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Studies on fertilization of dill (*Anethum graveolens* L.) and basil (*Ocimum basilicum* L.)

II Oil yield of dill affected by fertilization

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Abstract. The influence of different levels of basic fertilization and nitrogen top-dressing on the herb and oil yield of dill (*Anethum graveolens* L.) was studied in 1984 and 1985 in Finland. The total nitrogen doses were 0, 15, 30, 40, 80, 120 and 160 kg/ha.

The crop in 1984 yielded 12 000—34 000 kg/ha fresh dill herb and 10.3—21.1 kg/ha essential oil. The figures in 1985 were 10 600—21 000 and 9.4—16.6 kg/ha, respectively.

Of the 22 volatile components identified by gas chromatography — mass spectrometry, the four most abundant compounds were analysed quantitatively. These compounds were a-phellandrene, 3,6-dimethyl-2,3,3a,4,5,7a-hexahydrobenzofuran, β-phellandrene and limonene, composing 70—95 % of the total aroma content.

The optimum basic fertilization for the herb yield proved to be a compound fertilizer of the rate of 40-16-68 kg NPK/ha. The small nitrogen doses (30—40 kg N/ha) gave also good results in respect to oil yield and the amount of 3,6-dimethyl-2,3,3a,4,5,7a-hexahydrobenzofuran, the most important aroma compound in the dill herb.

Index words: calcium nitrate, compound fertilizer, dill, essential oil, nitrogen

Introduction

Growth conditions, e.g. soil and fertilization, play an important role not only in the production of green mass, but also in the oil production of herb plants. The effect of nutrition has been investigated mainly by applications of the main nutrients (NPK), N being the main factor. In general, the aim of the studies on fertilization of herb plants has been to find out the optimum application level in respect to both the herb yield and aroma content and composition.

Flück (1954) has stated that an increase in fertilization will generally first increase the oil content, and after a certain optimum level, decrease that. According to Ruminska (1978) there is not direct influence between the fertilization and oil content or composition.

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Often the effect is indirect. For instance, N application prolongs the juvenile phase of plants increasing thus the green mass production and proportionally also the oil content. SINGH et al. (1971) have recorded the highest essential oil content in dill with 45 kg N and 30 kg P/ha. According to ATANASSOV et al. (1976) the highest oil content in the dill herb was received with equal doses (70 kg/ha) of N and P. The fertilization did not clearly affect the aroma. HORNOK (1978, 1983), instead, found significant effect of the main nutrients on the oil content of dill herb.

N has been reported to be of the main importance in the dry matter and oil production of dill herb, while P is of the major role in producing dill seed oil. The essential oil production proved to decrease in the beginning of the considerable dry matter production. Application of 60-40-40 kg NPK/ha was found to be the optimum for the herb production. N has not affected the oil composition, P has increased the oil content, and the oil content and composition has remained unaffected by K (HORNOK 1978). In later studies the N doses up to 160 kg proved to increase the aroma of dill herb. P decreased the oil content and K was of minor importance. On the other hand, P and K had an important role in the seed production of dill (HORNOK 1983).

Fertilization of herb plants has been investigated mostly in Middle Europe, only a few studies are carried out in the northern conditions. Thus research in this field is necessary, especially now that there is growing interest in the herb production in Nordic countries. The influence of different levels of basic fertilization and N top-dressing on dill was studied in two successive years in Finland. The effects on both the herb yield and the essential oil was investigated. The detailed results on the herb yield is reported earlier (HÄLVÄ and PUUKKA 1987).

Materials and methods

Materials

The experiments were carried out in the humous fine sandy fields, at the University of Helsinki. Dill ('Dura') was sown at the end of May at the rate of 20 kg/ha in rows 12.5 centimeters apart. The data on the soil analyses before the fertilization is presented in Table 1.

