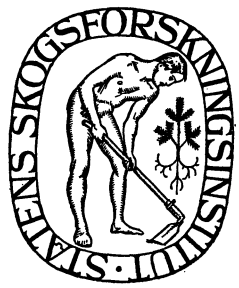

Studies on Forest Nutrition

Studier över skogens näringsförhållanden

II. An Experiment with Application of Radioactive Phosphate to Young Spruces and Birches

II. Ett försök med gödsling av unga granar och björkar med radioaktivt fosfat

by

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II. An Experiment with Application of Radioactive Phosphate to Young Spruces and Birches

The use of radioactive isotopes seems one of the best ways to investigate the physiological activity of plant roots under natural conditions. The roots of forest trees are very often associated with mykorrhiza fungi. On account of the variable efficiency of these mykorrhizas in nutrient uptake root frequency and root appearance may be inaccurate measures of the root activity in the soil and its different horizons. And even if direct root observation may still provide much useful information, we need a convenient method to determine the "sphere of influence" of the root systems of different forest constituents. Such a method would be of particularly great value in the study of the competition between different tree species or between different age or height classes of the same tree.

Radioactive tracers are already much used in tree physiology, but mostly in connection with translocation problems (*e.g.*, BECKMAN & KUNTZ 1951, FERRELL & HUBERT 1952, FRAZER & MAWSON 1953). Results of physiological interest have also been obtained when radioactive isotopes have been applied to trees in mutation work (EHRENBERG & GRANHALL 1952). Recently ZENTGRAF & BARNER (1955) have made an attempt to study nutrient uptake by roots from different horizons by immersion in solutions containing radioactive phosphorus. How interesting as the results of such studies may be, they cannot be substituted for investigations of the normal nutrient uptake from the soil.

The experiment to be described here is of a very preliminary nature, mainly intended to provide information about the suitable dosage for further experiments on a larger scale. As some results of ecological and physiological interest were obtained at the same time, it has been considered worthwhile to publish a brief report.

Experimental Section

The experimental area (see Fig. 1 and the schematic plan in Table I) was situated on the peninsula of Männö in lake Bornsjön, 20 km SW of Stockholm. The plot was a well-growing spruce plantation (planted with 2/2 spruces in 1943) on old arable soil. The spacing of the spruces was approximately 1 × 1 m. The height of the spruces at the start of the experiment, and the height increment in 1954, are given in Table I.

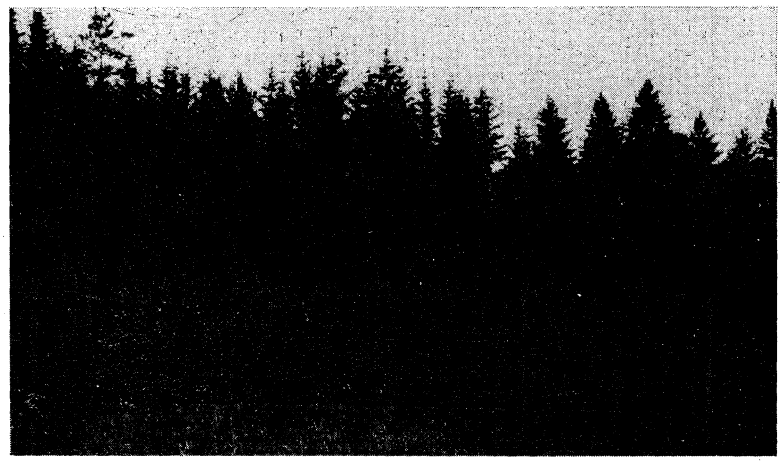

Fig. 1. The spruce plantation at Männö.
Grankulturen vid Männö. (14. VI. 1954).

Soil samples from the horizon 0—10 cm were collected in December 1954 from five different spots in row E (see Table I). A sample mixed from these five samples has been analyzed by Statens Lantbrukskemiska Kontrollanstalt using conventional soil analysis methods. The soil was described as a light clay rich in fine sand and humus. Its pH was 5.7, and the phosphorus extractable with lactate buffer amounted to 0.7 mg P_2O_5 per 100 g air-dry soil. The extracted potassium amounted to 15.9 mg K_2O per 100 g air-dry soil.

