A PROGRAM FOR IMPROVEMENT OF BASKET WILLOW ON THE CARPATHIAN PLAINS OF HUNGARY

by

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ABSTRACT

An inventory of the most important indigenous and exotic Salix clones for basket making was carried out in Hungary. Eleven clones were selected from those presently growing in various parts of the country. The vegetative and generative characteristics of the shoots were described. Interspecific hybridization was carried out using five different combinations. The germination of Salix seed was studied by taking a series of photographs. Vegetative propagation by means of shoot cuttings and by "T" bud grafting were tried.

A selection method was used for evaluating the different clones within the country. Five experimental plantations were set out on the more important soil regions and the eleven clones were planted in randomized blocks, each 10 by 10 meters in size. Each clone was replicated four times and 170 cuttings of each were planted in a block. The height growth of the 5th and the 10th ramets in each row were measured bi-weekly during the growing season in 1955 and in 1956. More than 100,000 height measurements were recorded.

The influence of the clone, year, and locality on the average height attained was evaluated by means of an analysis of variance, and an attempt was made by using the components of variance to estimate the heritability.

The simple correlation coefficients were calculated to approximate the degree of association of the average tree height, weight and volume of different clones in the five localities during the years 1955-1959 inclusive.

Form of sprouts, cellulose content of one-year-old shoots, and meteorological conditions were studied. Experiments were undertaken concerning spacing and fertilization as part of the basket-willow improvement work.

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ACKNOWLEDGEMENTS

This investigation was carried out in connection with a general tree-improvement program established by the Hungarian Academy of Science. Grateful acknowledgement is made of financial support, during 1955, and 1956, from the Osier-Growing and Basket Manufacturing Company, Budapest.

The author wishes to express his sincere thanks to several colleagues and to all others who have helped in various ways. Special thanks is due to Dr. P. G. Haddock and Dr. J. H. G. Smith, without whose help, advice and encouragement, the completion of this project, involving 5 years' delay and scattered information from more than 10,000 miles distance, would have been impossible.

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INTRODUCTION

The weaving of willow shoots, usually one year old, into baskets, screens or furniture is a craft older than history. It was practiced at the Glastonbury Lake village in the early Iron Age (Edlin, 1949). M. Porcius Cato (235-140, B.C.) stated in his "De re rustica" that willow is more profitable than the grape (Pech, 1892).

Osiers are used in many different forms and the number of different kinds is almost infinite. In Europe, before the First World War, every grade of basket, from the coarsest to the finest was made from willow. The heaviest farm baskets are receptacles for handling rough merchandise and are made out of unpeeled rods and sticks, while peeled rods go into market, clothes, fruit or even dog baskets, furniture, hampers and trunks. The split willow wares, the so-called skeins are comparable to bamboo ware.

Willow was widely cultivated for basket weaving in the 18th and 19th century in Europe. Pech (1892) mentioned that France in 1867 had 67,000 hectares of willow plantations on the best wheat-growing soil. Prussia planted only 19,000 hectares and imported the willow sprouts from France. There were willow-plantations on both sides of railroads in Austria-Hungary in 1879, according to Marosi (1896). Kanski (1948) indicates that willow growing and basket making has a long history in Poland. The large number of articles, - Brassai (1843), Bedo (1866), Marc (1878), Borbas (1883), Angyal (1886), Faber (1897), Foldes (1900), Szocs (1900), Vadas (1900), Drucker (1907), Baszel (1913), Kekessy (1930), Brundl (1957), etc., - indicates that willow growing and basket making were widespread rural crafts in Hungary.

At one time they were centered on the river side, but as these highly fertile soils were used for farming, it became necessary to cultivate the osier on the less fertile parts of the river valleys. The situation was completely changed after the Second World War. The State established the Osier-Growing and Basket Manufacturing Company in 1950. In order to obtain quick growth and high quality, the best soils were chosen for the new plantations, preferably on land that is occasionally flooded and at other times well drained. Nearly 1,500 hectares were planted up to 1956, and the yearly planting program was set at 360 hectares. The principal osier-growing districts now lie in south Hungary (Fig. 1) west of the Danube and north of the Drava River. The other main center lies on the south-east corner of the country on the area which bordered on the west side with part of the Tisza River, on the south and east with the international border and on the north side with Koros River. This area has a basket-making industry in which close to 500 laborers are employed. Besides these central areas there are many smaller areas scattered over Hungary and no one county is without its larger or smaller willow plantation.

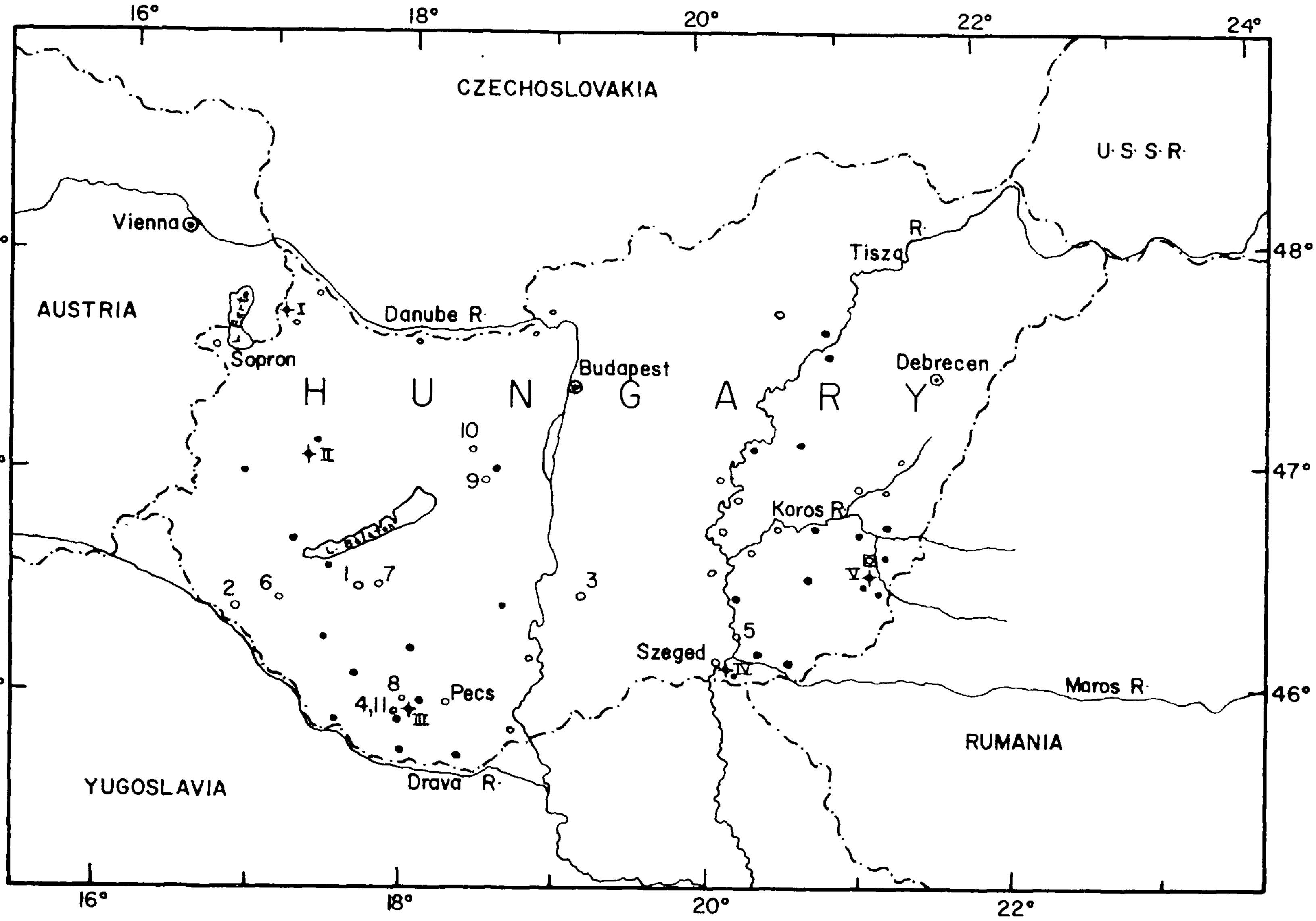
OBJECTIVE

The objective was to determine the quantitative and qualitative characteristics of the willow species and races currently used for basket making. The following improvement program was accepted on February 24, 1955.

1. Establishment of a collection from the different Salix species and races which are important for basket making.
2. Classification of the qualitative and quantitative characteristics of the most commonly used species and races by means of clonal selection.
3. Investigation of the methods of "generative hybridization".
4. Investigating the methods of so-called "vegetative hybridization".

The term hybridization requires explanation. Hybridization means the crossing of individuals of unlike genetic constitution. Hybridization can only occur by the sexual fusion of nuclei from two different organisms. Interspecific hybridization occurs when crosses take place between members of different species, - intraspecific hybridization, when crosses are between individuals of the same species, - and interracial hybridization, when the crosses are between members of populations within the species. During the first year's work only interspecific hybridization was used and therefore the term hybridization unmodified will here be used to mean interspecific hybridization.

The fundamental relationship between vegetative and generative hybridization is stressed by the Michurinists. They (Lysenko, 1938; Glushchenko, 1950) claim that hybridization can occur by grafting as follows. When a scion of one plant is grafted on to the rootstock of another, both components will, if the graft is successful continue to grow and develop. There is an exchange of food substances and other metabolites between the graft components. The hereditary character of each component should be changed by the grafting without nuclear fusion. The existence of vegetative hybrids was questioned even by the Russian scientists (N. I. Vavilov, V. S. Nemchinov) but after the Meeting of Lenin Academy of Agricultural Sciences from July 31 to August 7 in 1948, the Michurin-Lysenko theory was accepted as the only true and official



- Localities in which basket willows are grown commercially
- Localities in which basket willows are grown successfully
- Locality in which baskets are made

I—II Localities from which the clones were collected for experiment

I—V Localities in which experimental plots were set up

0 25 50 75 100
miles

• ÷ 100 hectares ÷ 2·47 acres

Fig. 1 Range of basket willow growing in Hungary explanation in biological work. Lysenko stated on the last day of the meeting: "We already have every ground to believe that every graft of a plant in its youthful stage produces changes in heredity" (Lysenko, 1950). For this reason vegetative hybridization had to be included in the Salix improvement program, otherwise the latter would not have been acceptable.

METHODS AND RESULTS

Materials Used

Eleven clones were collected from the important willow growing parts of Hungary (Figure 1 and Table 1) and were planted in Szigetvar in the spring of 1954.

Table 1. Origin of different clones.

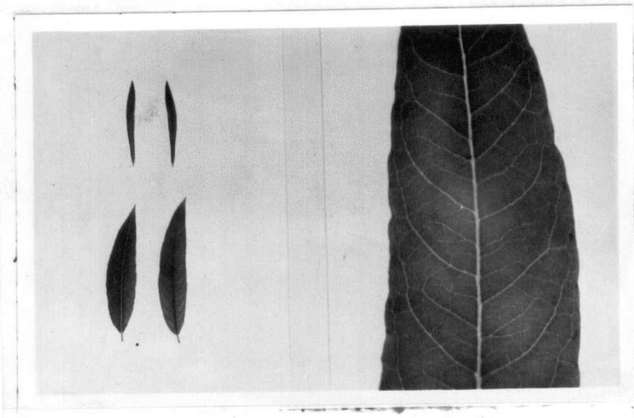
Clone designation	Species, variety or race	Origin of clone Nearest city or village	Latitude	Longitude
1.	S.viminalis L.	Alsobogat	46° 35'	17° 42°
2.	S.viminalis L.	Becsehely	46° 32'	19° 12'
3.	S.viminalis L.	Fadd	46° 27'	16° 48'
4.	S.amygdalina L.	Szigetvar	46° 03'	18° 05'
5.	S.amygdalina v.glaucophylla Seeman	Algyo	46° 18'	20° 12'
6.	S.alba var.vitellina Stokes.	Szocseny	46° 28'	17° 10'
7.	S.alba var.vitellina Stokes.	Merenye	46° 31'	17° 50'
8.	S.purpurea L.	Csonkamindszent	46° 03'	18° 00'
9.	S.acutifolia Willd.	Kaloz	47° 04'	18° 32'
10.	S.americana pendula Hort.	Szekesfehervar	47° 09'	18° 28'
11.	S.americana pendula Hort.	Szigetvar	46° 03'	18° 05'

Vegetative Characteristics of Shoot

Characteristics of leaves, color of shoot and pith:wood:bark ratio were noted and recorded during the experiment. Data concerning color characteristics of shoots are unavailable, therefore only the leaves and pith:wood:bark ratio are mentioned.