In 1984 the five fertilization treatments including the unfertilized control were applied. The soil was fertilized by 40 kg/ha compound fertilizer (10-4-17) before sowing dill. The nitrogen top-dressing by calcium nitrate (NO3-N 16, Ca 20) was broadcast two weeks later. The total nitrogen rates were 0, 40, 80, 120 and 160 kg/ha, respectively. In 1985 the effect of the lower doses was studied more accurately: two more treatments, 15 and 30 kg N/ha with the compound fertilizer were broadcast before sowing (HÄLVÄ and PUUKKA 1987).

The field trials were set up according to the

Table 1. Oil content (g/kg dry weight) and composition of the essential oil (% of the total oil) in the dill herb in 1984 and 1985.

N kg/ha	Oil content		α-Phellandrene		Limonene		β-Phellandrene		Benzofuranoid*	
	-84	-85	-84	-85	-84	-85	-84	-85	-84	-85
0	8.0	7.8	40.1	48.2	2.6	2.6	7.4	7.4	33.8	32.4
15		6.6		49.2		2.6		7.4		30.8
30		8.7		50.6		2.6		7.7		27.8
40	5.6	6.0	37.3	48.5	2.7	2.5	7.7	7.2	31.1	34.2
80	5.0	7.0	32.0	58.6	2.6	2.6	6.8	7.6	37.2	30.3
120	5.4	9.2	26.9	55.4	2.8	2.6	7.4	7.6	35.6	25.1
160	7.8	6.2	32.9	41.8	2.7	2.7	7.4	7.7	33.2	31.3

* Benzofuranoid = 3,6-dimethyl-2,3,3a,4,5,7a-hexahydrobenzofuran.

method of completely randomized blocks with four replications and plots of 10 m². The crops were grown using general farming practices. Dill was harvested before the bud-formation. The plant height, fresh herb yield and the amount and composition of aroma compounds were measured in both years. After harvest the herb samples were packed into polyethylene bags, frozen and stored in —20°C, and analysed within two weeks (HUOPALAHTI 1985). The detailed results on herb production are published separately (HÄLVÄ and PUUKKA 1987). The data on herb yields was studied by analyses of variance and regression (STEEL & TORRIE 1980).

Isolation of aroma compounds

Aroma compounds were isolated by extracting 45 grams of chopped frozen dill for six hours with 350 ml of a mixture of redistilled n-pentane and diethylether (1:2, v/v) by using a modified Soxhlet-technique as described by HUOPALAHTI and LINKO (1983). The extract was concentrated to the volume of 2 ml with a Widmer column.

Gas chromatography and mass spectrometry

The quantitative gas chromatographic determinations were performed on a Varian 3700 gas chromatograph equipped with FID connected to Hewlett Packard 3388 A integrator. The fused silica capillary column (0.32 mm i.d. × 25 m; film thickness 0.20 μm) coated with OV-351 was applied for the separations. The oven temperature was programmed at the rate of 2°C/min from 70°C to 230°C after an isothermal period of 2 min. The flow rate of carried gas (helium) was 1.3 ml/min.

The quantitative estimations of aroma compounds were performed by using linalool as the internal standard. In the calculation of the total essential oil content (aroma content) 50 corresponding peaks were summed up. The identifications of the aroma compounds was carried out on a VG Analytical 7070E mass spectrometer with an energy of 70 eV.

Results and discussion

Herb yield

In the present study on the effects of fertilization on dill the unfertilized herb was yellowish and developed slowlier than the fertilized ones.

The dill grown on control plots yielded 11 000—12 000 kg/ha. In 1984 the smallest fertilizing rate (40 kg N/ha) gave fresh dill yields of 32 500 kg/ha. Further increase in N application did not increase the yields significantly. In 1985 the herb yields were generally smaller: the fertilized plots produced fresh herb 14 000—21 000 kg/ha (Fig. 1A). The differences in the yields are propably due to the weather and soil conditions in the two years (HÄLVÄ and PUUKKA 1987).

When studying the relation between the two fertilizers (compound fertilizer and calcium nitrate) and the herb yield, the effect of calcium nitrate did not prove to be significant. Thus the variability of the yields was accounted for by the basic fertilizer, only (HÄLVÄ and PUUKKA 1987).

