ARBORETUM KÓRNICKIE
Rocznik XXII — 1977

Władysław Chałupka, Henryk Fober

Studies on the effect of mineral fertilisation on flowering and cone and seed crops in Scots pine (*Pinus silvestris* L.) through an analysis of the litter drop*

INTRODUCTION

The intensity of seed yield in Scots pine is associated with the natural fertility of the site. In Finland it has been shown that on three forest site types of increasing fertility — *Calluna, Vaccinium* and *Myrtillus* — the seed crops were in a 1 : 2 : 3 ratio (Sarvas, 1962). Also in Turkey on fertile soils pine stands yielded much more seeds than poor sites (Boydak, 1975). These observations are confirmed by the results of numerous fertilizer experiments.

The effect of mineral fertilisation on the generative development of trees can be studied in various ways but the most commonly employed method is to fertilise individual trees or stands and then analyse the flowering or seed crop in relation to the treatments. This type of experiments are the subject of studies conducted by many authors.

The initiation of female flowers takes place in conditions of rich supply of mineral nutrients (Wareing, 1958, 1959). A very significant effect on the number of female flowers has been exerted by a complex NPK fertilisation (Kozubov, 1969) or by treating with mineral mixtures containing NPK (Nanson, 1965). Enescu and Giurgiu (1968) have obtained after supplying NPK a tripling of the percentage of shoots with female flowers and Wareing and Longman (1960) after a combined phosphate and ammonium nitrate fertilisation obtained an increase in the proportion of trees yielding cones. Also applications of single fertilizers proved effective. Ammonium nitrate on pine grafts increased the number of female cones one year after application (Giertych, 1970). Supply of nitrogen increased by 30% the number of one-year-old cones (Höhne and Fiedler, 1967) and in another experiment it increased the number cones per tree and the individual cone weights (Höhne and Fiedler, 1970). According to Bergman

* This study has been partially supported by grant No. FG-Po-260 from the US Department of Agriculture under PL-480.

(1960) potassium favours the frequency of female flower initiation. In the detailed studies of Wareing and Longman (1960) potassium fertilisation increased both the number of cones and the percentage of trees producing cones.

The effect of mineral fertilisation on male flowering is debatable. The opinion prevails that the initiation of male strobiles takes place under conditions of mineral deficiencies (Wareing, 1958, 1959). Giertych (1969) has shown that formation of male flowers can be stimulated by a deficiency of nitrogen. He also obtained a negative effect of potassium fertilisation on the male flowering of Scots pine grafts. On the other hand there are indications that complex NPK fertilisation will increase both the number of male strobiles (Kozubov, 1969) and the weight and yield of anthers (Kozubov, 1971).

Under the influence of appropriate treatment with mineral fertilizers it is possible to obtain a substancial increase in the number of mature cones on trees and at the same time a greater seed crop. In literature there are indication that the seed crop can be increased both after using complex NPK fertilizers (Kozubov, 1968; Azniev, 1970) or after treatment with individual elements, as for example with nitrogen (Hausser, 1960; Kozubov, 1971), phosphorus (Chirov, 1964; Faulkner, 1966; Enescu et al., 1968) or calcium (Azniev, 1970). Enescu and Giurgiu (1968) report a fourfold increase in the percentage of shoots yielding seeds following the spraying of needles with the microelements boron and manganese.

Studies on the flowering and fecundity of trees and stands must be extended over several years. The periodic and irregular occurrence of seed years causes the data on flowering or crops collected in one year to be of limited value and only those collected over several years can be considered more reliable.

In the present study for four years after fertilisation observations were conducted on the flowering using binoculars for a visual estimate of the number of male and female strobiles. Also periodically the litter droped from the canopy was collected into catchment boxes. In this way it was possible to determine accurately the number of female cones, the weight of the male strobile residues and the number of seeds, as well as the number of conelets aborted immediately after anthesis, and the weight of 1000 seeds. As can be judged from the literature review presented above all these features could be substancially dependent on the variablity in the soil environment.

In order to obtain a fuller picture of the conditions in which the trees found themselves after the fertilisation treatments soil samples were collected and analysed. Also samples of secondary bark were taken from the trees for mineral analyses and increment cores for stem analyses of growth.