(a) Characteristics of Leaves

On most of the observed clones two kinds of foliage are produced on the same shoot, early leaves and late leaves. This foliar dimorphism has its origins in a pronounced difference in leaf ontogeny. The early leaves originate in the developing bud in the fall and during winter as embryonic leaves. The first late leaves are also present in the winter bud but as arrested primordia and succeeding late leaves are initiated at the tip of the growing shoot and develop uninterruptedly to maturity during the growing season according to Critchfield (1960), who reported this situation with respect to leaf dimorphism in Populus trichocarpa. The expansion of the preformed early leaves is almost completed by late spring, when the first late leaves begin to grow rapidly. The formation of late leaves may continue to the end of the growing season. The early leaves are found at the base of long shoots, whereas the late leaves are confined to that part between the early leaves and the apex of the shoot. The development of the late leaves continues during the growing season with the less mature leaves occurring close to the apex. The development of the early leaves ceases early in the growing season. Later, off coloration and defoliation occurred on Nos. 1, 2 and 8 clones. The defoliation did not result in reduced height growth. To describe their characteristics, leaves were taken from three different parts of the shoot, from the base (early leaves), from the middle (late leaves) and from close to the tip (developing late leaves). The sample was taken in the middle of July, when the development of early leaves ceased, and the late-leaf development was still underway. The samples were mounted on herbarium sheets, photographs were taken (Plates 1,2,3, and 4) and the following characteristics of well developed late leaves were described: shape, apex, base, margin, length of petioles, length of leaves, stipules, surfaces (Tables 2 and 3).



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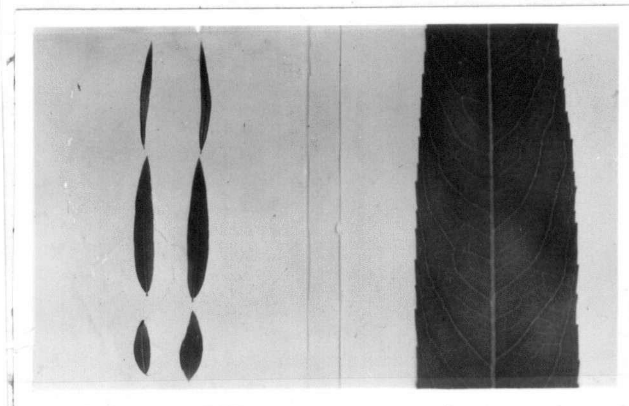

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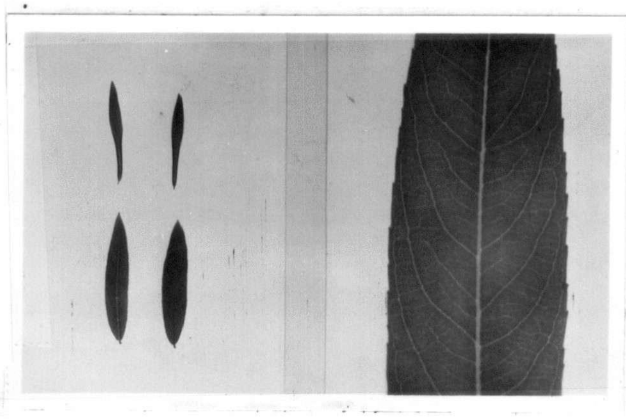

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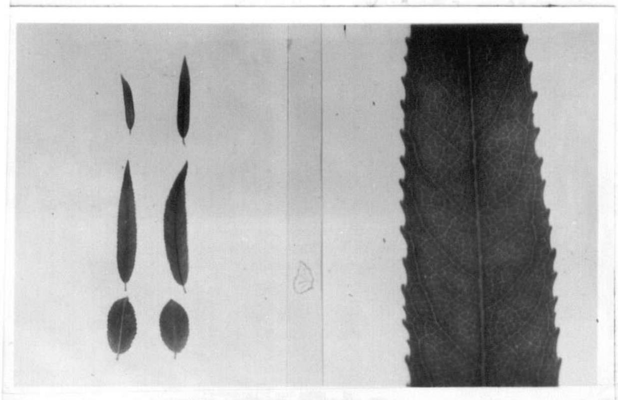
Plate 1. Leaf characteristics of clones No. 1(a), No. 2(b), and No. 3(c).



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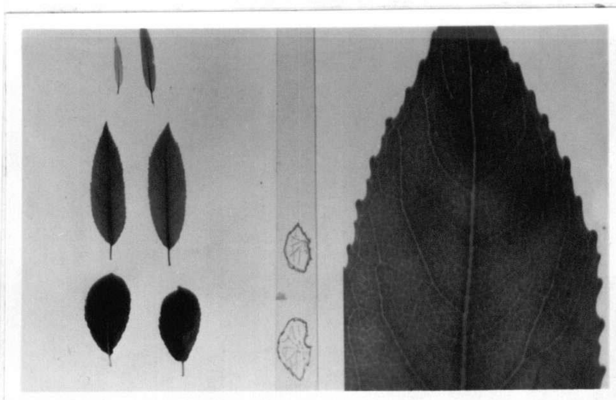

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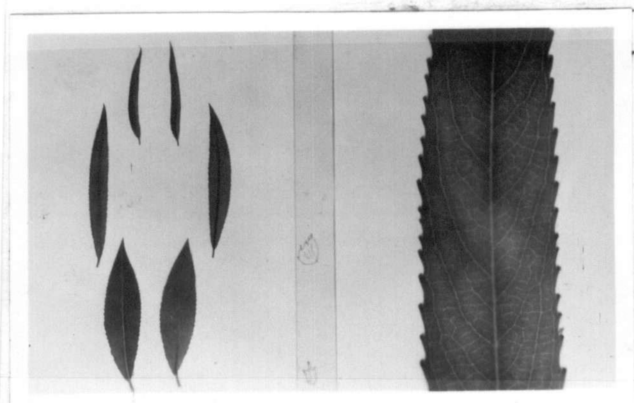

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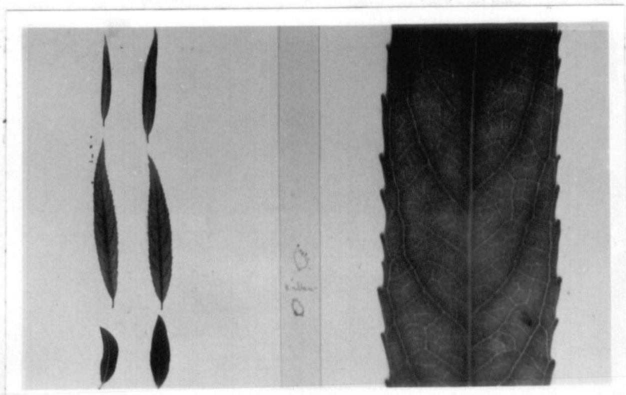
Plate 2. Leaf characteristics of clones No. 4(a), No. 5(b), and No. 6(c).

Table 2. Late leaf shape, apex, margin, length of petioles, characteristics of different clones.

Clone No.	Late leaf characteristics				
	Shape	Apex	Base	Margin	Petioles (length in mm.)
1	linear lanceolate	acuminate	acute	repand	green length:4-8
2	linear lanceolate	acuminate	acute	finely glandular serrate	yellowish green length:3-6
3	linear lanceolate	acuminate	acute	finely glandular serrate	light green length:3-6
4	ovate lanceolate	acuminate	acute	coarsely glandular serrate	4 glands length:8-12
5	broad lanceolate	acute	obtuse	coarsely glandular serrate	many glands length:10-18
6	ovate lanceolate	acuminate	cuneate	coarsely glandular serrate	4-6 glands length:6-8
7	ovate lanceolate	acuminate	cuneate	coarsely glandular serrate	4 glands length:6-12
8	oblanceolate	acute	acute	lower part repand upper part finely serrate	green length:2-4
9	linear lanceolate	acuminate	acute	coarsely glandular serrate	red length:3-6
10	oblong lanceolate	acuminate	obtuse	glandular serrate	red length:4-6
11	oblong lanceolate	acuminate	obtuse	glandular serrate	red length:4-6



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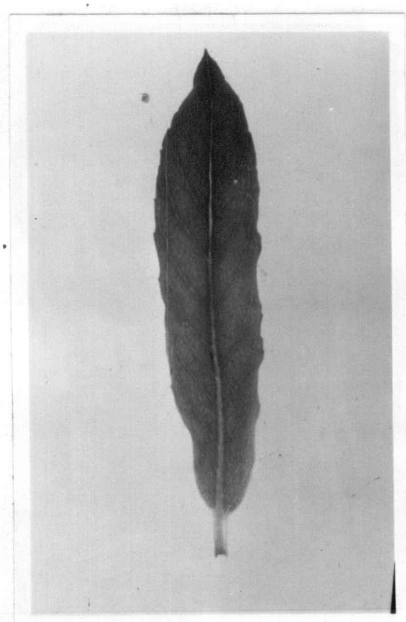

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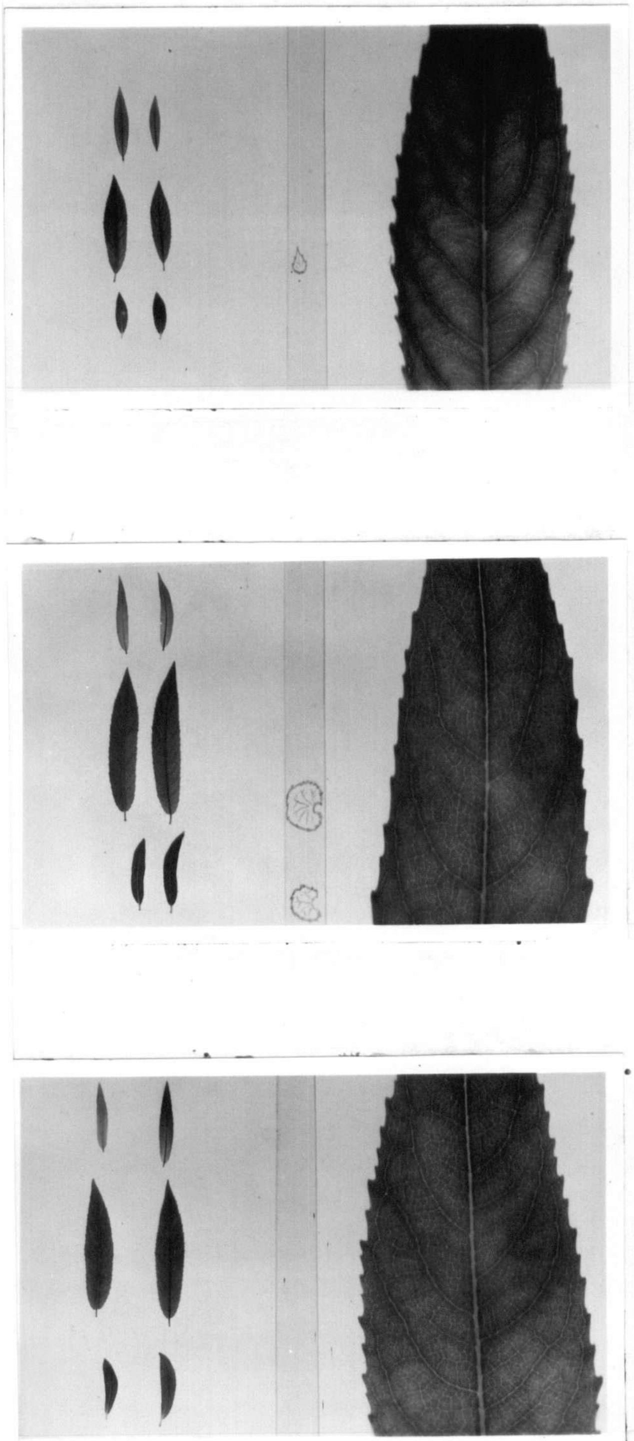
Plate 3. Leaf characteristics of clones No. 7(a) and No. 8(b).



a

b

c

Plate 4. Leaf characteristics of clones No. 9(a), No. 10(b), and No. 11(c).