The optimum basic fertilization was a compound fertilizer application of 40-16-68 kg/ha. In 1984 the relation between the yield and the amount of the nitrogen applied proved to be quadratic. The estimation of the yields with the nitrogen fertilizer indicates that the dill yield will increase up to the fertilizing rate of 115 kg N/ha after which the yield will decrease (HÄLVÄ and PUUKKA 1987).

In 1985 the effect of nitrogen fertilization accounted for only 31—37 % of the variation among the treatments and no better coefficient of determination was found using different models.

Oil yield

Table 1 shows the total oil content and the relative amount of the main compounds in the dill herb during 1984 and 1985. The oil yields (Fig. 1b) on control plots were 10.3 and 9.4 kg/ha, respectively. In the first year the smal-

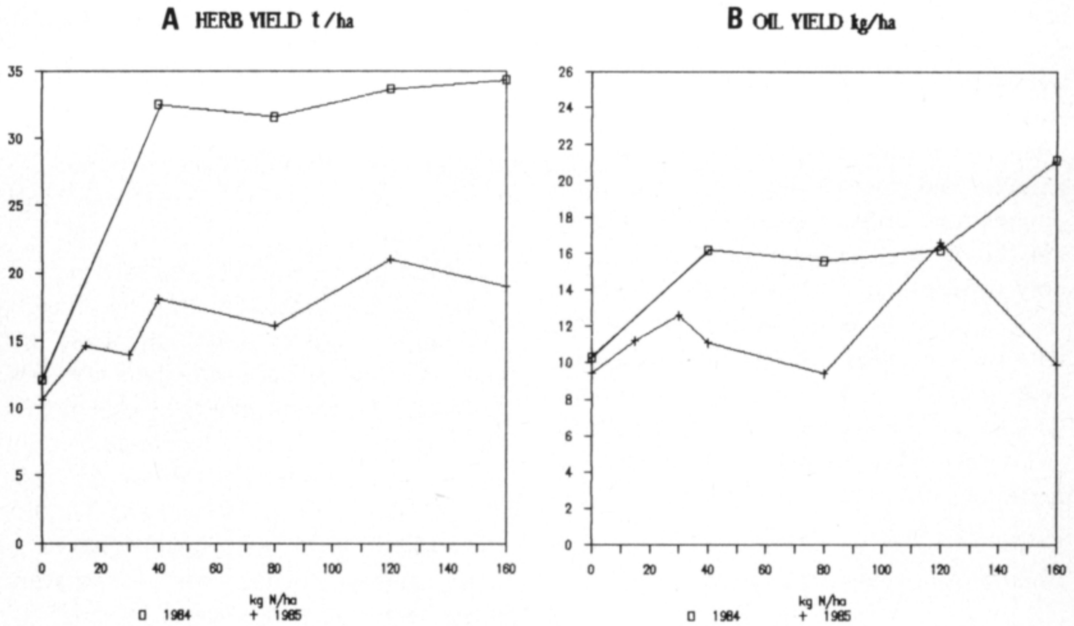

Fig. 1. Fresh dill (A) and essential oil yields (B) at different fertilization levels in 1984 and 1985.

lest fertilization rate (40 kg N/ha) gave oil yield of 16.2 kg/ha and there was no increase until the largest application. In 1985 a rather high yield (12.6 kg/ha) was reached already with the nitrogen dose of 30 kg/ha.

The total oil content (g/kg dry weight) is rather high on control plots (Table 1) compared to the oil yields which are calculated on fresh weight basis. The nitrogen treatment of 30—40 kg/ha produced rather high and constant oil yields. In the other reports the maximum dill oil yields were reached by higher doses than in this study (Flück 1954, Atanassov 1976, Hornok 1980, 1983). Only Singh et al. (1971) have reported on the optimum dose of 45 kg N/ha. The difference compared with the earlier results is probably partly due to different harvest time and soil conditions (Chubey and Dorrell 1976, Porter et al. 1983, Clark and Menary 1984). According to Porter et al. (1983) the maximum oil yield was reached just after the blooming of dill.