MATERIALS AND METHODS

DESCRIPTION OF THE EXPERIMENTAL AREA AND ITS ESTABLISHMENT

The stand selected for the study lies in Forest District Babki (formerly Kórnik) in Range Błażejewo, Compt. 9a. The climatic conditions in the area can be judged from the average values of some parameters from the nearest meteorological station in Kórnik (76,8 m elev.) over the years 1953 - 1971; Temp.: +7.8°C, temp. amplitude 23.0°C, insolation 1592.6 hrs., precipitation 528.6 mm, length of the growing season 223 days.

The basic data on the stand in Compt. 9a was obtained from the working plan for Forest District Kórnik made in 1964. It is located at 17°05′ Long. E, 52°13′ Lat. N and 80 m elev. The mean age of the pine trees was 67, mean height 23 m, mean diameter 26 cm, mean standing volume 300 m^3/ha, stocking 0.8, quality class I, crown density moderate. The stand covers a flat area. The forest site type is described as a mixed moist forest on a slightly podsolic soil, slightly loamy deep sand. The ground vegetation is rich with *Rubus* sp., *Calamagrostis* sp., *Pteridium aquilinum*, *Oxalis acetosella* etc. In the stand itself pine is the dominating species and only sporadically birch and spruce occur. Over about 60% of the subcompartment area there occurs an underlayer of *Quercus robur*, *Corylus avellana*, *Rhamnus frangula* and *Prunus spinosa*.

In the spring of 1971 in the above mentioned stand an experimental area was established composed of 54 square plots 10 are in area each,

Table 1

The amounts of fertilizers applied to the pine stand

Replicates			Fertilizers in kg per 10 are		
I	II	III	nitrogen	phosphorus	potassium
plot numbers					
17	22	48	0	0	0
3	36	43	20	0	0
7	31	40	40	0	0
4	28	51	0	10	0
6	33	54	20	10	0
11	27	50	40	10	0
2	30	38	0	20	0
15	24	42	20	20	0
5	25	44	40	20	0
1	21	53	0	0	5
9	35	52	20	0	5
16	19	41	40	0	5
10	20	49	0	10	5
12	26	39	20	10	5
14	34	46	40	10	5
8	32	45	0	20	5
13	29	37	20	20	5
18	23	47	40	20	5

that is 5.4 ha in all. The identification of the plots and the localisation of the catchment boxes was made similarily as in the experiment with spruce (C h a ł u p k a, 1976).

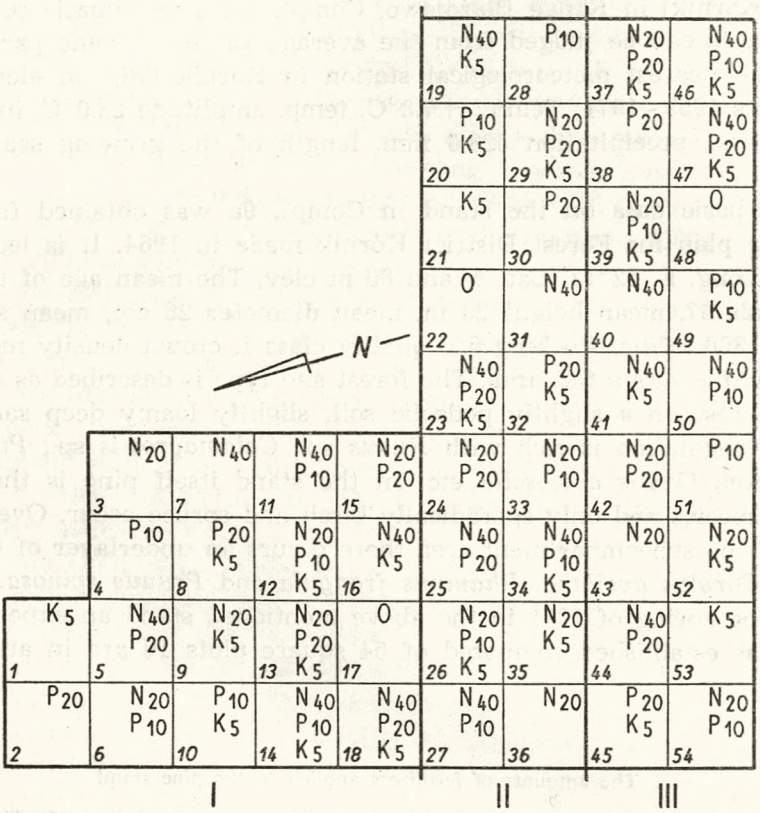

Fig. 1. Distribution of replicates and fertilizer treatments on the experimental plots

FERTILIZER TREATMENT

In the study three mineral fertilizers were employed: ammonium nitrate (34.5% N) in three doses, granular superphosphate (19% P_2O_5) in three doses and potassium salt (60% K_2O) in two doses, in all the 18 possible combinations. The amounts of fertilizers given to the various plots are shown in Table 1.