If the sample analyzed is representative of the area, the plot should be considered as well supplied with potassium but clearly deficient in phosphorus, as far as field crops are concerned. Forest soils often contain comparatively little extractable phosphorus in comparison with arable soil, and yet no indications of a general phosphorus deficiency in the forests of Sweden have been obtained (TAMM 1955a). The phosphorus content of spruce needles from Männö (Table I) is not low in comparison with the values found in normal spruce stands (TAMM, unpubl.). The nitrogen and potassium values are high, while the calcium content can be considered as normal. The Männö spruces seem well supplied with nutrients as well as water; it is thus not surprising that their growth is excellent.

The experiment was laid out on May 14, 1954, in a part of the plantation where some birches grew among the spruces. It was considered of interest to find out whether there were any differences between the two tree species in their response to the radioactive phosphate solution.

The P^{32} used in this experiment was made from red phosphorus by irradiation at Harwell and oxidized to phosphoric acid at Ultuna. The absolute

amount of P^{32} was estimated to 200 millicurie on May 7 contained in 50 ml of a H_3PO_4 solution; this figure however only gives the order of magnitude of the activity.

In this experiment were used 10 litres of a solution of potassium dihydrogen phosphate, to which the active solution was added. The phosphorus concentra-

Table 1. Characteristic properties of the sampled spruces: Height before treatment; height increment in 1954; and nutrient contents in 1954 needles (1) and 1953 needles (2) from exposed branches (second whorl from top).
With a schematic plan of the Männö experimental area.

Karakteristiska egenskaper hos de undersökta granarna: Höjd före behandlingen; höjdtillväxt år 1954, samt näringshalterna i årsbarr (1) och fjolårsbarr (2) från exponerade kvistar.
Med en schematisk plan över Männöförsöket.

Schematic plan Schematisk plan	Row Rad	Average height of trees Medelhöjd m	Average height increment in 1954 Tillväxt 1954 m	Dry weight percentages of nutrients in December 1954 Näringshalter i % torrvikt (december 1954)							
				N		P		K		Ca	
				1	2	1	2	1	2	1	2
△ △ △ △ △	U	2.6	0.7	1.86	1.42	0.23	0.22	0.91	0.81	0.68	0.76
△ △ △ △ △	T	—	—	—	—	—	—	—	—	—	—
△ △ △ △ △	S	—	—	—	—	—	—	—	—	—	—
△ △ ○ △ ○ △ ○ △ ○ ○ ○	R	—	—	—	—	—	—	—	—	—	—
△ ○ △ ○ △ ○ △	P	2.9	0.4	—	—	—	—	—	—	—	—
△ △ △ △ △	A	3.7	0.75	1.75	1.52	0.21	0.19	0.93	0.88	0.44	0.55
△ △ △ △ △	B	2.4	0.6	—	—	—	—	—	—	—	—
△ △ △ △ △	C	3.2	0.8	—	—	—	—	—	—	—	—
△ △ △ △ △	D	3.4	0.85	—	—	—	—	—	—	—	—
△ △ △ △ △	E	3.2	0.8	1.78	1.72	0.20	0.20	0.90	0.91	0.46	0.53
△ △ △ △ △	F	3.0	0.8	—	—	—	—	—	—	—	—
△ △ Drain Dike											

Legend
△ Spruce *Picea Abies* Karst.
○ Birch *Betula verrucosa* Ehrh.
▭ Furrow

Teckenförklaring
Gran
Björk
Fåra

tion of the solution was 4.21 mg P per ml. The water used for the preparation of the solution was taken from a drain in the neighbourhood of the plot and thus not particularly pure.

Two parallel furrows, about 2 dm wide and 1—2 dm deep, were dug on each side of one spruce row (called A in Table I). The furrows were 5 m long, and the distance between them the same as the spacing of the spruce rows, or 1 m. One half of the radioactive solution was then watered out in each furrow, while the spilling of anything of the liquid outside the furrows was carefully avoided. After watering, the turfs were replaced. The activity of the ground was then measured with a portable counter. A slight activity was found in some of the slits between the turfs, and soil was spread on these places, until the instrument gave no deflection.