(a) Table 3. Late leaf length, stipule and surface characteristics of different clones.

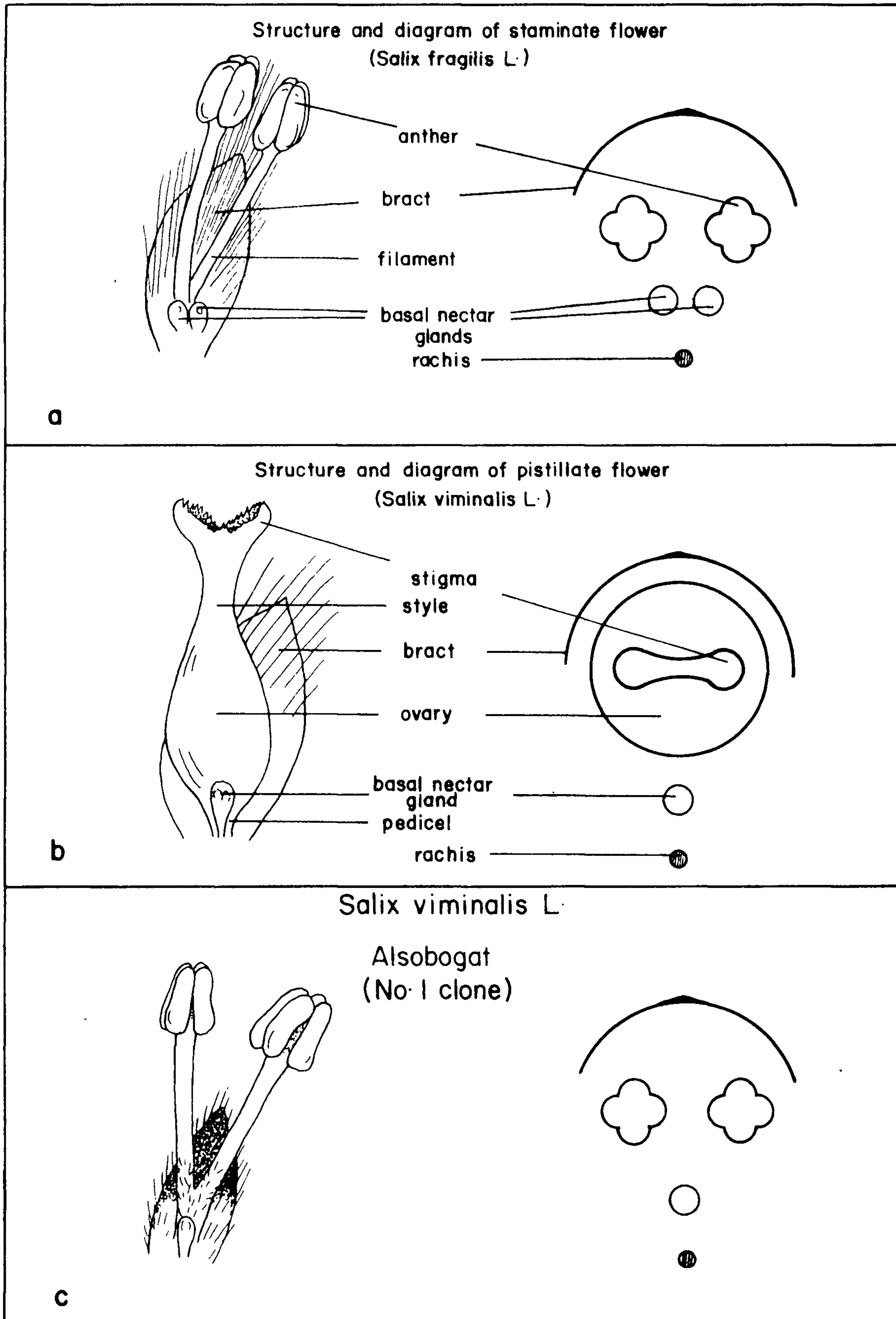
Clone No.	Late leaf characteristics			
	Length (mm)	Stipule	Surface	
			Upper	Lower
1	80-130	small, lanceolate deciduous	dark green	bluish-green pubescent
2	60-120	small, lanceolate deciduous	dark green	bluish-green pubescent
3	60-120	small, lanceolate deciduous	dark green	glabrous
4	60-120	semi-reniform	dark green	light-green glabrous
5	100-180	semi-reniform	dark green	grayish glaucous
6	70-130	lanceolate	dark green	whitish glaucous
7	80-120	oval	dark green	glaucous
8	20-50	oval	green	bluish-green pubescent
9	40-80	small, lanceolate	dark green	bluish-green pubescent
10	60-120	reniform	dark green	bluish-green pubescent
11	50-100	reniform	dark green	bluish-green pubescent

(b) Pith:Wood:Bark Ratio

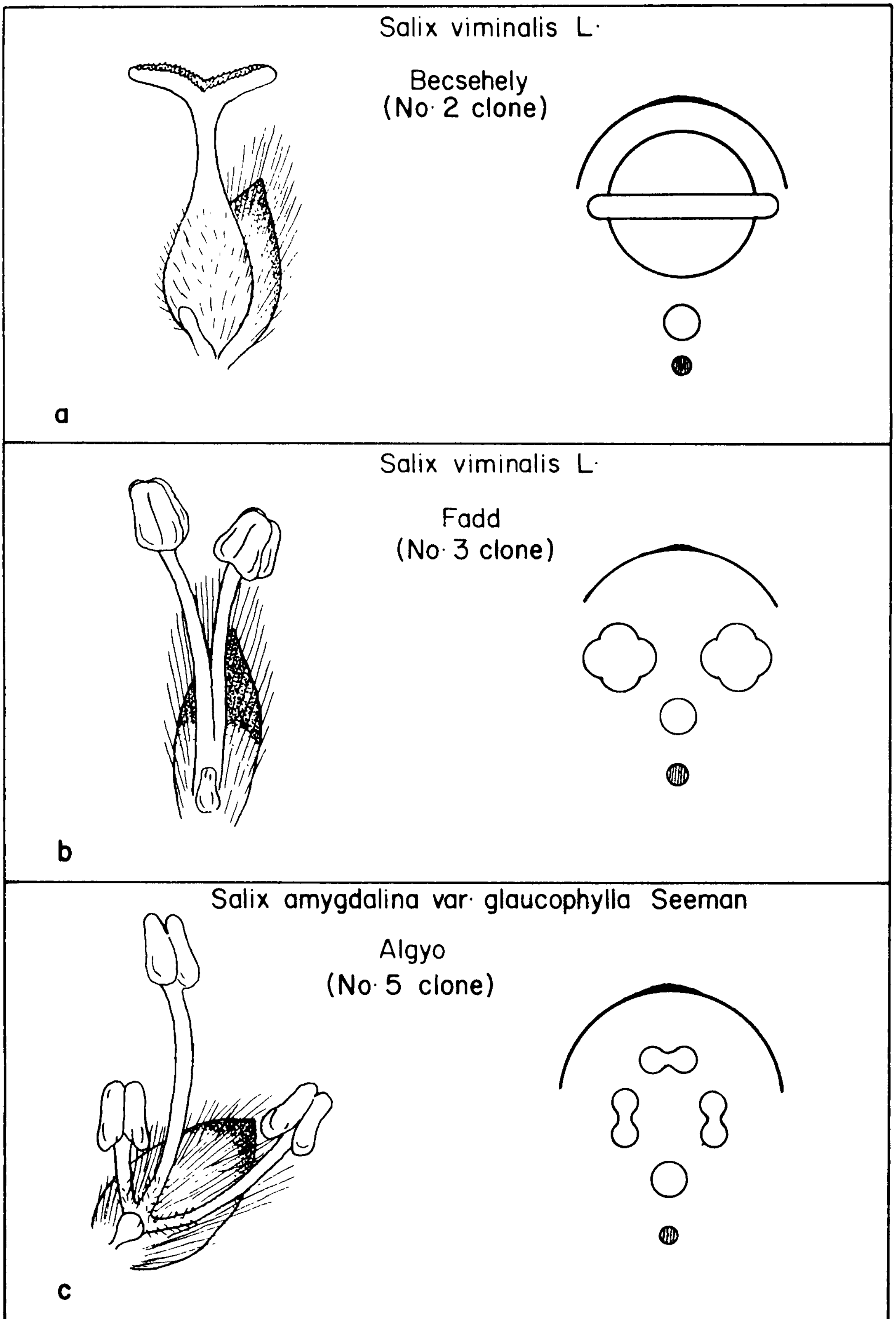
Cross sections of the one-year-old shoot were made every 30 cm. and the pith, wood, and bark diameters were measured. Five shoots were used from each clone (Table 4).

Table 4. Pith-wood-bark ratio in percent of the diameter.

Clone	Pith	Wood	Bark	Total
	in percent of diameter			
1.	33.2	58.0	8.8	100.00
2.	34.1	57.7	8.2	100.00
3.	33.0	62.5	4.5	100.00
4.	25.4	65.9	8.7	100.00
5.	27.6	65.5	6.9	100.00
6.	32.7	58.7	8.6	100.00
7.	32.8	58.1	9.1	100.00
8.	38.9	52.6	8.5	100.00
9.	29.6	63.9	6.5	100.00
10.	-	-	-	-
11.	31.5	58.4	10.1	100.00



Fig·2 Structure and diagram of a/staminate flower, b/pistillate flower, c/Salix viminalis L· (No·I clone)



Fig· 3 Structure and diagram of a/Salix viminalis L· (No· 2 clone), b/Salix viminalis L· (No· 3 clone), c/Salix amygdalina var· glaucophylla Seeman (No· 5 clone)

Generative Characteristics of Shoot

The identification of different Salix species using only the vegetative characteristics is often a matter of great difficulty, therefore to get more detailed information from the clones, the flower characteristics were described in the early spring. No flower buds occurred on No. 4, 6, and 7 clones, therefore they are not included in the description. The twigs with flower buds on them were kept in water culture in the greenhouse to hasten the development of flowers. The catkins were dissected under a microscope and the structure and diagram of the individual flower were drawn (Fig. 2(a) & (b). At the same time, the well developed catkins were described.

