ACTA SOCIETATIS
BOTANICORUM POLONIAE
Vol. XLV, nr 1—2
1976

A descriptive model o Scots pine (*Pinus silvestris*) L. seedling's growth during the first growing season *

TERESA GOWIN, LEOKADIA UBYSZ

Institute of Sylviculture, Warsaw SGGW Agricultural Academy

(Received: February 25, 1976)

Abstract

Scots pine seedlings were grown in pots from seed under outside conditions. Plant material was harvested ten times in fortnight periods, throughout the growing season. At each harvest, each plant was divided into particular organs and their dimensions as well as fresh and dry weight were determined. Seasonal course of growth of particular organs as well as changes in specific leaf area and distribution of dry matter between shoot and root were investigated. Net assimilation rate (NAR) and relative growth rate (RGR) were calculated from the fitted logistic growth curves.

INTRODUCTION

Differences in plant productivity depend, on great deal, on the processes of particular organs formation. The assimilatory organs and their dimensions as well as proportions between organs are of particular importance. Study of the seasonal course of growth, changes of the assimilatory surface area, net assimilation rate and growth rate including the earliest growth stages, are necessary for understanding of pine seedlings productivity and should provide elements for modeling these processes.

Initially the study was planned as a comparative one in seedlings grown from seed iradiated by various doses of X-irradiation. However, as the difference between experimental variants in this experiment appeared to be slight the radiation aspect became less important and all variants were used for illustrating the growth pattern of pine seedling.

* This project was supperted by funds made available from Marie Skłodowska-Curie Fund established by contributions of the United States and Polish Governments.

MATERIAL AND METHODS

Scots pine seeds were irradiated with 0.5; 1.0; 2.0; and 4.0 Kr doses of X-rays with the use of Fisher Ferranti machine. Air dry seeds were irradiated under the conditions: 80 KV, 12 mA, intensity of 1 Kr/min and temperature of 20°C.

Plants were grown in pots filled with a mixture of compost soil and sand (1 : 1). Each pot containing 6.4 kg of air dry mixture was supplied with 192 mg of pure nitrogen in the form of ammonium sulphate. Soil was watered daily up to 60% of its capillary capacity. The number of plants was reduced to 30 per pot. Seedlings were grown under outside conditions and only during nights and rainy periods they were kept under the glass.

Plant material was harvested ten times in fortnight periods, through-out the growing season. There were 30 plants harvested each time in each experimental variant. Each plant was divided into particular organs and their dimensions as well as fresh and dry weight were determined. Needle surface area was measured with photoplanimeter technique. Method of growth analysis (Blackman 1919, Briggs et al., 1920) was used for calculation of net assimilation rate (NAR) and relative growth rate (RGR). To calculate these growth characteristics, the data were taken from the fitted logistic growth curves. The growth curves were approximated according to two logistic models:

$$h(t) = A \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{a+bt} \exp.\left(-\frac{x^2}{2}\right) dx$$

and

$$h(t) = A \exp. (a+bt) [1+\exp. (a+bt)]^{-1}$$

where h(t) is the expected value of the certain characteristic in t time A, a, b — are parameters of the curves where A is the highest experimental value of the function. Parameters of the function were obtained by least squares estimates by an iterative procedure, on condition to achive the maximum of determination.

The variance analysis was carried out for all investigated features, in all experimental variants, for 10 harvest times.

RESULTS

Intensive elongation of seedlings was observed since the middle of July till the end of August (Fig. 1). Dry weight increament as well as the final weight of seedlings showed the same patterns as hight growth (Fig. 2).

Intensive accumulation of organic matter was observed at the middle of July until the end of Sėptember.

Intensive accumulation of organic matter in needles begun at the end of July and finished at the end of growing season (Fig. 3, 4, 5).

Rapid increase of specific leaf area (area per gram of dry weight of needles) was observed in June (Fig. 6). Specific leaf area decreased rapidly till the beginning of August and decreased slowly in the later period. Intensive increase of needle surface area on the main shoot was noticed since June till the middle of August; later this increase was slower and intensive needle growth of lateral shoots begun (Fig. 7, 8).

Intensive increase of stem weight was observed in July (Fig. 9). Further accumulation of organic matter took place towards the end of the growing season, but its rate was slower comparing to the period of intensive growth. Lateral shoots begun to develop in the second half of August and finished their growth after the short period (Fig. 4—7). Root intensive growth begun in the middle of August (Fig. 10). The rate of this growth did not decrease even in the middle of October.

Highest value of the shoot to root ratio was found in the middle of June (Fig. 11). Considerable decrease of this ratio was noticed after two weeks time and its value remained at a rather constant level during the following fortnight period. The value of the shoot to root ratio increased considerably in July. Later on a rapid decline of this value was noticed until the beginning of October.

Highest net assimilation rates (NAR) and relative growth rates (RGR) were found at the end of June (Fig. 12, 13, 14). They remained at high level since the middle of July until the middle of August; but they were slightly lower than values at the beginning of July. Net assimilation rate (NAR) and relative growth rate (RGR) decreased gradually after that period and showed the lowest values during the first half of October.