On May 25 an attempt was made to measure the activity by means of the portable instrument (Tracerlab α-, β-, γ-Survey Meter with a specially constructed house for the Geiger-Müller tube). Measurable but strongly varying activity was found in all spruces in row A, and in three out of five spruces in row B. The spruces in row C were not active enough to be measured with the instrument used. Even on the same tree the activity varied considerably from branch to branch. As a rule the buds (which were just bursting) were most active.

An observation of interest, though not directly connected with the trees, was that a marked soil activity could now be measured over the former furrows. It is of course possible that the frequent but not very strong rains between May 14 and 25 had washed away the soil covering the active layer. Yet it seems more probable that the earthworms (which were frequent in the habitat) had transported some of the active phosphate to the soil surface. The tracer technique seems to be a suitable means for quantitative studies of the soil-mixing activity of the earthworms.

Needle samples for laboratory determination of the activity were also collected on this occasion, but the activity was found to be too low to be conveniently measured with the technique usually employed at Wenner-Gren's Institute for Experimental Zoology, Stockholm. Such measurements were made instead on samples collected on June 14 (Table II). Aliquots of the samples (spruce needles and birch leaves) were dried and ashed in platinum dishes (at 600°). The activity measurements were then made at Wenner-Gren's Institute on tablets compressed from the ash. Due to self-absorption these values are about 10 per cent lower than values measured on very thin preparations; the last column in Table II has therefore been calculated on values corrected for this error.

Field measurements could not be made on June 14, because the instrument did not work well in the wet weather.

Results and Discussion

The results of the activity measurements are given in Table II. The figures for 1954 spruce needles show a high activity in the spruces from between the two furrows (row A), while the activity is considerably lower in the two rows on both sides (P and B). The spruces in row P are more active than those in row B, which may have something to do with their slower growth (see Table I); the slow growth is due to competition from the birches growing in rows P and R. Only weak activity is shown by the spruces in row C, and the figures for rows D, E, and F must be considered as within the experimental error. Judging from this result very few of the roots of the young spruces in this place extend more than 2.5 m, and the main part reaches less than 1.5 m. An alternative explanation would be that the rate of translocation of phosphorus from roots to stem and needles is slower than 2.5 m per month, but earlier studies on the rate of migration of nutrients in trees—made with tracer technique or otherwise—make this hypothesis less probable. Yet the rate of migration of different elements ought to be measured in further experiments of this type.

The amount of radioactive phosphorus used has made the young spruces active enough to make laboratory measurements possible, and also field measurements would no doubt have given interesting results, if weather

Table II. The activity of birch leaves and spruce needles, collected 14. VI. 1954 at Männö. The activity of the fertilizer solution was 215,000 counts per minute per ml, or 51,000 counts per minute per mg P, measured at the same time as the samples. Phosphorus percentages are means of duplicate determinations.

Aktiviteten hos björkblad och granbarr, insamlade på Männö den 14.VI. 1954. Aktiviteten hos den utvattnade fosfatlösningen var samtidigt 215 000 imp. per min. per ml eller 51 000 impulser per min. per mg P. Fosforbestämningarna är medeltal av dubbelprov.

Species Trädslag	Row Rad	Issue of needles Barr-årgång	Dry weight of sample Torrvikt av undersökt prov g	Counts/min. Imp./min. per sample per prov	Counts/min. Imp./min. per g dry weight per g torrvikt	P % dry weight P % torrvikt	Counts /min. Imp./min. per mg P	Amount of P originating from fertilizer, % of total P % av total P som härrör från tillfört P
Birch	P	—	11.83	18,000	1,520	0.345	440	0.96
Spruce	P	1954	6.52	2,500	383	0.346	111	0.24
»	A	1954	5.78	6,300	1,090	0.264	413	0.90
»	A	1953	10.24	1,520	149	0.098	152	0.33
»	A	1952	8.56	1,130	132	0.086	154	0.34
»	B	1954	7.02	1,330	189	0.319	59	0.13
»	C	1954	4.43	396	89	0.385	23	0.05
»	D	1954	6.36	10	2	0.316	1/2	0.001
»	E	1954	4.70	10	2	0.364	1/2	0.001
»	F	1954	8.29	10	1	0.270	1/2	0.001