(a) Flower Characteristics of Different Clones at the Opening of Flower

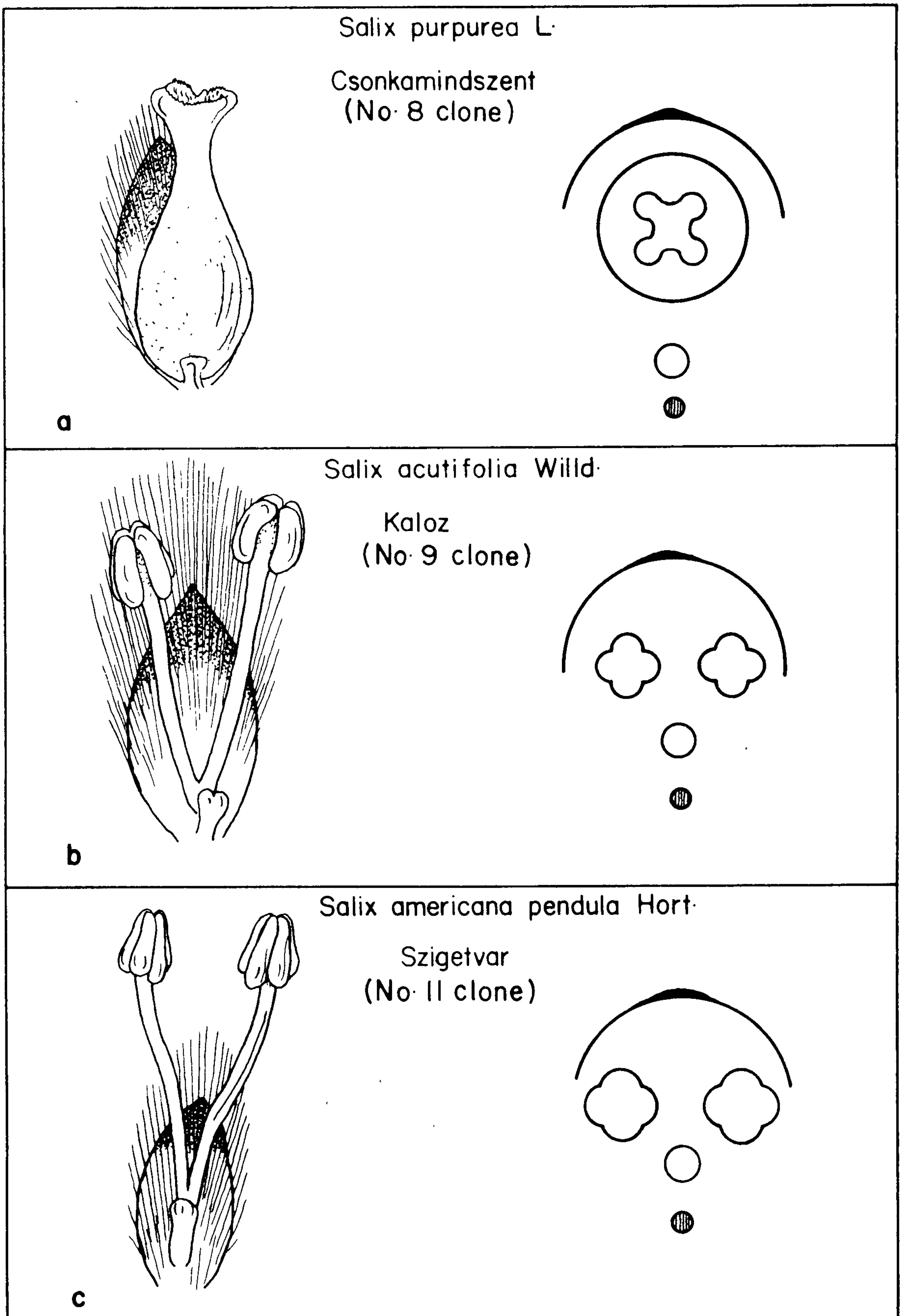
No. 1 clone (Fig. 2(c): male, catkins subsessile, 3-5 times as long as wide, 2-4 cm. long, two stamens, each with four-parted yellow anthers, filament glabrous, one basal nectar gland, with the same length as the anther, bracts elliptical, dark-green tinged at apex, heavily pubescent.

No. 2 clones (Fig. 3(a): female, catkins with short stalk, 4-6 times longer than wide (Fig. 5), usually 3-6 cm. long, ovary conic ovoid, pubescent, style nearly as long as ovary, two stigmas, slender, elongate, reflexed, 1.5-2.0 mm. long, one linear gland, much longer than the pedicel.

No. 3 clone (Fig. 3(b): male, catkins with short stalk, 3-5 times as long as wide, usually 2-5 cm. long, two stamens, each with four-parted yellow anthers, filament glabrous, one basal nectar gland, shorter than the length of the anther, bracts elliptical, apex acuminate and dark tinged, heavily pubescent.

No. 5 clone (Fig. 3(c): male, catkins on short leafy branchlets, 3-8 cm. long, three stamens each with two parted yellow anthers, filament pilose at base, one basal nectar gland, shorter than anther, bracts ovate, dark tinged at the apex, heavily pubescent.

No. 8 clone (Fig. 4(a): female, catkins with short stalks, 4-5 times as long as wide (Fig. 6), usually 1.5-3.0 cm. long, ovary ovoid, sessile, tomentose, style short, with four divergent stigmas, one basal nectar gland, bract ovate, dark purple or nearly black at the apex, pubescent.



Fig· 4 Structure and diagram of a/Salix purpurea L·(No· 8 clone), b/Salix acutifolia Willd·(No· 9 clone), c/Salix americana pendula Hort· (No· 11 clone)

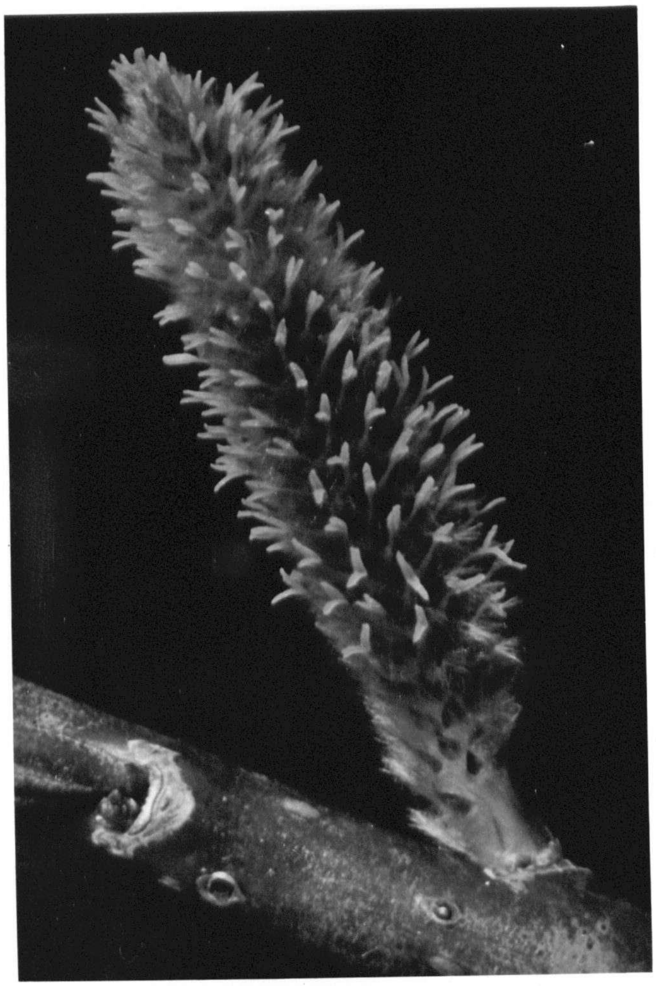


Figure 5. Female catkin of No. 2 clone. The two parted, slender, elongated stigmas are clearly visible.

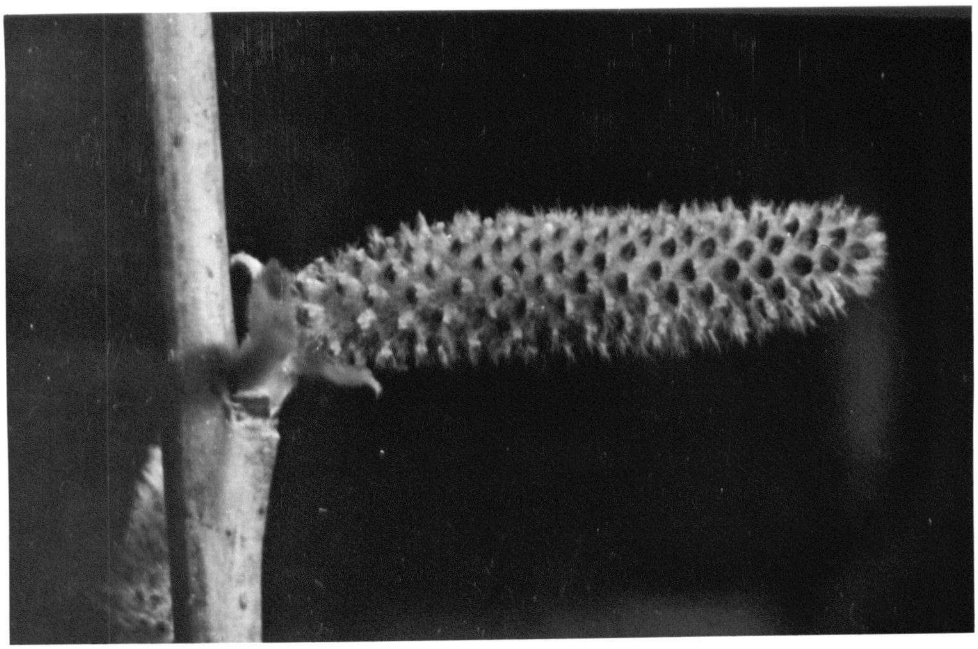


Figure 6. Female catkin of No. 8 clone. Four parted stigma and dark tinged bracts are the typical characteristics of this clone.

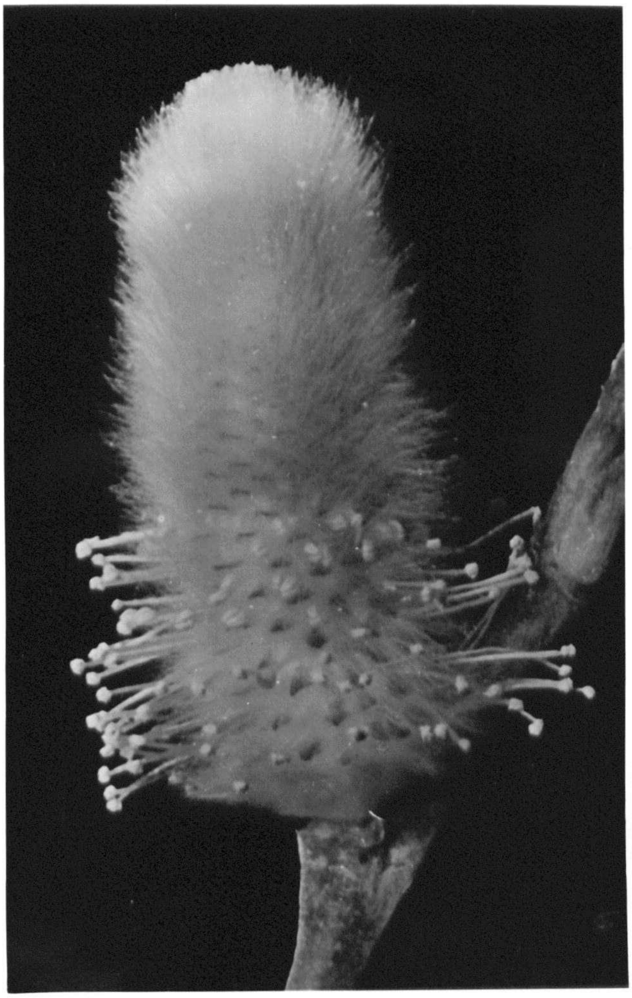


Figure 7. Male catkin of No. 9 clone. The pollen is shed progressively from the base to the apex.

No. 9 clone (Fig. 4(b): male, catkins sessile, cylindric, 3-6 cm. long, two stamens each with four-parted yellow anthers, filament glabrous, one basal nectar gland, shorter or the same length as the anther, bracts elliptical red or purple tinged, heavily long bearded (Fig. 7).

No. 10 clone (Fig. 4(c): male, catkins sessile, 2-3 cm. long, curved, two stamens, each with four-parted yellow anthers, filaments pilose at the base and partly fused, one basal nectar gland same length as the anther, bracts oval, purple tinged, pubescent.

Generative Hybridization

Interspecific hybridization is simpler to carry out in the genus Salix than in any other group of forest trees. The flower and seed development is rapid, which makes it possible to keep the twigs alive in water culture from dormancy to seed maturity. The genus is dioecious and no emasculation is necessary before pollination.

