Chemical weed control and its effect on the response to potassium fertilisation

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INTRODUCTION

Growth check of Norway spruce *(Picea abies (L.) Karst)* and Scots pine *(Pinus sylvestris L)* on reedswamp peat in Moanvane, Emo forest, Co. Laois, appeared, on investigation, to be due to potassium deficiency (O'Carroll, 1966).

Pottassium fertiliser was applied on an experimental basis to the crops involved in early June 1964, the crops being then aged 20-22 years, and having a mean height in the worst affected areas of from 1.3—3.8m. By August of that year there was a marked upsurge in the vigour of the ground vegetation in the plots treated with potassium, and by late Autumn the visual symptoms of deficiency had disappeared from the trees in those plots. At the same time the foliar potassium levels had been significantly increased from a mean of 0.36% of dry matter in control plots to 0.64% in plots treated with potassium. No significant increase in height growth was obtained however until 1966, and then the increase was slight. This was disappointing in view of the rapid and spectacular responses to phosphate fertiliser obtainable in Sitka spruce *(Picea sitchensis* Bong, Carr*)* growing on western blanket bog peats where the limiting factor was phosphate deficiency. One possible cause of the slow development of the response, and its small size, was competition from the more vigorous ground vegetation which had resulted from the fertiliser treatment.

At this time it was becoming apparent that potassium deficiency was likely to be a fairly widespread problem on certain peat soils in the east midlands. It was therefore necessary to investigate whether a simple top dressing of potassium fertiliser would be adequate, or whether intensive vegetation control methods would also be needed.

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EXPERIMENTS

Three experiments were begun in the summer of 1967 to test the hypothesis that ground vegetation was in competition with the trees and was reducing the effeciency of applied potassium fertiliser as reflected in tree growth.

The experiments were located in existing young plantations at Clonavoe and Derrycricket, both in Edenderry forest, Co. Offaly, and at Boherbaun in Athy forest, Co. Kildare.

These sites were chosen on the basis of the presence in the crops of the distinctive symptoms of potassium deficiency. These symptoms have often been described and illustrated (e.g. van Goor 1970) but may briefly be described as follows: A partial or gradating chlorosis of the needles in which the points of the needles are yellower than the bases, and with a gradual decrease in yellowness in the needle from the point to the base. In addition in Norway spruce the needles nearer the bud are usually more severely affected than those further back on the same twig. These symptoms were strongly developed at Clonavoe and Derrycricket, and present, though not well developed, at Boherbaun.

Soils

The soil at Clonavoe and Derrycricket consists of over 2m of woody fen peat (Barry 1969) overlying limestone glacial drift. The Boherbaun site, with over 1m of peat underlain by shell marl, represents the organic component of the Finnery soil complex (Conry *et al* 1970).

Crops

The crops at all three sites consisted of a mixture of three lines of Norway spruce alternating with one line of Scots pine, a common mixture on sites in the midlands with a high risk of late spring frosts.

Clonavoe was planted in 1966 with Norway spruce of Bodenseegebiet and Oberschwaben origin, and Scots pine of Scottish origin. Derrycricket and Boherbaun were both planted in 1959 using Norway spruce probably of Danish origin and Scots pine of Scottish origin.

All sites were ploughed before planting using the double mouldboard Cuthbertson plough (for description of plough see Taylor, 1970). Clonavoe was treated after planting with ground rock phosphate at the rate of 3 oz. (85g) per plant (365 kg/ha). Derrycricket was similarly treated in 1963, and Boherbaun was probably treated at the same rate with either basic slag or ground rock phosphate after planting.

The mean heights of the crops at the beginning of the 1967 growing season are given in Table 1.

TABLE 1

MEAN HEIGHT (METRES) OF EXPERIMENTAL CROPS AT START OF 1967 GROWING SEASON

Site	Age (years)	Mean height (metres)	
		Norway Spruce	Scots pine
Clonavoe	2	0·36	0·34
Derrycricket	8	0·64	0·91
Boherbaun	8	0·85	1·44

Vegetation

The vegetation at Clonavoe and Derrycricket was characterised by a mixture of the grasses creeping red fescue (*Festuca rubra,* L.), sweet vernal *(Anthoxanthum odoratum L.) and Agrostis canina* L., with the common rush (*Juncus effusus* L.) colonising the plough furrows. The other species differed at the two sites, consisting of, at Clonavoe, marsh cinquefoil (*Potentilla palustris* Scop.) and *Cirsium palustre* Scop., and, at Derrycricket, meadow-sweet) (*Filipendula ulmaria* Maxim.) and *Epilobium palustre* L.