The fertilizer combinations were distributed randomly over the three blocks (replicates) as shown in Fig. 1. The replicates were arranged according to the site variation as manifested by the increasing amount of hazel in the understorey from North to South. The fertilizers were di-

stributed on the 27th and 28th of May 1971. Slight rainfall which occurred in the following days favoured the dissolution of the fertilizers and their penetration into the soil.

SOIL ANALYSES

Towards the end of October 1973 soil samples were collected from the experimental area for analysis. The analyses were conducted by Doc. W. Dzięciołowski and his group at the Agricultural Academy in Poznań. The method of taking soil samples and the characters analysed were the same as listed in the study on spruce (Chałupka, 1976).

COLLECTION OF DATA ON GROWTH

At the end of February and in early March 1973 samples of secondary bark (bast and cambium) were taken for analyses. In early February 1975 increment bores were taken from sample trees for analysis of the growth responses. The analyses performed were the same as in the spruce study (Chałupka, 1976).

COLLECTION OF DATA ON FECUNDITY

The collection and analysis of litter falling into catchment boxes was performed similarily as in the spruce experiment (Chałupka, 1976). The first collection was made in September 1972 for the period 25. IV. 1972 - 18. IX. 1972 and the last in April 1975. As a result of the analysis of litter the following characters were obtained for statistical treatment: 1) number of conelets dropping after anthesis, 2) number of cones falling after seed fall, 3) weight of male strobiles, 4) number of seeds, 5) weight of 1000 seeds, 6) total dry weight of the litter.

Additionally each year towards the end of May the intensity of male and female flowering was estimated with the help of binoculars on a four point scale.

The characters mentioned above have been analysed by annual periods. It was also possible to perform joint analyses for some characters covering the whole period of investigation.

All the data originating from the experimental stand, concerning characters of fecundity, growth, and soil have been treated by the variance analysis similarily as in the study with spruce (Chałupka, 1976).

RESULTS

Table 2 contains all the significant results obtained in the study on the response of flowering and growth to the fertilizer treatments. The data is presented individually for each year and jointly for the whole

Table 2

Effect of mineral fertilisation on the pine stand in Kórnik. Significant results as determined by the variance analysis

Source of variance	Year of experiment	Characters									
		wt. of male flowers	male flower estimate	no. of 2-years old cones	female flower estimate	no. of seeds	wt. of 1000 seeds	% of seeds falling in winter	% Ca in secondary bark	dry wt. of litter	girth increment
N	2	+									
	3										
	4										
	Σ										
P	2										
	3										
	4										
	Σ										
K	2						++	+			
	3			+	++	+			++		
	4			+							
	Σ			+						+	
N×P	2										
	3										
	4										
	Σ										
N×K	2										
	3										
	4										
	Σ										
P×K	2	+									
	3										
	4		+								
	Σ	+									
N×P×K	2										+
	3										++
	4										
	Σ										+
Blocs	2						++				
	3										
	4	+									
	Σ	+				++					

period. The consecutive years in the table correspond to the years of litter collection. For the spring-spring collection periods (cones, male strobiles, litter) the duration in question is 25.IV.1972 - 25.IV.1973 for the 2nd year, 25.IV.1973 - 17.IV.1974 for the 3rd year and 17.IV.1974 - 14.IV. 1975 for the fourth year, while for the autumn-autumn collection period (seeds) the duration was 18.IX.1972 - 31.X.1973 for the second year and

31.X.1973 - 31.X.1974 for the third year. At the same time the years of collection correspond to certain specified years of flowering as indicated in Tables 3, 4, 5 and 6.

FEMALE FLOWERING AND CONE YIELD

An estimate of flowering was conducted over four years, while the collection of cones covered three years (Table 3).

