IRRIGATION AND FERTILIZATION OF OLD NORWAY SPRUCE ON OUTWASH PLAIN IN GLUDSTED PLANTATION, JUTLAND

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H. HOLSTENER-JØRGENSEN AND E. HOLMSGAARD

(Særtryk af Det forstlige Forsøgsvæsen i Danmark beretning nr. 352, bd. XLII, h. 1, 1988).

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PREFACE

The experiment reported below could be carried out only thanks to support from the EEC through Research contract no. BOS-103-DK (G). Statens Jordbrugs- og Veterinærvidenskabelige Forskningsråd (The Danish Agricultural and Veterinary Research Council) granted funds to arrange for wind-fall protection of the experimental area by the pruning of trees in its surroundings (Grant J. no. 13-3321).

Palsgaard State forest district, through *M. Elbæk-Jørgensen,* forest superintendent, placed the experimental area at our disposal, and *A. P. B. Dam,* the ranger, directed with great accuracy the irrigation of the irrigated plots and made frequent inspections of the experiment.

M. Egebjerg Pedersen, ranger at The Danish Forest Experiment Station, carefully performed the timber measuring operations in the field, and the laboratory technicians *I. Nielsen* and *H. Mortensen* did the annual-ring measurings and made the calculations concerning the timber-measuring dates. *H. C. Olsen,* research assistant, was in charge of the annual-ring measurings and made an analysis of these data.

To the mentioned institutions and persons we express our warm thanks for their contributions to the completion of this investigation.

1. INTRODUCTION

For a couple of decenniums experiments with fertilization and irrigation have belonged to The Danish Forest Experiment Station's research programme, cf. the survey of literature. The methods used have been closely related to ordinary forest practice, and the effects of the treatments have been considerable and clear. Yet, no experiment has been made to elucidate how old, mature Norway spruce stands respond to irrigation.

Such stands are interesting objects, because any excess increment is obtained on trees that have already reached valuable dimensions, so that an early felling is preferable to waiting too long in order to exploit the excess yield. It is true that an excess increment will involve increasing annual-ring thicknesses, which may mean a poorer quality, cf. *Lynge Madsen et al.* (1985). However, this wood is produced on the outside of the stem, and it is partly cut away at the conversion of the stem into building timber. A greater part of the original quality timber of the stem can be utilized, and the yield of the excess increment will continue to be valuable for other purposes, such as chips for chipboard etc.

In this connection it is natural to mention that the present-day initiatives aiming at producing wood products in short rotation for cellulose or fuel often involve intensive fertilization and irrigation programmes. It would seem probable that it is economically more rational to produce cellulose and fuel wood in existing quality stands through a supply of fertilizers and irrigation.

This is the motive for a long-harboured wish to carry through an experiment in old, mature Norway spruce.

2. SURVEY OF LITERATURE

Holmsgaard (1955) has shown that the increment expressed by annualring thickness in, inter alia, Norway spruce and beech is dependent on the precipitation during the growing season. Water is a minimum factor. In Denmark this applies even to our best moraine localities with a high plant-accessible water capacity in the root zone. The soil-water reserves cannot compensate for a low summer precipitation (*Holstener-Jørgensen,* 1958).

A number of Danish irrigation experiments have shown that the biomass above ground (wood, needles) can be considerably increased by programmed irrigation during the growing season.

Holstener-Jørgensen & Holmsgaard (1977) have demonstrated that when young Norway spruce on good moraine is irrigated at varying intensities, a yield curve is obtained which in the area that corresponds to the year-to-year variation in the summer precipitation has the same slant of the curve as *Holmsgaard* (1955) found through his analyses.

Holstener-Jørgensen et al. (1979) found in the same experiment that the litter fall was a function of the water supply of the plots. The better the water supply is, the more extensive is the litter, which leads to the conclusion that a better water supply gives a higher production of needle biomass. This agrees with the results of irrigation experiments in decoration-greenery stands, where optimum irrigation increases the decoration-greenery production (branches, twigs and needles) very considerably (*Holstener-Jørgensen & Johansen,* 1975, 1977, 1978, 1979 and 1982). This is natural, as the production must depend upon the quantity of assimilation organs.