At Boherbaun the predominant grasses were *Molinia caerulea* Moench. and creeping red fescue, accompanied by wild valerian (*Valeriana officinalis* L.), purple loosestrife (*Lythrum salicaria* L.), meadow-rue (*Thalictrum flavum* L.), meadow-sweet and others of minor occurrence.

Experimental treatments and design

Two factors, potassium fertiliser and herbicide, each at two levels, one of which in each case was zero, were tested. Combined in a 2 x 2 factorial design these give four treatment combinations viz.—

- O Control. No potassium or herbicide.
- K Potassium as 3cwt potassium chloride per acre (376 kg/ha) supplying 188 kg K per ha.
- H Gramoxone W (Paraquat) at 6 pints in 100 gallons of water per acre (8.4 1 in 1,123 1/ha).
- KH Treatments K and H combined.

All treatments were applied during the first half of July 1967 and regrowth in all herbicide-treated plots was sprayed in November and each subsequent Autumn. The aim was to keep those plots as free as possible from all vegetation other than the trees.

Plot size was .037 ha (.09 acre) at Clonavoe and Derrycricket, and 0.40 ha (.10 acre) at Boherbaun.

The four treatment combinations were replicated four times at each site, in randomised blocks at Clonavoe and Boherbaun, and in a latin square at Derrycricket.

ASSESSMENTS

Annual leader growths of both species for 1967, 1968, 1969 and 1970 were measured. In addition, mean height was assessed at the end of the 1969 growing season.

Foliage of Norway spruce (from the top whorl) was collected at Derrycricket and Boherbaun in January 1969 for chemical analysis. Two replications at each site were sampled. The foliage was analysed for N, P, K and Mg.

Some frost damage was observed on the spruce at Clonavoe and Derrycricket in the Summer of 1969, and this was assessed by means of a scoring system, each tree being scored as a unit. No damage was scored O, damage to lateral buds confined to the lower parts of the tree was scored 1, and damage to buds over all parts of the tree was scored 2. The final score for each plot was expressed as a percentage of the maximum possible score for that plot (2 × number of live trees).

All data were subjected to standard variance analysis, the percentage data from the frost damage assessment having first been transformed to angles by the arcsin transformation.

RESULTS AND DISCUSSION

Leader growth

Average leader growths for all treatment combinations for each of the four years after treatment (1967-1970) on each of the three sites are given with their standard errors in tables 2-4. Each is the mean of four replications. Where there were no significant effects of treatments this is indicated by the letters N.S. Where there was a significant interaction between the two factors, potassium and herbicide, the least significant difference at the 5% probability level is given. (L.S.D. 5%) and this is used to compare all four means. Where one or both of the main effects was significant, without significant interaction, the means for both levels of the significant factor or factors are given (K_0 and K_1 indicate without and with potassium fertiliser respectively, and H_0 and H_1 indicate without and with herbicide).

TABLE 2

CLONAVOE
MEAN LEADER GROWTH (CM) DURING FOUR YEARS AFTER TREATMENT

	Norway Spruce				Scots Pine			
	1967	1968	1969	1970	1967	1968	1969	1970
O (Control) ...	2·8	6	9	12	7·1	9	16	18
K	2·7	12	22	36	5·7	16	32	35
H	2·7	9	9	14	6·6	12	18	20
KH	3·3	11	16	32	5·9	14	31	34
Standard error ...	0·28	0·37	0·62	1·2	0·65	1·08	2·3	2·5
L.S.D. 5%* ...	N.S.*	1	2	4	N.S.	—	—	—
K_0	—	—	—	—	—	10	17	19
K_1	—	—	—	—	—	15	31	34

*L.S.D. 5%=Least significant difference at the 5% level of probability.
N.S.=not significant.

