

# Fertilisers in the Forest: a Guide to Materials

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## FOREWORD

This leaflet has been written primarily as a guide to British foresters who seek information on the best materials to correct nutrient deficiencies in forest trees. Because the conclusions should be generally applicable in temperate coniferous forests on acid soils, the summary has been translated into French and German.

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### FRONT COVER

Plate 1. Rock phosphates, half natural size. *Top row*, from Khouribga, Morocco; *bottom row*, from Gafsa, Tunisia. *Left to right*, unground, ground and granulated forms. The different particle sizes in the two granulated samples are due to the processes used in manufacture. 24029.

## SUMMARY

The Forestry Commission fertilised 7,200 ha of plantations in 1960–61, 51,000 ha in 1973–74. From 1969 on, roughly two-thirds of the treated area had phosphate alone, one third PK mixture, and less than one per cent had N fertiliser.

Rock phosphates from North Africa are the best P fertilisers. The unground form is used for aerial work but is still a dusty material.

Potassium chloride (muriate of potash) is the only recommended K fertiliser. A mixture of unground phosphate rock and crude potassium chloride makes an acceptable PK fertiliser for forestry.

Urea is the cheapest and most concentrated N fertiliser, but may lose N to the air as ammonia. Ammonium nitrate is more reliable, but less concentrated.

Although fertilisers could contaminate surface waters, this should not occur with careful work and, for K and N, spring or summer application. Contamination of ground water is improbable. People working with fertilisers must wear suitable clothing and pay attention to safety measures.

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## RESUME

La Forestry Commission a fertilisé 7 200 ha de plantations en 1960–61, 51 000 ha en 1973–74. A partir de 1969, les deux tiers environ de la surface traitée n'ont reçu que du phosphate, un tiers un mélange PK, et moins de 1%, de l'azote.

Les phosphates naturels d'Afrique du Nord sont les meilleurs engrais P. La forme non moulue est utilisée pour les applications aériennes, mais fait encore beaucoup de poussière.

Le chlorure de potasse est la seule forme recommandée d'engrais potassique. Un mélange de phosphate naturel non moulu et de chlorure de potasse constitue un engrais forestier convenable.

L'urée est le moins cher et le plus concentré des engins azotés, mais peut perdre de son azote sous forme d'ammoniac gazeux. Le nitrate d'ammoniaque est plus sûr, mais moins concentré.

Bien que les engrais puissent contaminer les eaux de surface, cela ne devrait pas se produire en prenant quelques précautions, et, pour N et K, par des épandages de printemps ou d'été. La contamination des eaux plus profondes est improbable. Le personnel qui manipule les engrais doit être habillé en conséquence, et respecter les consignes de sécurité.

J-P. Maugé

## ZUSAMMENFASSUNG

Die britische "Forestry Commission" hat 1960–61 7.200 ha Aufforstungsflächen gedüngt; im Jahre 1973–74 lag die Zahl bei 51.000 ha. Von 1969 an wurden rund 2/3 der gedüngten Flächen mit Phosphat allein, 1/3 mit einer Mischung aus Phosphat und Kali und weniger als 1 % mit Stickstoff abgedüngt.

Rohphosphate aus Nordafrika haben sich als die besten Phosphatdüngemittel erwiesen. Die ungemahlene Form wird für die von Flugzeugen aus erfolgende Ausbringung verwendet. Obwohl ungemahlen, ist dieses Düngemittel doch noch ein relativ staubiges Material.

Kaliumchlorid (muriate of potash) wird allein als Kalidüngemittel empfohlen. Eine Mischung von ungemahenem Rohphosphat und grobem Kaliumchlorid ergibt einen geeigneten PK-Dünger für die Forstwirtschaft.

Harnstoff ist der billigste und am stärksten konzentrierte Stickstoffdünger, aber es können gasförmige Stickstoffverluste in Form von Ammoniak entstehen. Ammoniumnitrat gilt zwar als zuverlässiger, sein Stickstoffgehalt liegt aber niedriger.

