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AN ELECTRONIC AUXANOMETER FOR FIELD USE

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SELOSTE:

SÄHKÖINEN PAKSUUSKASVUMITTARI MAASTOKÄYTTÖÖN

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This paper describes the design and functioning of an electronic auxanometer designed for field use, and some results obtained with it. The changes in stem radius are monitored with a micrometer screw turned by an electric motor. A potentiometer transforms the position of the screw into an electronic signal, which is recorded. The accuracy of the device is app. 1—2 um. Field experiments with the auxanometer are described and discussed. The accuracy of the device was found to be sufficient for measuring hourly changes in stem radius.

INTRODUCTION

Intensive studies on the effect of environmental factors on daily diameter growth have been carried out recently (e.g. FRITTS and FRITTS 1955, KOZLOWSKI and WINGET 1964, HUIKARI and PAARLAHTI 1967, LEIKOLA 1969, ODIN 1972, WORRAL 1973). Various types of devices have been used in the studies mentioned above. The development of diameter growth meters is widely described by LEIKOLA (1969). The most common type of meter is called auxanometer or auxanograph (LEIKOLA 1969). The auxanograph is attached to the stem and the changes in stem radius are registered on paper. This method is frequently used in diameter growth studies (e.g. FRITTS and FRITTS 1955, KOZLOWSKI and WINGET 1964, LEIKOLA 1969). More recently various types of electronic device have been developed for measuring daily changes in radius (e.g. ODIN and OPENSHAW 1971, KLEPPER *et al.* 1971, SHERIFF 1976).

The diurnal variation of certain factors (e.g. the temperature and water status of the stem) affects diameter growth. In order to describe accurately the stem radius response to changes in environmental factors, radial growth changes occurring within a few hours or less have to be detected (e.g. GALLAGHER *et al.* 1976). This makes it necessary to introduce highly sensitive methods for monitoring these rapid changes at least to an accuracy of 10 *um* (e.g. ODIN and OPENSHAW 1971, GALLAGER *et al.* 1976).

This paper describes the construction of an electronic auxanometer capable of measuring hourly changes in stem radius, and field experiments carried out with the instrument. Some results of growth analysis are also presented.

CONSTRUCTION OF THE AUXANOMETER

The operation principle of the meter is to follow by means of a micrometer screw the radial movements of a piece of metal fixed on the bark of a tree stem. The screw and the plate act as a capacitor, the capacitance of which depends on the distance between the plate and the screw. The micrometer screw is turned by an electric motor so that the capacity between the metal plate and the micrometer screw remains inside preset capacity limits. A potentiometer fixed on the same axis as the screw transforms the position of the screw into an electric signal, which is then recorded by a strip chart recorder (see Fig. 1). One revolution of the screw corresponds 200 um. The resolution of the meter is 1—2 *u*m.

The small metal plate is fixed to the bark of the tree with glue. The screw, motor and potentiometer are attached to a hook lying above them, and to two nails one on each side, in such a way that the distance between the fixation points and the measuring point is as small as possible. The effect of shrinkage is thus minimized.

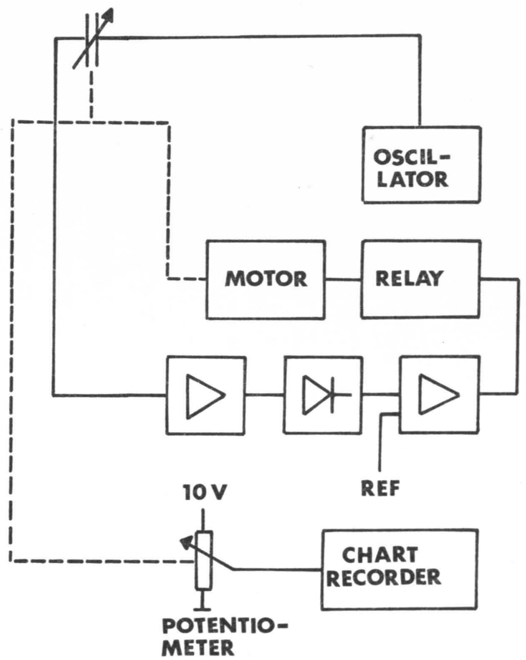


Figure 1. Schemntic diagram of the auxanometer. Solid line: Operation current. Dashed line: Control signal.