TABLE 3

DERRYCRICKET
MEAN LEADER GROWTH (CM) DURING FOUR YEARS AFTER TREATMENT

	Norway Spruce				Scots Pine			
	1967	1968	1969	1970	1967	1968	1969	1970
O (Control) ...	7·9	8	10	12	15	13	16	22
K	8·1	15	32	36	16	22	40	50
H	8·4	11	18	24	14	17	32	39
KH	8·4	15	30	44	14	18	36	43
Standard error ...	0·45	0·63	1·65	3·0	1·42	1·57	2·2	1·41
L.S.D. 5% ...	N.S.	2	6	—	N.S.	—	8	5
K_0	—	—	—	18	—	15	—	—
K_1	—	—	—	40	—	20	—	—
H_0	—	—	—	24	—	—	—	—
H_1	—	—	—	34	—	—	—	—

TABLE 4

BOHERBAUN
MEAN LEADER GROWTH (CM) DURING FOUR YEARS AFTER TREATMENT

	Norway Spruce				Scots Pine			
	1967	1968	1969	1970	1967	1968	1969	1970
O (Control ...	21	26	35	40	34	38	52	56
K	21	30	35	43	31	37	51	57
H	21	29	34	38	32	37	51	55
KH	21	30	40	52	30	37	53	57
Standard error ...	1·58	1·90	2·2	2·1	1·40	1·68	1·9	2·1
L.S.D. 5% ...	N.S.	N.S.	N.S.	7	N.S.	N.S.	N.S.	N.S.

There were no significant effects on growth on any site in 1967. Presumably the time of application of the treatments was too late for any effect on leader elongation to develop during that growing season.

In Clonavoe the effects, differing in the two species, were fairly consistent in each of the following years. In Norway spruce, potassium applied without herbicide significantly increased leader growth each year, but when potassium fertiliser was combined with vegetation control the result each year was a significant reduction in growth compared with potassium alone. In 1968 the herbicide treatment without potassium gave a significant increase in growth compared with control, but this effect was no longer significant in 1969 and 1970.

In the Scots pine, leader growth was significantly increased by the potassium whether the vegetation was controlled or not. There was no significant effect of herbicide.

It is suggested that the effects on Norway spruce may be explained by assuming that the initial kill of the vegetation released sufficient potassium to allow a measurable growth increase in the trees; that where potassium was added as a fertilizer, portion was stored in the ground vegetation when that was allowed to remain, but when the vegetation was suppressed by spraying with herbicide a considerable portion of the applied potassium was lost from the rooting zone. Of interest in this connection are the results of Bjorkman *et al* (1967) who investigated the retention of applied nitrogen on plots with sparse and with dense ground cover. On the plots with denser cover they found that after one growing season 33% of the applied nitrogen was retained in the total vegetation (trees, ground cover, and all roots) compared with only 21% on plots with sparse vegetation.

The absence of any significant effect of herbicide treatment on Scots pine growth on this site requires comment. Ingestad (1962) working with seedlings in nutrient solutions found that Scots pine was more tolerant of potassium deficiency than was Norway spruce, although the difference was relatively less with potassium than with other major nutrients. If this greater tolerance of Scots pine is taken as applying here also, it could follow that the relatively small changes in potassium supply brought about by the herbicide treatment may have resulted in effects on growth too small to be detected in this experiment. It is also possible that the deeper rooting habit of the Scots pine rendered it less sensitive to changes in nutrient supply near the soil surface where the influence of the ground vegetation would be greatest.

In Derrycricket (Table 3) the effects on Norway spruce in 1968 and 1969 were similar to those at Clonavoe, except that the use of herbicide did not significantly reduce growth when it was combined with potassium fertiliser. In 1970 the interaction was no longer significant statistically, but it may be seen that the effect of herbicide appears to be very much less in the presence of potassium than in its absence. In Scots pine, only potassium had a significant effect in 1968. In both 1969 and 1970 there was a significant interaction between the two factors. In 1969 the effects were the same as those on Norway spruce on this site. In 1970 the effects were the same as those on Norway spruce at Clonavoe, i.e. herbicide with potassium resulted in significantly reduced growth compared with potassium alone. These results may appear to be in conflict with the explanations offered for the lack of effect of herbicide on Scots pine in Clonavoe, but they are not in fact. If we advert to the low rate of uncontrolled variation in the 1970 assessment of Scots pine in Derrycricket, as reflected in the standard error of the means in relation to their magnitude, it is clearly possible that effects not detected in the Clonavoe assessments might be detected in the more sensitive Derrycricket assessment. These results are quite consistent with the hypothesis that the effects of treatments on species differed in degree rather than in kind.

