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Introduction and objectives

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AMOUNT AND FATE OF NPK FERTILISER APPLIED TO SUGAR BEET CROPS IN THE EUROPEAN UNION

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Introduction and objectives

Sugar beet is grown in all 15 countries of the European Union where it plays an important part in the economy of farms involved in production. Few soils can sustain regular high yields of beets without addition of one or more of the three major plant nutrients nitrogen (N), phosphorus (P) and potassium (K). Consequently a large amount of effort has been put into discovering optimum soil concentrations of NPK and amounts of fertiliser needed to rectify shortages.

During the past 15 years attention has turned increasingly to the possible harm being done to the environment by the various chemical inputs into crop production, including fertilisers. The authors therefore decided to take an over-view of how much NPK was now being applied for EU sugar beets. Average yields and nutrient concentrations in sugar beet storage roots and tops were then used to calculate the amount taken up from the soil. Hence the amount left in the soil, and returned to it if tops are ploughed in, was examined in relation to leaching into ground waters and build up in soil concentrations. Finally the amount of NPK taken to the factories and its eventual export in lime and by-products was estimated.

Use of fertiliser for sugar beets in the EU

The amount of NPK fertiliser used for beet production varies greatly between European countries (Table 1). Most fields in all countries receive some of the three major nutrients. The weighted average amounts of NPK applied in the mid 1990s were 137kg/ha N, 96kg/ha P₂O₅ and 156kg/ha K₂O. In a previous survey of the same countries (Draycott, 1972) the weighted average amounts were 155kg/ha N, 113kg/ha P₂O₅ and 190kg/ha K₂O. Thus there has been a significant fall in quantities of all three nutrients over the 20 year period.

Assuming that all the NPK was applied as ammonium nitrate (35% N), triple superphosphate (46% P₂O₅) and potassium chloride (60% K₂O) the total amount of fertiliser used for EU beet production amounts to over 2m t. In broad terms about a tonne of fertiliser is applied on average to each hectare of sugar beet.

Table 1 - Area of sugar beets, approximate average application and estimated total quantity of NPK applied for sugar beets in EU in 1995

	Area 1000 ha	Application kg/ha			Quantity 1000t		
		N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅	K ₂ O
Austria	51	130	126	151	6.6	6.4	7.7
Belgium/Luxembourg	107	165	126	178	17.6	13.5	19.1
Denmark	66	110	68	115	7.3	4.5	7.6
Finland	33	142	95	65	4.7	3.1	2.2
France	428	130	110	240	55.6	47.1	102.7
Germany	565	110	60	150	62.2	33.9	84.8
Greece	45	150	103	48	6.8	4.6	2.2
Ireland	33	160	100	220	5.3	3.3	7.3
Italy	278	95	135	125	26.4	37.5	34.8
Netherlands	121	155	117	143	18.8	14.2	17.3
Portugal	1	165	155	90	0.2	0.2	0.1
Spain	172	205	120	95	35.3	20.6	16.3
Sweden	48	145	69	133	35.3	3.3	6.4
United Kingdom	177	105	65	125	18.6	11.5	22.1
Total	2125				292	204	331

Uptake and offtake of NPK

The average yield of fresh, clean, sugar beet roots in EU is about 51t/ha; this is equivalent to a crop producing yields of dry matter of 12.4t/ha roots and 4.6t/ha tops. Using typical DM concentrations (Draycott, 1972) the amount of nutrients taken up by tops and roots can be estimated (Table 2).

For the EU crop of 2.1M ha this amounts to 1.1m t of N, P₂O₅ and K₂O. Generally, the tops are left on the field to be ploughed in or consumed by grazing animals. Nutrient offtake is therefore much smaller with 0.38m t being removed from the land. With respect to fertiliser input, where roots are removed and tops left on the field there is a net input into the soil of between 100 and 200 thousand tonnes of each nutrient. Where both roots and tops are removed the soil is in deficit of similar quantities of N and K but still receives a net input of P. These budgets have ignored use of organic manures on beet fields where residues are likely to be positive irrespective of top disposal method.

Table 2 - Average application of NPK for sugar beets in EU and calculated amounts in tops (leaves plus crown) and storage roots at harvest

	N	P ₂ O ₅ kg/ha	K ₂ O
Application	137	96	156
Amount in tops	124	36	175
roots	74	32	75
tops + roots	198	68	250
		1000t	
EU crop in tops	264	77	372
roots	157	66	159
tops + roots	421	145	531

Effect of fertiliser and crop residues on soil nutrient status

Average usage of NPK in EU is shown in Table 2, weighted for crop area grown in each country. Also shown are amounts of NPK present in the crop with a root yield of 51t/ha. This allows calculation of the amount of NPK left in the field after a crop of sugar beet. If tops are ploughed back 63kg/ha N, 64kg/ha P₂O₅ and 81kg/ha K₂O are the residues, some in the form of unused fertiliser and some in plant material.

