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Seed rate, sowing time and harvest time in dill (*Anethum graveolens* L.) for freeze drying

*Udsædsmængde, såtidspunkt og høsttidspunkt i dild (*Anethum graveolens *L.) til frysetørring*

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Summary

The influence of seed rate, sowing time and harvest time on yield and quality of dill (*Anethum graveolens* L.) for freeze drying was investigated in field trials. In 1988 and 1989 the cultivar 'Blanko' was grown at three seed rates (5, 10 and 20 kg/ha) and four sowing times. Plants were harvested leaving 6-8 cm stubble at three developmental stages: A. just before umbel appearance, B. the beginning of umbel appearance and C. appearance of umbels on approximately 10% of the plants.

The highest yield was obtained at the highest seed rate tested. The yield of leaves in per cent of total yield decreased with increasing seed rate, but dry matter content in leaves was not significantly influenced. In the summer sowing the highest total fresh yield and fresh yield of leaves were obtained in sowing II and were 17.4 t/ha and 4.9 t/ha respectively. In 1988 autumn sowing was not harvested due to a severe attack of *Alternaria*, but in 1989 the highest yield was harvested in the autumn sowing. Optimum harvest time was at the beginning of umbel appearance.

The surface colour of the freeze dried leaves varied only slightly in the summer sowings. In the autumn sowing the lower leaves became yellow at the later harvests – especially at the highest seed rate tested.

Key words: Dill, *Anethum graveolens* L., surface colour, proportion of leaves, umbel appearance, accumulated day-degrees, growing period, dry matter content, seed rate, sowing time, harvest time, freeze drying.

Resumé

Udsædsmængdens, såtidspunktets og høsttidspunktets indflydelse på udbytte og overfladefarve i dild (*Anethum graveolens* L.) til frysetørring blev undersøgt i markforsøg. I 1988 og 1989 blev sorten 'Blanko', dyrket ved tre udsædsmængder (5, 10 og 20 kg/ha) og fire såtidspunkter. Planterne blev høstet ved 6-8 cm stubhøjde ved tre udviklingstrin: A. umiddelbart inden skærmfremkomst, B. begyndende skærmfremkomst og C. skærmfremkomst på ca. 10 pct. af planterne.

Det højeste udbytte blev høstet ved den højest afprøvede udsædsmængde. Udbyttet af nåle i procent af totaludbyttet faldt ved stigende udsæds-

mængde, men tørstofprocenten i nålene var ikke signifikant påvirket. I sommerholdene blev det højeste totaludbytte og udbytte af nåle opnået ved såtid II og var henholdsvis 17,4 t/ha friskvægt og 4,9 t/ha friskvægt. I 1988 blev efterårsholdet ikke høstet pga. udbredt angreb af *Alternaria,* men i 1989 høstedes det højeste udbytte i efterårsholdet. Det optimale høsttidspunkt var ved begyndende skærmfremkomst.

De frysetørrede nåles overfladefarve varierede kun svagt i sommerholdene. I efterårsholdet blev de nedre blade gullige ved de sene høsttidspunkter – især ved den højest afprøvede udsædsmængde.

Nøgleord: Dild, *Anethum graveolens* L., overfladefarve, nåleprocent, skærmfremkomst, temperatursum, kulturperiode, tørstofprocent, såmængde, såtidspunkt, høsttidspunkt, frysetørring.

Introduction

Dill (*Anethum graveolens* L.) is an annual plant of the *Umbelliferae* family grown primarily for production of herb or essential oil. The demand for spices is increasing and there is a growing interest in producing dill herb for freeze drying in addition to fresh use.

Only few investigations have been made to determine optimal cultural conditions in spice plants. The highest yield of fresh dill herb (including umbels) was found when plants were grown at 15 cm row width and 10 cm between plants within the row which was the closest plant spacing tested (1). Good quality dill herb for freeze drying has a high proportion of leaves and no umbels should occur in the final product. Plants are normally harvested immediately before umbel appearance. Therefore optimum plant density in dill for freeze drying might be higher than reported (1).