conditions had been favourable on June 14. The rapid but less accurate field measurements would allow comparisons between different parts of the trees, and between different trees in the same row. On the other hand, fertilization of larger trees than 3 m high spruces would require larger amounts of tracer isotopes, at least if shortlived ones like P^{32} are used. Amounts up to about one curie would not appear too large for this purpose, but of course the handling and distribution of such great quantities would require special precautions.

In the present experiment the area treated with the active solution was kept low, as we wanted to get a wide range from very active to inactive plant samples. In ecological experiments with forest trees using still larger amounts of radioactive material more dilute solutions distributed over larger areas are recommended in order to avoid radiation injuries especially in root meristems.

The results so far reported are of interest chiefly for the organization of further experiments with tracer isotopes. Yet some conclusions of more direct physiological interest can be drawn from the data in Table II: 1) The birches show a much higher activity than the spruces growing at the same distance from the source of activity (both from row P). This difference might be caused by differences in rooting habits or in root injuries due to the digging, perhaps also due to the locally intense radiation. Another possibility is that the birches take a larger proportion of the phosphorus used for the new growth directly from the soil, as compared with the spruces. An investigation during another season might give other results, since HAGEM (1947) has found the root activity of conifers to be particularly high during autumn.

2) Another observation of great physiological interest concerns the activity of the old spruce needles. The young needles grew out between treatment and collection, and it is easy to understand that a relatively high proportion of their phosphorus comes from the soil. The old spruce needles, however, do not increase their phosphorus content during this season. There may even be a decrease, as is the case with the nitrogen content of spruce needles, which has been found to decrease from spring to early summer (TAMM 1955 b). It is then surprising to find that the phosphorus activity in one- and two-year-old needles was high, about one third of that found in young needles. Evidently there occurs an intense exchange of phosphorus between the older needles and other organs, in spite of the insignificant changes in total content of phosphorus.

Summary

An experiment with addition of P^{32} to a young spruce plantation was made in May, 1954. Conclusions are drawn about the range of the spruce roots in this habitat, and about the amounts of radioactive isotopes suitable for

ecological experiments with forest trees. The leaves of some birches growing within the experimental area contained a higher proportion of active phosphate than the young needles of spruces growing at the same distance from the source of activity, as measured one month after treatment.

Growing spruce needles contained a higher proportion of active phosphorus than older ones, but the comparatively high figures for the activity of the phosphorus in both one- and two-year-old needles show that an intense exchange of phosphorus compounds must occur between these needles and other organs.

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Sammanfattning

II. Ett försök med gödsling av unga granar och björkar med radioaktivt fosfat

I maj 1954 utlades i en granplantering på halvön Männö i Bornsjön sydväst om Stockholm ett gödslingsförsök med radioaktivt fosfat. Syftet var att erhålla en uppfattning om de lämpliga mängderna av radioaktivt preparat för fortsatta större försök, varjämte man kunde beräkna att få vissa upplysningar om rotsystemens storlek hos de 15-åriga, ca 3 m höga granarna.

Det visade sig att barren hos de granar som befann sig en halv meter från endera eller bägge de fåror vari den aktiva lösningen vattnades ut, efter en månad var tydligt aktiva, medan granar på 1,5 m avstånd endast var mycket svagt aktiva. Granar på 2,5 m avstånd eller längre bort visade ingen aktivitet. Några björkar på en halv meters avstånd från den ena fåran blev betydligt mera aktiva än granar växande i samma rad. De växande granbarren visade betydligt högre aktivitet än ett- och tvååriga barr, men den uppmätta aktiviteten i dessa senare visar dock att det måste försiggå ett intensivt utbyte av fosforhaltiga ämnen mellan dessa äldre barr och andra organ.