On sandy soils in Jutland, where both water and nutrients are at a minimum, *Holstener-Jørgensen & Holmsgaard* (1975) found a great, positive interaction between irrigation and fertilization of young Norway spruce.

Common to the mentioned experiments is that they were carried out in young stands. In young wood-producing stands, investments in fertilization and irrigation will hardly be profitable, whereas the profit obtainable on decoration-greenery stands can cover such investments. As an extra plus for decoration-greenery stands, irrigation can stabilize the production by keeping the year-to-year variation at a minimum.

In old wood-producing Norway spruce stands on poor sandy soil, experiments show that the effect of fertilization is so great that it will be profitable to fertilize, at any rate during the last 10 years of the rotation (*Holstener-Jørgensen & Bryndum,* 1973, *anon.,* 1976 and *Holstener-Jørgensen et al.,* 1982). It further appears that the effects of fertilization are greatest in years with a comparatively high precipitation during the growing season. Therefore, there are good reasons for investigating the combined effect of irrigation and fertilization in old Norway spruce stands.

3. EXPERIMENTAL AREA AND METHODS

The experimental area is in Gludsted plantation, Palsgaard State forest district. This is a flat area of heathland planted with Norway spruce which, at the establishment of the experiment in 1983, was 82 years from seed.

The stand was damaged by storm both in November 1981 and in January 1983. However, it was found warrantable to establish the experiment in intact, homogeneous parts of the stand, it being decided to undertake a high pruning of stems in belts around the experimental area to protect the area against further windfalls. This pruning was done in the late summer of 1983.

The arrangement of the experimental area appears from the sketch in Figure 1, in which the pruned tree belts are hatched and the treatments of the plots are shown by letter symbols. The plot sizes appear from Table 1, which also shows the mensuration data at the establishment of the experiment. Within each of the 3 blocks, the treatments are randomized among the 4 plots of the block.

The *fertilization* has consisted in an annual spring supply of 336 kg per ha of the mixed fertilixer 23-3-7 with Mg and Cu, which has the following content of plant nutrients:

22.6 % total N
compounded of 10.9 % NO_3^--N
11.7 % NH_4^+-N
2.9 % citrate- and water-soluble P
of which 2.1 % water-soluble P
6.6 % water-soluble K
0.1 % EDTA-soluble Cu
0.02 % water-soluble B
4.0 % water-soluble S

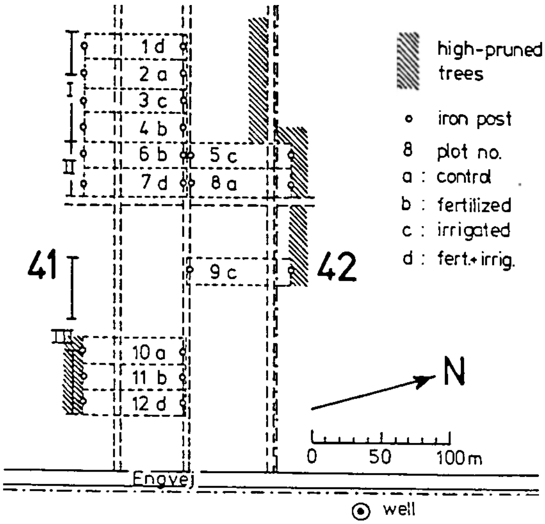

Figure 1. Sketch of the experimental area.
Figur 1. Skitse af forsøgsarealet.

Table 1. Results of tree measurings in spring 1983 in Experiment 1294, Gludsted plantation.
Tabel 1. Resultater af træmålinger i foråret 1983 i forsøg 1294, Gludsted plantage.