Dill is a long day plant and can be sown from the end of April until the beginning of August. Decreasing daylength results in a delayed formation of reproductive organs, an increase in leaf number and general productivity (3, 5, 7).

When dill is grown for industrial use production have to be adjusted to the processing capacity. Therefore it is desirable to be able to time production i.e. both harvest time and yield. According to the flowering physiology of dill the growing period and the yield capacity might vary with sowing time.

The present investigation was carried out in order to examine the influence of seed rate, sowing time and harvest time on yield and quality of dill (*Anethum graveolens* L.) for freeze drying.

Materials and methods

In a field experiment the dill (*Anethum graveolens* L.) cultivar 'Blanko' was grown for freeze drying. The trials were carried out in 1988 and 1989 at the Department of Vegetables, Årslev, on a sandy loam.

The experimental factors were three seed rates (5, 10 and 20 kg/ha) and four sowing times (three summer sowings and one autumn sowing). Sowing I was carried out as soon as the soil was ready and sowing II and III followed with 14 day intervals (Table 1). Sowing IV was carried out immediately after harvest of sowing I. The dill was harvested at three developmental stages: A. just before umbel appearance, B. the beginning of umbel appearance and C. appearance of umbels on approximately 10% of the plants. The plants were cut leaving 6-8 cm stubble.

The experimental design was two-factorial experiments with three replicates each year. For each sowing time the design was a split-plot design with seed rate as randomised mainplot and harvest time as systematic subplots.

The dill was sown at 12 cm row distance. Preplant fertilizer (50 kg N/ha) was applied before sowing and supplementary 50 kg N/ha was applied during growth. Diseases and pests were controlled as recommended to obtain optimum plant growth. Irrigation was performed in dry periods. Weeds were controlled by flame cultivation before emergence of the dill and afterwards all weeding was done by hand.

Total yield which included yield of leaves, petioles and stems was measured. The harvested dill was frozen (−18°C) and threshed. During threshing stems, umbels and petioles were separated and the yield of the 'needle-like' leaves was

Table 1. Sowing date and harvest date for harvest B (the beginning of umbel appearance) in 1988 and 1989.
Så- og høstdato for høsttid B (begyndende skærmfremkomst) i 1988 og 1989.

1988			1989		
Sowing *Såtid*	Sowing date *Sådato*	Harvest date *Høstdato*	Sowing *Såtid*	Sowing date *Sådato*	Harvest date *Høstdato*
I	26/5	22/7	I	5/5	3/7
II	8/6	8/8	II	19/5	14/7
III	23/6	22/8	III	2/6	24/7
IV	5/8	-	IV	18/7	25/9

–: Not harvested. *Manglende høst.*

measured. For each sowing leaves from one harvest time were freeze dried and dry matter yield of leaves was measured. Freeze drying was performed at the temperature interval −32°C to room temperature in an Atlas Autovac Gauge, type 3294 B in 24 – 30 hours. The surface colour of the freeze dried product was recorded visually.

Statistical methods

Data are means of two years and they have been analysed as a three-factorial block design regarding year at random. Analysis of variance were performed on each variable using the Statistical Analysis System (6). The main effects of seed rate, sowing time and harvest time and their two and three way interactions were tested using General Linear Models procedure. The denominator in the F-test was the interaction between the effect in question and year. Means of main effects were separated by a test for Least Significant Difference (LSD) with a significance level of 5%.

Results

Yield was higher in 1988 than in 1989. On average over the three summer sowings yield of leaves was almost 2 t/ha higher in 1988. On the contrary dry matter content was higher in 1989 which to a certain extent counterbalances the dry matter yield difference.

Seed rate

Table 2 shows the influence of seed rate on total

Table 2. Effect of seed rate on total yield, proportion of leaves, yield of leaves, dry matter content of leaves and dry matter yield of leaves. Average of sowing- and harvest time in 1988-89.
Såmængdens indflydelse på totaludbytte, nåleprocent, nåleudbytte, tørstofprocent i nåle og tørstofudbytte af nåle. Gns. af så- og høsttidspunkter i 1988-89.

