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The effects of growth conditions on the yield and quality of essential oil of *Mentha piperita*

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The results of a factorial experiment designed to study the effects of nitrogen, phosphorus and potassium, alone and in combination, on the yield of green herb, and on the yield and composition of the essential oil of *Mentha piperita* are reported. The experiment was made on reclaimed peatbog in Ireland. The main conclusion is that there is a significant increase in the yield of essential oil when nitrogen is added in high concentration. This also results in a decrease in the menthol content of the oil. Superphosphate also reduces the percentage menthol content of the oil. Mixtures of all three fertilisers reduce the percentage oil yield.

PREVIOUS work has shown that virgin dried peat can produce satisfactory crops of *Mentha piperita* provided a minimum application of potash, phosphate and nitrogen is added, together with sufficient lime to give a pH between 5 and 6 (O'Connor, 1960).

The present work investigates the effect of nitrogen, phosphorus and potassium, alone and in combination, on (*a*) the yield of green or fresh herb and of essential oil, and (*b*) the composition of the oil of *Mentha piperita*.

Experimental

MATERIALS AND METHODS

Plants of *Mentha piperita* obtained from Kent in 1950 and propagated vegetatively were planted in rows 2 feet apart in the Spring of 1962. The plots were hand weeded during the growing period and the crop was harvested before flowering in September, 1962. The site of cultivation was dried peat bog as previously described (O'Connor, 1960).

The soil under the peat consisted of calcareous glacial drift having a pH of between 6·0 and 7·0 in the first 6 inches. The overlying peat had a pH of 5·2 to 5·7, its calcium content was between 2·5 and 3·5%, its phosphorus and potassium contents were 0·01 to 0·02% and 0·2 to 0·5% respectively, whilst its nitrogen content was approximately 1·5%. The levels of cobalt, copper and molybdenum in the peat were less than 0·01%.

SCHEME USED IN THE LAYOUT OF EXPERIMENTAL PLOTS

N = Nitrocal. P = Superphosphate. K = Potassium sulphate

Block I		Block III		Block III	
(1) NK	(2) NPK	(9) K	(10) Control	(17) NK	(18) P
(3) K	(4) Control	(11) P	(12) NPK	(19) N	(20) PK
(5) PK	(6) N	(13) N	(14) NP	(21) K	(22) Control
(7) P	(8) NP	(15) PK	(16) NK	(23) NP	(24) NPK

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Nitrogen, phosphate and potash were combined factorially and the experiment was laid down to a randomised block design of 3 replications. The layout is shown on the accompanying chart. The rates of addition for nitrogen, phosphate and potassium were 3, 6 and 2 cwt per acre respectively. Plot size was 15 sq yd and each plot received a basal application of 1 cwt of potassium sulphate and 3 cwt of superphosphate per acre to provide conditions for minimum growth of the plants. Nitrocal (N) which was used to supply nitrogen had the following analysis: 58% ammonium nitrate, 33·36% calcium carbonate, 3–6% magnesium carbonate, and the remainder silica. Phosphate and potassium were supplied as superphosphate (P) and potassium sulphate (K) respectively.

The crop from each of the experimental plots was harvested during one day using a motor mower. Fresh herb was weighed immediately and then was spread out in a thin layer under cover to wilt. When sufficiently dry and crisp, the herb from each plot was separately placed in polythene bags.

Distillation was carried out in a copper still using steam at 15 lb/in^2. The oil was separated from water, dried over sodium sulphate and weighed; it was not rectified. Samples of oil were placed in dry, brown glass bottles and stored in darkness. Each oil sample was examined by gas-liquid chromatography using an Aerograph Hi Fy 600 apparatus. Column: 20% hexose diacetate hexaisobutyrate (SAIB) on 60–80 mesh Embacel Kieselguhr. Length: 10 ft of $\frac{1}{8}$ inch diam. stainless steel tube. Oven temperature: 151–152°. Gas flow: 25 ml/min N_2 and H_2.

Identification of the peaks was effected by the use of authentic specimens of the known components. Peak areas, which are approximate, are given as height × width at half height; they were checked by counting squares.

A number of unidentified compounds were present in traces in the oil. Two compounds, eluted from the column after octan-3-ol but before menthofuran, were present in slightly larger quantities.

Results and discussion

YIELD OF HERB

Table 1 shows that nitrogen significantly increases the yield of fresh herb (P, 0·01) given by first year plants. Second or third year plantations produce much larger yields of fresh herb, but the yields represent a crop much in excess of that usually given by first-year crops on ordinary mineral soil.

Some interaction occurs between nitrocal and superphosphate (P, 0·05); thus in the absence of nitrocal, superphosphate increased the yield from 3·5 to 4·9 tons per acre, but with nitrocal present superphosphate had no effect. Similarly, potassium sulphate increased the yield from 3·4 to 5·1 tons per acre in the absence of nitrocal but there was no effect with nitrocal present (P, 0·001).

The replicates varied significantly from 4·4 to 6·1 tons per acre, which gives an indication of the variation encountered. This result suggests that with a high application of nitrogen, potassium and superphosphate are unnecessary. In the absence of nitrogen, potash and superphosphate produce a beneficial effect.

It should be noted that only those plots treated with nitrogen alone, or in combination with phosphorus or potassium, contain nitrogen in excess of the 1·5% present in the natural peat.