Water content in stem and needles maintains on the similar level until beginning of August (Fig. 15, 16). In the later period a great decrease of water content was observed. This decrease was more distinct in the needles than in stem. During the whole growing season — the roots showed high per cent of water content (Fig. 17) until August. In the later period only slight decrease of water content was observed as compared with needles and stem.

Variance analysis showed that irradiation of seed with different doses of X-rays brought about only slight differences in the course of growth and organic matter accumulation. Low X-rays doses caused a slight growth stimulation, while the 4.0 Kr dose caused a slight growth inhibition.

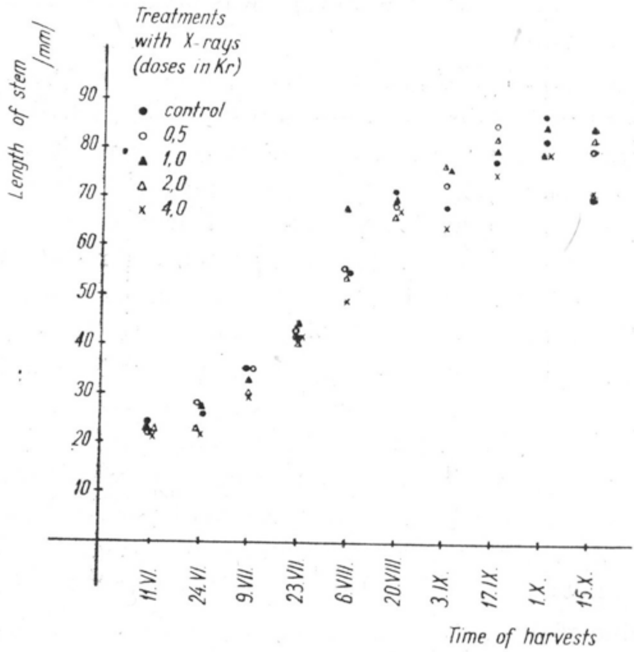

Fig. 1. Length of stem of seedling

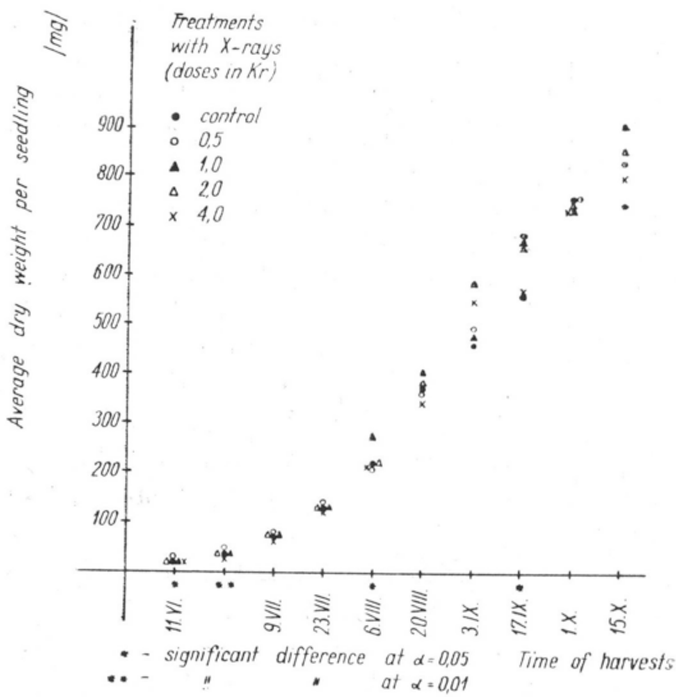

Fig. 2. Average dry weight per seedling

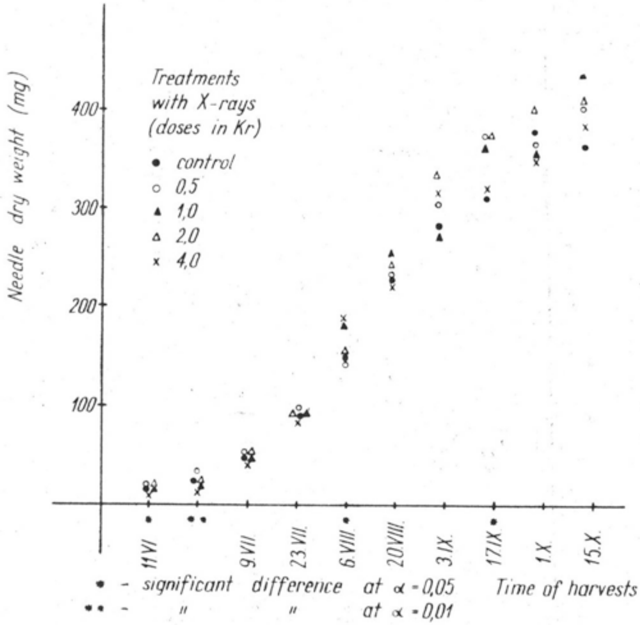

Fig. 3. Needle dry weight

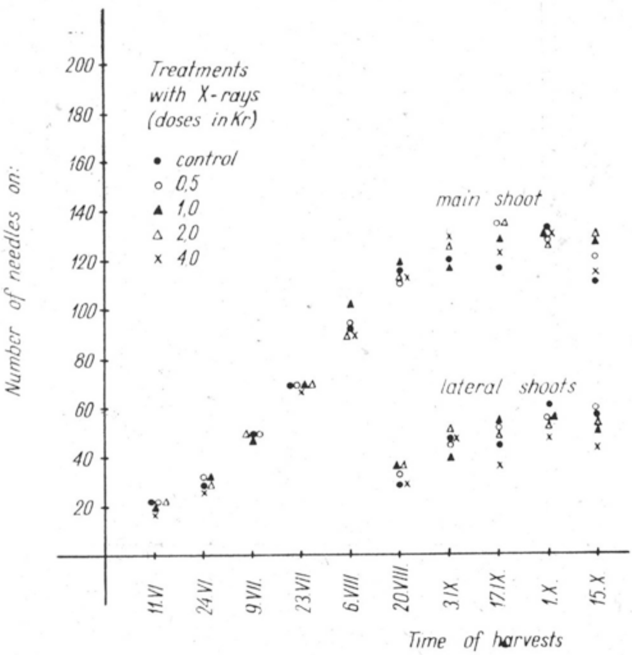

Fig. 4. Number of needles on main shoot and lateral shoots

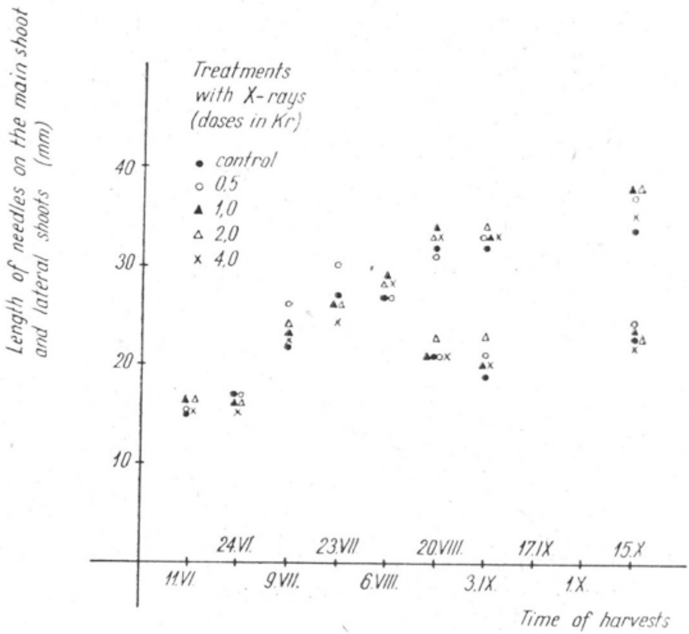

Fig. 5. Length of needles on the main shoot and lateral shoots

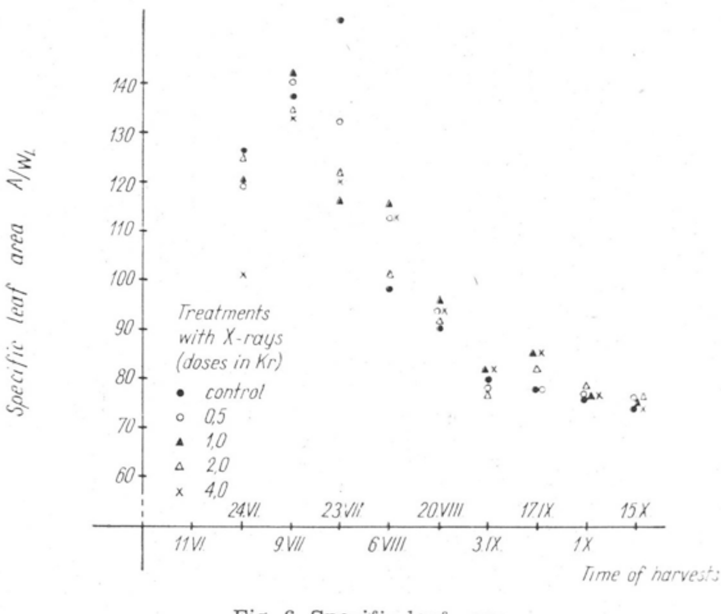

Fig. 6. Specific leaf area

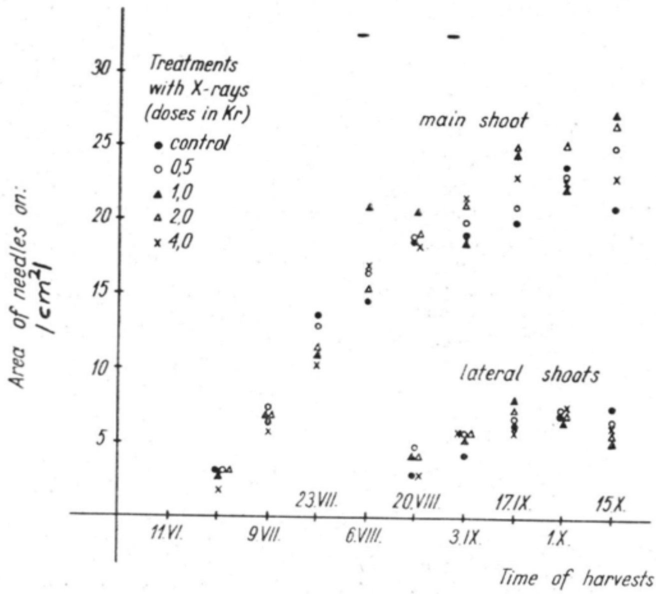

Fig. 7. Area of needles on main shoot and lateral shoots

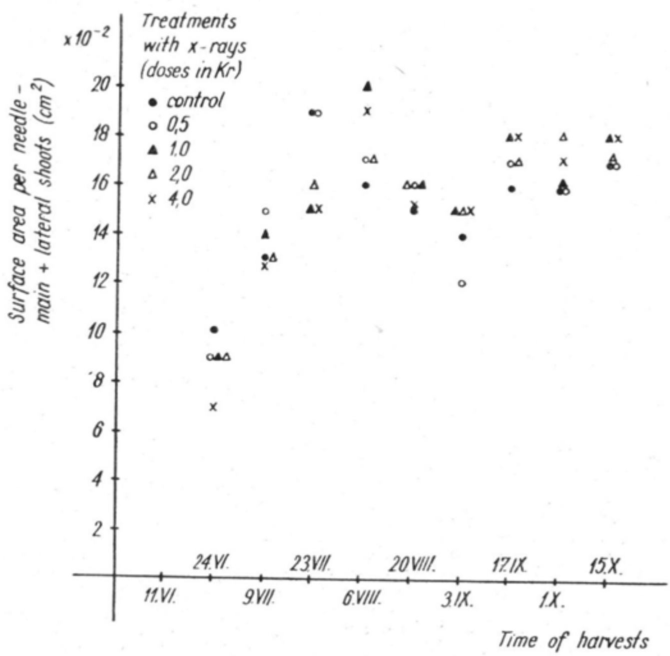

Fig. 8. Surface area per needle (main + lateral shoots)

