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The effect of fertigation on yield and quality of four white cabbage (*Brassica oleracea* var. *capitata* L.*)* cultivars

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ABSTRACT

The influence of fertigation and broadcast mineral fertilization on yield and quality of 4 cabbage cultivars (*Brassica oleracea* var. *capitata* L.) was studied in a field trial in Ljubljana. Five treatments were formed: K – classical fertilization with 150 kg N ha^{-1} (broadcast incorporated); F_{NPK} – all nutrients (NPK) were applied via fertigation; F_N – P, K were added by classical methods and total N by fertigation; $F_{NPK/30\%}$ - 30% of total N was incorporated before transplanting, total P and K and remaining N were applied via fertigation; $F_{N/30\%}$ - total P and K and 30% of total N were incorporated before transplanting, the remainig N was applied via fertigation. During the harvest, the height and width of the cabbage, the length of stalk, weight of head with leaves and without leaves, height and width of cleaned head, firmness of head and core length were measured and the number of external trimmed leaves was counted. The largest average marketable yield was achieved by fertigation with soluble nutrients, combined with pre-plant broadcast nitrogen incorporation, with each individual cultivar as follows: Hermes F1 (38.7 t ha^{-1}), Parel F1 (71.1 t ha^{-1}) and Tropicana F1 (70.7 t ha^{-1}) and the lowest by fertigation with N, where the total amount of P and K were pre-plant broadcast incorporated, with cultivars as follows: Hermes F1 (20.9 t ha^{-1}) and Parel F1 (50.4 ha^{-1}) and Tropicana F1 (63.0 t ha^{-1}) and Fieldwinner F1 (66.1 t ha^{-1}). The firmness of cabbage heads was also influenced by the method of nutrient application.

Key words: cabbage (*Brassica oleracea* var. *capitata* L.*)*, fertigation, classical fertilization, yield, quality

IZVLEČEK

VPLIV FERTIGACIJE NA PRIDELEK IN KAKOVOST ŠTIRIH KULTIVARJEV ZELJA (*Brassica oleracea* var. *capitata* L.*)*

V raziskavi smo proučevali vpliv fertigacije in klasičnega gnojenja na pridelek in kakovost štirih sort zelja (*Brassica oleracea* var. *capitata* L.). Uporabili smo 4 načine gnojenja: K – klasično gnojenje s 150 kg N/ha^1 (gnojilo zadelano v tla pred presajanjem), F_{NPK} – vsa

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hranila (NPK) smo dali s fertigacijo; F_N – P, K smo dali po klasični metodi, celokupen N s fertigacijo; $F_{NPK/30\%}$ - 30% od skupne količine N smo zadelali v tla pred presajanjem, preostali N ter celokupen P in K s fertigacijo; $F_{N/30\%}$ - celoten P in K in 30% od skupne količine N smo zadelali v tla pred presajanjem, preostali del N pa s fertigacijo. Ob spravilu smo vrednotili višino in premer rastline, število veh, dolžino kocena, maso glave z vehami, maso očiščene glave, višino in premer očiščene glave, zbitost, dolžino vretena ter maso korenin. Največje povprečne tržne pridelke smo dobili pri fertigaciji z vodotopnim NPK gnojilom, kjer smo 30% od skupne količine N zadelali v tla pred presajanjem, pri posameznih kultivarjih, kot sledi: Hermes F1 (38,7 t ha^{-1}), Parel F1 (71,1 t ha^{-1}) and Tropicana F1 (70,7 t ha^{-1}), najnižje pa pri fertigaciji z N, kjer smo celotno količino P in K zadelali v tla pred setvijo, pri kultivarjih, kot sledi: Hermes F1 (20,9 t ha^{-1}), Parel F1 (50,4 ha^{-1}), Tropicana F1 (63,0 t ha^{-1}) in Fieldwinner F1 (66,1 t ha^{-1}). Uporaba različnih metod gnojenja je vpliva tudi na čvrstost glavic, ki je ena od pomembnejših kakovostnih lastnosti zelja.

Ključne besede: zelje (*Brassica oleracea* var. *capitata* L.*)*, fertigacija, klasično gnojenje, pridelek, kakovost

1 INTRODUCTION

White cabbage (*Brassica oleracea* var. capitata) is an important field vegetable crop in Slovenia. About 740 ha are cultivated annually (Statični letopis Slovenije, 2002). The total nitrogen fertilizer recommendation for early cabbage is 150 kg ha^{-1}, one third should be present at planting, 1/3 over 1 month and 1/3 over 2 months (Odet et al., 1988).

