Effects of Irrigation, Nitrogen Fertilization and Soil Type on Yield and Quality of Cauliflower

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ABSTRACT. The influence of irrigation, nitrogen rate and source, and soil type on yield, quality and nitrate nitrogen content of cauliflower was studied in field experiments. Irrigation provided at soil moisture potentials of −20 and −40 kPa secured a higher yield than that of −60 kPa. Yield of cauliflower curds increased with nitrogen rates up to 600 kg N/ha. Among the tested nitrogen fertilizers, calcium nitrate produced the highest yield of cauliflower curds. Out of five tested soil types, highest cauliflower yield was obtained on a low moor peat and on silty clay loam. Nitrogen fertilization resulted in a linear increase of nitrate nitrogen in cauliflower leaves and curds. Nitrate nitrogen content of leaves and curds was influenced by cultivar, soil type, and rate and form of nitrogen. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: getinfo@haworthpressinc.com]*

KEYWORDS. Cauliflower, irrigation, nitrogen rate, nitrogen source, soil type, cultivar, nitrate content, *Brassica oleracea var. botritis*

INTRODUCTION

Cauliflower, *Brassica oleracea var. botritis*, has a high water and nitrogen requirement. Although adequate water supply is needed through-

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out the entire growth period, best results are obtained when irrigation is applied at the onset of curd formation (Salter 1961, Wiebe 1981). Irrigation improved curd quality and usually higher on soils with greater water holding capacity. Nilsson (1980) however revealed that the effect of soil type is less than that of nitrogen fertilization. Increased nitrogen rates from 150 to 300 kg N per hectare significantly increased the cauliflower yield (Skapski, 1961 and Nilsson, 1980). Pimpini et al. (1971a) obtained increased yield of cauliflower for N rates of up to 500 kg nitrogen per hectare. According to Skapski et al. (1968), the optimal nitrogen rates for nonirrigated and irrigated cauliflower were 100 and 200 kg N per hectare, respectively. To promote growth and yield, many cauliflower growers apply up to 500 kg N ha^{-1}, especially on irrigated fields. High nitrogen fertilization, however, may lead to an undesirable increase of the NO_3^--N content in the cauliflower curds (Nilsson 1980, Pimpini et al. 1971b). Weier and Scharpf (1983) point out that the accumulation of nitrate occurs to a greater extent in the leaves than in the curds. The objective of this work was to assess the influence of irrigation, nitrogen fertilization and soil type on yield, quality and NO_3^--N content of cauliflower.

MATERIALS AND METHODS

Field experiments with cauliflower were conducted during 1988 to 1990 at the Research Institute of Vegetable Crops in Skierniewice, Poland (51°.58′ N, 20° 10′ E). The cauliflower was grown from greenhouse produced transplants, which were planted in field in the middle of May and harvested in the middle of July.

In an experiment on the effect of irrigation conducted in 1990, cauliflower cv. 'Serrano F_1' (S & G Seeds) was grown on a sandy loam soil (Table 1) at four soil moisture levels (soil tension of -20, -40, and -60 kPa plus a nonirrigated check). Irrigation frequency was determined by tensiometer measurements. Single water doses of 20 mm were applied.

In an experiment on the effect of nitrogen fertilization conducted in 1989, cauliflower cvs. 'Andes' and 'Linas' (Royal Sluis) and 'Serrano F_1' (S & G Seeds) were grown on a sandy loam soil (Table 1) at nitrogen rates of: 37, 75, 150, 225, 300, 375, 450, 525, 600, 675, 750, 825 and 900 kg N per hectare. Rates up to 450 kg N ha^{-1} were applied broadcast, before planting, whereas higher rates were split into

TABLE 1. Some properties of soils used in experiment

Soil property	Soil types				
	Sand	Sandy loam	Sandy clay loam	Silty clay loam	Peat soil
Mechanical composition (%)					
Sand (1-0.1 mm)	87	68	51	8	–
Silt (0.1-0.2 mm)	8	19	21	55	–
Clay (< 0.02 mm)	5	13	28	37	–
Organic matter (% d.w.)	3.09	1.16	2.13	1.09	81.6
Available water (mm/0.1 m)	10.3	12.5	23.5	26.1	35.0
Volume weight (g cm^{-3})	1.49	1.63	1.62	1.38	0.21

preplant application of 450 kg N ha^{-1} and a sidedress one of the remainder applied 3 weeks after transplanting.

The influence of nitrogen source on yield and nitrate nitrogen content of cauliflower cv. 'Serrano F_1' (S & G Seeds) was researched in 1989 on sandy loam soil. Ammonium nitrate, calcium nitrate, ammonium sulphate, or urea, was used in a rate equivalent to 400 kg nitrogen per hectare.