Block no. *Blok nr.*	Plot no. *Parcel nr.*	Treat-ment *Behand-ling*	Area ha *Areal ha*	Stem number No./ha *Stamtal stk./ha*	Mean height m *Middel-højde m*	Mean diameter cm *Middel-diameter cm*	Basal area m²/ha *Grund-flade m²/ha*	Stem volume m³/ha *Stamme-masse m³/ha*
I	1	d	0.13649	1004	16.1	18.1	25.67	228.55
	2	a	0.15449	887	16.2	18.4	23.57	210.77
	3	c	0.12749	871	16.5	18.4	23.27	212.33
	4	b	0.15450	997	16.3	18.3	26.19	236.07
II	5	c	0.13200	1038	15.7	17.8	25.94	225.62
	6	b	0.13200	1053	16.0	18.3	27.73	244.91
	7	d	0.17700	847	16.6	19.0	23.99	218.63
	8	a	0.17700	904	15.5	18.3	23.89	203.66
III	9	c	0.14100	887	16.0	19.0	25.08	219.50
	10	a	0.14250	842	16.7	19.4	24.94	227.82
	11	b	0.13800	913	16.1	18.7	24.98	220.80
	12	d	0.14250	877	16.4	19.1	25.21	226.57
Mean *Middel*			0.14625	927	16.2	18.5	25.04	222.94

Treatment symbols: a = untreated control plots
Behandlingssymboler: *ubehandlede kontrolparceller*

b = fertilized plots
gødede parceller

c = irrigated plots
vandede parceller

d = fertilized and irrigated plots
gødede og vandede parceller

The 336 kg fertilizer per ha corresponds, as an empirical fact, to an annual production of needles with carrying twigs of 10 t per ha. The fertilizer was broadcast by hand.

The *irrigation* was done by a normal field irrigation system. A pipeline with a sprinkler for each 15 m was placed right through the middle of the plots that were to be irrigated. These plots were irrigated as required during the period April 1 to September 30. The proper times for irrigation were fixed in the following way:

Precipitation data for the said period were taken from the Meteorological Office's rain-gauge at the ranger's house 2000 m to the south-east of the experimental area. A potential evapotranspiration curve was drawn up (*Holstener-Jørgensen & Holmsgaard,* 1975), and by difference formation between evaporation sum as from April 1 and precipitation sum with the addition of amounts of irrigation water in mm also as from April 1, the timing of the irrigation was determined. Irrigation was employed each time this difference surpassed 50 mm. To reduce the loss by evaporation, the irrigation took place in the night, and an amount of water corresponding to 50 mm was applied. Table 2 shows the irrigation count for each year of the experiment.

4. MEASURING METHODS

All trees in each plot had a measuring mark painted om them at the height of 1.3 m, and each year after the end of the growing season they were callipered cross-wise at the individual inspection. The reading was in mm. The basal area per ha for each plot was calculated with 2 decimals, and the basal-area increment for each plot and growing period was calculated as the difference between the basal area after the end of the growing period and the basal area at the beginning of the growing period. The mean error of the individual difference is ± 0.156 m^2 per ha and year, which is 14.4 % of the average basal-area increment of 1.08 m^2 per ha and year. This degree of precision is satisfactory.

From each plot, 50 trees were systematically (area-representatively "randomly") selected and marked for height-measuring, which was performed by Løvengreen's hypsometer with readings in dm. At each measuring, the same 50 trees were measured, and a

Table 2. Survey of precipitation and irrigation quantities in each experimental year.
Tabel 2. Oversigt over nedbørsmængder og vanding i de enkelte forsøgsår.