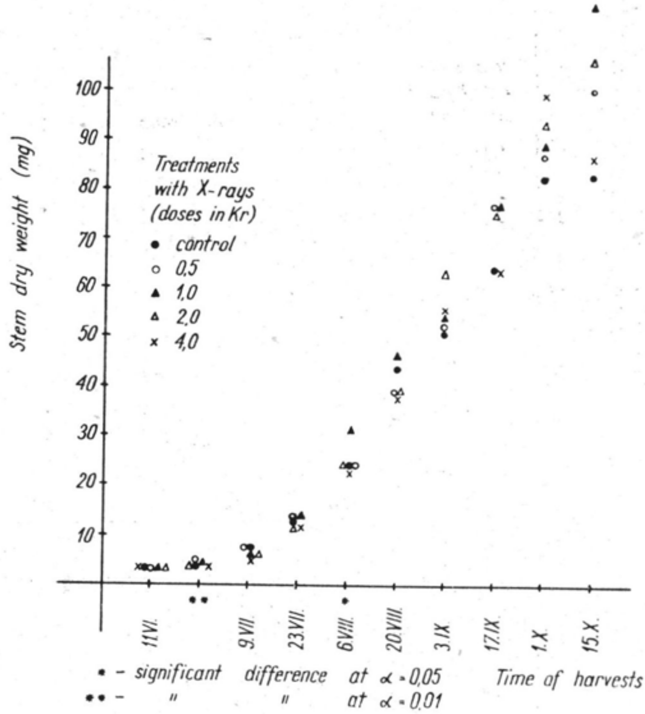

Fig. 9. Stem dry weight

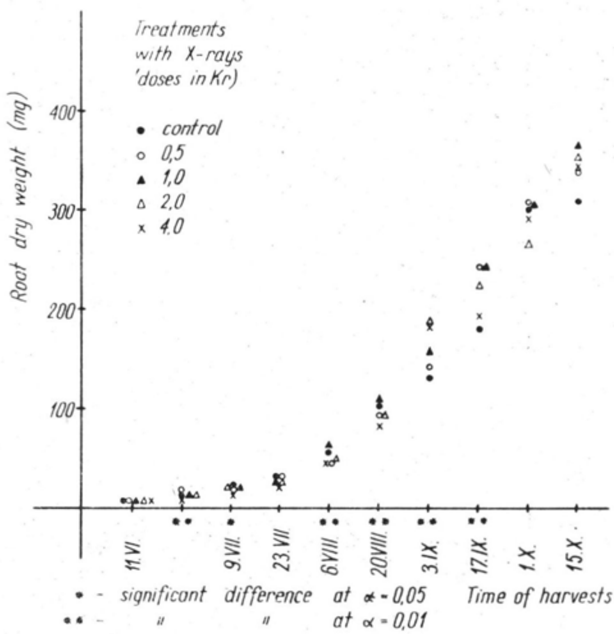

Fig. 10. Root dry weight

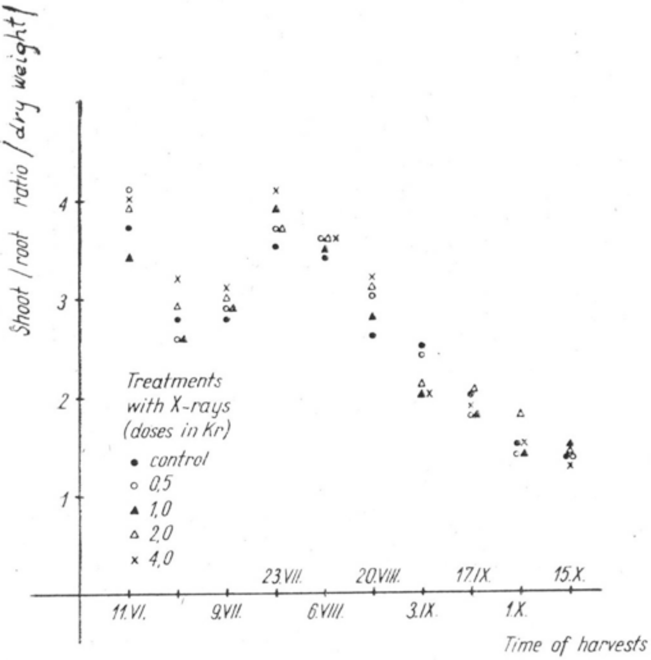

Fig. 11. Shoot/root ratio

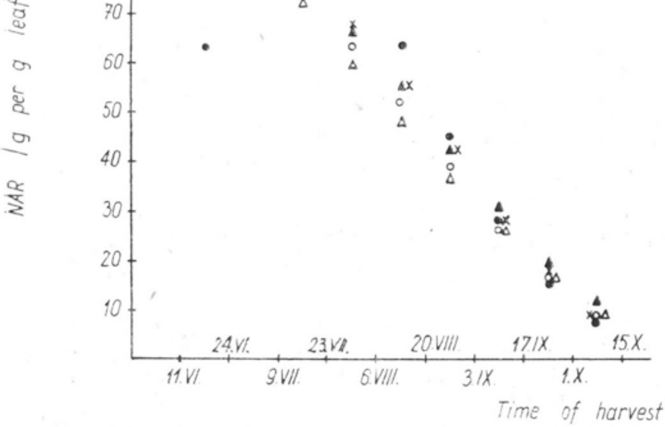

Fig. 12. Net assimilation rate per dry weight of leaf

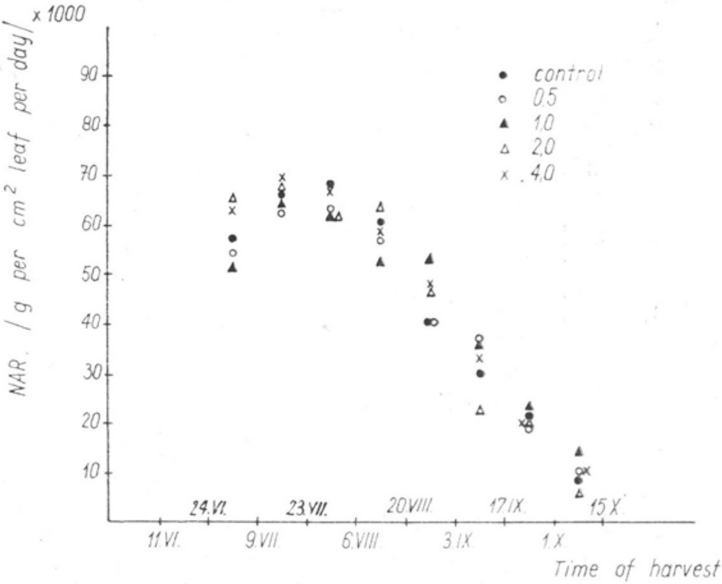

Fig. 13. Net assimilation rate per leaf area

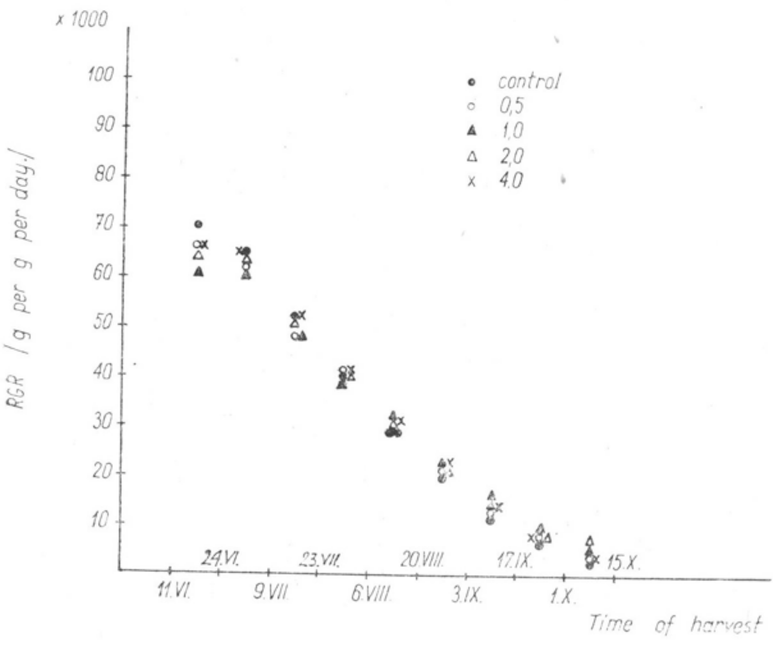