The introduction of fertigation (i.e. simultaneous drip-irrigation and fertilization) has opened new possibilities for controlling water and nutrient supplies to crops and maintaining the desired concentration and distribution of ions and water in the soil. Many authors have shown that fertigation increased the yield or nutrient use efficiency under many conditions with different crops (Everaarts and De Moel, 1998; Ristimäki, 1999; Salo et al. 2002; Romic et al, 2003).

The main advantages of drip-fertigation over drip-irrigation combined with broadcast/binding fertilization can be summarized as follows: (1) Because of the flexibility in delivery of nutrients and water, time fluctuation of nutrient concentrations in the soil over the course of the growing season is reduced. The attenuated fluctuation with the drip-fertigation system therefore ensures higher and more consistent yields compared to broadcasting/binding fertilization. (2) Easy adaptation of the amounts and concentrations of specific nutrients to crop requirements, according to the stage of development and climatic conditions; (3) Precise application of nutrients according to crop demand, thus avoiding excess fertilizer concentrations in the soil and leaching out of the wetted soil root volume. (4) Applications of water and fertilizers to only a part of the soil volume; the addition of nutrients only to the wetted area, where active roots are concentrated, enhances fertilizer use efficiency and reduces leaching of nutrients to deep undergound water by seasonal rains (Bresler, 1977; Bar-Yosef, 1999; Hagin and Lowengart-Aycicegi, 1999; Romic et al., 2003).

Everaarts et al. (1993) reported that band placement of nitrogen fertilizer may increase the yield in Brassica field vegetables.

The objective of our research was to examine the effect of the method of nutrient application, such as broadcast (K), broadcast combined with fertigation and fertigation, on yield and quality of four white cabbage cultivars. One hundred and fifty kg N ha^{-1} was applied in all the treatments.

2 MATERIALS AND METHODS

The experiment was conducted in the experimental field of the Biotechnical Faculty (latitude: 46° 04' N, longitude 14° 31' W, 300 m above M.S.L), University of Ljubljana, from 17th March to 23th September 2003. Commercially important cultivars of early and mid early white cabbage (Hermes F1, Tropicana F1, Parel F1 and Fieldwinner F1) were planted. White cabbage transplants were greenhouse-grown in a plug tray system, each in 5 cm deep by 3 cm wide transplant cells filled with peat-based substrate.

Soil characteristics of the experimental fields are given in Table 1.

Table 1. Chemical properties of the soil (0-0.30 m)

pH –KCl	Organic matter (%)	P (mg $100g^{-1}$ P_2O_5)	K (mg $100g^{-1}$ K_2O)	Soil type
7.2	2.5	27	21	Heavy clay loam

Soil cultivation, as preparation for planting, was carried out in mid-April, when 0.15-metre-high and 1.4-metre-wide beds were created using a rotary tiller cultivator. All beds were covered with black PE mulch and uniformly irrigated using T-tape systems that delivered 500 litres $hour^{-1}$ of water per 100 m of tubing with emitting orifices spaced at 20 cm intervals.

All transplants were hand-transplanted at 8weeks into four rows of 2.4 –metre long plots with within- and between-row spacing of 0.40 m and 0.40 m, respectively. Plots contained 24 plants each.

The experimental design was arranged as a randomized complete block factorial design with fertigation methods as treatments. Each treatment was replicated four times. The selected methods of fertigation were as follows: (i) F_N; (ii) F_{NPK}; (iii) $F_{N/30\%;}$ (iv) $F_{NPK/30\%:}$ (iv) K – classical fertilization with 150 kg N ha^{-1} (broadcast incorporated). For the F_N treatment, total amounts of P and K as granular fertilizer were broadcast and incorporated by raking before transplanting and the soluble N source was applied via fertigation. For the F_{NPK} treatment, all soluble nutrients were applied via fertigation. For the $F_{N/30\%}$ treatment, the total P and K amounts and 30% of the total N rate was applied as granular fertilizer as a pre-plant broadcast application and the remaining N via fertigation. For the $F_{NPK/30\%}$ treatment, 30% of the total N rate was applied as a pre-plant broadcast application, with the remaining N and NPK applied via fertigation. The application of fertigation treatments began 2 weeks after transplanting and was continued weekly. Irrigation was applied to maintain soil moisture at 0.020 to 0.040 MPa, as indicated by soil tensiometers places at a 15-cm depth in each replicate. The harvest dates for each individual cultivar were 26th July 2003 for cv. Parel F1, 6th August for cv. Hermes F1, 25th September for cv. Tropicana F1 and 23th September 2003 for cv. Fieldwinner F1. At harvest, only the centre two rows were used for data collection. During the harvest, the height and width of the cabbage plant, the length of stalk, weight of head with leaves and without leaves, height and width of cleaned head, firmness of head and core length were measured and the number of external trimmed leaves was counted. Data were analysed using analysis of variance to examine treatment effects, and means were separated by Duncan's multiple range test at $P \leq 0.05$.