Oil composition

The aroma of the dill herb is not affected only by the oil content but also by its composition. Among the 50 components resolved of dill extract by gas chromatography and 22 compounds identified only four compounds were chosen to closer investigations (Table 1). In most cases these compounds — α-phellandrene, limonene, β-phellandrene and 3,6-dimethyl-2,3,3a,4,5,7a-hexahydrobenzofuran — represented 70—95 % of the total oil content. Moreover, their sensory characteristics apparently strongly affect the overall aroma of dill herb before bud-formation (Huopalahti 1986).

α-phellandrene was the major compound in the herb in all fertilization levels ranging from 32.0 to 40.1 % in 1984 and from 41.8 to 58.6 % in 1985, respectively. Relative amount of α-phellandrene and the other aroma compounds, too, have been reported to vary according to the growth stages (El-Gengaihi and Hornok 1978, Huopalahti and Linko 1983, Porter et al. 1983, Clark and Menary 1984). Because the development stages are seldom reported, the other published results are not quite comparable.

The compound 3,6-dimethyl-2,3,3a,4,5,7a-hexahydrobenzofuran (in Table 3 benzofuranoid) is the most important aroma compound in the dill herb (Huopalahti 1986). The maximum relative amount of the compound was reached with the nitrogen application of 80 kg/ha (37.2 %) in 1984 and 40 kg/ha (34.2 %) in 1985, respectively.

The relative amount of β-phellandrene was at a rather constant level (6.8—7.6 %) at all fertilization applications. Also the amount of limonene stayed rather constant (2.6—2.8 %). The lack of carvone illustrates that the herb has been harvested at the early stage of maturity. The carvone content has been reported to increase after blooming (Porter et al. 1983).

The results of this study clearly point out that the optimum dill herb in respect to the herb and oil yield, and the amount of 3,6-dimethyl-2,3,3a,4,5,7a-hexahydrobenzofuran, the character impact compound in dill herb, is reached by a rather low nitrogen supply (30—40 kg N/ha). In one year only the triple application increased the oil yield.

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References

Atanassov, Z., Zlatev, S., Zlateva, M. & Stoyanov, M. 1976. Green mass and etheral oil content of dill (*Anethum graveolens* L.) as influenced by mineral fertilization. Rastenievud. Nauki. 13: 138—143.

Chubey, B.B. & Menary, R.C. 1976. Quality and yield of dill oil produced in Manitoba. Can. J Plant Sci. 56: 215—216.

Clark, R.J. & Dorrel, D.G. 1984. The effect of harvest date on the yield and composition of Tasmanian dill oil (*Anethum graveolens* L.) J. Sci. Food Agric. 35: 1186—1190.

El-Gengaihi, S.E. & Hornok, L. 1978. The effect of plant age on content and composition of dill essential oil, *Anethum graveolens* L. Acta Hort. 73: 213—218.

Flück, H. 1954. The influence of the soil on the content of active principles in medicinal plants. J. Pharmacy Pharmacology 6: 153—163.

Hornok, L. 1978. Effect of major nutrients (NKP) and different rates on the yield of some essential oil bearing plants. Kertézeti Egyetem Közleményei. 42 (10) 1: 235—244.

—, 1980. Effect of nutrition supply on yield of dill (*Anethum graveolens* L.) and the essential oil content. Acta Hort. 96, 1: 337—342.

—, 1983. Influence of nutrition on the yield and content of active compounds in some essential oil plants. Acta Hort. 132: 239—247.

Huopalahti, R. & Linko, R. 1983. Composition and content of aroma compounds of dill. Schreier, P. (Ed.). Flavour '81. pp. 369—376. Berlin.

Huopalahti, R. 1985. Dill aroma and its changes during the storage in two kinds of frozen bags. Progress Flavor Res. p. 309—319. (Eds. J. Adda). Amsterdam.