(a) Collection and Storage of Pollen

The prolific pollen bearing twigs of Clone No. 11 were collected in the second half of February in 1955. The length of the twigs was between 40-60 centimeters. They were put in tap water in approximately 2-liter heavy glass bottles. A warm greenhouse was used to give plants a start of approximately 6 to 8 days. The temperature varied from 15°-17°C. at night to 22°-26°C. in day time. No artificial light was used during this period. The pollen started to shed on the eighth or tenth days. It was collected twice a day and was kept in cotton-stoppered bottles in the refrigerator at a temperature of about 0°C.

Pollen collecting ceased a few days before the middle of March in 1955.

(b) Preparation of Female Catkins

The twigs bearing female flowers were collected in the middle of March. These were of a length 60-80 centimeters, longer than the male shoots in order to provide more food reserve for seed maturation. The female shoots were kept in tap water culture as in the case of male shoots. Only No. 3 clone provided female flowers on the one-year-old shoot. But in order to broaden the experiment, other female shoots were collected from the Botanical Garden of Sopron University (Table 5).

Table 5. Summary of Salix crosses attempted, number of seeds obtained, number of seedlings transplanted and survived in 1955.

Cross Number	Female Parent	Male Parent	Total no. of seeds obtained on June 1	No. of seedlings transplanted on July 4	No. of seedlings Oct.15	Yield of seedlings as percentages of seed sown
67	S.viminalis Sopron	No.11	923	475	236	39.1
68	S.viminalis Csomoder	No.11	99	12	9	11.0
69	S.viminalis Becsehely	No.11	432	188	142	30.4
70	S.viminalis Fertod	No.11	113	64	48	23.0
71	S.caprea Sopron	No.11	57	40	23	24.7
Total			1,624	779	458	28.2

(c) Pollination, Collection and Sowing of Seeds

Pollination was carried out from March 21 to April 9. The pollen was put on the stigma with a fine paint-brush, usually in the early morning when the receptivity was at a maximum. The flowers were repollinated two days later when the apical part of the indeterminate catkin was in the mature stage.

Salix is an entomophilous genus and during the pollination the exclusion of insects was a problem. The space isolation was used and the greenhouse was sprayed two to four times a day, depending on the outside weather.

The seed maturation started on April 30 and ended on May 31. The seeds were separated from the tuft, cleaned, counted and sown on the surface of fine sand. The sand was kept in five-cm. clay pots which were put in a shallow basin with about 1½-2 cm. of water to ensure adequate moisture for the germinating seed. The seeds were not covered with sand, but each pot was provided with a Jacobsen bell-jar to provide high humidity. The pots were kept in the greenhouse.

(d) Germination of Salix Seed

Germination is the resumption of growth by the embryo which has lain dormant in the seed. This begins as soon as the resting seed imbibes moisture. In the commonly accepted botanical use of the term, germination occurs when the radicle begins to protrude beyond the seed coat. Baldwin (1942) described germination as follows: "when the tip of the

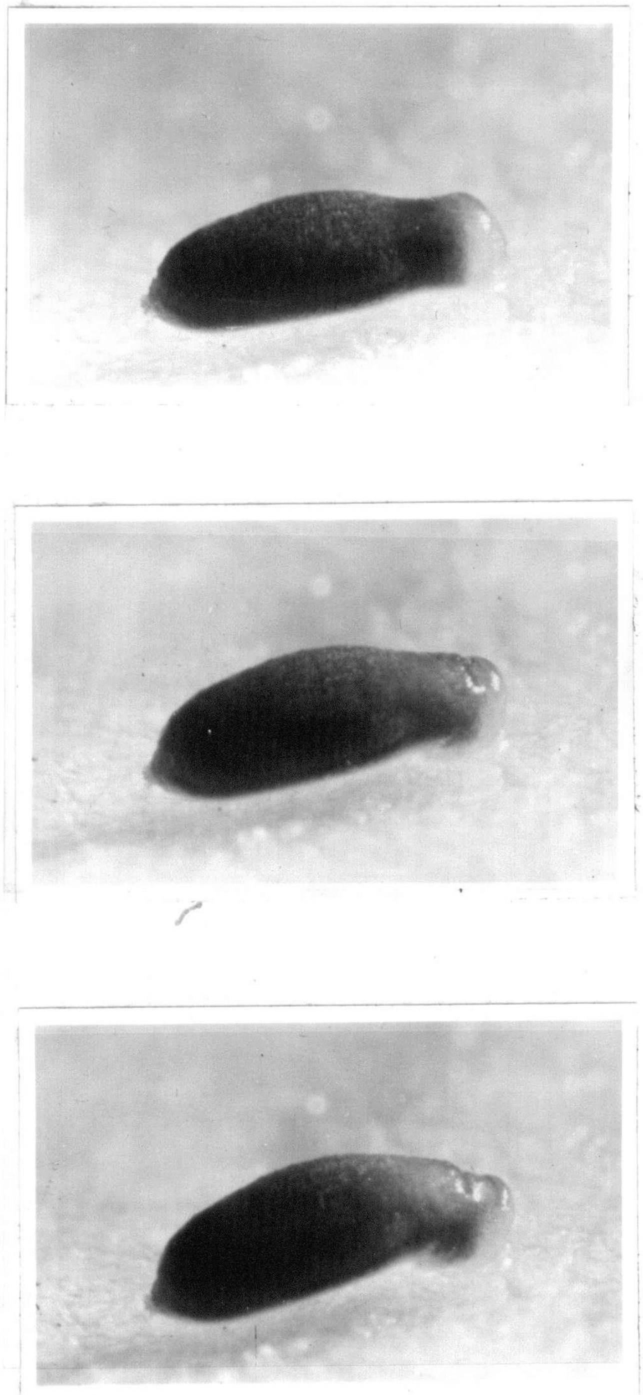


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Plate 5. The normal germination of *Salix* seed at the second hour, (a), the fourth hour (b), and the sixth hour (c).

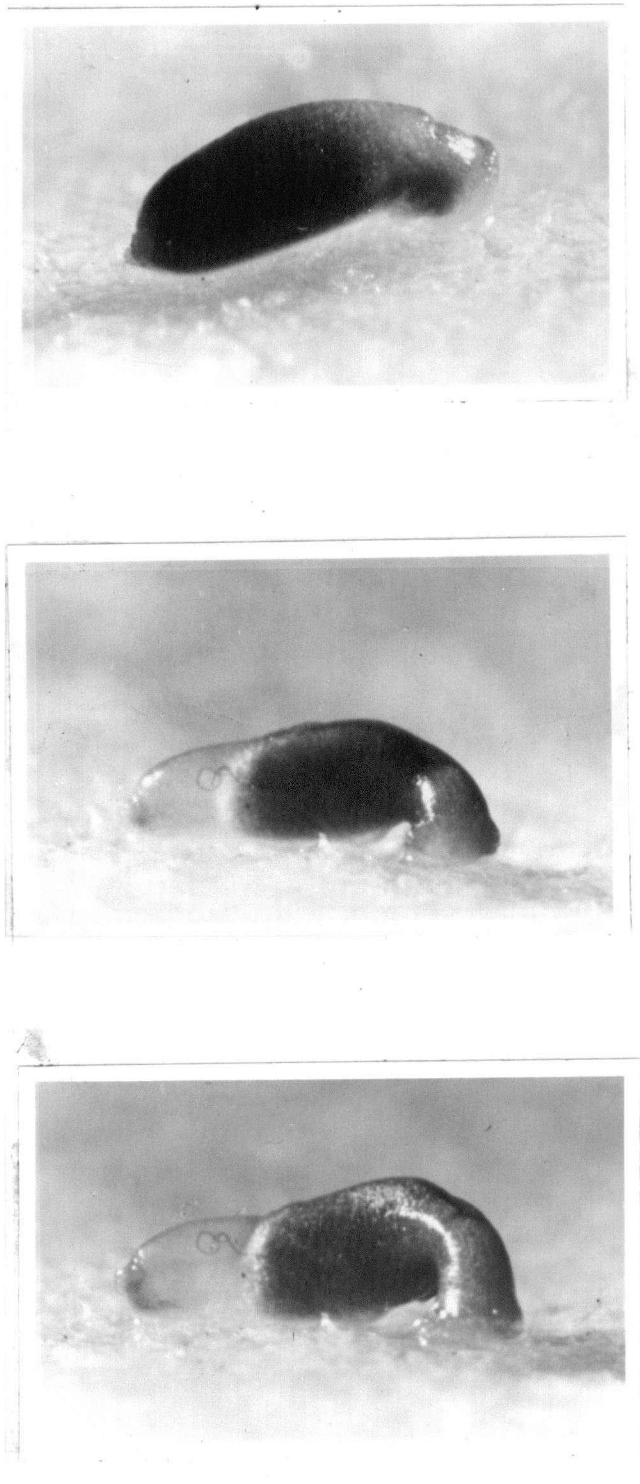

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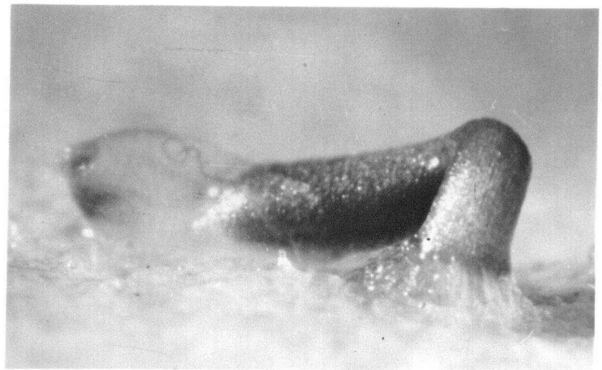
Plate 6. The normal germination of Salix seed at the eighth hour (a), the tenth hour (b), and the fourteenth hour (c).



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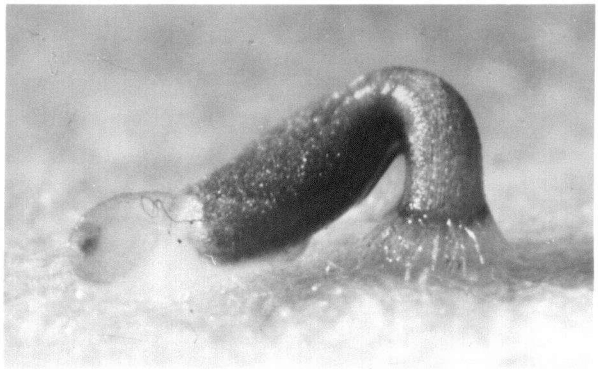

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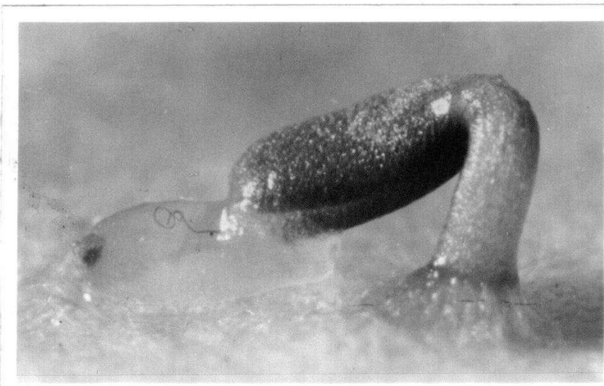

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Plate 7. The normal germination of Salix seed at the twenty-second hour (a), the twenty-sixth hour (b), and the thirtieth hour (c).

radicle has elongated far enough beyond the seedcoat to show a normal growing tip and give indications of developing into a healthy seedling". To study the germination of Salix seed, close-up photographs were taken after 2, 4, 6, 8, 10, 14, 22, 26, 30, 50, 624, and 744 hour(s). Individual Jacobsen germinators were used (Figure 8).