The effect of soil type on yield of cauliflower (cv. 'Serrano F_1') was studied in 1990. The soil types included: a sandy soil, sandy loam (both are pseudo podsols), sandy clay loam (brown soil), silty clay loam (alluvial soil) and low moor peat soil. Select soil properties are shown in Table 1. The different soils, collected from natural sites, were transferred in layers, representing three main horizons for each soil, to a set of microplots, located on the Institute's Experiment Field in Skierniewice. The 5 m^2 microplots, each, were constructed as floorless, concrete containers, reaching 100 cm below and 20 cm above the ground level. All soil types were fertilized with 400 kg of nitrogen per hectare. In all experiments phosphorus and potassium were applied in amounts necessary to bring up the soil content to 80 mg P and 200 mg K per 1 liter of soil, according to soil analysis after the modified Spurway method (Nowosielski et al. 1976). In all experiments the cauliflower plants were spaced 50 cm between the rows and 50 cm within the rows. All treatments had 3 replications and single plots of 5 m^2 each, were arranged in a randomized block design. At harvest the weight of leaves and curds, and the quality of curds (Skapski, 1961)

were determined. Curds from each treatment were analyzed for dry matter and for nitrate nitrogen content, by a specific nitrate electrode (Orion, model 9207).

Data of each experiment were subjected to analysis of variance, and means were separated by Student's t Test at P = 0.05.

RESULTS AND DISCUSSION

Effect of irrigation. Mean weight of leaves and curds of cauliflower plants reached higher levels when irrigation was applied at soil matric potential of −20 or −40 kPa (Table 2). Irrigation applied at a lower soil moisture level of −60 kPa was less effective in increasing the leaf and curd weight. The lowest leaf and curd weight was obtained on the nonirrigated treatment. These results are in agreement with those obtained by Wiebe (1981). Increase of soil moisture tended to delay the time of harvest. Thus harvest commenced 4 days later for the well irrigated treatment of −20 kPa as compared on the nonirrigated control. Similar response of cauliflower to irrigation was reported by Nilsson (1980). Irrigation did not influence the leaf-to-curd weight ratio, but it improved the curd quality. Cauliflower irrigated at soil matric potential of −20 kPa produced compact, firm curds, with high curd quality coefficient of 3.8 g cm^{-2}. A decrease of soil moisture resulted in a decrease of the curd density coefficient, which in the nonirrigated check treatment declined to the level of 3.0 g cm^{-2}.

TABLE 2. Influence of irrigation on earliness, leaf and curd weight and curd quality of cauliflower cv. 'Serrano F_1'

Soil potential at irrigation	Earliness (no. days from planting to harvest)	Average leaf weight	Average curd weight	Leaf/curd ratio	Curd quality coefficient (g cm^{-2} fresh matter)
−20 kPa	62	1645 ab	833 a	2.0	3.8 a
−40 kPa	60	1763 a	725 b	2.4	3.5 a
−60 kPa	57	1432 b	585 c	2.4	3.4 ab
Nonirrigated control	58	985 b	502 c	2.0	3.0
LSD (P = 0.05)	NS	214	107	NS	0.4

Means within a column followed by the same letter are not significantly different at the 5% level.

These results support the previous findings in which irrigation of cauliflower applied during a drought period significantly improved the curd quality (Skapski et al. 1968).

Effect of nitrogen fertilization. Nitrogen fertilization affected both the leaf and curd yield of cauliflower. The highest yield of leaves and curds was produced at nitrogen rates of 675 and 600 kg N ha^{-1}, respectively. Further elevation of the nitrogen fertilization led to reduced leaf and curd weight. Cultivar 'Serrano F_1' surpassed the cvs. 'Andes' and 'Linas' in yield of leaves and curds. Nitrate nitrogen content of the cauliflower plants was positively affected by nitrogen fertilization. At nitrogen rates up to 375 kg N ha^{-1} the NO_3^--N content in leaves was lower than that in the curds, whereas at higher nitrogen fertilization the opposite relation was observed. The cultivars 'Andes' and 'Linas' accumulated considerably more NO_3^--N in leaves and curds than did 'Serrano F_1' (Table 3). The observed increase in NO_3^--N accumulation is in agreement with previous findings of Pimpini et al. (1971b) and Nilsson (1980). Weier and Scharpf (1983) found that the NO_3^--N content of curds was lower than that of the leaves. We observed this only at higher rates of nitrogen fertilization. At lower nitrogen rates, which produced N deficiency symptoms, NO_3^--N content of curds was greater than that of leaves.