There were two types of cones collected, the aborted conelets in the year of anthesis and the mature two year old cones, with most of their seeds already shed. These two cone collections though made simultaneously in the same litter crops come from the flowering of different years and therefore have to be treated differently, as shown in Table 3. The

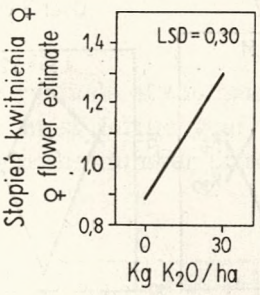

Fig. 2. The effect of potassium fertilisation on the intensity of female flowering in 1973

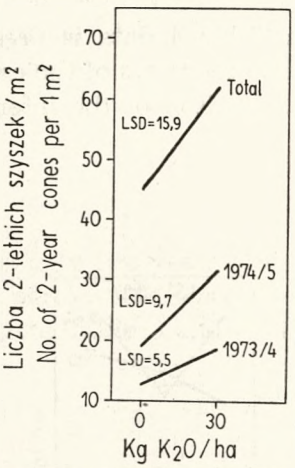

Fig. 3. The effect of potassium fertilisation on the fall of mature cones in the third and fourth year of the study (flowering years 1971 and 1972), and jointly for 3 years

Table 3

The female flower estimates and the fall of cones from the pine stand canopy in Kórnik

Year of flowering	Female flower estimate	Year of collection	Mean no. of 1-year old conelets per 1 m²	Year of collection	Mean no. of 2-years old cones
1970	–	–	–	25. IV. 72 - 25. IV. 73	11.2
1971	–	–	–	25. IV. 73 - 17. IV. 74	15.6
1972	1.9	25. IV. 72 - 25. IV. 73	9.5	17. IV. 74 - 14. IV. 75	27.3
1973	1.1	25. IV. 73 - 17. IV. 74	7.0	–	–
1974	1.1	17. IV. 74 - 14. IV. 75	3.6	–	–
1975	1.2	–	–	–	–

individual years of the experiment differed little in the flowering intensity. The highest flowering was observed in 1972, which was also reflected in the conelet drop and mature cone crop from that year.

A significant positive effect of potassium fertilisation was observed only in year 1973 (Fig. 2). Also potassium treatment has increased the yield of two-year-old cones in the third (Fig. 3) and fourth year of the study as well as for the total period of investigation. On the other hand there was no effect of this treatment on the conelet drop after anthesis.

MALE FLOWERING

In Table 4 data is presented illustrating the fall of male strobiles during three years of the experiment.

Comparison of the intensity of flowering with the weight of falling

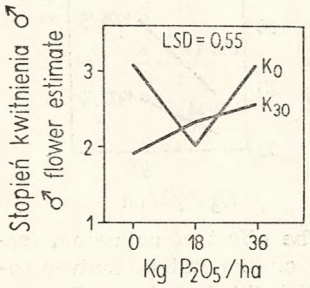

Fig. 4. The effect of the phosphorus-potassium fertilisation on the intensity of male flowering in 1974

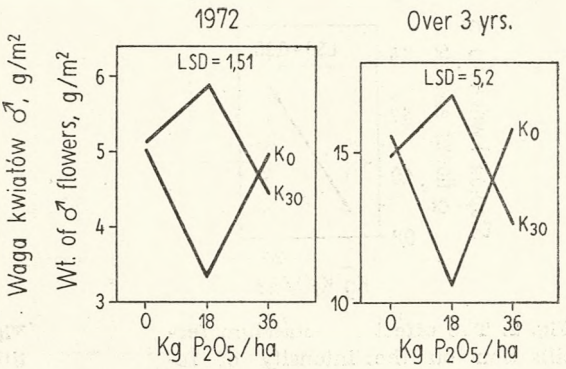

Fig. 5. The effect of phosphorus-potassium fertilisation on the weight of male strobiles shed after the 1972 pollination and jointly for 3 years

strobile residues per m² of the experimental area shows certain discrepancies, which could be the result of differences in individual flower weight in different years or changes in the criteria for estimating flowering intensity from year to year (the estimate was comparative between plots

Table 4

The male flower estimates and the fall of male flowers from the pine stand canopy in Kórnik

Year of flowering	Year of collection	Male flower estimate	Mean wt. of male flowers g per m²	% of male flowers falling in summer
1972	25. IV. 72 - 25. IV. 73	2.0	4.81	99.2
1973	25. IV. 73 - 17. IV. 74	1.6	4.55	98.4
1974	17. IV. 74 - 14. IV. 75	1.7	5.01	97.7
1975	–	1.5	–	–

observed simultaneously — but the standards could have easily altered from year to year). From Table 4 it can also be seen that bulk of the strobiles fall off in the summer immediately after pollination.