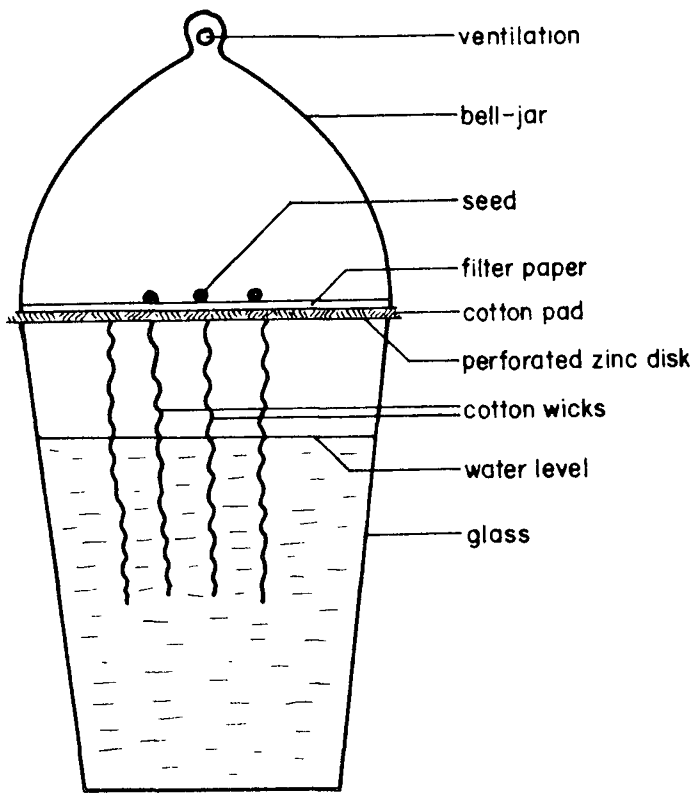
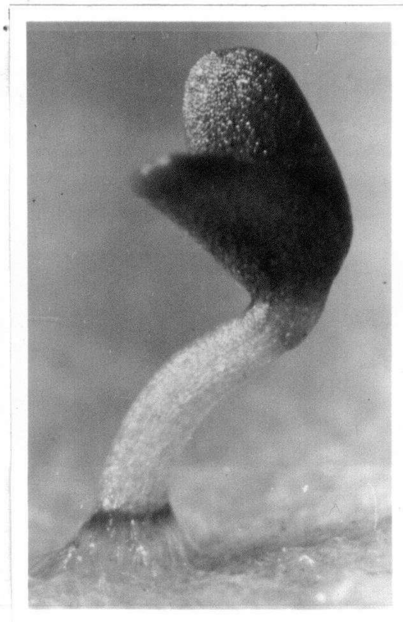


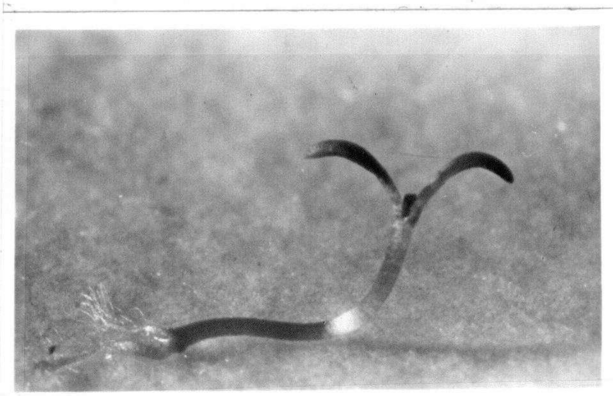
Figure 8. Individual Jacobsen germinator.

The apparatus was kept in the laboratory, at the normal room temperature, between 18°C. to 22°C., close to the window. No artificial light was applied.

In this environment germination starts very early. At the second hour (Plate 5) a jelly-like disc formed at the end of the hypocotyl and the elongation of hypocotyl began, continuing until the tenth hour (Plate 5(b) & (c), 6(a) & (b)). During this time the end of the hypocotyl gradually turned over on the blotting paper, and at the same time the detachment of the seed coat begins. Between the 10th and the 14th hour (Plate 6(b) & (c)) fine root-hair formation started. Hair formation was completed by the 22nd hour (Plate 7(a)) and the germinating seed was then sufficiently strong to begin rising from



a



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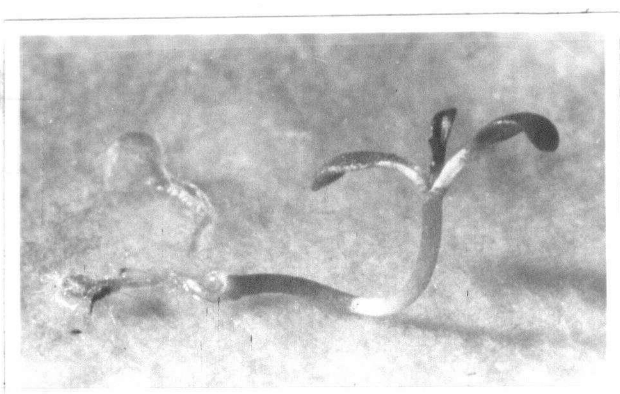


c

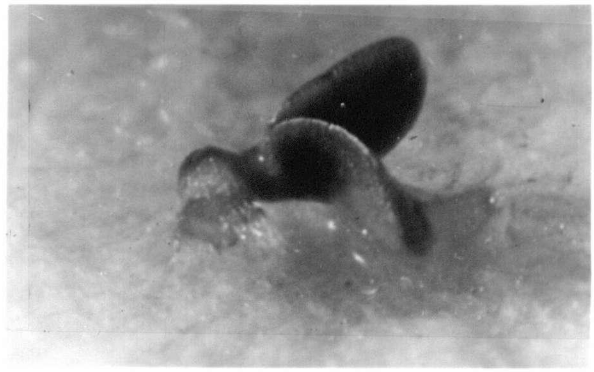
Plate 8. The normal germination of Salix seed at the fiftieth hour (a), the six hundred and twenty-fourth hour (b), and the seven hundred and forty-fourth hour (c).

a

b

c

Plate 9. Germination of Salix seed at the sixth hour (a,b), and the eighth hour (c). Injury at the sixth hour is not lethal, but causes distortion in growth.



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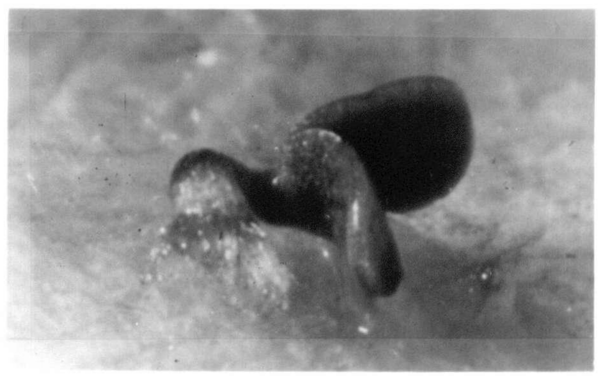

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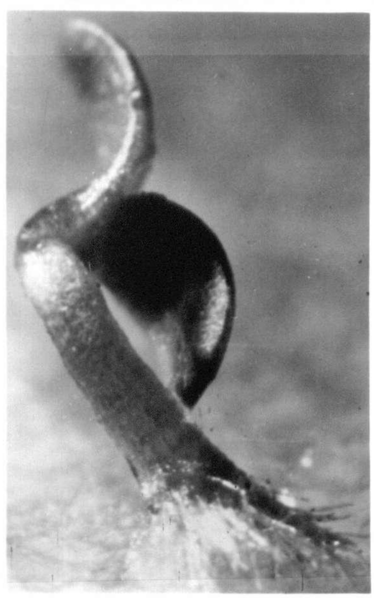
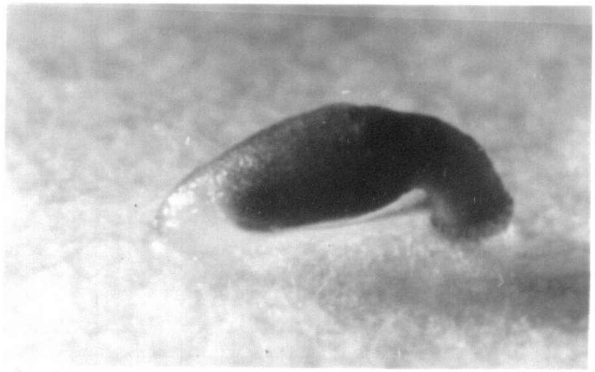


c

Plate 10. Germination of Salix seed at the tenth hour (a), the twelfth hour (b) and the fifty-first hour (c). The injured seedling is able to stand up approximately at the same time as the uninjured seedling.



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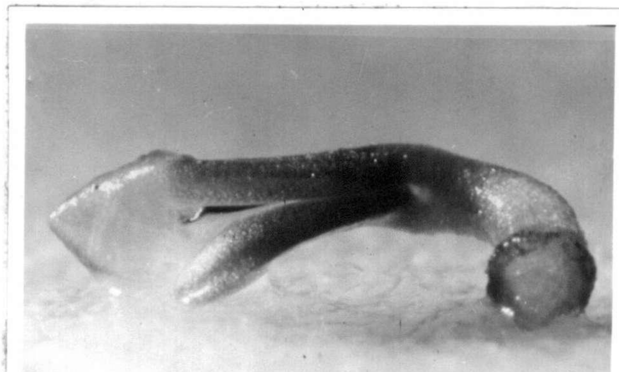

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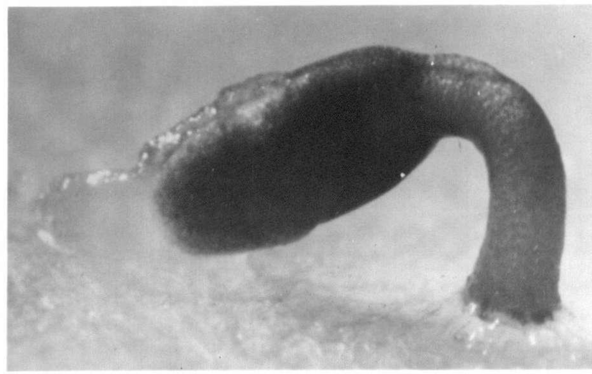
Plate 11. Germination of Salix seed after the fourteenth hour (a), the fifty-first hour (b), and the fifty-seventh hour (c). Shortly after the fourteenth hour injury or movement is always lethal.



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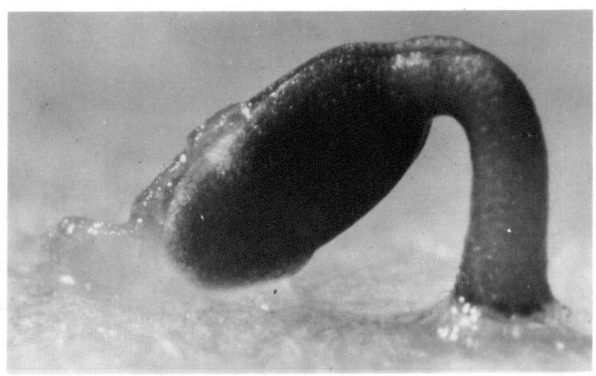

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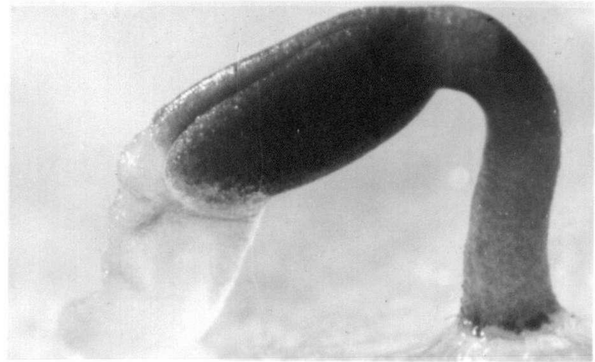


c

Plate 12. Germination of Salix seed at the twenty-fourth hour (a), the twenty-sixth hour (b), and the thirtieth hour (c). The seed coat is gradually detached during the period of germination.

its bed. The "standing up process" was completed by the 50th hour (Plate 8(a)). During this time the seed coat gradually becomes detached. The root was well developed and the first leaf appeared by the 624th hour (26th day) (Plate 8(b)). The second assimilating leaf appeared by the 744th hour (31st day) (Plate 8(a)).

To study the most critical time of germination, the germinating seeds were moved at the 6th hour (Plates 9 & 10) and after the 14th hour (Plate 11).