Nitrogen fertilization did not influence the earliness of cauliflower, except for an observed tendency to earlier harvest at the lowest N rate, under which only small, low quality curds were produced and many developed at a premature stage of plant growth (Table 4). This shows that such low nitrogen fertilization is not sufficient to meet the plant requirements. At inadequate levels of N the leaf/curd weight ratio was high for all cultivars. The cauliflower plants showed normal growth and a concentrated maturity with nitrogen rates from 150-900 kg N/ha. The cauliflower was harvested after 58 to 61 days from transplanting. This was in agreement with Nilsson (1980) but did not confirm the findings of Pimpini et al. (1971a) that high nitrogen fertilization rates delayed the harvest of cauliflower. Nitrogen fertilization positively influenced the quality of cauliflower curds. The quality coefficient of curds was highest at nitrogen doses above 225 kg N ha^{-1}. Increased nitrogen fertilization reduced the dry matter content of cauliflower curds, in agreement with Nilsson (1980).

Effect of nitrogen source. The greatest average weight of leaves and curds of cauliflower was produced with calcium nitrate. Fertilization

TABLE 3. Effect of nitrogen fertilization on yield and NO_3^--N content of cauliflower (mean of 3 cultivars)

Treatment	Yield (kg m^{-2})		NO_3^--N (mg kg^{-1} fresh matter)	
	leaves	curds	leaves	curds
Nitrogen - rate (kg ha^{-1})				
37	1.80f	0.48d	152h	230f
75	2.36ef	0.68d	152h	220f
150	3.44de	1.12c	214gh	254ef
225	3.48de	1.44c	251fg	253ef
300	3.92cd	1.36c	284fg	294de
375	4.48a-d	1.84b	294f	314cd
450	5.12a-c	1.84b	374e	329b-d
525	5.32ab	2.12ab	418de	320cd
600	5.00a-c	2.48a	438c-e	361a-c
675	5.64a	2.08b	481b-d	373ab
750	5.08a-c	1.92b	505a-c	401a
825	5.08a-c	1.92b	534ab	411a
900	4.40b-d	1.84b	574a	407a
LSD (P = 0.05)	1.23	0.36	71	52
Cultivar				
'Andes'	3.60b	1.40b	402a	368a
'Linas'	39.6b	1.32b	443a	385a
'Serrano F_1'	5.68a	2.24a	280b	203b
LSD (P = 0.05)	0.82	0.41	96	66

Means within a column followed by the same letter are not significantly different at the 5% level.

with urea was less effective than was fertilization with the other nitrogen carriers (Table 5). Nitrogen source also influenced the nitrate nitrogen content of the curds, which was significantly lower after fertilization with urea than with the other three nitrogen fertilizers. The nitrogen fertilizers did not affect the leaf/curd weight ratio nor the quality coefficient of curds.

Effect of soil type. Yield, quality and nitrate nitrogen content of cauliflower were affected by soil type (Table 6). The highest leaf weight was from the low moor peat soil, and the lowest one from sand. Also, curd weight and the quality coefficient were higher on the low moor peat, characterized by higher water holding capacity, than on the sandy soil. The nitrate nitrogen content in the curds grown on low

TABLE 4. Influence of nitrogen fertilization on earliness, quality and dry matter content of cauliflower (means of 3 cultivars)

Treatment	Earliness (days from planting to harvest)	Leaf/curd weight ratio	Curd quality coefficient ($g\ cm^{-2}$)	Dry matter of curds (%)
Nitrogen - rate ($kg\ ha^{-1}$)				
37	54	3.9a	1.8e	8.8a
75	57	3.5a	2.2de	8.4ab
150	59	3.0b	2.4cd	8.3ab
225	58	2.4b	3.0ab	7.5cde
300	58	2.8bc	2.7bc	8.0bc
375	60	2.4cd	3.2a	7.9bcd
450	60	2.9b	3.1ab	7.7be
525	61	2.7d	3.0ab	7.0ef
600	58	2.4cd	3.1ab	7.4fg
675	59	2.3d	3.2a	7.2de
750	58	2.7bcd	3.0ab	7.3cde
825	58	2.4cd	3.3a	7.1ef
900	59	2.3d	3.1ab	6.7g
LSD (P = 0.05)	NS	0.4	0.4	0.7
Cultivar				
'Andes'	55	2.5	2.9b	7.2
'Linas'	63	2.9	2.6b	7.5
'Serrano F_1'	57	2.5	3.4a	7.8
LSD (P = 0.05)	NS	NS	0.6	NS

Means within a column followed by the same letter are not significantly different at the 5% level.

moor peat soil and silty clay loam (alluvial soil) was significantly higher compared to the other three soil types (Table 6).