Obwohl Düngemittel zu Verunreinigungen des Oberflächenwassers führen können, ist dies bei sorgfältiger Ausbringung und speziell bei N- und K-Düngungen im Frühjahr oder Sommer weitgehend auszuschliessen. Eine Verunreinigung des Grundwassers ist unwahrscheinlich. Menschen, die mit Düngemitteln umgehen, sollten entsprechend gekleidet sein und Sicherheitsmassnahmen beachten.

H. Baule

# FERTILISERS IN THE FOREST: A GUIDE TO MATERIALS

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## INTRODUCTION

British foresters have in recent years greatly increased their use of fertilisers to correct and prevent nutrient deficiencies in forest trees and thereby improve growth. Table 1 gives some figures of fertiliser use in the Forestry Commission.

Only nitrogen (N), phosphorus (P) and potassium (K) are applied intentionally, though other nutrient elements may be applied incidentally with them, the most important of these being calcium and sulphur. (Magnesium

is used in forest nurseries, but nurseries are outside the scope of this guide).

It is the purpose of this publication to set out the merits of the different forms of N, P and K fertilisers currently available and indicate those most suitable for use in British forests. Relative prices will change and other considerations (e.g. handling qualities, environmental effects) may also influence the final choice. Profitability of forest fertilising, which varies with time and circumstance, is not discussed.

TABLE 1  
AREAS OF FORESTRY COMMISSION FOREST TREATED WITH FERTILISERS, TO  
NEAREST 50 HECTARES, FOR SOME RECENT YEARS

### A. BY NUTRIENT ELEMENTS

| Year    | N   | P      | NP  | K   | PK     | NPK | Total  |
|---------|-----|--------|-----|-----|--------|-----|--------|
| 1960/61 | —   | 6,900  | —   | —   | 300    | —   | 7,200  |
| 1969/70 | 450 | 23,000 | —   | 50  | 2,700  | —   | 26,200 |
| 1971/72 | 200 | 13,600 | —   | 50  | 9,200  | —   | 23,050 |
| 1972/73 | (0) | 25,650 | 100 | (0) | 14,650 | —   | 40,400 |
| 1973/74 | 650 | 32,050 | —   | —   | 18,300 | (0) | 51,000 |

(0) = less than 25 ha.

### B. BY METHOD OF APPLICATION

| Year    | Manual | Helicopter | Fixed-wing aircraft | Total  |
|---------|--------|------------|---------------------|--------|
| 1960/61 | 7,100  | —          | 100                 | 7,200  |
| 1971/72 | 3,500  | 18,550     | 1,000               | 23,050 |
| 1972/73 | 4,500  | 33,050     | 2,850               | 40,400 |



## HISTORY

Phosphate fertilisers were the only ones used in British forests (except in research) until the late 1950s, when potassium deficiency in some peatland plantations was recognised. N fertilisers, as shown in the table, are still used only on a small scale. Basic slag was the first P fertiliser used in forestry but this later gave way to ground mineral phosphate (known as GMP), which was finely ground phosphate rock mainly imported from North Africa. In South Wales and South-West England triple superphosphate was also used in the post-war period and triple superphosphate is still preferred for hand application in parts of South-West England. The introduction of unground phosphate rock in the mid-1960s led to a great increase in the treatment of existing forests from the air.

## DESIRABLE PROPERTIES OF A FORESTRY FERTILISER

For use in forestry a fertiliser must have several properties: it must be cheap per unit of

nutrient; it must be sufficiently concentrated to give low application costs; it must be in a physical form suitable for mechanical spreading either from the ground or the air; it must be long-lasting, i.e. not easily washed away or decomposed to lose its nutrients to the atmosphere; and, finally, it should not contaminate the environment.

## MATERIALS

### Phosphate Fertilisers

The range of simple<sup>(1)</sup> phosphate fertilisers currently available is shown in Table 2.

The three criteria of high concentration, low cost per unit of P, and suitable physical form limit the choice of material considerably.

Of the two water-soluble materials, single superphosphate is relatively expensive per unit of phosphorus and its concentration is sufficiently low to make spreading costs high.

(1) Materials supplying only one of the three main nutrients are described as "simple" fertilisers.