Year *År*		April *April*	May *Maj*	June *Juni*	July *Juli*	August *August*	Sept. *Sept.*	Sum *Sum*
1983	mm precipitation *nedbør*	98.2	145.8	25.8	4.6	17.0	138.1	429.5
	mm irrigation water *vandingsvand*	0	0	90	100	100	0	290
1984	mm precipitation *nedbør*	12.1	32.4	67.0	43.4	48.5	104.8	308.2
	mm irrigation water *vandingsvand*	0	100	50	100	50	0	300
1985	mm precipitation *nedbør*	64.8	34.7	85.6	71.7	100.6	106.0	463.4
	mm irrigation water *vandingsvand*	0	50	50	50	0	0	150
1986	mm precipitation *nedbør*	33.1	67.6	24.3	76.5	86.6	30.3	318.4
	mm irrigation water *vandingsvand*	0	50	100	50	50	0	250

height curve was calculated for each plot at each measuring. The calculation was done semilogarithmically (log d, see *Henriksen,* 1950).

The height measurements were checked at the conclusion of the experiment, 15 trees in each plot having been felled, partly for cutting out discs at breast height for annual-ring measuring, partly for measuring of the genuine height increment. At this latter measuring the heights were measured from the measuring mark at the height of 1.3 m, and by forming differences between heights measured on standing trees and heights measured on the same trees lying, a set of data were obtained for estimating the reliability of the height measurements.

A total of 713 differences were available for this analysis, and it shows that the individual standing height had been measured with a mean error of ± 0.276 m, which is 1.6 % of the typical height. The result is satisfactory. The average deviation amounts to 0.034 m, which is of the same magnitude as could be expected from the practice of painting measuring marks, which, in fact, is part of the set of data.

The true height increment has been determined with a mean error of ± 2.70 cm or abt. 11 %. This, too, is a reasonable certainty, considering that the limit of top shoots is not very precisely defined, especially as far as the oldest are concerned.

The standing stem volume has at each measuring been calculated as the product of the basal area, the height at the diameter of the mean-stem basal area, and form factor according to *Olsen's* (1976) tables. The stemvolume increment in m^3 per ha is the difference between standing wood volume before the growing season and after the growing season. For each plot the increment has, according to the statistical analyses, been determined with a mean error of ± 1.603 m^3 per ha and year, or abt. 13.2 %. The degree of precision is, the same as that of the basal-area increment determinations.

5. RESULTS

Table 3 contains a survey of the experimental results after the 4 growing seasons covered by the experiment. The last column shows the mean error of the values of the other columns.

The *basal-area increments* have been subjected to an analysis of variance separating the variances into years, blocks, treatments, and the interactions between these 3 elements. The analysis shows a tendency towards interaction between year and block ($0.05 < p < 0.20$), which needs no further comment.

There are highly significant ($p < 0.001$) differences between the basal-area increments of the years, which are due first and foremost to the climatically conditioned variations in the increments of the untreated and the only fertilized plots.

There are highly significant ($p < 0.001$) effects of treatment ascribable exclusively to the irrigation, since, at a further separation, 99.7 % of the total square sum of treatments falls on the irrigation. So, there is no effect of fertilization in this experiment, nor any interaction between fertilization and irrigation. For the total experimental period the effect of irrigation is abt. 35 %. In 1983 it is abt. 31 %. In 1984, which was the driest year (see Table 2), it is abt. 47 %, in 1985 abt. 31 %, and in 1986 abt. 36 %. There seems to be no basis for expecting a delayed effect during a period of needle-volume build-up.

The *true height increments* show the same variations as the basal-area increments. An analysis of variance discloses that there is a highly significant interaction ($p < 0.001$)

Table 3. Survey of the experimental results for the total experimental period.
Tabel 3. Oversigt over forsøgsresultaterne for hele forsøgsperioden.

	Untreated *Ubehandlet*	Fertilized *Gødet*	Irrigated *Vandet*	Fertilized and irrigated *Gødet og vandet*	Mean error *Middelfejl*
Basal-area increment m^2 per ha and year *Grundfladetilvækst* *m^2 pr. ha og år*	0.93	0.91	1.25	1.24	± 0.045
Relative *Relativ*	1.00	0.98	1.34	1.33	
True height increment cm per year *Ægte højdetilvækst* *cm pr. år*	20.85	18.97	27.98	28.50	± 0.78
Relative *Relativ*	1.00	0.91	1.34	1.37	
Stem-volume increment m^3 per ha and year *Stammemassetilvækst* *m^3 pr. ha og år*	10.65	10.44	13.91	13.61	± 0.463
Relative	1.00	0.98	1.31	1.28	

between treatment and year, which is due first and foremost to the fact that there was no effect during the first experimental year. This is a well-known phenomenon in Norway spruce, in which, for instance after fertilization, the reaction during the first year is an increase of the diameter increment.