The statistical analysis has shown that some fertilizer treatments affected male flowering. Phosphorus in its medium dose and in the absence of potassium lowered the intensity of male flowering in the fourth year of the experiment (Fig. 4) and the weight of the male cones in the second year (Fig. 5) as well as the joint weight of the dropped strobiles over the three years (Fig. 5). In this latter case however the drop in the weight of male flowers caused by the mean level of phosphorus application was not significant relative to the unfertilised control but only relative to the maximal dose of P application. Also the maximal dose of nitrogen application has significantly increased the weight of male flowers dropping after the 1972 flowering (Fig. 6).

SEED PRODUCTION

Observations of the natural seed fall covered only two years (Table 5).

The most fertile year during the studied period 1972 was also reflected in the number of seeds produced (compare Table 3 and 5). From

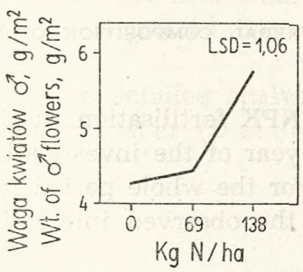

Fig. 6. The effect of nitrogen on the weight of male strobiles dropped after the 1972 pollination

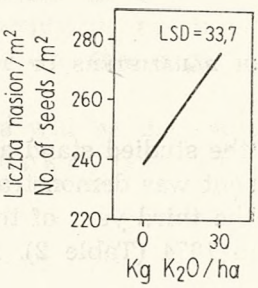

Fig. 7. The effect of potassium fertilisation on the number of seeds in the third year of the study (flowering year 1972)

the data shown in Table 5 it appears also that in the year of better crops seeds fall from the cones more rapidly (a higher percentage of them falls in the winter) and also they are heavier.

Table 5

Seed fall from a pine stand canopy in Kórnik

Year of flowering	Year of collection	Mean no. of seeds per m²	% of seeds falling in winter	Wt. of 1000 seeds
1971	18. IX. 72 - 31. X. 73	91.7	40.7	3.99
1972	31. X. 73 – 31. X. 74	257.6	77.4	4.93

All the seed characters described above and analysed statistically have shown responses to the fertilisation with potassium. This fertilizer increased the number of seeds that fell during the better crop year

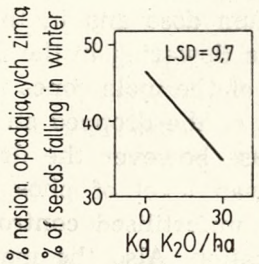

Fig. 8. The effect of potassium fertilisation on the percentage of seeds falling in the winter of the second year of the study (flowering year 1971)

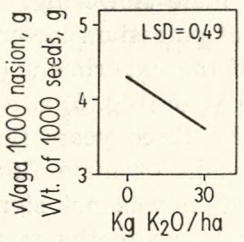

Fig. 9. The effect of potassium fertilisation on the weight of 1000 seeds in the second year of the study (flowering year 1971)

(Fig. 7). This same potassium fertilisation significantly lowered in the year of poorer crop the percentage of seeds that fell during the winter by about 12% (Fig. 8) and the weight of 1000 dried seeds from 4.32 g to 3.65 g (Fig. 9).

GROWTH PARAMETERS OF THE TREES AND THE MINERAL COMPOSITION OF THE SECONDARY BARK

In the studied stand a significant effect of NPK fertilisation on girth increment was demonstrated in 1972 (the 2nd year of the investigation), 1973 (the third year of the investigation) and for the whole period from 1971 to 1974 (Table 2). An interpretation of the observed interactions

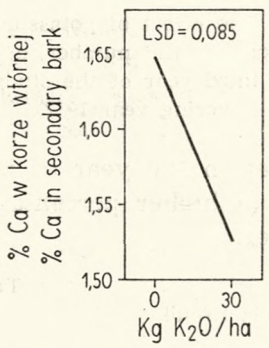

Fig. 10. The effect of potassium fertilisation on the content of calcium in the secondary bark

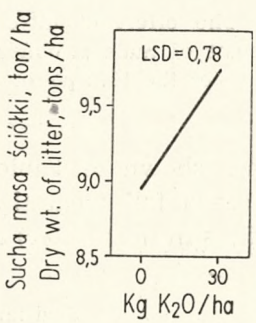

Fig. 11. The effect of potassium fertilisation on the total litter drop over two years of the study

is rather difficult in view of the absence of any individual effects of the fertilizers.