FIELD EXPERIMENT AND RESULTS

The measuring system was tested at the ecological experiment station near the University Forestry Station at Hyytiälä (61° 50′N, 24°20′E, 150 m a.s.l.) in summer 1975. 27-year-old Scots pines *(Pinus sylvestris* L.) were used in the experiment. The mean diameter of the trees was 10.6 cm and the mean height 9 meters. Three auxanometers were used in the experiment and they were attached to the stem at a height of four meters.

The measurements were started in May at the beginning of the growing season and continued throughout the whole growing season, ending in August. The primary data for changes in stem radius was collected using a chart recorder (model Honeywell Versaprint 231). The measurements were carried out continuously and the readings were recorded every two minutes (see Fig. 2).

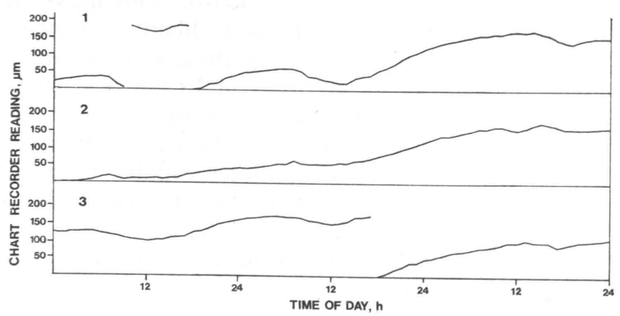


Figure 2. Chart recorder reading of the auxanometers 1,2, and 3 during the period June 11—13, 1975.

The readings from the chart recorder were read once an hour. In the first step the changes in stem radius were computed over the time interval of two hours (see Fig. 3). For further analysis the daily growth values were also computed. In the first step the rate of change in stem radius within a two hour period was found to be closely correlated with temperature. A time lag of about six hours was found between changes in temperature and their effect on changes in radius. The biggest change in stem radius occurs in late afternoon or early evening. When transpiration is fast the stem shrinks owing to water loss from xylem cells. This generates additional variance in the growth data.

The dependence of daily radial growth on environmental factors and on self regulation of the tree is analysed with a model analogous to that presentend by Hari *et al.* (1977) for daily height increment. In the model the daily amount of growth is explained by temperature and the inherent growth rhythm. Results from the analysis are presented in Fig. 4.

Figure 3.

Above. Air temperature during the period June 11—14, 1975.
Middle. Irradiance during the same period.
Below. Two hour changes in stem radius. The period as above.

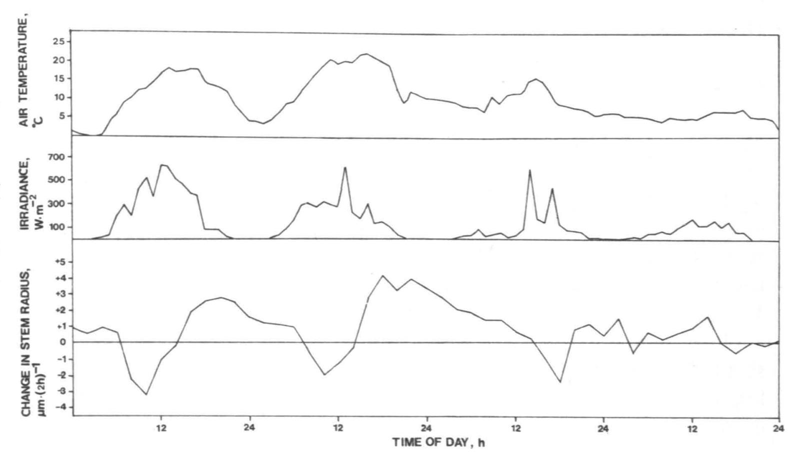
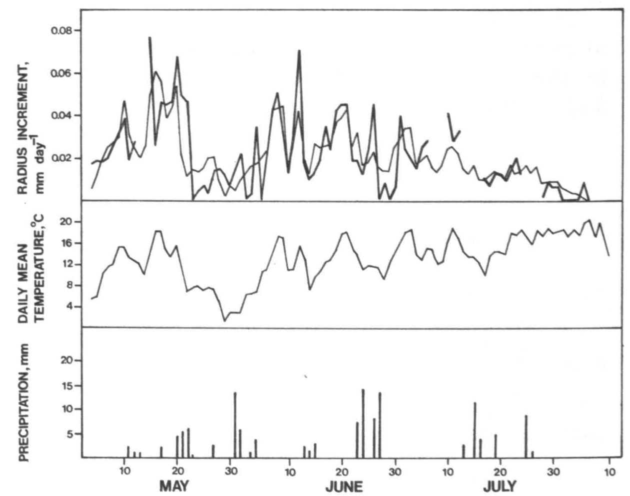


Figure 4.