3 RESULTS AND DISCUSSION

The results of the effects of various methods of nutrient application on total marketable yield are given in Figure 1.

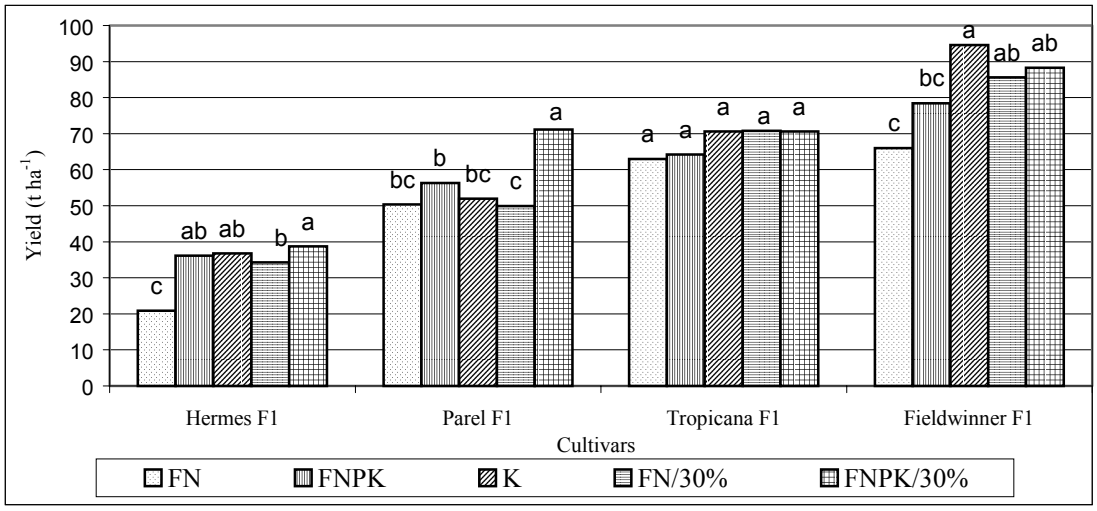

Figure 1. Effect of various methods of nutrient application on marketable yield (t ha^{-1}) of four white cabbage cultivars. Means with the same letter are not significantly different at α= 0.05 (Duncan test).

The yield of three cabbage cultivars (Hermes F1, Parel F1 and Fieldwinner F1) was influenced strongly by the method of nutrient application. A significant positive effect of pre-plant broadcast application with one-third of the total N amount on marketable yield was observed with cv. Hermes F1 and Parel F1. Fertigation with soluble N (F_N) significantly decreased marketable yield with cv. Hermes F1 and Fieldwinner F1.

When marketable cabbage yields from the various nutrient application methods were compared, it should be noted, however, that with all cultivars, fertigation with soluble N, P and K (F_{NPK}) increased marketable yield per unit area over fertigation only with soluble N (F_N). Cabbages fertilized with complete NPK fertigation produced higher yields (Hermes F1 – 36.1 t ha^{-1}, Parel F1 – 56.3 t ha^{-1} and Fieldwinner F1 – 78.4 t ha^{-1}) than those fertilized only with soluble N fertigation and with the total P and K being pre-plant broadcast incorporated (Hermes F1 – 20.9 t ha^{-1}, Parel F1 – 50.4 t ha^{-1} and Fieldwinner F1 – 66.0 t ha^{-1}).

Uniformity of head weight is an important quality characteristic. Treatment effects on the uniformity of individual head weight were also studied by evaluating the effects on the coefficient of variation. The lower the coefficient of variation, the more uniform in weight are the heads per treatment.