Likewise there is a significant ($0.001 < p < 0.01$) difference between blocks. Block I (see Figure 1) has generally the longest top shoots. There is, moreover, a significant ($0.01 < p < 0.05$) difference between years, which is due first and foremost to the fact that during the experimental period the irrigated plots have increasing average top-shoot lengths. These are for irrigated and fertilized + irrigated plots:

1983: 19.9 cm; 1984: 29.7 cm; 1985: 30.1 cm; 1986: 33.3 cm.

Finally, there is a significant ($0.01 < p < 0.05$) effect of treatments, which also in this case are ascribable to the irrigations alone, as 97.3 % of the total square sum of treatments falls on the irrigations when a further separation is made.

As already pointed out there is no effect on the height increments during the first experimental year, the effects in percentages otherwise being these:

1983: – 1 %; 1984: 98 %; 1985: 70 %; 1986: 24 %.

This sequence (development) differs from the development in the basal-area increments; but no immediate explanation seems to be available.

The *stem-volume increments* have the same variations as the basal-area and height increments. The analysis of variance shows that there is no significant interaction.

There is a highly significant ($p < 0.001$) difference between years, due first and foremost to the variation from year to year in the increments in the untreated plots and in the only fertilized plots.

There are also highly significant ($p < 0.001$) effects of those treatments that rest alone

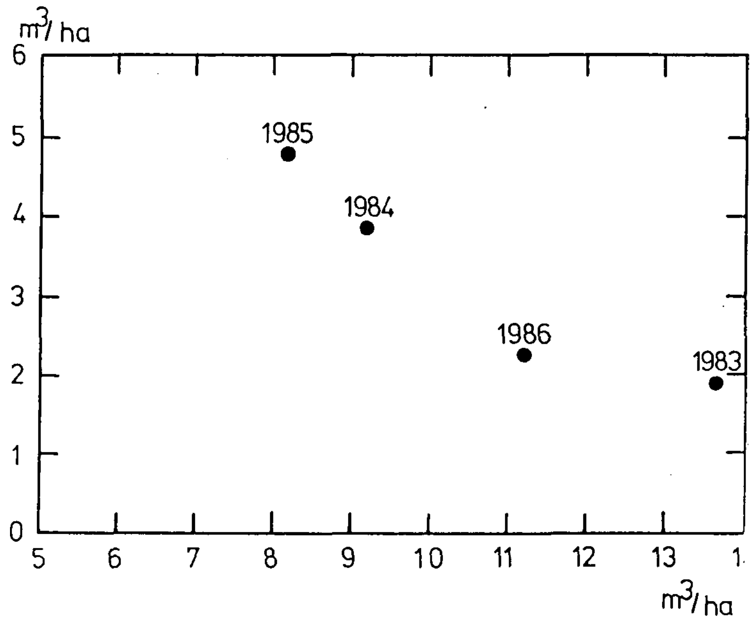

Figure 2. Average excess increments in m³ per ha and year in the irrigated plots (irrigated and fertilized + irrigated) plotted against the concurrent increment in the non-irrigated plots (controls and fertilized). The years are indicated at the points.

Figur 2. Gennemsnitlige mertilvækster i m³ pr. ha og år i de vandede parceller (vandede og gødede + vandede) lagt op over den samtidige tilvækst i de uvandede parceller (ubehandlede og gødede). Årene er anført ved punkterne.

on the irrigation, and which contribute with 99.3 % to the square sum of treatments. The excess increment for irrigation averages for the whole period 3.22 m³ per ha and year. The average increment in the irrigated plots (untreated and only fertilized) is 10.54 m³ per ha and year, so that the excess increment amounts to 30.6 %.