Taking the increment on the plots that were unfertilized (controls) as the point of reference and employing the least significant difference (LSD) it is possible to say that in no case was there a significant increase in girth increment relative to the control, while some unbalanced fertilizer combinations have depressed growth. Such an effect was for example observed in 1972 and for the whole period after phosphorus fertilisation in the absence of both nitrogen and potassium.

There was no effect of the mineral fertilisation on the content of late wood in the individual growth rings.

Chemical analyses made in the third year of the study (in 1973) have shown a significant negative effect of potassium fertilisation on the content of calcium in the secondary bark (Fig. 10).

SOIL

In general the mineral fertilisation has altered 18 out of 21 soil parameters measured in the studied stand. Some results are only discussed that appear related to the flowering responses discussed above. Potassium fertilisation increased the content of potassium in the mineral fraction of the soil. The maximal dose of phosphorus in absence of potassium increased the content of phosphorus in the organic soil fraction.

A more detailed analysis of all the soil data will be the subject of a separate paper (Dzięciołowski, Chałupka, Giertych — in press).

LITTER FALL

The amount of litter falling from a stand has been analysed in the third and fourth year of the study. In both these years the total amount of litter was almost the same and more than a half of this litter fell from the canopy during the vegetative season (Table 6).

Table 6

Litter fall from a pine stand canopy in Kórnik

Year of flowering	Year of collection	Mean litter fall in tons per ha	% of litter falling in summer
1973	25. IV. 73 - 17. IV. 74	4.71	66.6
1974	17. IV. 74 - 14. IV. 75	4.70	52.0

The statistical analyses (Table 2) have shown that the fertilisation with potassium increased the amount of litter that fell altogether during two years (Fig. 11).

DISCUSSION

It is striking that the effects of the fertilizer applications tested in this study have had so little effect on the flowering and seed crops. One has to remember however that fecundity is conditioned not only by mineral nutrition but also by other factors. According to Giertych (1967) primarily internal factors have to be considered, which represent a certain precondition for flowering. Only after these conditions are satisfied will the external factors come to play a role, such as climatic conditions, soil and artificial treatments. Thus an appropriate supply of mineral nutrients is only one of the possible factors that could modify the flowering process.

On the basis of the results obtained one can assume that in the conditions of this investigation mineral substances were not limiting the development of trees. On the relatively fertile site on which the trees grew they have had all the nutrients needed for growth and flowering. Thus we have not obtained any clear reaction to fertilisation, neither in girth growth nor in the flowering response. The site was indeed very rich and Scots pine is not a very demanding species. Thus it appears that fertilisation of good pine stands on rich soils does not improve volume production nor does it help with cone yields (Seed stands are usually on rich sites). In these conditions flowering and seed yields are limited by other factors, possibly climatic (Fober, 1976), and artificial modification of crop should be sought through other techniques than fertilisation, or possibly combined fertilisation with other treatments such as root prunning (Bergman, 1955).

When studying flowering in mature stands it is important to have a technique of reliably estimating the response. The flower estimate must be accurate, but cannot depend on the felling of the trees and counting all the flowers, since this would make repeated observations impossible. Visual estimates with the help of binoculars proved not very accurate. Density of the crowns and the line of view from below the canopy prevents full penetration of the crown which will lead to serious errors particularily in years of poor flower crops. The conditions of accuracy are met by the other method employed of analysing the litter falling from the canopies, adapted from Sarvas (1962) and used also in the spruce study (Chałupka, 1976). This method however is very time consuming, because the sorting of the litter can only by done by hand.

In our study a positive influence of potassium on the visually estimated degree of flowering in 1973 is less certain because of limitations of the estimating method, however this same effect on the number of mature cones collected in the period from April 1974 till April 1975, that is originating from the more abundant flowering of 1972 deserves greater attention. Even though the visual estimate of flowering in 1972 did

not give any significant differences related to potassium fertilisation, the numerical values are consistent with the trend shown to be significant in the number of mature cones collected. The flowers of 1972 were initiated in 1971 that is presumably after the fertilizer treatment was made in that year. A positive effect of potassium on female flowering has been reported before by other investigators (Bergman, 1960; Wareing and Longman, 1960).