The highest uniformity of cabbage head weight was achieved with cultivars Hermes F1, Parel F1 and Fieldwinner F1, by growing cabbage with $F_{NPK/30\%}$ (Table 2). The lowest uniformity was achieved with cultivars Tropicana F1, Hermes F1 and Fieldwinner F1 by applying only soluble N via fertigation, and P and K pre-plant broadcast incorporated.

Table 2: Coefficient of variation of individual head weight (%), for four cabbage cultivars

Application method	Hermes F1	Parel F1	Tropicana F1	Fieldwinner F1
K	24.8	20.2	28.4	24.8
F_N	36.6	19.4	27.6	27.8
F_{NPK}	27.4	22.8	19.8	24.3
$F_{N/30\%}$	28.0	31.0	22.2	24.9
$F_{NPK/30\%}$	19.8	19.1	26.7	23.3

Table 3. Effects of various methods of nutrient application on the characteristics of white cabbage plants for each individual cultivar.

Cultivar	Treatment	Plant		Length of stalk (cm)	Number of external trimmed leaves	Root weight (g)
		Height (cm)	Width (cm)			
'Parel F1'	K	21.2 c	20.0 b	4.8 a	11.2 b	8.1 cd
	F_N	20.8 c	20.3 b	4.5 ab	11.5 ab	7.0 d
	F_{NPK}	21.2 c	21.3 a	4.4 b	12.3 a	8.6 c
	$F_{N/30\%}$	22.0 b	21.4 a	4.8 a	11.5 ab	10.2 b
	$F_{NPK/30\%}$	22.8 a	21.8 a	4.4 b	12.0 ab	11.8 a
'Hermes F1'	K	22.1 b	18.3 c	6.5 b	15.5 ab	4.8 a
	F_N	19.9 c	17.1 c	6.7 b	14.5 c	4.4 b
	F_{NPK}	21.8 b	20.6 b	6.6 b	16.3 a	5.5 a
	$F_{N/30\%}$	21.5 b	20.0 b	6.5 b	14.8 bc	5.5 a
	$F_{NPK/30\%}$	22.9 a	22.2 a	7.1 a	14.9 bc	5.4 ab
'Tropicana F1'	K	25.5 b	21.7 a	6.2 a	9.5 a	19.6 ab
	F_N	25.4 b	19.8 b	7.0 a	8.9 a	18.1 b
	F_{NPK}	26.3 ab	19.6 b	5.6 a	9.0 a	19.8 ab
	$F_{N/30\%}$	27.0 a	20.0 b	5.8 a	9.9 a	19.2 ab
	$F_{NPK/30\%}$	26.6 a	20.1 b	5.3 a	10.3 a	21.0 a
'Fieldwinner F1'	K	25.8 ab	22.7 ab	6.2 a	12.3 c	22.8 a
	F_N	24.8 c	22.5 ab	5.6 a	15.3 a	17.7 b
	F_{NPK}	26.1 a	22.3 b	5.8 a	12.7 bc	22.0 a
	$F_{N/30\%}$	25.0 bc	22.7 ab	5.4 a	13.7 bc	21.8 a
	$F_{NPK/30\%}$	25.9 ab	23.2 a	7.2 a	14.0 ab	23.9 a

The various methods of nutrient application had a significant effect on the characteristics of the cabbage plants (Table 3). The plant height was significantly increased when 30% of total N was pre-plant incorporated, and the remaining N and total amount of P and K applied via fertigation, with cultivars Parel F1, Hermes F1 and Fieldwinner F1. Plant width was the smallest when classical (K-control) pre-plant broadcast fertilization was applied with cultivars Parel F1 and Hermes F1. No significant differences were observed in the length of stalk with cultivars Tropicana F1 and Fieldwinner F1 when the various nutrient application methods were applied. The $F_{NPK/30\%}$ application method significantly decreased the length of stalk with Parel F1 plants, and significantly increased the length of stalk with Hermes F1 plants.

Root weights were statistically significantly decreased with fertigation only with soluble N (F_N), with all tested cultivars.

The shape of heads, expressed as the relation between the length and width of the heads, was not influenced by treatments in any of the tested cultivars (Table 4). The relative core length was influenced by the various methods of nutrient application, but never exceeded 50%, which is an undesirable characteristic for white cabbage cultivars. Apparently significant differences occurred in firmness among the treatments with cultivar Hermes F1, where fertigation with nitrogen (F_N and $F_{N/30\%}$) statistically significantly decreased the firmness of the cabbage heads. Similar results were obtained by Everaarts and De Moel (1998) by growing white cabbage with higher nitrogen availability, where the relatively long core length may have been the reason for softer head tissue and the consequently low quality of the cabbage yield.

