more favourable weather conditions.
- The marketable root yield and the proportion of high-quality roots in the total yield in both genotypes were found to be the highest at the lowest nitrogen rate applied (60kgN/ha).

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UTICAJ AZOTNOG ĐUBRENJA NA KOMPONENTE PRINOSA MRKVE

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Rezime

U cilju utvrđivanja uticaja azota na produktivnost mrkve, postavljeni su vegetacioni ogledi sa dva genotipa mrkve (sorta *Nantes* i hibrid *Almaro F₁*), tokom vegetacionih sezona 2005. i 2006. godine. Ogled je izveden u četiri varijante sa rastućim dozama azota (0, 60, 120 i 180 kgN/ha), na zemljištu tipa smonica u oga-
jnjačavanju. Tokom ispitivanja praćen je uticaj azota na individualnu masu korena, ukupan prinos i prinos tržišnog korena. Najbolji efekat na povećanje individualne mase korena, kao i postizanje najvećeg prinosa kod sorte imala je doza od 120 kgN/ha, a kod hibrida doza od 60 kgN/ha. Prinos tržišnog korena, kao i procentualno učešće visokokvalitetnih korenova u ukupnom prinosu kod oba ispitivana genotipa, bio je najveći primenom najmanje doze azota (60kgN/ha).