—, 1986. Gas chromatographic and sensory analyses in the evaluation of the aroma of dill herb, *Anethum graveolens* L. Lebensm. — Wiss. Technol. 19: 27—30.

Hälvä, S. & Puukka, L. 1987. Herb yield of dill and *basil* affected by fertilization. (In press).

Ruminska, A. 1978. Der Einfluss der Düngung auf den Wirkstoffgehalt und den Ertrag von Heil- und Gewürzpflanzen. Acta Hort. 73: 143—164.

Porter, N.G., Shaw, M.L., Shaw, G.J. & Ellington, P.J. 1983. Content and composition of dill herb oil in the whole plant and the different plant parts during crop development. New Zeal. J. agric. Res. 26: 119—127.

Singh, R., Singh, L.B. & Singh, C.P. 1971. Response of N and P on yield and essential oil content of dill in nonsaline alkali soils. Fertilizer News. 16: 48—49.

Steel, R.G.D. & Torrie, J.H. 1980. Principles and procedures of statistics, a biometrical approach. 633 p. New York.

SELOSTUS

TILLIN JA BASILIKAN LANNOITUS

II Lannoituksen vaikutus tillin (*Anethum graveolens* L.) öljysatoon

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Pääravinteista typpi vaikuttaa selvimmin maustekasvien satoon ja haihtuvien öljyjen määrään. Lannoituksen kannalta hankaluutena on se, että kasvimassan ja öljyn tuotantoon tarvittavat optimilannoitemäärät ovat usein erilaiset. Typen lisäksi tillin viljelyssä myös fosfori on tärkeä; lajia pidetään yhtenä fosforin puutteeseen herkästi reagoivana kasvina. Kaliumlannoituksen vaikutus on sen sijaan vähäisempi.

Vuosina 1984 ja 1985 tutkittiin moniravinteisen peruslannoituksen (10-4-17) ja kalkkisalpietarina (NO3-N 16, Ca 20) annetun lisälannoituksen vaikutusta tillin lehtisatoon ja haihtuvan öljyn määrään ja laatuun. Typen määrinä ilmoitetut lannoitekäsittelyt olivat 0, 15, 30, 40, 80, 120 ja 160 kg N/ha.

Analysoitaessa perus- ja lisälannoituksen vaikutusta tillisatoon havaittiin, että sadon vaihtelu selittyi yksinomaan peruslannoituksella. Optimilannoitemäärä oli 40-16-68 kg NPK/ha. Pienet lannoitemäärät (30—40 kg N/ha) olivat edullisimmat myös haihtuvan öljyn määrälle ja laadulle.

Vuonna 1984 jo pienimmällä lannoituksella saatiin merkitsevästi enemmän satoa (32 500 kg/ha) kuin lannoittamattomalta alueelta, eikä lannoituksen lisäys lisännyt enää satomäärää. Vuonna 1985 sadot olivat pienemmät, lannoitetuilla alueilla 13 800—21 000 kg/ha. Typpilannoitus selitti vain 31—37 % satovaihtelusta vuonna 1985.

Vuonna 1984 haihtuvan öljyn sato oli 10.3—21.1 kg/ha ja vuonna 1985 9.4—16.6 kg/ha. Tuoreesta tillinäytteestä tunnistettiin 22 yhdistettä kaasukromatografia-massaspektrometrian avulla. Tärkeimmät haihtuvat yhdisteet olivat a-fellandreeni, 3,6-dimetyyli-2,3,3a,4,5,7a-heksahydrobentsofuraani, limoneeni ja β-fellandreeni. Näiden yhdisteiden osuus oli 70—95 % kokonaisöljystä. Lehtitillin aromin kannalta tärkeimmän yhdisteen, 3,6-dimetyyli-2,3,3a,4,5,7a-heksahydrobentsofuraanin, korkein pitoisuus saavutettiin jo pienellä lannoituksella.