At Boherbaun there were no effects at all in Scots pine, while in Norway spruce there were none in 1967, 1968 or 1969. In 1970 there was a significant interaction between the factors. On examining the means (Table 4) we can see that potassium alone and herbicide alone did not have any significant effect while both together significantly increased growth. As stated already the potassium deficiency symptoms were less pronounced at Boherbaun than at Clonavoe or Derrycricket, thus indicating a less intense deficiency. This is supported by the foliar analysis (see below). The fact that herbicide at Boherbaun significantly increased the foliar concentration of nitrogen, accompanied by an increase in phosphorus concentration which nearly, but not quite, reaches significance, suggests that there may be simultaneous mild deficiencies here of nitrogen, phosphorus and potassium, and that the potassium fertilization is effective only when the supply of nitrogen and/or phosphorus is increased by controlling the vegetation. If this is so, it is probable that these deficiencies could be corrected more cheaply and more effectively by fertilization than by herbicide treatment, as in the case of potassium at Clonavoe and Derrycricket.

Mean height

While leader growth may be taken as the simplest measure of treatment effect on growth in any particular year, the mean height reached after a number of years may be a better index of the effects of the treatments in terms of practical forestry. Mean heights at the end of the 1969 growing season are set out in Table 5. At Clonavoe in spruce we have a significant increase due to potassium, and a significant reduction due to herbicide when

TABLE 5

MEAN HEIGHT (M) AT END OF 1969 GROWING SEASON

	Clonavoe		Derrycricket		Boherbaun	
	Spruce	Pine	Spruce	Pine	Spruce	Pine
O (Control) ...	0·54	0·68	0·96	1·43	1·80	2·80
K	0·74	0·84	1·26	1·75	1·76	2·72
H	0·57	0·70	1·08	1·56	1·67	2·70
KH	0·65	0·87	1·26	1·68	1·78	2·71
Standard error ...	0·012	0·049	0·050	0·095	0·084	0·120
L.S.D. 5% ...	0·04	—	—	N.S.	N.S.	N.S.
K_0	—	0·69	1·02	—	—	—
K_1	—	0·85	1·26	—	—	—

this was combined with potassium. At Clonavoe in pine and at Derrycricket in spruce we have significant increases due to potassium with no significant effect of herbicide. At Derrycricket in pine, and in both species at Boherbaun there are no significant effects of treatments.

Foliar nutrient content

The results of foliar analyses carried out on the spruce at Derrycricket and Boherbaun in January 1969 are given in Table 6. These appear to confirm the impression gained from the relative intensity of the development of potassium deficiency symptoms at the two sites that Derrycricket was more deficient in potassium than Boherbaun.

TABLE 6

FOLIAR NUTRIENT CONTENT (% DRY MATTER) IN JANUARY 1969 (TWO REPLICATES AT EACH OF TWO SITES)

	Derrycricket				Boherbaun			
	N	P	K	Mg	N	P	K	Mg
O (Control) ...	1·86	·36	·30	·14	1·58	·20	·60	·12
K	2·11	·27	·70	·12	1·40	·20	·75	·11
H	2·12	·34	·50	·12	2·02	·24	·80	·11
KH	1·98	·28	·68	·10	2·02	·22	·65	·11
Standard error ...	·134	·017	·047	·0029	·109	·012	·065	·0048
L.S.D. 5% ...	N.S.	—	—	—	—	N.S.	N.S.	N.S.
K_0	—	·35	·40	·26	—	—	—	—
K_1	—	·28	·69	·23	—	—	—	—
H_0	—	—	—	·26	1·49	—	—	—
H_1	—	—	—	·22	2·02	—	—	—

The effect of herbicide on nitrogen and phosphorus contents at Boherbaun have already been referred to. It has been suggested (e.g. Conner and White, 1970) that triazine herbicides may directly increase nitrogen concentration in conifer tissue, but no such mechanism is postulated in this case.