Fig. 14. Relative growth rate

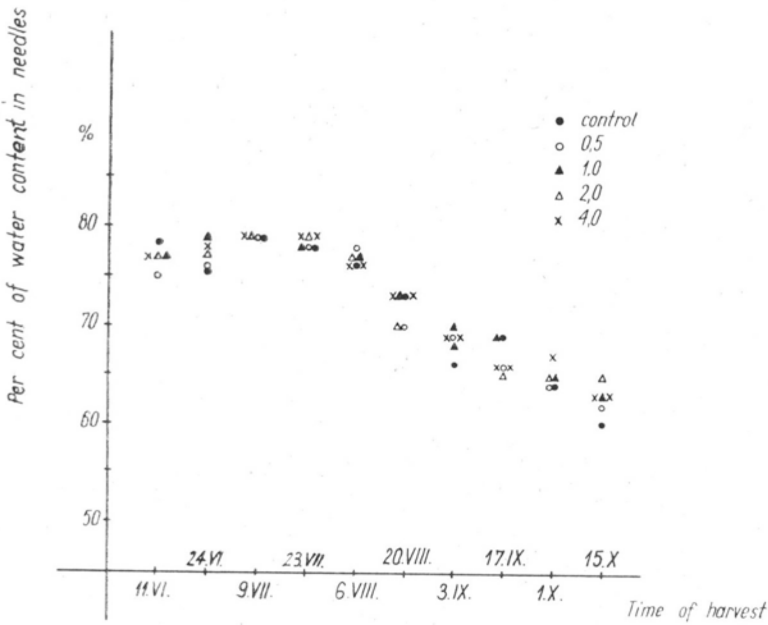

Fig. 15. Per cent of water content in needles

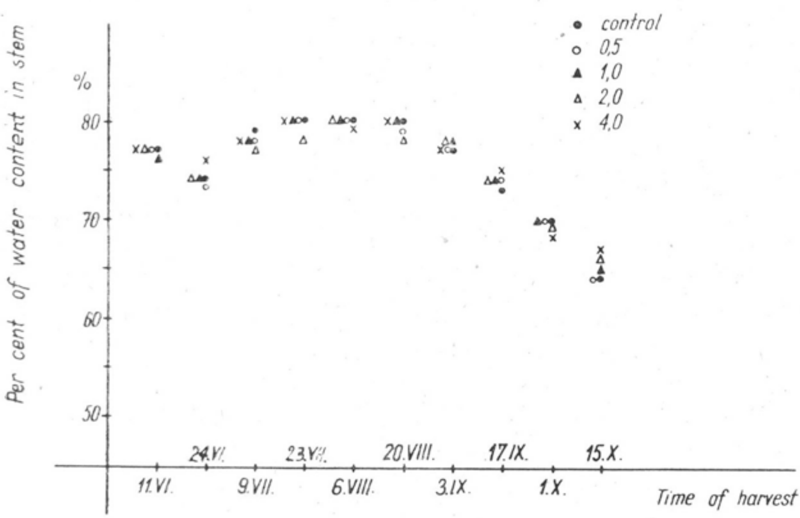

Fig. 16. Per cent of water content in stem

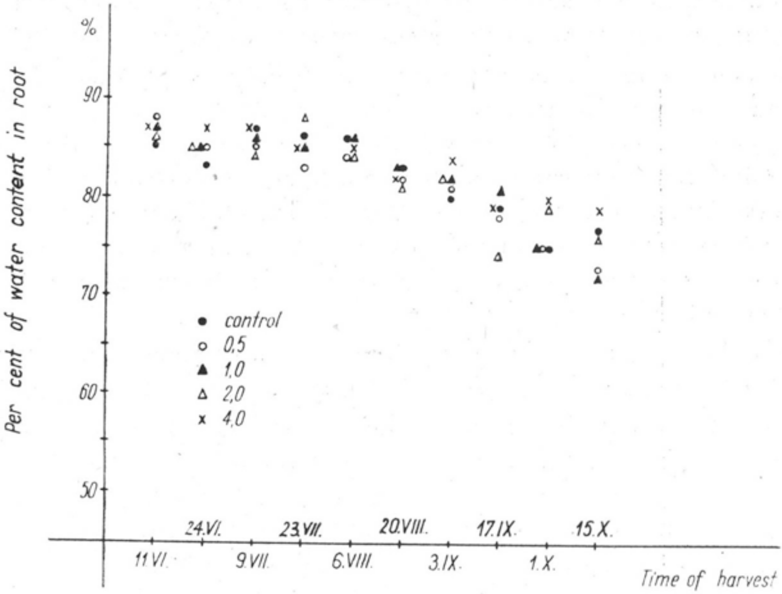

Fig. 17. Percent of water content in root

DISCUSSION

The described growth pattern and course of organic matter accumulation, in Scots pine seedlings, are in general in agreement with the data reported by other authors (Rutter 1957; Sand and Rutter 1959; Ingestad 1960; van der Driessche and Wareing 1966; Gowin and Góral 1968; Pollard and Wareing 1968; Sweet and Wareing 1968). However, in the above mentioned papers data are missing as concerned the earliest growth stages, the lateral shoot formation and the total area of the assimilatory organs.