The effect of these residues on short and long-term soil fertility in a pan-European context has not been possible to quantify but the authors have evidence from surveys and field experiments in UK that available (Olsen's) P and exchangeable (molar ammonium nitrate) K in soils have increased. Few beet fields are now categorized as 'low' for either element. In recent experiments there was little response by beet to freshly applied K fertiliser indicating there was already sufficient present in soil (Armstrong *et al* 1998). A similar result is expected for P and for Mg.

Average applications of NPK in UK are already some of the lowest in EU (Table 1). With yields currently averaging about 53t/ha and nearly all tops ploughed in residues from beet are calculated in Table 3. (In both UK and other EU countries it is part of fertiliser planning that some residues are used by following crops e.g. wheat is frequently grown after beets without further PK.)

Table 3 - Average residues from fertiliser applied for beet in UK

	N	P ₂ O ₅ kg/ha	K ₂ O
Application	105	65	125
Removed in roots	77	34	78
Residue	28	31	47

Thus on the basis of little or no response to fresh fertiliser these residues suggest there is scope for further precision in use of fertiliser in UK and perhaps more so in some other EC countries. To this end the authors are engaged in a review of how fertiliser should be used to best advantage in the new millennium.

Nutrients in drainage water and drinking water quality

In contrast to many sugar beet producing countries (e.g. parts of USA and the arid areas of South America and Eastern Europe) the climate of North West Europe provides more than enough winter rainfall to return soils to field capacity. Further rainfall then saturates and leaches nutrients into underground aquifers or through land drains into water courses. Such water is often used subsequently for human consumption.

In 1980 the EU issued a council directive concerning drinking water quality. Table 4 summarises these guide concentrations for major plant nutrients. They serve as useful indicators to assess the environmental impact of fertiliser use in relation to crop production.

Table 4 - Summary of EU guideline upper concentrations of nutrients in drinking water

Nutrient	Concentration - mg/l
NO ₃ ⁻	25 (5.65mg/l nitrate - N)
K ⁺	10
Na ⁺	20
Mg ²⁺	30
Cl ⁻	25
Ca ²⁺	100
PO ₄ ³⁻	0.4 (0.175mg/l phosphate - P)
SO ₄ ²⁻	24

Prior to this directive, measurements were begun on water leaving an experimental field in land drains where sugar beet was grown in rotation with cereals. Fertiliser N was used to produce optimum yield without excess and PK was planned carefully in relation to soil analysis recommendations.

Water percolating through the soil and leaving the drainage system contained variable concentrations of nutrients. In many winters nitrate concentrations were well below the guideline for much of the time but in some years it was exceeded slightly. In no year was either the K or Na guideline concentration exceeded, except on two occasions for Na when it had been applied as fertiliser for sugar beet. P concentrations were very low indeed for much of the time but on three occasions it exceeded the guideline by a small amount.

Fate of NPK during processing

Table 2 shows that annually an estimated 157,000t N, 66,000t P₂O₅ and 159,000t K₂O are delivered to EU sugar factories within roots. The sucrose and other soluble components of the roots are extracted by diffusion and the resultant 'juice' purified with lime. For the EU crop it is

estimated that about 2.5m t DM of factory lime are produced annually. Most of the lime is returned to arable fields or grassland. Assuming an average analysis of 0.6% N, 1.6% P₂O₅ and 0.2% K₂O on a dry matter basis then the quantities of nutrient leaving the factories in lime are 15,000t of N, 40,000t P₂O₅ and 5,000t K₂O. Thus only a small amount of N and K is accounted for in the factory lime. Most of the remaining phosphate, and some nitrogen, is within the insoluble part of the root (the marc) which is returned to agricultural production as animal feed. After sucrose crystallization, the soluble components constitute molasses which contain the remaining K, N and P. The molasses have a variety of uses but much return to the farm as animal feed. Small amounts of nitrogen are lost to the atmosphere as ammonia or other gaseous emissions during processing. Similarly losses of all three nutrients in waste water are small due to strict legal limits in EU.

Summary

- 1 The 15 countries of EU grow a total of 2.1 million hectares (5.2m acres) of sugar beet with an average yield just over 50t/ha (20t/a).
- 2 Nearly all EU soils need NPK fertiliser to sustain economic yields and a total of 1.1m t N, P₂O₅ and K₂O are applied each year before sugar beet.
- 3 Average NPK analyses of plant dry matter have been used to estimate how much of this is taken to factories and how much remains on fields. This shows over EU as a whole there is a large residue of NPK left on beet fields, hence increasing concern about its fate.
- 4 Of the fertiliser taken to factories in storage roots (estimated at about 0.4m t N, P₂O₅ and K₂O) some finds its way back to fields in lime. Much of the remainder exits factories in pulp and molasses, and quantities are shown.
- 5 There is evidence that fertiliser could be balanced more closely to crop requirement and offtake. In many cases we believe use of fertiliser is excessive.
- 6 In UK measurements have been made over a 25 year period of concentrations of nutrients in water draining out of land in a sugar beet/cereal rotation. Fertiliser use was within recommendations for economic yields and maintenance of soil fertility. This work illustrates good crop production can be achieved with little impact on the environment.

Literature cited

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