However, as might be expected, the excess increment varies from year to year. In Figure 2 the average excess increment for irrigated plots (irrigated and irrigated + fertilized) has year by year been plotted against the average annual increment in the non-irrigated plots (untreated and fertilized). It appears that these two quantities are negatively correlated. A small current increment in the non-irrigated plots implies a heavy effect of irrigation. It is noticeable that these very compressed figures show a rank-order correlation coefficient of – 1.00. Accordingly the effects in percentages vary between 14 % (1983) and 59 % (1985).

6. ANNUAL-RING ANALYSES

At the conclusion of the experiment after the growing season of 1986, 15 trees were, as mentioned, felled in each plot. These sample trees were used for top-shoot measurings, and stem-discs for annual-ring analyses were cut out at the height of 1.3 m.

On each disc the width of the annual rings was measured with an exactness of 1/10 mm on two diametrically opposite, randomly chosen radii. 14 annual rings were measured on each disc, i.e. the annual rings that correspond to the 4 experimental years and the 10 preceding annual rings.

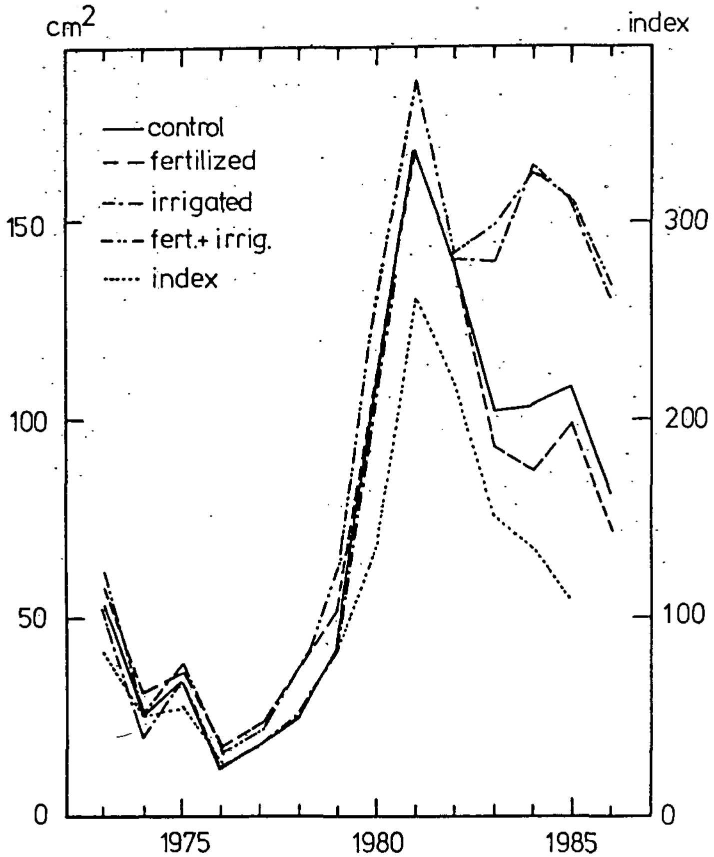

Figure 3. Average estimated basal-area increment (sum) for 15 annual-ring-analysis trees during the 14 measuring years, of which the last 4 were experimental years, together with annual-ring index for Norway spruce in the host district (*Holmsgaard & Olsen,* 1988).

Figur 3. Gennemsnitlig estimeret grundfladetilvækst (sum) for 15 årringsanalysetræer i de 14 måleår, hvor de sidste 4 er forsøgsår, samt årringsindex for rødgran på forsøgsdistriktet (Holmsgaard & Olsen, 1988).

By means of the annual-ring widths and the radii, the basal area and basal-area increment of each tree can be calculated year by year and used in a statistical analysis. A series of statistical analyses were made in which it was attempted, i.a., to adjust for the initial basal area of each tree, which is an expression of the dominance of the tree. In short, only the trivial factors: block, year and treatment seem to have any decisive influence. It also appears that of these factors the treatment is highly significant, and, as all other analyses show (see above), only irrigation is of importance. Throughout it is highly significant.