Needle aurface area in early growth stages and particulary the specific leaf area index are worthly of particular notice. Considerable changes of this index during the first weeks of growth result form a relatively intensive growth of needle surface area with only organic matter accumulation at high water content of needles. Needles of the lateral shoots are characterized by short period of intensive growth.

Mutual relation between shoot and root of different plants was investigated by many ecologists. Value of this ratio during the growing season depends on different rates of growth of the shoot and root, different distribution of organic matter between aerial part of plants and the roots, and ecological factors (e.g. Troughton 1956; Mullin 1963; Ledig and Perry 1965; Ledig et al. 1970; Berchert 1973). Some changes in S/R ratio during the growing season may be also viewed as a homeostatic mechanism for maintaining a balanced S/R ratio during the disturbance of growth or in stress situation (Wareing 1970).

The general opinion is that during the first growing season, trees show a constant decrease of this ratio (Mullin 1963, Ledig and Perry 1965, Sweet and Wareing 1968, Ledig et al. 1970). However, the results of our experiments showed different shoot-root relation during the initial growth stages of seeedlings. During about two months, both the decrease and increase of the shoot to root ratio was observed. Constant decrease of the shoot to root ratio took place after that period like it was reported earlier by other authors.

Investigations, reported in this paper, showed highest net assimilation rate (NAR) of pine seedlings in the middle of July. These results agree with results of parallel investigation of photosynthesis rate, by use of manometric method (Żelawski, Łotocki and Nalborczyk 1974) which showed, that in the middle of July the rate of this process was also the highest. Changes of the NAR value indicate that photosynthe-productivity of needles is highest during the period of their intensive growth and decreases towards the end of the growing season. It is also in agreement with the results obtained by Ledig and Perry (1969) for NAR courses in loblolly pine seedlings. According to Larson (1962, 1964) most of the photosynthates is used by the actively growing organs during the periods of intensive shoot elongation and intensive growth of needles. Relatively small amounts are translocated at that time to the stem. It is not until the intensive growth stage is finished, that most of the photosynthates is incorporated into the wood. Góral (1973) found that a large portion of the photosynthates (about half of the assimilated carbon) is retained by needles, during the period of their intensive growth. The roots are acceptors of considerable amount of photosynthates only at the end of the growing season, since they do not finish growth for a long time in autumn.

The stimulation and inhibition effects of seed irradiation with low doses of X-rays depend, both, on internal factors, e.g. seed water content, as well as on the external conditions during the experiment following irradiation, e.g. nutrition, weather, etc. (Skok 1965; Nalborczyk et al. 1971; Żelawski et al. 1974). In our experiment, low X-rays doses caused a slight growth stimulation, while the 4.0 Kr dose caused a slight growth inhibition. The character and degree of stimulation and inhibition changed a little during the growing season. Irradiation doses of 2.0 and 4.0 Kr retarded, slightly, the initial growth of seedlings. The stimulation effect of lower X-rays doses (0.5; 1.0; 2.0 Kr) increased towards the end of the growing season, while the inhibition effect of the 4.0 Kr dose decreased.

CONCLUSIONS

1. Differences in the course of growth of particular organs are manifested by: earlier ending of growth of the assimilatory organs comparing to that of the stem and root, the longest period of root growth, and short period of lateral shoots growth.

2. Specific leaf area (surface area per 1 g dry weight of needles) increases rapidly and shows the highest value during the initial growth stages; later on value of this index decreases gradually till the end of growing season.

3. Largest changes in organic matter distribution, between the aerial part and roots, take place during the initial growth stages of seedlings. later the shoot to root ratio decreases gradually towards the end of the growing season.

4. The highest values of net assimilation rate (NAR) and relative growth rate (RGR) occur during the period of intensive growth of the assimilatory organs.

5. Seasonal changes of water content in needles, stem and root have not the same character. During the whole growing season only the roots show high per cent of water. The stem and needles have the high level of water content during the period of intensive hight growth of seedlings; later a distinct decrease of water content occurs especially in needles, then in stem.

6. It seems that higher X-rays doses retard, slightly, the initial seedlings growth, but the inhibition effect decreases towards the end of the growing season; lower irradiation doses show a slight stimulation effect on seedlings growth.

REFERENCES

Blackman V. H., 1919. The Compound Interest Law and Plant Growth, Ann. of Bot. 33: 353-360.

Borchert R., 1973. Simulation of rythmic tree growth under constant conditions, Physiol. Plant. 29: 173-180.

Briggs G. E., Kidd R., and West C., 1920. A quantitative analysis of plant growth, Ann. Appl. Biol. 7: 103-123, 202-223.

Gowin T., Góral I., 1968. Growth and dry matter accumulation of Scots pine (*Pinus silvestris* L.) seedlings grown from seed of different provenience., Ekol. Pol. 15: 324-333.

Góral I., 1973. Distribution of radioactive products of photosynthesis in Scots pine (*Pinus silvestris* L.) seedlings during the first vegetation season., Acta Soc. Bot. Pol. 4: 541-553.

Ingestad I., 1960. Studies on the nutrition of forest tree seedlings. III. Mineral nutrition of Pine. Physiol. Plant. 13: 513—533.

Larson P. R., 1962. Auxin gradients and the regulation of cambiel activity [In:] Tree growth. Ed. Kozlowski T. T., Ronald Press, N. 4: 97-117.