TABLE 2  
PHOSPHATE FERTILISERS

| Material              | % total P <sub>2</sub> O <sub>5</sub><br>(% total P) | Solubility                                   | Physical form                              | Comments  |
|-----------------------|--|--|--|---|
| Single superphosphate | 18-21<br>(8-9)                                       | Soluble in water                             | Normally granular                          | Good physical form, quick-acting, expensive     |
| Triple superphosphate | 44-47<br>(19-21)                                     | Soluble in water                             | Normally granular                          | As above  |
| Basic slag            | 7-22<br>(3-10)                                       | c. 80% of best grades soluble in citric acid | Powdered or minigranular                   | Dirty when powdered. Has a marked liming effect |
| Rock phosphate        | 25-40<br>(11-17)                                     | 8-50% soluble in citric acid                 | Coarsely ground, finely ground or granular | See Table 3 and text                            |

Triple superphosphate is ideal in two respects, it has the highest concentration of any material which can be used in practice and its granular form makes it very suitable for spreading. It is however much more expensive per unit of phosphorus than rock phosphate and, although the recent relative increase in the cost of the raw material compared with the manufacturing costs will lessen the difference,

this will militate against the use of triple superphosphate except in special circumstances.

Basic slag (known in Germany as *Thomas-phosphat* and in France as *scories*) is becoming increasingly difficult to obtain and eventually, with changes in steel-making processes, grades suitable as fertilisers are likely to disappear altogether. Because of its low concentration,

TABLE 3  
ROCK PHOSPHATES

| Source             | Number of samples | Form       | P <sub>2</sub> O <sub>5</sub> Content, per cent |                                    |                                  | Percentage passing BSS <sup>(2)</sup> |          |
|--------------------|-------------------|------------|---|------------------------------------|----------------------------------|---------------------------------------|----------|
|                    |                   |            | Total   | Citric acid soluble <sup>(1)</sup> | Citric soluble as per cent total | 100 mesh                              | 200 mesh |
| Gafsa, Tunisia     | 4                 | Unground   | 29  | 10                                 | 33                               | 59                                    | 4        |
|                    | 2                 | Ground     | 27  | 11.5                               | 43                               | 82                                    | 36       |
|                    | 3                 | Granulated | 29  | 13.5                               | 46                               | —                                     | —        |
| Khouribga, Morocco | 2                 | Unground   | 33  | 9.5                                | 29                               | 17                                    | 2        |
|                    | 2                 | Ground     | 33  | 9.5                                | 30                               | 85                                    | 9        |
|                    | 1                 | Granulated | 30  | 9                                  | 31                               | —                                     | —        |
| Israel             | 2                 | Granulated | 31  | 7.5 <sup>(3)</sup>                 | 24 <sup>(3)</sup>                | —                                     | —        |
| Senegal            | 2                 | Ground     | 37  | 7.5                                | 20                               | 90                                    | 34       |
| Nauru              | 1                 | Ground     | 38  | 8                                  | 21                               | 94                                    | 51       |
| Florida, USA       | 1                 | Unground   | 29  | 6                                  | 20                               | 14                                    | 5        |
| Kola, USSR         | 1                 | Ground     | 39  | 3                                  | 8                                | 86                                    | 49       |

Notes: (1) 5g of the material ground to pass a 1 mm sieve and shaken with 500 ml of 2 per cent citric acid for half an hour at 20°C.

(2) 100 mesh: a sieve with apertures 0.15 mm across.

200 mesh: a sieve with apertures 0.075 mm across.

(3) See text, p. 8.

its fineness, and its blackness, it is unsuitable for forestry use; the minigranular form is not easily available.

Rock phosphates are the only source of P used on any large scale in forestry. As already mentioned, before and for some time after the war GMP was the preferred material, but could not be used from the air because it clogged the distributors (and also of course because fine material blows a great distance in any wind). The product known as unground phosphate rock, which is the material as mined and crushed and then passed through a screen of about a quarter inch (6 mm) mesh, is now used for virtually all aerial work. Table 3 shows however that there is considerable variation in the amount of fine material in the different origins of these "unground" phosphate rocks and there is still appreciable drift when they are applied from the air: in fact, half to two-thirds of the four unground Gafsa samples passed through a sieve with apertures of 0.15 mm. Nevertheless, the important point is that the unground phosphate rocks pass satisfactorily through the distributors.