Seeding rate *Såmængde*	Total yield (leaves, petioles and stems) *Total-udbytte (blade, stilk og stængel) (t/ha)*	Proportion of leaves *Nåle-procent (pct.)*	Yield of leaves *Nåle-udbytte (t/ha)*	Dry matter content of leaves *Tørstof-procent i nåle (pct.)*	Dry matter yield of leaves *Tørstof-udbytte af nåle (t/ha)*
1. 5 kg/ha	10.9	31.4	3.3	14.6	0.48
2. 10 kg/ha	14.7	29.1	4.1	14.8	0.60
3. 20 kg/ha	17.7	28.4	4.9	14.9	0.71
LSD	2.3	1.7	0.5	n.s.	0.01

yield, proportion of leaves, yield of leaves, dry matter content of leaves and dry matter yield of leaves. Total yield increased significantly with increasing seed rate but the proportion of leaves decreased. However the fresh and dry matter weight of leaves increased significantly with higher seed rate.

Sowing time

In 1988 sowing IV was not harvested due to severe attack of *Alternaria*. Therefore results from sowing IV represent only one year.

Table 3 shows the influence of sowing time on yield parameters. In sowing I - III the total yield and yield of leaves were highest in sowing II. The proportion of leaves decreased with advanced sowing and was significantly highest at sowing III. The dry matter content of leaves increased slightly, but not significantly. Yield was remarkably lower in sowing III especially in 1989 where harvest had to be advanced due to early umbel appearance.

Of all tested sowing times total yield, yield of leaves and dry matter yield of leaves were highest in sowing IV (the autumn sowing 1989), but it was not significantly higher than in sowing II.

Interaction between seed rate and sowing time influenced total and dry matter yield of leaves significantly, showing an increasing effect of seed rate with delayed sowing.

Harvest time

Table 4 shows the effect of harvest time on yield parameters. Total yield and yield of leaves was significantly higher at harvest time B and C. Total yield was 2 t/ha higher at harvest C than at harvest time B. The proportion of leaves decreased slightly with later harvest, but not significantly. The yield of leaves increased by only 0.1 t/ha from harvest B to harvest C, which was not significant.

The growing period from sowing to the beginning of umbel appearance was 52-61 days in the summer sowings (Table 5). Development lasted approximately 8-17 days longer in the autumn sown plants. The linear relationship between sowing day number and accumulated day-degrees >5°C accounted for 80% of the variation in degree days from sowing to harvest.

Surface colour

The surface colour of the freeze dried product was judged visually. No effect of seed rate was

Table 3. Effect of sowing time on total yield, proportion of leaves, yield of leaves, dry matter content of leaves and dry matter yield of leaves. Average of seed rates and harvest times in 1988-89.
Sådidens indflydelse på totaludbytte, nåleprocent, nåleudbytte, tørstofprocent i og tørstofudbytte af nåle. Gns. af udsædsmængder og høsttidspunkter i 1988-89.

Sowing *Sådid*	Total yield (leaves, petioles and stems) *Total-udbytte (blade, stilk og stængel) (t/ha)*	Proportion of leaves *Nåle-procent (pct.)*	Yield of leaves *Nåle-udbytte (t/ha)*	Dry matter content of leaves *Tørstof-procent i nåle (pct.)*	Dry matter yield of leaves *Tørstof-udbytte af nåle (t/ha)*
I	12.6	27.5	3.4	16.3	0.6
II	17.4	28.3	4.9	14.4	0.7
III	10.6	33.5	3.5	13.2	0.5
IV*)	19.2	28.1	5.1	15.4	0.8
LSD	5.7	4.1	1.6	n.s.	n.s.

*) Only 1989. *Kun 1989.*

Table 4. Effect of harvest time on total yield, proportion of leaves and yield of leaves. Average of seed rates and sowing times in 1988-89.
Høsttidspunktets indflydelse på totaludbytte, nåleprocent og nåleudbytte. Gns. af udsædsmængder og høsttidspunkter i 1988-89.