Above. The daily measured (thick line) and computed (thin line) radius increment in 1975.
Middle. The daily mean temperature in 1975.
Below. The daily precipitation in 1975.



DISCUSSION

Attachment of the instrument to the stem appeared to be satisfactory. The measuring shaft follows the movement of the plate without touching it and therefore does not press the stem during the measurements. The error due to thermal expansion of the auxanometer was not estimated, but only very small if any variation in the data was found to be due to thermal expansion. Technical functioning of the instrument appeared to be satisfactory. No data was recorded on 10 out of 102 days due to some problem in the measuring system. The accuracy of the device (app. 1—2 um) was found to be enough for measuring hourly changes in the stem radius.

Setting the device at a height of four meters raised the accuracy of the measurements. The width of the annual rings at this height were found to be 1.5 times greater than that at breast height. The diurnal growth pattern has been, however, observed to be similar in all parts of the stem (Kozlowski and Winget 1964, Huikari and Paarlahti 1967, Leikola 1969). It can be seen from Fig. 3 that there is a close relationship between changes in the stem radius and air temperature. A time lag of about six hours was observed in the effect of temperature on growth. This is in agreement with earlier results concerning the effect of temperature on shoot growth (e.g. Hertz 1929, Mork 1941, Hari 1976).

The water potential in the stem varies at different times of the day due to changes in the transpiration flow (e.g. Kozlowski and Winget 1964, Leikola 1969, Ahti 1973, Mitscherlich 1975). During the late evening and night the stem is filled with water thus causing the stem to swell. At noon and in the afternoon the diameter of the stem decreases due to the water loss from the cells in transpiration. These hydrostatic changes cause inaccuracies in the monitoring of growth (Leikola 1969). In order to obtain accurate information about cambial growth, intensive studies on water status in the stem and on the course of transpiration flow are required.

Daily radial growth seems to be mainly controlled by temperature and the inherent growth rhythm. The model based on the assumption that temperature is the only environmental factor causing variation in radial growth rate explained 60 per cent of the observed variance. After periods of heavy rainfall poor correlation was found between measured and calculated values (see Fig. 4). This is probably due to hydrostatic changes in the stem, as already mentioned above.

Measuring accuracy of greater than 10 um is needed for measuring short-term changes in stem radius (see e.g. Odin and Openshaw 1971, Gallager *et al.* 1976, Sheriff 1976). The instrument described above satisfied the criteria of accuracy. It also appeared to work satisfactorily in the field although the technical design of the measuring system cannot be regarded as being complete. In further studies the main attention should be paid to the water status of the tree in order to eliminate the disturbing effect of bydrostatic changes in the growth data.

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SELOSTE:

SÄHKÖINEN PAKSUUSKASVUMITTARI MAASTOKÄYTTÖÖN

Artikkelissa esitellään maastokäyttöön suunniteltu sähköinen paksuuskasvumittari sekä eräitä sillä saatuja mittaustuloksia. Puun säteen muutoksia seurataan sähkömoottorilla toimivalla mikrometrillä. Potentiometri muuntaa mikrometrin asennossa tapahtuneet muutokset sähköiseksi signaaliksi, joka rekisteröidään piirturille. Laitteen mittaustarkkuus on noin 1—2 um Tämä tarkkuus havaittiin riittäväksi haluttaessa mitata puun säteen tunneittaisia muutoksia.

HUURI, OLAVI O.D.C. 176.1
Betula pendula f. carelica Sok.