Figure 3 shows the average estimated basal-area increment for the 15 trees year by year. It appears that, on the whole, the trees are conforming to the same increment model during the 10 years preceding the initiation of the treatments. As from 1983 the irrigated plots dissociate and attain a considerably higher increment level. By a special symbol, index values are inserted for annual-ring widths in Palsgaard Norway spruce during the same period (*Holmsgaard & Olsen,* in preparation), which shows that the experimental

Table 4. Survey of the stump-surface estimation for rot in 15 trees of each plot at the conclusion of the experiment.
Tabel 4. Oversigt over stødfladebedømmelsen for råd på 15 træer i hver parcel ved forsøgets afslutning.

	Number of stumps with attack grade *Antal stød med angrebsgrad*				
	0	1	2	3	4
Untreated *Ubehandlet*	18	7	4	7	9
Fertilized *Gødet*	21	6	2	4	12
Irrigated *Vandet*	18	3	1	13	10
Fertilized and irrigated *Gødet og vandet*	20	3	5	10	7

area has the same increment reactions as other parts of the district. By the irrigation it has been possible to keep the increment level of the stand equal with the 1981 increment, which was exceptionally high throughout the country.

7. HETEROBASIDION (FOMES) ANNOSUS

At the conclusion of the experiment after the growing season of 1986, 15 trees in each plot were cut down for other purposes, as mentioned earlier. The stump surfaces were classified according to the severity of the Heterobasidion annosus attacks by means of a 5-step scale, in which 0 indicates no visible attack while 4 denotes actual heart-rot (see *Yde-Andersen,* 1964).

Table 4 summarizes the results of the classification of the total of 180 stump surfaces. The table demonstrates directly that, allowing for the dispersion, there is no difference between the treatments. Affirmatively a chi^2-test gives a value of 13.01 with 12 degrees of freedom, which shows a very low probability ($0.30 < p < 0.50$) of differences.

The result is not unexpected, since earlier investigations of the influence of fertilization on the attack in old Norway spruce have not been able to demonstrate any such influence either (*Yde-Andersen,* 1977).

It should further be mentioned that 57 % of the trees have been attacked and that 40 % of the trees show heavy attacks (attack grades 3 and 4).

8. OTHER OBSERVATIONS

Figure 1 shows by hatching the pruned belts established around the experimental area as a protection against further windfalls. As such, their effect has apparently been perfect, since after the establishment of the experiment less than 1–2 % of the stem number in the experimental plots have been blown over, and everywhere as scattered falls, which have been of no importance for the experiment. Taking into consideration that the storm preceding the establishment of the experiment may have disposed the blown-down trees for windfall (broken roots etc.), it must be emphasized that the mentioned good result cannot be regarded as a proof of the efficiency of pruning as a protection against windfall. But it may serve to emphasize that a high priority must be given to well-planned experiments to elucidate the efficiency of pruning as a windfall-protective measure.

The windfalls in Gludsted plantation have, as a matter of course, occasioned a heavy breeding of the bark beetle *Ips typographus.* Obviously the pruned trees must have been attractive, since after the first growing season abt. 10 % of the pruned trees died (information received from the ranger), to all appearances as a result of Ips typographus attacks. Also after the second growing season a number of trees died (5–8 %), and in this case there was no doubt that attacks by Ips typographus played an essential role. Later on the pruned trees have been developing well, so that at the conclusion of the experiment they appeared to be rather vital.

Otherwise there has been no kind of damage worth mentioning in the experiment.

9. DISCUSSION AND CONCLUSION

The results submitted are so clear and unambiguous that a thorough-going discussion is unnecessary. The irrigation has proved to be able to maintain a high level of productivity in the area, and thereby the purpose of the experiment is fulfilled. An annual current increment of abt. 13 m^3 per ha seems at the given age to be optimum.