CONCLUSIONS

1. High yield of good quality cauliflower was produced when irrigation was applied at soil matric potential of -20 to -40 Kpa.
2. Nitrogen fertilization up to the rate of 600 kg N ha^{-1} increased yield and improved curd quality without delaying harvest time.
3. Among the tested nitrogen sources, calcium nitrate gave the highest yield of cauliflower. No influence of nitrogen source on

curd quality was found, except for the nitrate nitrogen content, which was lowest in plants fertilized with urea.

4. From the five soil types tested, silty clay loam and the low moor peat soil produced highest yields. Results obtained on sand were poor.
5. Nitrate nitrogen content of cauliflower was related to rate and source of nitrogen fertilization as well as to cultivar and soil type.

TABLE 5. Influence of nitrogen source on yield, quality and NO_3^--N content of cauliflower cv. 'Serrano F_1'

Source of nitrogen	Average leaf weight (g)	Average curd weight (g)	Leaf/curd ratio	Curd quality coefficient ($g\ cm^{-2}$)	NO_3^--N content in curds ($mg\ kg^{-1}$ fresh matter)
Ammonium nitrate	1740 b	960 b	1.8	4.3	197 a
Ammonium sulphate	1800 b	990 b	1.8	4.3	206 a
Calcium nitrate	1900 a	1080 a	1.8	4.3	197 a
Urea	1620 c	920 b	1.8	4.2	158 b
LSD (P = 0.05)	98	83	–	NS	38

Means within a column followed by the same letter are not significantly different at the 5% level.

TABLE 6. Influence of soil type on yield, quality and NO_3^--N content of cauliflower cv. 'Serrano F_1'

Soil type	Average leaf weight (g)	Average curd weight	Leaf/curd ratio ($g\ cm^{-2}$)	Curd quality coefficient	NO_3^--N content in curds ($mg\ kg^{-1}$ f.m.)
Sand	1120 c	760 c	1.5 b	4.1 b	152 b
Sandy loam	1620 b	960 b	1.7 ab	4.5 ab	156 b
Sandy clay loam	1390 bc	970 b	1.4 b	4.4 ab	151 b
Silty clay loam	1710 b	1150 a	1.5 b	4.4 ab	206 a
Low moor peat soil	2200 a	1090 a	2.0 a	4.8 a	197 a
LSD (P = 0.05)	472	118	0.4	0.6	40

Means within a column followed by the same letter are not significantly different at the 5% level.

LITERATURE CITED

Nilsson T., 1980. The influence of soil type and irrigation on yield, quality and chemical composition of cauliflower. Swed. J. Agric. Res. 10: 65-75.

Nowosielski O., A. Bereœniewicz., E. Jaszczot., M. Mijas., and E. Szwonek, 1976. Vereinfachte Methode der Analyse gärtnerisch genutzter Böden bei Anwendung eines Universal-Extraktes. Tag.-Ber., Akad. Landwirtach.-Wiss. DDR, Berlin 146: 95-100.

Pimpini F., F. Venter., and A. Wunsch, 1971a. Über den Einfluss verschiedener Stickstoff-Formen und steigender Stickstoff-Mengen auf das Wachstum von Blumenkohl in Kulturgefässen. Gartenbauwissenschaft 36: 1-17.

Pimpini F., F. Venture., and A. Wunsch, 1971b. Der Einfluss verschiedener Stickstoff-Form und steigender Stickstoff-Mengen auf den Gehalt an Gesamt-Stickstoff und Nitrat in Blumenkohlpflanzen. Gartenbauwissenschaft 36: 511-523.

Salter P.J., 1961. The irrigation of early summer cauliflower in relation to stage of growth, plan spacing and nitrogen level. J. Hort. Sci. 36: 242-253.

Skapski H., 1961. Badania nad wp^{3}ywem warunków wzrostu rozsady nawczesnoœæ i jakoœæ ró¿ kalafiorów. Biul. Warzyw. V: 57-73.

Skapski H., K. Viscardii., and J. Jagoda, 1968. Wp^{3}yw deszczowania oraz nawo¿enia mineralnego i organicznego na plon kalafiorów. Biul. Warzyw. IX: 101-119.

Weier K., and H.C. Scharpf, 1983. Zur Stickstoffdüngung von Blumenkohl. Gemüse 24/21: 54-56.

Wiebe H.J., 1981. Influence of soil water potential during different growth periods on yield of cauliflower. Acta Hort. 119: 299-300.

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