Granular forms of phosphate rock would be ideal for use from aircraft and from ground machines (and for hand application too), but they are not yet commercially available in Britain, although they have been used with success in experiments. The cover picture shows two origins of phosphate rock in the unground, finely ground and granulated forms.

Although unground phosphate rock is less fine than the old GMP, it is still an unpleasant material to use by hand; this is the main reason why triple superphosphate is still used occasionally for small areas of forest.

### Choice of Rock Phosphate

Agricultural experience has suggested that Gafsa phosphate is the best material, but this evidence is derived from experiments on annual crops which require a quick-acting material. Furthermore, few agricultural soils have a pH of less than 5.5 while few forest soils have a pH above 5.5: rock phosphate

acts more rapidly in acid soils than in near-neutral ones. Agricultural experience has also suggested that rock phosphates with a high solubility in 2 per cent citric acid are the most effective. Forestry Commission experiments comparing different forms of rock phosphates have confirmed this to some extent by showing that the forms with low citric soluble contents, e.g. from Kola, are slower to improve growth and to increase the concentration of phosphorus in the needles of conifers (Mackenzie, 1972). However, some recent information from Finland suggests that natural apatite rock, similar to that from Kola, has a much longer period of action than either superphosphate or Gafsa phosphate and that the total effect on growth may be the same as for the more rapidly acting forms (Karsisto, 1974).

One possible conclusion is that while the more highly citric soluble forms should definitely be preferred for treating phosphate-deficient crops and for an initial dressing at planting, the less soluble forms could prove satisfactory for top-dressing older and better crops.

Until further evidence from long-term experiments is available it seems wise to use only those forms which have both a high total P content and 25 per cent or more of the total phosphate soluble in citric acid. An inspection of Table 3 suggests that phosphate rocks from North Africa should be preferred and that the materials from Senegal, Florida, Nauru and Kola should not be used in the meantime. The only two samples of Israeli rock phosphate in Table 3 differed markedly, one having only 18 per cent of its phosphorus soluble in citric acid; this material has performed less well than Gafsa phosphate in recent experiments. If Israeli phosphate is on offer the solubility in citric acid should be tested.\*

The reasons for the difference in performance of the various phosphate rocks depend on their chemistry, which is complex. The

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\*It is understood that any Israeli rock phosphate marketed in this country will have a stated 30 per cent of the total phosphorus soluble in citric acid. If this is so tests will be unnecessary.



forester is interested only in cost per unit of P, speed of action, concentration, and suitable physical form for handling. Those who are interested in reading about the history of rock phosphates and something of their chemistry can consult the sources listed in the bibliography, where there are also some items concerned with the use of phosphate fertilisers in forestry.

### Potassium Fertilisers

The choice for the forester is quite simple: potassium chloride (KCl), known also as

muriate of potash, is the only material which is cheap enough and concentrated enough for forest use. There are however many different grades available which vary in purity and particle size. The theoretical potassium content is 50 per cent (60 per cent  $K_2O$ ), the actual concentration achieved may be rather less depending on the degree of refining.

In general, the cheapest source is the best value, provided the particle size is suitable for the method of application being used. Four examples from the range of physical forms are shown in Plate 2.