Concerning irrigation it should be remembered that De danske Landboforeninger (the Danish farmers' union) in their magazine "Landsbladet" each week during the growing season publish precipitation, evapotranspiration and deficit from abt. 40 measuring stations evenly spread over the country. Thereby the necessary nationwide data are at the foresters' disposal when they are to decide whether and when irrigation should be employed.

One thing, however, the experiment has further revealed namely that no effect has been found of fertilization. This is surprising considering earlier experience (see the survey of literature); but as no credible explanation of this circumstance has been offered, the question of why it is so must remain unanswered.

SUMMARY

In 82-year-old Norway spruce in Gludsted plantation a fertilization/irrigation experiment was established in the spring of 1983 (Figure 1). Timber measuring data at the establishment appear from Table 1. Table 2 shows the precipitation measured and the quantities of irrigation water employed during the 4 growing seasons covered by the experiment. The fertilization consisted of an annual supply of 336 kg per ha of the NPK-fertilizer 23-3-7 with Mg and Cu.

Table 3 contains an overall survey of the experimental results. The fertilization has had no effect, but the irrigation has increased the basal-area increment by 33–34 %, the height increment by 34–37 %, and the volume increment by 28–31 %. The latter means 3.2 m^3 per ha and year.

In Figure 2 the mean excess increment in irrigated and fertilized + irrigated plots has been superimposed year by year on the mean increment in controls and fertilized plots. Where the increment in these plots is high, the excess increment due to irrigation is relatively low and vice versa.

The basal-area increment computed on the basis of annual-ring analyses confirm the other timber measuring results, and new annual-ring indexes for this forest district agree very well with the experimental results (Figure 3).

Stump-surface estimation of the attack grade of Heterobasidion annosus has, as was expected, revealed no influence of the treatments. 57 % of the stump-surfaces show attacks and 40 % show heavy attacks (attack grades 3 and 4).

High pruning of trees in belts around the experimental area (hatched parts in Figure 1) seems to have protected the area effectively against windfalls.

Immediately after the pruning some trees died as a result of heavy attacks of Ips typographus.

RESUMÉ

I 82-årig rødgran i Gludsted plantage anlagdes i foråret 1983 et gødsknings/vandingsforsøg (Figur 1). Træmålingsdata ved anlæg fremgår af tabel 1. Tabel 2 viser, hvilken nedbør der har været, og hvor meget der er vandet i de 4 vækstperioder, forsøget har strakt sig over. Gødskningen har bestået i årlig tilførsel af 336 kg pr. ha af NPK-gødningen 23-3-7 med Mg og Cu.

Tabel 3 giver en samlet oversigt over forsøgsresultaterne. Gødskning har ikke givet udslag, mens vandingen har forøget grundfladetilvæksten med 33–34 %, højdetilvæksten med 34–37 % og massetilvæksten med 28–31 %, dette svarer til en mertilvækst på 3,2 m^3 pr. ha og år.

I figur 2 er middel-mertilvæksten i vandede og gødede + vandede parceller år for år lagt op over middeltilvæksten i kontrol og gødede parceller. Ved høj tilvækst i disse parceller er mertilvæksten for vanding relativt lavt og omvendt.

Grundfladetilvækst beregnet på basis af årringsanalyser bekræfter de øvrige træmålingsresultater, og der er en god sammenhæng mellem nye generelle årringsindeks for skovdistriktet og forsøgsresultaterne (Figur 3).

Stødfladebedømmelse af rodfordærverangrebsgraden har som forventet ikke afsløret nogen indflydelse af behandlingerne. 57 % af stødfladerne viser angreb og 40 % viser hårde angreb (angrebsgrad 3 og 4).

Grønkvistning af træer i bælter omkring forsøgsarealet (skraverede områder på figur 1) synes at have beskyttet arealet effektivt mod stormfald.

Umiddelbart efter grønkvistningen døde en del træer som følge af kraftige Ips typographus angreb.

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