Harvest time *Høsttidspunkt*	Total yield (leaves, petioles and stems) *Totaludbytte (blade, bladstilk og stængel) (t/ha)*	Proportion of leaves *Nåleprocent (pct.)*	Yield of leaves *Nåleudbytte (t/ha)*
A. Before umbel appearance *Før skærmfremkomst*	11.0	32.7	3.5
B. The beginning of umbel appearance *Ved begyndende skærmfremkomst*	15.3	29.0	4.4
C. Umbels on approximately 10% of the plants *Skærmfremkomst på ca. 10 pct. af planterne*	17.3	26.8	4.5
LSD	3.1	n.s.	1.1

Table 5. Growing period (from sowing until the beginning of umbel appearance) and accumulated day-degrees for each sowing in 1988 and 1989.
Kulturperiode (fra såning til begyndende skærmfremkomst) og temperatursum for hvert såtidspunkt i 1988 og 1989.

1988			1989		
Sowing *Såtid*	Growing period (days) *Kultur-periode (dage)*	Accumulated*) day-degrees *T.sum*) (°C)*	Sowing *Såtid*	Growing period *(days) Kultur-periode (dage)*	Accumulated*) day-degrees *T.sum*) (°C)*
I	58	599	I	59	499
II	61	655	II	56	562
III	60	650	III	52	553
IV	–	–	IV	69	702

–: Not harvested. *Manglende høst.*
*) Accumulated day-degrees i.e. the sum of average daily temperatures >5°C.
Temperatursum, dvs. summen af daglige gennemsnitstemperaturer >5°C.

found on quality in the summer sowings. Colour was slightly influenced by sowing time since leaves on plants from sowing II and III had a lighter green and paler colour. In the autumn the lower leaves became yellow at the later harvests – especially at the highest seed rate tested. The plants of the cultivar 'Blanko' have white ligules, but hardly any appeared in the freeze dried product and did not reduce quality in the final product.

Discussion

The lower yield level in 1989 was mainly due to a low emergence rate. Sample counts in 1989 showed that the number of plants pr. m^2 was less than 50% of the expected. The emergence rate varied between sowings which may account for some of the variation in yield between sowings.

Yield was highest at the highest seed rate tested in all four sowings. In the autumn sowing the lower leaves of the plants became yellow at the highest seed rate and the quality of the final product was reduced. This might be avoided by reducing seed rate or increasing row distance in the autumn sowing. Further the risk of diseases which may be severe in autumn will be reduced.

The proportion of leaves decreased with increasing seed rate. On average the proportion of leaves was 29.6%. Proportions of leaves of 55.5% at 7.5 cm stuble height were found in Finnish investigations (2). This discrepancy may be due to different definitions of the proportion of leaves. In this experiment the proportion of leaves included only the small 'neddle-like' leaves. Petioles and stems were seperated by threshing.

In the summer sowings yield was highest when seeds were sown from medio May to the beginning of June. As dill is a long day plant, increasing daylength and higher temperature promote umbel appearance and reduce the time to harvest (5). This may account for the lower yield in sowing III – where umbels appeared quickly and the harvest had to be advanced in 1989. In the autumn hardly any umbels appeared although growth continued until October/November. The yield capacity was high. However in autumn dill is often attacked by disease which may be difficult to control and the herb can deteriorate in a rather short time.

Highest yield was obtained at harvest C but at harvest B the yield of leaves was only 0.1 t/ha lower. The time from the beginning of umbel appearance to umbels at 10% of the plants was 3-4 days for plants harvested in June or July. Therefore the risk of an overstrong umbel development is high by delaying harvest. This indicates that optimum harvest time is at the beginning of umbel appearance.

Dill can be sown from the end of April until the beginning of August. The growing period was 55-60 days from sowing to the beginning of umbel appearance which means that in Denmark it is possible to grow two cultures of dill on the same area within a year. The growing period was shortest when plants were sown in June. The accumulated day-degrees $>5^0$C from sowing to harvest was higher than those found in Finland (4) but is in accordance with the findings that the accumulated day-degrees required were lower the farther north the location.

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