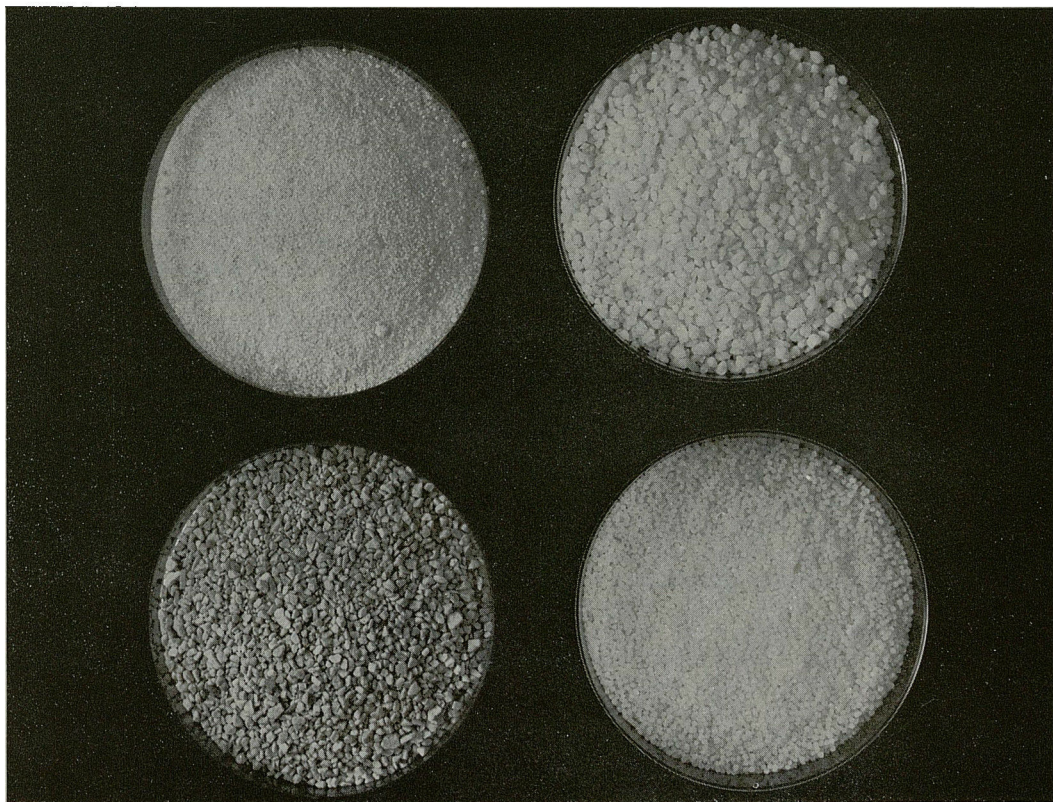


Plate 2. Four forms of potassium chloride, half natural size. *Top left*, fine crystals; *top right*, coarse granules; *bottom left*, impure coarse granules; *bottom right*, small prills. C.5019.

The other commonly available material, potassium sulphate ( $K_2SO_4$ ) is less concentrated, containing 42 per cent K (50 per cent  $K_2O$ ) and is also much more expensive per unit of K.

### Nitrogen Fertilisers

Numerous forms of simple N fertiliser exist and are listed in Table 4, but only urea and ammonium nitrate have been used in practice in British forests.

TABLE 4  
NITROGEN FERTILISERS

| Chemical Name                        | Proprietary Names                                   | %N             | Chemical Formula                          | Comments  |
|--------------------------------------|---|----------------|---|---|
| Urea                                 | —   | 46             | $CO(NH_2)_2$                              | Prilled <sup>(1)</sup> . Stable when dry. May lose N to the air after application.  |
| Ammonium nitrate                     | “Nitram”<br>“Nitrashell 34”                         | 34·5<br>34     | $NH_4NO_3$                                | Absorbs moisture from the air. Strong oxidising agent.  |
| Ammonium nitrate + ammonium sulphate | Fisons “Nitro 26”                                   | 26             | $NH_4NO_3 + (NH_4)_2SO_4$                 | Absorbs moisture from the air.  |
| Ammonium nitrate + calcium carbonate | “Nitro-Chalk”<br>“Nitrashell 23”<br>“Nitrashell 26” | 21<br>23<br>26 | $NH_4NO_3 + CaCO_3$                       | Absorbs moisture from the air.  |
| Ammonium sulphate                    | —   | 20·6           | $(NH_4)_2SO_4$                            | Acidifying.   |
| Calcium nitrate (double salt)        | —   | 15·5           | $5Ca(NO_3)_2 \cdot NH_4NO_3 \cdot 10H_2O$ | Difficult to obtain. Satisfactory physically when prilled. Sometimes referred to in foreign literature as calcium-ammonium nitrate. |

Note: <sup>(1)</sup> Prills: Small pellets made by dropping the molten material through a rising current of air.

Urea is usually the preferred material because of high concentration and low cost per unit of nitrogen. It has one serious disadvantage compared with ammonium nitrate: under warm moist (but not wet) conditions it may decompose and some of the nitrogen is then lost to the atmosphere as gaseous ammonia.

In the high rainfall areas of upland Britain one might think that urea is an ideal material, for once dissolved and washed into the soil, it is very firmly held by the organic matter. However, dry weather for a few days may be quite sufficient to cause loss of nitrogen and experiments in Britain and Scandinavia have shown that urea is sometimes much less effective than ammonium nitrate.