The treatments have also had an effect on male flowering in 1972 which is indicated by the increase in the total weight of male strobiles with an increase in the amount of nitrogen supplied. A similar result was obtained in the parrallel study on spruce stands (Chałupka, 1976).

In the period from autumn 1973 to autumn 1974 there was an increase in the number seeds after potassium fertilisation which confirms the above mentioned observation of increase in cone number of the same crop year. Similarily as in the spruce stand (Chałupka, 1976) in a year of good cone crop a greater proportion of seeds falls in the winter. However potassium, which increased the seed number decreased the percentage of seeds falling in the winter. This may prove unsatisfactory for natural regeneration. Seed fall will extend till late spring when conditions for germination may be unsatisfactory because of drying of the soil or copious ground vegetation.

In spite of the fact that a medium dose of phosphorus in the absence of potassium fertilisation decreased the intensity of male flowering it did not change the content of phosphorus in the organic soil fraction and this took place only after the full P fertilizer treatment was applied. This may indicate that the trees have absorbed totally the phosphorus supplied in the medium dose, which caused the above reaction in male flowering and absence of a reaction in the soil. The maximal dose may have been superflous and therefore it had no effect on the flowering but increased the level of the element in the soil. However in line with the following thinking the trees should have absorbed half of the maximal dose and reacted in flowering at least as strongly as after the medium dose. This however was not the case, which seems to indicate that the maximal dose has caused other reactions in the soil than the medium dose and thus blocked the absorption of P by the trees.

One has to remember that an interpretation of the results of studies on the effect of fertilisation on flowering in trees is not a simple proposition since we are dealing here with a whole number of intermediate factors. The first reaction to fertilisation, to a change in the soil environment, is not always possible to observe in soil analyses and yet plays an important role in the modification of tree nutrition. It is only as a consequence of the changes in nurition that flowering responses may occur. Fertilisation need not always cause changes in nutrition and nu-

trition need not always cause changes in flowering. Scholz (1972) for example has obtained a stronger effect on seed cone crops when he applied fertilizers on more fertile sites. Here the fertility of the site seems to have been an obstacle to responces since none of the elements appears to be truly limiting.

SUMMARY

In a 74-years old Scots pine stand of first quality class growing on slightly loamy deep sand, 10 are plots have been fertilised in 1971 by 18 different combinations of N, P and K fertilizers in three replicate blocks. The doses per plot were 20 or 40 kg of ammonium nitrate, 10 or 20 kg of superphosphate and 5 kg of potassium salt. In the middle of each plot a metal catchment box was positioned from which between 1972 and 1975 twice annually (in April and September or October) the litter was collected for analysis of: the content of dropped conelets after anthesis, number of mature cones falling after seed shed, weight of male strobile residues, number of seeds and the weight of 1000 seeds, as well as the dry weight of the whole litter. Additionally each year a visual estimate was made with the help of binoculars of the male and female flowering in the spring.

Potassium fertilisation has had a positive effect on the visual estimate of female flowering in 1973, on the fall of mature cones from the 1971 and 1972 flowering and on the total number of cones collected over the three years of the investigation. Potassium fertilisation has also increased the number of seeds but in a poor crop year it decreased the weight of 1000 seeds and the percentage of seeds falling in the winter.

Nitrogen increased the weight of male strobile residues after the pollination in 1972. Male flowering was also dependent to some extent on the mutual relations between phosphorus and potassium fertilisation.

The employed fertilizer treatments have not produced any changes in the girth increments of the trees, and generally proved also unnecessary for flowering on this fertile site.

Institute of Dendrology
Kórnik nr. Poznań

LITERATURE

1. Azniev J. N. — 1970. Vlijanie udobrenij na semenošenie sosny obyknovennoj. Lesoved. i Lesn. ch-vo, vyp: 3, Minsk: 80 - 85. Ref. Žurn. Lesov. 1971: 7.56.167.
2. Bergman F. — 1955. Research on inducing fruiting of Pine, Spruce and Birch. Svensk, SkogsvFören. Tidskr. 53 (3): 275 - 304. For. Abs. 18: 1955 no. 3941.