Table 4. Effects of various methods of nutrient application on the head characteristics of white cabbage for each individual cultivar.

Cultivar	Treatment	Head		Weight of head		Relative	Firmness (1-5)
		Height (cm)	Width (cm)	with leaves (g)	without leaves (g)	core length (%)	
'Parel F1'	K	13.1 b	11.5 b	1010.3 c	865.6 bc	38.9 b	4.8 a
	F_N	13.0 b	11.6 b	996.8 c	839.4 bc	42.9 b	4.9 a
	F_{NPK}	13.4 b	12.2 a	1124.5 b	937.9 b	43.5 a	5.0 a
	$F_{N/30\%}$	13.2 b	11.2 b	1053.1 ab	832.3 c	39.2 b	4.6 b
	$F_{NPK/30\%}$	14.9 a	12.5 a	1401.5 a	1185.7 a	41.3 ab	5.0 a
'Hermes F1'	K	11.4 a	10.8 ab	796.0 ab	612.3 ab	36.6 a	4.2 a
	F_N	9.7 b	9.0 c	472.3 c	348.0 c	41.9 b	2.1 c
	F_{NPK}	11.3 a	10.8 ab	776.1 ab	601.7 ab	39.5 b	4.1 a
	$F_{N/30\%}$	11.1 a	10.4 b	741.6 b	571.3 b	38.8 bc	3.6 b
	$F_{NPK/30\%}$	11.2 a	11.0 a	826.2 a	645.7 a	35.9 a	4.4 a
'Tropicana F1'	K	10.9 cd	14.6 a	1356.6 a	1176.1 a	45.1 a	5.0 a
	F_N	10.4 d	14.4 a	1273.8 a	1049.4 a	43.4 ab	5.0 a
	F_{NPK}	11.0 bc	14.7 a	1285.4 a	1070.1 a	44.7 ab	5.0 a
	$F_{N/30\%}$	11.7 a	14.8 a	1386.6 a	1172.2 a	45.3 a	5.0 a
	$F_{NPK/30\%}$	11.5 ab	14.9 a	1404.0 a	1177.0 a	40.1 b	5.0 a
'Fieldwinner F1'	K	13.1 a	16.4 a	1910.4 a	1576.3 a	33.7 c	5.0 a
	F_N	11.1 c	14.4 d	1405.2 c	1100.4 c	41.2 a	4.9 a
	F_{NPK}	12.1 b	15.2 cd	1589.4 bc	1307.4 b	36.8 bc	5.0 a
	$F_{N/30\%}$	12.1 b	15.6 bc	1750.7 ab	1426.4 ab	41.9 a	5.0 a
	$F_{NPK/30\%}$	12.3 b	16.0 ab	1823.1 a	1471.7 a	39.4 ab	5.0 a

4 CONCLUSIONS

Drip-fertigation has been mentioned as an option to increase yield or reduce the amount of nutrients applied with many field crops (Guertal, 2000; Jaimez et al. 1999; Carballo et all. 1994, Thompson et al., 2000). The present experiment shows that various methods of nutrient application can have positive or negative effects on white cabbage yield. Positive effects on marketable yield were found when NPK and N fertigation, combined with pre-plant broadcast nitrogen (a third of total N amount) were applied. However, the marketable yield of Hermes F1, Parel F1 and Fieldwinner F1 was higher with NPK fertigation in comparison with N fertigation. The treatment $F_{NPK/30\%}$ positively influenced the uniformity of cabbage head weights with cultivars Hermes F1, Parel F1 and Fieldwinner F1. However, with cultivars Tropicana F1, Hermes F1 and Fieldwinner F1, a negative effect on the uniformity of cabbage head

weights was found when soluble N was applied via fertigation and the total amounts of P and K were pre-plant incorporated.

The important quality characteristic of firmness of cabbage heads was also influenced by fertigation with N with two cultivars, Hermes F1 and Fieldwinner F1. Fertigation with N strongly decreased the firmness of cabbage heads, especially with Hermes F1.

The results of the presented research show that under Slovenian ecological conditions, fertigation with N or with NPK, combined with pre-plant broadcast fertilizations, offers the grower a useful tool for increasing yield and quality.

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