Larson P. R., 1964a. Contribution of different aged needles to growth and wood formation of young red pines. For. Sci. 10: 224-238.

Ledig F. T. and Perry T. O., 1965. Physiological genetics of the shoot — root ratio. [In:] Proc. Soc. Amer. Foresters, 1960, p. 39-43, Detroit Mich.

Ledig F. T. and Perry T. O., 1969. Net assimilation rate and growth in loblolly pine seedlings. For. Sci. 15 (4): 431-438.

Ledig F. T., Borman F. H. and Wenger K. F., 1970. The distribution of dry matter growth between shoot and root in loblolly pine. Bot. Gaz. 131 (4): 349-359.

Mullin R. F., 1963. Growth of white spruce in the nursery. For. Sci. 9, 68-72.

Nalborczyk E., Żelawski B. and Kołakowska M., 1971. Effect of X-rays on seed germination and growth of Scots pine (*Pinus silvestris* L.) seedlings of different provenience. Acta Soc. Bot. Pol. 40: 403-412.

Pollard D. F. W. and Wareing D. F., 1968. Rates of dry matter production in forest tree seedlings., Ann. Bot. 32: 573-591.

Rutter A. J., 1957. Studies in the growth of young plants of *Pinus silvestris* L. [In:] Annual cycle of assimilation and growth. Ann. Bot. 21: 1399-1426.

Sands K. and Rutter A. J., 1959. Studies in the growth of young plants of *Pinus silvestris* L. The relation of growth to soil moisture tension. Ann. Bot. 23: 269-284.

Skok J., Chorney W. and Rakosnik E. J., 1965. An examination of stimulatory effects of ionizing radiation in plants. Rad. Bot. 5: 281-292.

Sweet G. B. and Wareing P. F., 1968. A comparison of the seasonal rates of dry matter production of trees coniferous species with contrasting pattern of growth. Ann. of Bot. 32: 721-734.

Troughton A., 1956. Studies on the growth of young grass plants with special references to the relationship between the shoot and root systems. J. Brit. Grassland Soc. 11: 56-65.

Van der Driessche R. and Wareing P. F., 1966, Dry matter production and photosynthesis in pine seddlings. Ann. of Bot. N. S. 30: 673-682.

Wareing P. F., 1950. Growth studies in woody species. I. Photoperiodism in first-year seedlings of *Pinus silvestris*. Physiol. Plant. 3: 258-276.

Wareing P. F., 1970. Growth and its co-ordination in trees. [in:] L. C. Luckwill and C. V. Cutting eds. Physiology of tree crops, Acad. Press. N. Y., p. 1-21.

Żelawski W., Łotocki A., and Nalborczyk E., 1974. Productivity of photosynthesis in Scots pine (*Pinus silvestris* L.) seedlings during their first and second growing season after X-irradiation of seeds. Annual report for USA. 1974.

Author's address:
dr. Teresa Gowin
Doc. dr. Leokadia Ubysz,
Institute of Sylviculture
Warsaw Agricultural University
Rakowiecka 26/30; 02-528 Warsaw

Opisowy model wzrostu siewek sosny zwyczajnej w ciągu pierwszego sezonu wegetacyjnego

Streszczenie

Siewki sosny zwyczajnej wyrosłe z nasion napromienionych dawkami: 0,5; 1,0; 2,0; 4,0 Kr hodowano w wazonach, w warunkach hali wegetacyjnej. Zbiory przeprowadzano co 2 tygodnie w 10 terminach w ciągu całego sezonu wegetacyjnego.

W każdym zbiorze oznaczano wymiary oraz świeżą i suchą masę poszczególnych organów każdej rośliny. Przebadano również sezonowe zmiany wskaźnika względnej powierzchni igieł i dystrybucji suchej masy pomiędzy część nadziemną i korzeń.

Posługując się metodą analizy wzrostowej przy wartościach otrzymanych z danych wyrównanych do krzywych logistycznych obliczono intensywności asymilacji netto (NAR) oraz względną intensywność wzrostu (RGR). W pracy przedstawiono w sezonowym przebiegu szczegółową charakterystykę wzrostu i kształtowanie się poszczególnych organów siewki sosny.

Stwierdzono, że w początkowej fazie wzrostu siewki dość gwałtownie rośnie wskaźnik względnej powierzchni igieł (tzn. powierzchni odniesionej do 1 g suchej masy igieł) co świadczy o intensywnym wzroście igieł przy jednocześnie niewielkiej akumulacji suchej masy.

Największe zmiany w dystrybucji suchej masy między część nadziemną i korzeń zachodzą w początkowych fazach wzrostu siewki, potem wielkość stosunku pędu do korzenia maleje stopniowo aż do końca sezonu wegetacyjnego. Najwyższe intensywności asymilacji netto (NAR) i intensywności względnego wzrostu (RGR) przypadały w okresie intensywnego wzrostu aparatu asymilacyjnego.

Napromienie nasion różnymi dawkami promieni X wywołało nieznaczne różnice w przebiegu wzrostu i akumulacji masy organicznej. Niskie dawki promieni X wywołały niewielką stymulację wzrostu, natomiast dawka 4,0 Kr — niewielką inhibicję wzrostu.