At Derrycricket the phosphorus and magnesium levels were significantly decreased by the potassium application, possibly a dilution effect due to the greatly stimulated growth.

Frost damage

The results of the assessment of late frost damage carried out in Clonavoe and Derrycricket in 1969 are given in Table 7. In both analyses the interaction between potassium fertilization and herbicide was signifcant. At Clonavoe the amount of frost damage was significantly increased by potassium alone and significantly decreased by herbicide alone when compared with control. At

TABLE 7

FROST DAMAGE TO NORWAY SPRUCE AT TWO SITES IN 1969

	Degrees (transformed)		% (back-transformed)	
	Clonavoe	Derrycricket	Clonavoe	Derrycricket
O (Control) ...	20·4	34·3	12	30
K	36·9	45·5	36	51
H	16·6	40·7	8	42
KH	23·7	40·6	16	42
Standard error ...	1·19	0·70	—	—
L.S.D. 5% ...	3·8	2·4	—	—

Derrycricket the amount of damage was significantly greater in all three other treatment combinations compared with control, but herbicide alone, and potassium and herbicide combined, were both significantly less damaged than potassium alone.

The general tendency of the potassium fertilizer has been to increase frost damage. It is believed that this is due to earlier flushing in the potassium-treated plots rather than to an increase in frost susceptibility as it is usually understood, although no quantitative evidence can be put forward in support of this.

The results for herbicide are contradictory. At Clonavoe, herbicide treatment significantly decreased frost damage. At Derrycricket the effect was significantly positive in the absence of potash and significantly negative in its presence. No simple explanation can be offered to account for this interaction.

General

The results of these experiments do not support the hypothesis on which they were based: that ground vegetation interferes with the utilization of applied potassium. In fact the opposite appears to be the case under some circumstances at least. The main difference between the crop at Moanvane (mentioned earlier) where growth responses to applied potassium were slow and small, and these crops where responses were satisfactory, is one of age. The Moanvane crop was 20-22-years-old when treated, while the crops treated in these experiments were 2-8 years old. The difference in establishment (Moanvane was not ploughed) is thought less likely to account for the difference in response, since there is no indication of a soil aeration problem at any of the sites.

CONCLUSIONS

Ground vegetation does not interfere with the uptake or utilization of potassium applied as a fertilizer on peats strongly deficient in potassium. Under such conditions, if the vegetation is regularly killed by spraying, some extra potassium is made available to the trees with some improvement in growth, but this effect can be obtained more efficiently by the application of a potassium fertilizer. On the other hand, when potassium is applied as a fertilizer, the ground vegetation may be important in the retention of the added potassium in the site.

The question of vegetation control in young forest plantations needs to be carefully reviewed, and the practice possibly confined to the level required for the prevention of physical competition, for e.g. light.

It is possible that earlier flushing induced by the potassium fertilizer may slightly increase the risk of damage due to late frost, but this risk is of little practical importance when measured against the beneficial effects of the fertilizer. The benefit is even greater since the accelerated height growth results in earlier emergence of the tree crowns from the zone near the ground where the danger of damage by late frosts is greatest.

The relative intensity of potassium deficiency on various sites appears to be indicated by the relative intensity of the development of deficiency symptoms in trees already growing on those sites.

SUMMARY

Slow and small responses to applied potassium in a potassium deficient 20-22-year-old crop of Norway spruce and Scots pine suggested the possibility that ground vegetation may prevent the efficient utilization of applied potassium. Three experiments were established in which potassium fertilizer and vegetation control by annual spraying with herbicide were tested factorially in 2-8 year old crops. Growth data for four years after treatment, and data on foliar nutrient contents and frost damage are given. On two of the experimental sites where the potassium deficiency was severe, vegetation control by itself lead to a small growth increase compared with potassium alone, but tended to decrease growth or be ineffective when the treatments were combined. It is suggested that the ground vegetation may play an important part in retaining applied potassium in the site. On the third site where the potassium deficiency was milder there were some indications that a nitrogen and/or phosphorus deficiency, alleviated to some extent by vegetation control. may also have been limiting growth.

Potassium fertilization significantly increased late frost damage

on the spruce, indirectly, it is believed, by causing an advancement in the time of flushing.

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