Plate 9(a) & (b) show, from the opposite sides, the transplanted germinating seed at the 6th hour. The root-collar ring and the tip of the radicle are clearly seen in this picture. Strong root hair formation starts at the 8th hour (Plate 9(c)), developing more heavily on the upper part of the root collar (Plate 10(a) & (b)). The injured seedling is able to stand up at the 51st hour. If the seed is moved after the 14th hour, the germinating process is different from that described above. Instead of forming root hairs, the radicle elongated (Plate 11(b)), but the seedling failed to rise and continue growth. The critical time therefore starts after the 14th hour, after which any movement seems to prevent normal development.

Although both are in the same family, Salix and Populus show a different type of seed coat detachment. In Salix the seed coat dissolves and is gradually cast off from the cotyledons (Plate 12 (a, b & c)), whereas in Populus the seed coat remains intact and the cotyledons grow out from them (Figure 9).

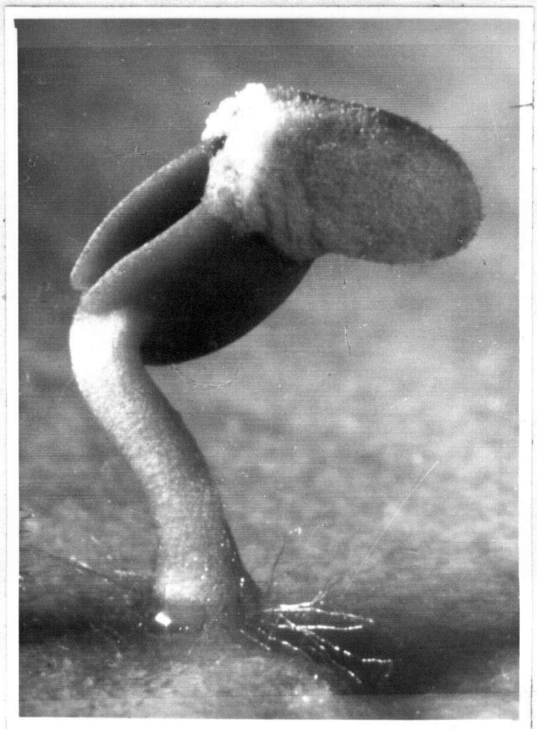


Figure 9. Germinating Populus deltoides Bartr. seed at the 50th hour.

Vegetative Propagation

Salix species have remarkable ability to grow from shoot cuttings and survival percentages are usually high.

(a) Vegetative Propagation by Shoot Cuttings

The survival was assessed at each experimental plantation on June 1, 1955. All 7480 planted cuttings were observed and the survival recorded.(Table 6).

Table 6. Survival percentages of the different clones at the different localities, on 1st of June, 1955.

Clone No.	Locality of Experiment					Average
	Csaszarret	Mersevat	Szigetvar	Klarafalva	Korostarcsa	
	percentages					
1.	96	99	91	96	94	95
2.	96	97	90	88	98	94
3.	97	95	88	94	92	93
4.	98	97	80	93	98	93
5.	94	91	67	85	80	83
6.	99	98	89	95	96	95
7.	99	98	82	95	99	95
8.	96	92	66	88	93	87
9.	96	87	52	90	85	82
10.	99	98	91	97	95	96
11.	98	98	88	94	98	95
Average	97	95	80	92	93	92

The analysis of variance between localities and clones (Table 7) shows highly significant differences between localities and between clones.

Table 7. Analysis of variance for survival of different clones at different localities.

Source of Variation	Degrees of Freedom	Net Sum Squares	Mean Sum Squares	Variance Ratio (F)
Locality	4	1926	481.5	17.66 ++
Clone	10	1295	129.5	4.75 ++
Residual	40	1090	27.2	
Total	54	4311		

++significant at $p = 0.01$; $jsd_L = 38.4$, $jsd_C = 22.2$

Assuming that locality of Szigetvar and Clone No. 10 are the controls Szigetvar shows significant differences from all the other localities and No. 10 clones differ from No. 5, No. 8 and No. 9 clone significantly. The highly significant difference between localities is probably partly due to later planting at Szigetvar. Planting was carried out in the third week of April at Szigetvar and in the first week of April in the remaining localities. Improper storage during the two-week period may have caused the moisture content to decrease thus affecting bud bursting, as well as shoot elongation. However, these affects had not appeared by June 1, when the percentage of survival was assessed. Later in June many of the unburst cuttings started to grow and at the end of the growing season the survival rate appeared to have increased considerably. Early planting is important to obtain good rooting of Salix.

(b) Vegetative Propagation by Bud Grafting

Very little is known about bud and rootstock compatibility in Salix. A little information is available from Wettstein (1933), Bogdanov (1936), Heimburger (1940) and Pauley (1948), but mostly for different genera.

The immediate interest has been directed to inter-specific compatibility of bud and rootstock under nursery conditions. A preliminary investigation started in Sopron at the end of July, 1955. Bud grafting was carried out on three different clones as rootstock with five different clones as bud. Cherny (1900), and Vadas (1900) mentioned that Salix amygdalina and Salix amygdalina var. glaucophylla are deep-rooting species or varieites. Kanski (1949) described Salix viminalis as having a well-spread root system. The rootstock therefore were chosen from this species. The buds were collected from No. 1, 4, 6, 8 and 11 clones. Of the fifteen combinations eight were carried out. One hundred buds were grafted on the rootstock (Table 8).

The "T" bud grafting method was used in every combination. The results of the budding were determined at the end of the growing season in 1955 (Table 8).

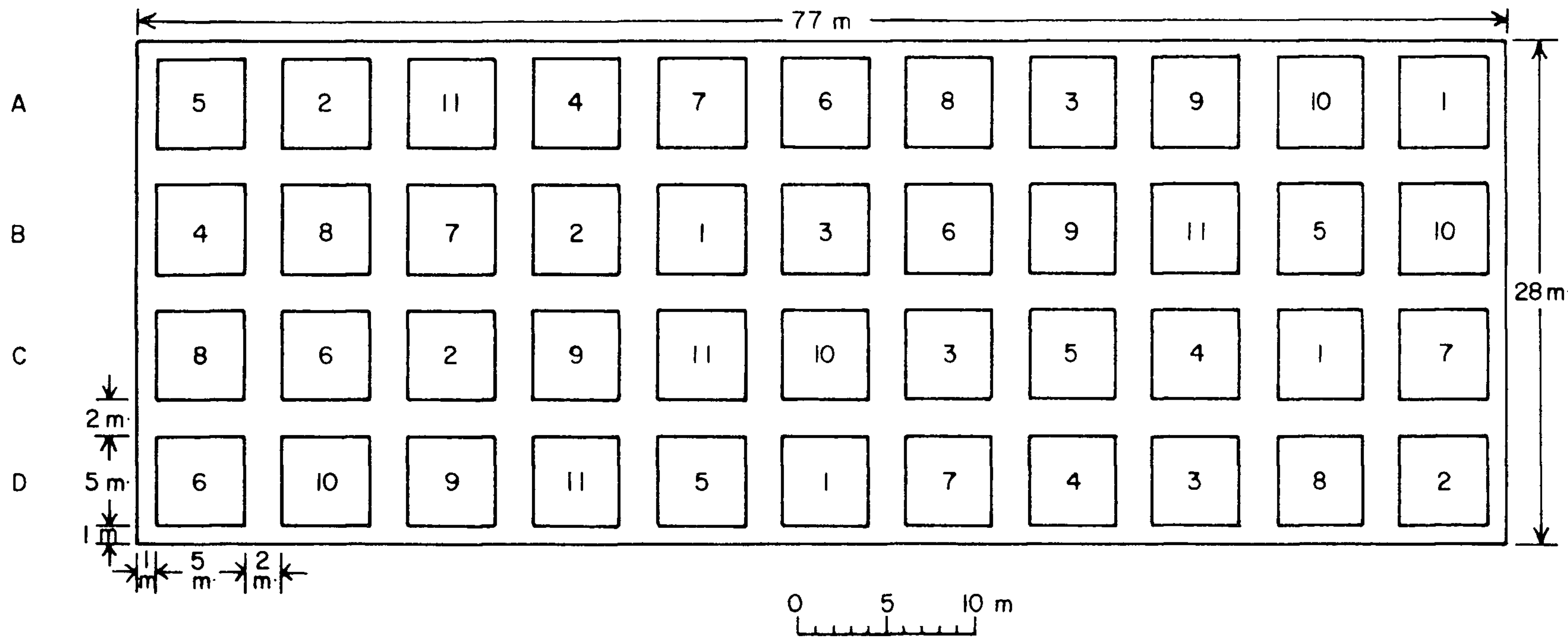
Table 8. Union formation at the end of the first growing season on different interspecific bud grafting.

Clone No. of Rootstock	Clone No. of Bud	Number of Grafts	Union Formation at the end of Growing Season
1	4	100	82
1	6	100	30
1	8	100	69
1	11	100	62
4	6	100	55
4	8	100	81
5	1	100	81
5	11	100	77
Total		800	67

Results regarding compatibility based on buds which have "taken" by the end of the same season in which the bud grafting was carried out must be regarded with some caution, since failure has been observed to occur suddenly in the second or third year.

The following results may be reported as promising combinations: No. 4 on No. 1, No. 1 on No. 5, No. 8 on No. 1 and No. 4. No. 6 clone gave very low 35 and 55 percentages in No. 1 and No. 4 rootstock respectively.

This result agrees with those reported by Pauley (1948) that compatibility in bud grafting is more likely a clonal characteristic.



I — II Different Clones

A — D Replications

Fig· 10 Plantation layout of randomized block design at the five different localities

Clonal Selection

Soil Preparation and Planting

(a) Plantation Layout

In order to investigate the range of conditions under which the various clones can be successfully grown, eleven clones were planted together for comparison. The randomized block design (Figure 10) was used with four replications, and the experiment was repeated in five different parts of the country, in the more important soil regions of the present and future willow plantations (Table 9).

Table 9. Description and position of the different areas.

Designation of Experiment	Place	Latitude	Longitude
I.	Csaszarret	47° 47'	17° 06'
II.	Mersevat	47° 13'	17° 22'
III.	Szigetvar	46° 03'	18° 05'
IV.	Klarafalva	46° 04'	20° 03'
V.	Korostarcsa	46° 52'	21° 01'

Csaszarret has limey peat soil, Mersevat loamy soil, Szigetvar alluvial loamy soil, Klarafalva neutral clay soil, and Korostarcsa neutral heavy clay soil.

The annual average precipitation during the period 1901-1941 varied from 559 mm. to 708 mm. at the closest meteorological stations (Table 10).

Table 10. Precipitation in mm. at the meteorological stations closest to the plantations during the 40 years average from 1901 to 1941.