Because ammonium nitrate has only three-quarters of the nitrogen concentration of urea, an aircraft for the same payload can only spread three-quarters of the area on one run. In fact, ammonium nitrate is rather denser than urea so the nitrogen in a given volume of the two materials will be about the same. However, since most machines are limited by weight rather than capacity, this difference does not affect choice. Loss of nitrogen from ammonium nitrate by leaching, while in principle likely to be greater than from urea, does not appear to be important in practice.

As ammonium nitrate is a strong oxidising agent it will make a bad fire worse. *It should therefore never be stored in wooden buildings nor together with other materials which will burn.*

The various brands of ammonium nitrate mixed with calcium carbonate are not used for top-dressing forests because they are less concentrated and therefore much more expensive to spread. (They are however the preferred forms for use in forest nurseries because the lower concentration makes it easier to apply them evenly and because they neither raise nor lower the pH appreciably).

Calcium nitrate is only mentioned because references to it will be found in the forestry literature from other parts of Europe: it is not normally obtainable commercially in Britain and its low N content makes it unsuitable for forestry use.

Ammonium sulphate and mixtures of ammonium sulphate and ammonium nitrate are again less concentrated than urea or ammonium nitrate itself and are therefore more expensive to spread. They are also acidifying.

### **Choice of N Fertiliser**

There are only two recommended materials: urea, which is the cheaper to buy and apply and which does not constitute a hazard to the environment, but which may on occasion be ineffective; and the more reliable ammonium nitrate, which is more costly to buy and apply and which could, in some circumstances, increase the nitrate concentration in drinking water. The choice will depend on local conditions and current costs.

### **Mixtures of More than One Nutrient Element**

Quite large areas of forest, as indicated in Table 1, are treated with both P and K, almost entirely with mixtures of unground phosphate rock and crude potassium chloride. The mixture normally used supplies roughly 50 kg P and 100 kg K per hectare, which is given by 375 kg of phosphate rock and 200 kg of potassium chloride, 575 kg/ha in all.

Since the material is a mixture and not a compound, it is important to see that the two components are uniformly mixed and that the ranges of particle size are roughly the same; otherwise the components may separate in transit or in the air after the mixture has left the aircraft.

It would be possible to manufacture a granular material consisting of rock phosphate and potassium chloride which would be ideal for forestry use.

N and P fertilisers have occasionally been used together, for example for spruce plantations growing on *Calluna* heathland, but the need does not justify a special material. Mixtures of unground phosphate rock and urea should be suitable.

## PROTECTING THE ENVIRONMENT AND THE WORKER

Although foresters and farmers use N, P and K fertilisers at similar rates, foresters use them much less frequently: a forest would seldom be treated with any one element more often than once every eight years or so. Because foresters use fertilisers in surroundings which are, by agricultural standards, very infertile, their use will cause marked environmental changes—that is the reason for using them; and it follows that carelessness or accidents could produce changes so large as to be undesirable. There are three main dangers:

- (i) contamination of surface or ground water;
- (ii) excessive enrichment of the soil with nutrients;
- (iii) harmful effects on workers.

Because the fertiliser, soil type, gradient, rainfall, wind direction, and proximity to open water all affect the likelihood of contamination, it is difficult to draw up rigid rules for all situations. The dangers however can be cut down or avoided altogether by forethought, care and an understanding of general principles.

### Contamination of Ground Water

Unground phosphate rock is washed into the upper layers of the soil by rain and the phosphorus slowly released by the action of the acid soil solution. Because there is little movement down the soil profile, except in coarse sandy soils, contamination of ground water is minimal. Urea, ammonium nitrate and potassium chloride all dissolve readily in water. The nitrogen in urea and the nitrate part of ammonium nitrate are rapidly converted into the ammonium form in acid soils, and both ammonium-nitrogen and potassium are held by the clay particles and organic matter, so again contamination of ground water is unlikely.