1978. Visaseura. Summary: Curly Birch Society. — SILVA FENNICA Vol. 12, No. 4, 4 p. Helsinki.

In 1956 The Curly Birch Society was founded in Finland. Its purpose is to promote the cultivation and use of curly birch and to coordinate the activities of curly birch cultivators, forest industry and research. The society has made excursions and held informative meetings every year. Furthermore, the society has arranged exhibitions and participated in more extensive agricultural and forestry fairs.

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PÄTIÄLÄ, RISTO-VEIKKO, BLOMBERG, KARIN, PIEPPONEN, SULO & PAAKKANEN, JUHANI O.D.C. 160: 176.1
Betula pendula f. carelica Sok.

1978. Havaintoja raudus- ja visakoivun mahlan sokeripitoisuudesta. Summary: On carbohydrates of the sap of silver birch and its forma curly birch. — SILVA FENNICA Vol. 12, No. 4, 4 p. Helsinki.

The carbohydrates of the sap of six curly and four silver birches were analyzed by gaschromatography as trimethylsilyl derivates both from hydrolyzed and unhydrolyzed samples. The sorbitol was identified from silver birch sap only. — In each of the two groups there were glucose and fructose. No other carbohydrates were discovered. The hydrolysis was without influence on results.

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RAULO, JYRKI & SIREN, GUSTAF O.D.C. 525: 176.1.
Betula pendula f. carelica Sok.

1978. Neljän visakoivikon päätehakkuun tuotos ja tuotto. Summary: Yield in volume and money of final cutting in four curly birch stands. — SILVA FENNICA Vol. 12, No. 4, 8 p. Helsinki.

The study material consists of one 52-year old and three 42—43-year old stands of curly birch *(Betula pendula f. carelica* Sok.) The yield suitable for plywood manufacture from the oldest stand was 34 777 kg/ha and that of curly-grained branch wood 39 452 kg/ha. The corresponding figures were, on average, 24 219 and 57 271 kg/ha. The yield from the stands were sold at the present day price. The result was economically better than from any other forest tree species grown in Finland.

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RAULO, JYRKI, SAARNIO, REINO & YLITALO, TIMO O.D.C. 815.4: 176.1 *Betula pendula f. carelica* Sok.

1978. Visakoivun karsittujen oksien kyljestyminen ja värivian leviäminen niistä runkoon. Summary: Sealing-off of pruned branch stumps in curly birch and subsequent spread of discolouration into the stemwood. — SILVA FENNICA Vol. 12, No. 4, 7 p. Helsinki.

The study material included 35 pruned branch stumps and 38 naturally pruned branch stumps. The mean diameter of the former was 31 mm and of the latter, only 15 mm. Of the pruned branch stumps, 23 per cent has become completely sealed-off within 12 years. The discoloration had spread into the stem as little from pruned branch stumps as from the naturally pruned ones even though they were greater in size. Advanced rot was not found in any of the samples studied.

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KIRJOITUSTEN LAATIMISOHJEET

Silva Fennica-sarjassa julkaistaan lyhyitä metsätieteellisiä tutkimuksia ja kirjoituksia kotimaisilla kielillä tai jollakin suurella tieteellisellä kielellä. Julkaistavaksi tarkoitettu käsikirjoitus on jätettävä Seuran sihteerille painatuskelpoisessa asussa. Seuran hallitus ratkaisee asiantuntijoita kuultuaan, hyväksytäänkö kirjoitus painettavaksi.

Kirjoitusten laadinnassa noudatetaan Silva Fennican numerossa Vol. 4, 1970, N:o 3 painettuja kansainvälisiä ohjeita. Suureissa, yksiköissä sekä symbolien ja kaavojen merkinnöissä noudatetaan ohjeita, jotka ovat suomalaisissa standardeissa SFS 2300, 3100 ja 3101. Oikoluvussa noudatetaan standardia SFS 2324.

Kirjoituksen alkuun tulee julkaisun kielellä lyhyt yhdistelmä tutkimuksen tuloksista. Samoin laaditaan tutkimuksen yhteyteen lyhyt englanninkielinen tiivistelmä, jonka lisäksi kunkin Silvan numeron loppuun painetaan irti leikattavan kortin muotoon kustakin tutkimuksesta englanninkielinen esittely. Sisällysluetteloa ei käytetä. Mahdolliset kiitokset esitetään lyhyesti johdannon lopussa ja merkitään painettavaksi petiitillä.