TABLE 1. EFFECT OF NITROGEN PHOSPHATE AND POTASSIUM ON YIELD

	Herb tons/acre[1]		Oil lb/acre[2]		% limonene[3]		% menthol[4]		% menthone[5]	
	−P	+P	−P	+P	−P	+P	−P	+P	−P	+P
−N	3·5	4·9	2·6	4·5	1·1	1·5	61·9	60·6	17·0	16·8
+N	6·3	6·1	10·0	7·6	1·3	1·3	59·7	58·0	20·0	18·8
Significance of N main effect	***		**		*		*		*	
Significance of NP interaction	*		N.S.		N.S.		N.S.		N.S.	
	−K	+K	−K	+K	−K	+K	−K	+K	−K	+K
−N	3·4	5·1	2·6	5·5	1·1	1·5	63·2	59·3	15·9	17·9
+N	6·5	5·9	10·0	3·4	1·3	0·7	59·4	58·3	18·0	20·8
Significance of K main effect	N.S.		N.S.		N.S.		*		*	
Significance of NK interaction	**		**		*		N.S.		N.S.	
	−P	+P	−P	+P	−P	+P	−P	+P	−P	+P
−K	4·7	5·1	2·6	4·5	1·1	1·5	61·6	61·0	17·5	16·4
+K	5·1	5·9	5·5	6·8	1·5	1·7	60·0	57·9	19·5	19·2
Significance of P main effect	N.S.		N.S.		***		N.S.		N.S.	
Significance of PK interaction	N.S.		*		*		N.S.		N.S.	

[1]s.e. per plot = 0·9. [2]s.e. per plot = 1·8. [3]s.e. per plot = 0·2. [4]s.e. per plot = 2·3. [5]s.e. per plot = 2·5.
N.S. = not significant. * 5%, ** 1%, *** 0·1% significance levels.

The above results are in good agreement with those of Baird (1957) for the growth of *Mentha piperita* on mineral soil, and also with those of Birkeli (1948). For *Mentha piperita* in water culture it has been shown that intermediate levels of nitrogen and potassium gave poorer growth than higher or lower concentrations of these nutrients (Crane & Steward, 1962). Maximum growth was obtained with a high level of calcium as would be expected since *Mentha piperita* behaves as a pronounced calcicole, occurring naturally on calcareous habitats.

YIELD OF OIL

Table 1 shows that the yield of oil in lb per acre was significantly increased when nitrogen was available (P, 0·01), while phosphate may have a slight beneficial effect (P, 0·1). This is in agreement with the work of Kotin (1950) and of Latypov (1960).

Significant interaction occurred between nitrogen and potassium; in the absence of nitrogen, potassium gave an increase of 2·9 lb of oil per acre, compared with a decrease of 6·6 lb per acre in the presence of nitrogen.

Interaction was also shown between phosphate and potassium in the presence of nitrogen. Absence of potassium in this case gave a particularly low yield of oil. This result conflicts with that obtained by Birkeli (1948) who found that both potassium and nitrogen are required in large quantities by *Mentha piperita* for the formation of the oil.

Oil yields per acre are exceptionally low compared with those usually obtained on ordinary mineral soil. The average percentage oil yield ranged between 0·032 and 0·071%. For comparison, plants from the same stock were grown on ordinary soil in three different locations. The average percentage yield of oil was 0·18% which is almost four times that from plants grown on peat. This remarkably low yield may be due to the lack of some essential trace element(s). Preliminary survey of the overlying peat revealed a very low trace element content in the case of copper, cobalt and molybdenum and it is possible that other essential trace elements may be entirely absent or may be present in too low a concentration.

COMPONENTS OF THE ESSENTIAL OIL

The effects of the different fertiliser treatments on the amounts of the various components of the oil may be summarised as follows.

Nitrogen depresses the limonene and menthol contents while increasing the menthone and isomenthone components.

Phosphate increases α-pinene, β-pinene and especially limonene (P, 0·01).

Potassium increases the menthone content and reduces that of menthol.

Fertiliser interactions. There was no nitrogen–phosphate interaction on any of the components.

Nitrogen and potassium interactions affect the content of α-pinene, limonene and cineol. Potassium in the presence of nitrogen depressed the content of these constituents, although increasing it when nitrogen was not present.

Phosphate and potassium: for both α-pinene and limonene, potassium depressed the yield where phosphate was absent but increased the yield where phosphate was present.

Nitrogen, phosphate and potassium. A particularly low limonene content was obtained where phosphate was absent but nitrogen and potash were both present.

TABLE 2. TOTAL AVERAGE MENTHOL CONTENT (%) OF OIL SAMPLES OBTAINED UNDER THE DIFFERENT FERTILISER TREATMENTS

Plot	Menthol	Menthyl acetate	Neomenthyl	Total %
N	59	5	4	69
P	63	6	5	73
K	60	5	5	69
NP	59	6	5	70
NK	60	6	5	71
PK	59	6	5	69
NPK	57	6	5	67
Control	64	6	5	74

A notable feature of all the oil samples is the consistently high menthol content, irrespective of the fertiliser treatment (Table 2). Total menthol content varied between 67 and 74%. It was highest in the oil obtained from the control plots and lowest in that obtained from the crop receiving all three fertilisers at the high rate. This finding may be related to the prevailing cold and wet weather which was a feature of the summer of 1962, and in this connection Bankowski (1953) has reported that the oil yield increases with a rise and decreases with a fall in temperature. Menthol content likewise rises with the temperature.

English Mitcham peppermint oil has a total menthol content between 42 and 64% and a menthone content between 29 and 42% (Parry & Ferguson, 1936). These figures for menthone are much higher than in our samples where the menthone content varied between 16% in the controls and 21% in plot NPK. The total menthol content of our samples is considerably higher than the maximum figure (64%) that they obtained.

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