### Contamination of Surface Water

In heavily ploughed forests, some 15 per cent of the land surface is furrows, so that 15 per cent of the fertiliser could fall directly into them and some of this will be washed into drains and thence into streams. This will be least where the practice of broadcasting fertiliser before ploughing is acceptable. Where crops have closed canopy most of the fine particles drifting in the wind will be caught in the foliage and less will fall directly into the furrows, which will in any case be drier for longer periods of time.

There are enough fine particles in rock phosphate and some forms of potassium chloride to blow a long way in high winds. Although high winds rule out flying, and hence aircraft spreading, drift of fertiliser can be a danger with ground machines operating on bare hillsides. If too much rock phosphate reaches a reservoir, a bloom of algae may result which, on dying, can reduce the oxygen sufficiently to kill plants, fish and other creatures, and block water filters. However, sampling done so far suggests that the normal use of phosphate in forestry does not produce algal blooms. Also, since algae do not grow much in the autumn, fears on this score may be allayed by spreading phosphate in autumn or early winter.

Because both K and N fertilisers are very soluble, heavy rain can wash them over the soil surface into drains and thence into water courses. K fertiliser should not cause any problems and N fertiliser is unlikely to cause algal growth (phosphorus is usually the main limiting factor to biological processes in upland waters) but ammonium nitrate could possibly raise the nitrate in drinking water above the permitted concentration, though this is very unlikely. K and N fertilisers are therefore best applied in the spring or summer when there are likely to be small soil moisture deficits and, as a consequence, rain enters the soil rapidly.

### Excessive Enrichment of the Soil

Because fertilisers are used infrequently there should be no excessive enrichment of the soil

with nutrients. Dangers arise only from erratic spreading, jettisoned loads or—most likely— from spillage around storage heaps and loading points or from abandoned bags of damp fertiliser. Especial care is needed in storing and handling fertilisers in the forest.

### **Hazards to Workers**

Potassium chloride and ammonium nitrate are salts (the former being very similar to common salt) and can be very painful in a cut or in the eye. Urea is less active but even so is better kept out of cuts and eyes. Rock phosphate, though not an active chemical, like any dusty material can cause distress if inhaled.

It is important to emphasise that fertilisers are not poisonous in the way that some pesticides are poisonous, but they can be unpleasant or even dangerous if they get into the wrong places. Protective clothing and safety equipment must therefore be provided by managers and used by people working with fertilisers.

*Eyes, nose and mouth* must be protected if the wind is strong enough to blow the fertiliser about. Goggles must have maximum screened ventilation and be treated against misting; several pairs can be used in turn. Masks with dust filters must be worn and the filters changed if breathing becomes difficult, or after 8 hours use. If working in goggles and mask is impracticable, for example working on steep slopes in high winds, then the work should be stopped until conditions improve.

*Hands and wrists* must be protected when working with potassium chloride or ammonium nitrate, by gloves impermeable to these chemicals.

The *body* must be protected by overalls of the boiler-suit type. The overalls should be washed in an industrial laundry or separately from domestic laundry.

### **Care of Machines**

It is important to remember that potassium chloride and ammonium nitrate are corrosive and will eat holes in most metals if left in contact with them. If machines are to last any length of time they must be cleaned out after using these materials.

### **Guidelines**

If the guidelines given below are followed they should lead to trouble-free application of fertilisers with no harmful effects on the environment or the workers. They are mainly a matter of common sense and will usually have already been observed by foresters.

#### *Avoiding contamination of water*

- (i) If appropriate, apply fertilisers before ploughing.
- (ii) Apply K and N fertilisers in the spring or summer months.
- (iii) Where algal growth in reservoirs is a possible worry, apply phosphate in autumn or early winter.
- (iv) Avoid direct contamination of water-courses; pay attention to swath width and wind direction.
- (v) Contact local water undertakings well beforehand if catchments to be treated feed reservoirs.
- (vi) Ensure that fertilisers applied by ground machines do not blow into water-courses or reservoirs.

#### *Avoiding excessive soil enrichment*

- (vii) Observe the accuracy and uniformity of application.
- (viii) Minimize spillage at loading sites and wastage due to bad storage.

#### *Protecting the workers*

- (ix) Provide the proper protective clothing and safety equipment; and see it is used.

#### *Protecting machinery*

- (x) Clean machines after using potassium chloride or ammonium nitrate.

### **ACKNOWLEDGEMENTS**

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