3. Bergman F. — 1960. Versuche zur Beschleunigung der Blütenbildung bei Kiefer. Forst und Jagd. Sonderheft "Forstliche Samenplantagen II".: 8 - 17.
4. Boydak M. — 1975. Eskişehir-Çatacik mintikasi ormanlarinda sariçam (*Pinus silvestris* L.) in tohum verimi üzerine araştirmalar. Istanbul Univ. Orman Fakültesi Dergisi, Ser A, Cilt XXV, Sayi 1: 1 - 240.
5. Chałupka W. — 1976. Effect of mineral fertilisation on the content of reproductive organs in the litter dropped by a Norway spruce (*Picea abies* (L.) Karst.) canopy. Arboretum Kórnickie XXI: 333 - 359.
6. Chirov A. A. — 1964. O meteorologičeskom metode prognoza urožaja semjan sosny. Lesn. Choz. 17 (9): 47 - 49.
7. Dzięciołowski W., Chałupka W., Giertych M. — 1976. Wpływ różnych kombinacji nawozów mineralnych na glebę pod drzewostanami świerkowym i sosnowym (in preparation).
8. Enescu V., et al. — 1968. The management of seed stands of Larch and Scots Pine. Stud. Cerc. Inst. Cerc. For., Bucureşti (Silv.) 26 (1): 53 - 70. For. Abs. 30: 1969 no. 3846.
9. Enescu V., Giurgiu V. — 1968. Results in an experiment to stimulate seed production in *Pinus sylvestris*. Rev. Pădurilor 83 (3): 109 - 112. For. Abs. 30: 1969 no. 504.
10. Faulkner R. — 1966. A review of flower induction experiments and trials 1948 - 1963. Rep. on For. Res. for Yr. ended March 1965 For. Comm: 207 - 218.
11. Fober H. — 1976. Relation between climatic factors and Scote pine (*Pinus silvestris* L.) cone crops in Poland. Arboretum Kórnickie XXI: 367 - 374.
12. Giertych M. — 1967. Rozmnażanie generatywne. In: Zarys fizjologii sosny zwyczajnej. PWN, Warszawa: 269 - 294.
13. Giertych M. — 1969. Badania nad regulacją rozwoju pędów sosnowych *Pinus silvestris* L. Zakład Dendrologii i Arboretum Kórnickie PAN Kórnik: 1 - 88.
14. Giertych M. — 1970. Generative development of scots pine (*Pinus silvestris* L.) grafts. Arboretum Kórnickie XV: 71 - 92.
15. Hausser K. — 1960. Düngungsversuche zu Kiefern mit unerwarteten Auswirkungen. Allg. Forstzeitschr. 15 (34): 497 - 501.
16. Höhne H., Fiedler H. J. — 1967. Beitrag zur Stickstoffdüngung mittelalter Kiefernbestände (III). Archiv. Forstw. 16 (5): 487 - 507.
17. Höhne H., Fiedler H. J. — 1970. Beitrag zur Stickstoffdüngung mittelalter Kiefernbestände. Archiv Forstw. 19 (9/10): 899 - 919.
18. Kozubov G. M. — 1969. The influence of mineral nutrition on Scots Pine reproductivity. 2nd FAO/IUFRO World Consult. For. Tree Breed., Washington 1969 No. FO-FTB-69-11/16.
19. Kozubov G. M. — 1971. Vlijanie mineral'nych udobrenij na reproduktivnuju dejatel'nost' sosny. In: Udobrenija i gerbicidy v lesnom chozjajstve evropejskogo severa SSSR. Izdatel'stvo „Nauka" Leningrad: 36 - 45.
20. Nanson A. — 1965. Stimulation de la production de strobiles femelles dans un verger à graines de *Pinus silvestris* L. par application d'engrais. Silv. Genet. 14 (3): 94 - 97.
21. Sarvas R. — 1962. Investigations on the flowering and seed crop of *Pinus silvestris*. Comm. Inst. forest. fenn. 53 (4): 1 - 198.
22. Scholz E. — 1972. Die Bewirtschaftung von Saatgutbeständen eine wichtige Voraussetzung für die Intensivierung der Reproduction des Waldfonds. Soz. Forstw. 22 (12): 372 - 374.
23. Wareing P. F. — 1958. Reproductive development in *Pinus sylvestris* L. [In:] K. V. Thimann (ed.), The physiology of forest trees. Ronald Press, New York: 643 - 654.