Kuvien ja piirrosten viivapaksuudet ja tekstikoko on valittava siten, että ne sallivat painatuksen vaatiman pienennyksen. Kuvien ja piirrosten painatuskoosta on syytä neuvotella etukäteen toimittajan kanssa, sillä tarpeettomia kustannuksia aiheuttavaa painatuskokoa ei sallita. Valokuvien tulee olla teknisesti moitteettomia ja kiiltävälle valkealle paperille suurennettuja. Värikuvia ei yleensä hyväksytä painettavaksi. Kuvat ja taulukot numeroidaan kummatkin erikseen juoksevasti, ja niiden otsikoista laaditaan erillinen luettelo kirjapainoa varten.

Jos vieraskielisessä lyhennelmässä viitataan tiettyihin kuviin ja taulukoihin, on nämä varustettava vieraskielisin otsikoin ja selityksin. Muut kuvat ja taulukot voivat olla yksikielisiä.

Lähdeviittauksissa tekijännimet sijapäätteineen kirjoitetaan isoin kirjaimin mikäli tekijännimen vartalo on muuttunut. Muutoin taivutuspääte kirjoitetaan pienaakkosin. Esimerkkejä: KOSKISEN (1972) tutkimus . . ., YLI-VAKKURIN (1972) tutkimus . . . Milloin tekjöitä on kolme tai useampia, mainitaan tekstissä vain ensimmäinen (esim. HEIKURAINEN ym. 1961). Vieraskielisessä tekstissä ym. korvataan merkinnällä et al. Jos julkaisulla on kaksi tekijää viitteessä, pannaan tekijöiden nimien väliin ja-sana painatuskielellä. Esimerkki: KELTIKANGAS ja SEPPÄLÄ (1973, s. 222) osoittivat . . .

Viitekirjallisuus luetteloidaan tekijännimien (kirjoitetaan isoin kirjaimin) mukaisessa aakkosjärjestyksessä. Jos tekijöitä on useampia, nimet erotetaan pilkulla, paitsi kaksi viimeistä, jotka erotetaan &-merkillä. Tekijän etunimistä suositellaan käytettäväksi vain alkukirjaimia. Tutkimusten nimet kirjoitetaan lyhentämättä. Julkaisusarjoista käytetään niitä lyhenteitä, jotka on painettu Silva Fennican numerossa Vol. 5, 1971, N:o 2. Täydellisempi luettelo on nähtävissä Seuran toimistossa. Kirjoituksen löytämisen helpottamiseksi mainitaan aikakauslehdistä myös sivunumerot. Suomenkielisistä tutkimuksista otetaan mukaan vieraskielisen lyhennelmän nimi. Volyymi merkitään julkaisusarjan nimen jälkeen. Jos kyseessä on aikakauslehti tai vastaava, numero merkitään volyymin jälkeen suluissa. Sivunumerot erotetaan kaksoispisteellä volyymistä tai suluissa olevasta numerosta. Jos samalla kertaa ilmestynyt volyymi sisältää useita tutkimuksia, merkinnässä sovelletaan ko. julkaisussa noudatettua tapaa. Esimerkkejä:

ILVESSALO, Y. 1952. Metsikön kasvun ja poistuman välisestä suhteesta. Summary: On the relation between growth and removal in forest stands. — Commun. Inst. For. Fenn. 40.1.

WILCOX, W. W., PONG, W. Y. & PARMETER, J. R. 1973. Effects of mistletoe and other defects on lumber quality in white fir. Wood & Fiber 4 (4): 272—277.

Englanninkielisen lyhennelmän ja mahdollisten kuva- ja taulukkotekstien käännättämisestä ja pätevän kieliasiantuntijan tekemästä tarkastamisesta huolehtii kirjoittaja. Seura voi maksaa kustannukset valtiovarainministeriön antamien ohjeiden mukaan. Jos kääntäjän lasku on ohjeiden edellyttämää tasoa korkeampi, kirjoittaja vastaa ylittävästä osuudesta.
Lähempiä tietoja antaa Seuran julkaisujen toimittaja.

KANNATTAJAJÄSENET — UNDERSTÖDANDE MEDLEMMAR

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Hämeenlinna 1978, Arvi A. Karisto Osakeyhtiön kirjapaino