Designation of Experimental Plantation	Place	Precipitation (mm.)			
		Average annual	Annual max.	Annual min.	During the Growing Season
I.	Csaszarret	592	898	392	359
II.	Mersevat	659	1113	382	392
III.	Szigetvar	708	1161	458	414
IV.	Klarafalva	577	937	341	336
V.	Korostarcsa	559	783	337	329

(b) Site Preparation

The methods of preparing the soil naturally varied considerably, but the common method is as follows: the soil was weeded thoroughly during the growing season previous to planting, ploughed deeply (30-35 cm.) in the early fall, and harrowed in the early spring. Four areas (II,

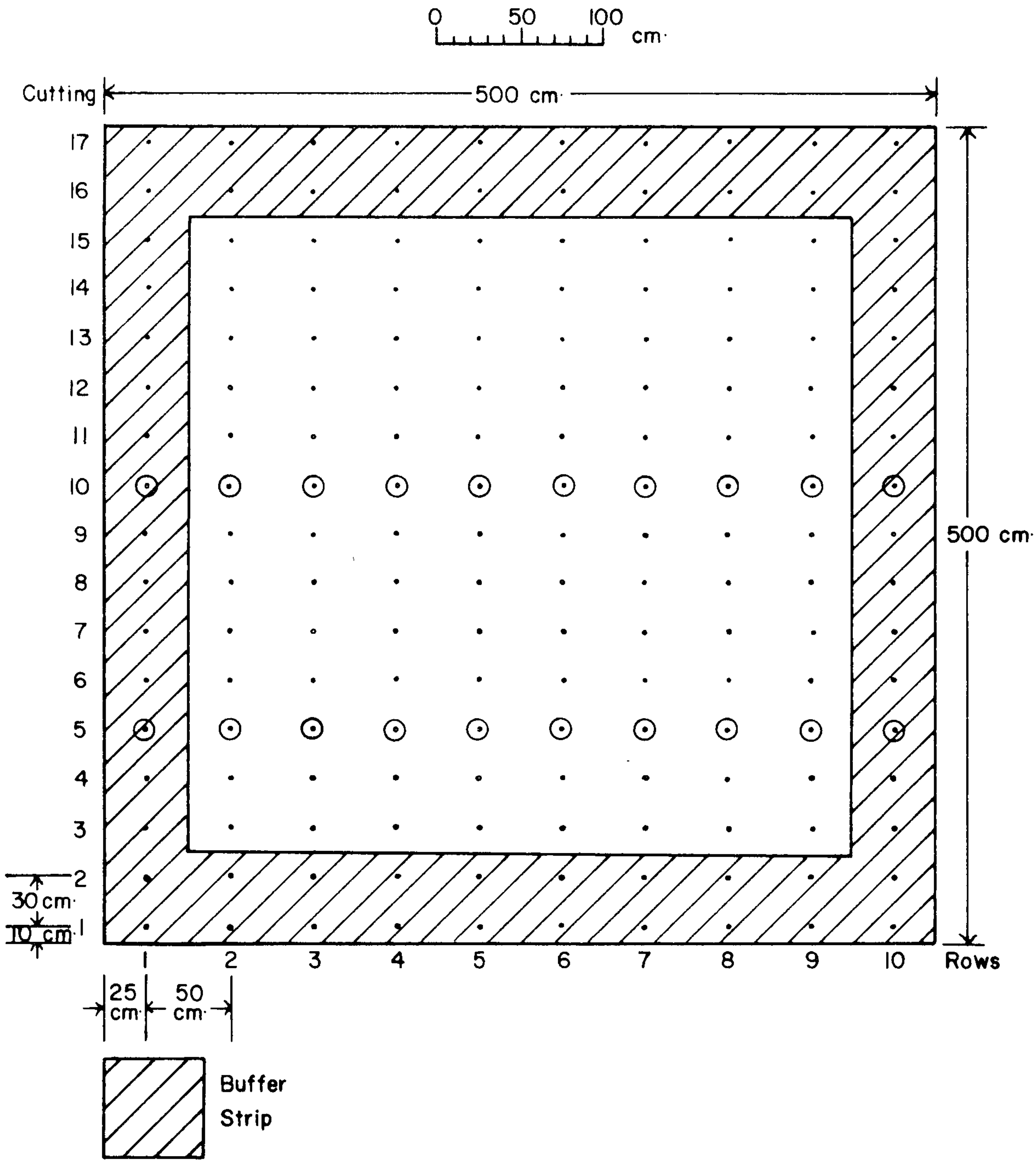


Fig. 11 Spacing arrangement inside a block

III, IV and V) were cultivated as mentioned above. One area (I) was treated partly the same way on the (B), (C) and (D) rows but the first (A) replication of the block was ploughed and harrowed a few weeks before planting was carried out. At the end of the first growing season the height growth was two to three times less than in some clones in the (A) row than in the remaining (B), (C) and (D) rows. The difference was greater at the end of the second growing season, because high mortality occurred in the less cultivated area. Site preparation improved the chances for successful rooting and survival of the different clones, when it was carried out during the growing season previous to planting.

(c) Collection of Cuttings

The cuttings used were taken 2 weeks before the time of planting. One-year-old, fully mature epicormic shoots from stools were used and cut up immediately after collection. The apical portion of the shoot was removed and only the basal portion was used. Knifecut pruners were used to make horizontal cuts at the basal end below a bud, and at the apex above a bud. The diameter of the cuttings ranged from 8 mm. to 15 mm. and the length varied between 25 and 30 cm.

(d) Packing and Shipping of Cuttings

Bundles of one-hundred cuttings were packed into potato sacks, eight bundles per sack. Both ends of the bundles were covered by wet moss. The parcels were sent by train, and usually arrived at the plantation area 4-5 days later.

(e) Spacing

The most commonly used spacing (50 cm. times 30 cm.) was applied to all experimental areas in each block. Ten rows were marked and in every row 17 seedlings were planted (Fig. 11), giving 170 seedlings in each block.

(f) Insertion of Cuttings

The proper number of cuttings were carefully distributed to the block and were heeled in the soil at the S.W. corner. A planting string 30 meters long was used and marked in intervals of 30 cm., the distance between cuttings, with bright yellow or white paint. The string was tightened over the row of the four blocks and the planting was carried out by four workers separately in each block. The cuttings were thrust into the ground manually by workers. The cuttings were placed in the soil vertically, so that only the top one cm. with one bud was above ground.

(g) Maintenance

A permanent research worker was employed at each plantation. His duty was to make the phenological and weather observations, measure growth every second week, conduct observations of insect damage, make collections of insects, and carry out daily maintenance work on the whole area, e.g. cleaning, spraying, etc. In cases where he could not finish the work in one day on the whole area, e.g. height measurement, cultivation, harvesting, etc., extra manpower was supplied to give as uniform a treatment as possible to the whole experiment.

Phenological Observations

During the growing season the time of bud bursting, survival percentages, color change of leaves, leaf falling, and bud setting were observed. In the remarks column, the insect damages were noted (Table 11).

Table 11. Form of phenological observations.

Repli-cation	Time of bud bursting I. II. III.	Survival	Color change in autumn I. II. III.	Leaves falling I. II. III.	Time of bud setting I. II. III.	Remarks
A B C D						

I. = characteristics occurred less than 10% of the shoots
II. = characteristics occurred 50% of the shoots
III. = characteristics occurred on 90% of shoots

Growth Measurements

In order to study the growing pattern of different clones, periodical height measurements of each shoot were taken in each of the 5th and 10th rows (Figure 11) every second week during the growing season. The measurements were taken on May 4, 18, June 1, 15, 19, July 13, 27, August 10, 24, September 7 and 21, a total of eleven times in 1955. The measurements were taken on April 25, May 9, 23, June 6, 20, July 4, 18, August 1, 15, 29, September 12 and 26, a total of twelve times in 1956. A total of 880 measurements were taken each time; 48,400 height measurements were collected in 1955, and 52,800 in 1956. The only information available for the years 1957, 1958 and 1959 is for height measured at the end of each of these years. The data are included in Tables 12-16.

Table 12. Average height growth of clones at Csaszarret in 1955-1959.

Clone No.	Year of observation (height in centimeters)					Total	Average	C.V. %
	1955	1956	1957	1958	1959			
1.	62	142	179	158	228	769	154	39
2.	59	96	114	113	177	559	112	38
3.	52	74	115	129	218	588	117	55
4.	52	55	135	158	182	582	116	51
5.	42	40	104	147	166	499	100	58
6.	51	65	137	168	203	624	125	52
7.	45	71	149	161	222	648	129	55
8.	59	92	165	186	222	724	145	47
9.	36	64	111	98	204	513	103	62
10.	41	104	133	147	177	602	120	43
11.	34	62	109	139	117	461	92	47
Total	533	865	1451	1604	2116	6569	597	
Average	48	79	132	146	192	597	119	

Table 13. Average height growth of clones at Mersevat in 1955-1959.

Clone No.	Year of observation (height in centimeters)					Total	Average	C.V. %
	1955	1956	1957	1958	1959			
1.	83	185	224	198	229	919	183	32
2.	66	149	198	188	234	835	167	38
3.	68	151	230	216	268	933	186	42
4.	51	46	95	132	176	500	100	55
5.	41	66	127	179	134	547	109	50
6.	44	83	170	168	216	681	136	51
7.	49	71	167	132	223	642	128	55
8.	43	81	158	162	212	656	131	51
9.	32	71	159	166	249	677	135	62
10.	34	84	155	159	211	643	128	54
11.	41	69	193	157	213	673	137	55
Total	552	1056	1876	1857	2365	7706	701	
Average	50	96	171	169	215	701	140	

Table 14. Average height growth of clones at Szigetvar in 1955-1959.

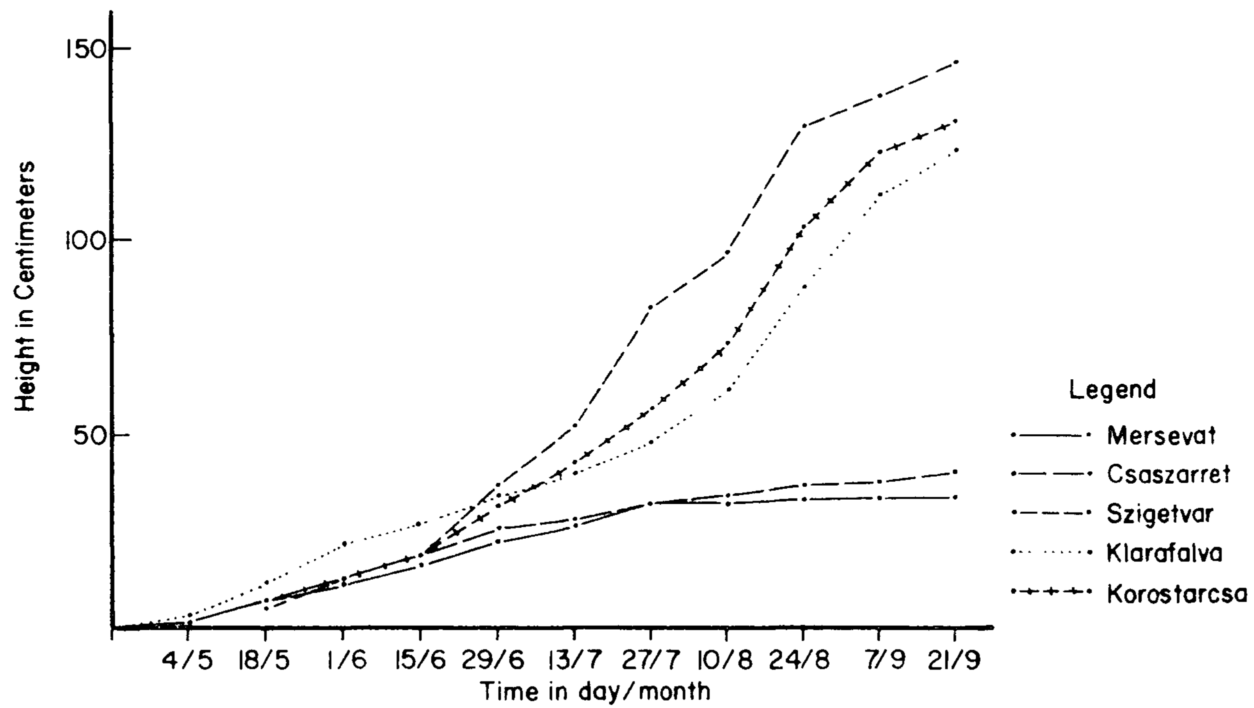
Clone No.	Year of observation					Total	Average	C.V. %
	1955	1956	1957	1958	1959			
	height in centimeters							
1.	157	178	193	226	274	1028	206	22
2.	176	200	237	261	193	1067	213	16
3.	203	231	199	247	224	1104	221	9
4.	139	184	180	169	167	839	167	10
5.	144	175	140	197	171	827	165	14
6.	160	208	198	208	160	934	186	13
7.	148	205	200	121	216	890	178	23
8.	89	159	164	198	176	786	157	26
9.	90	149	143	181	209	772	154	29
10.	147	156	165	205	178	851	170	13
11.	155	179	199	229	171	933	186	15
Total	1608	2024	2018	2242	2139	10031	912	
Average	140	184	183	204	194	912	182	

Table 15. Average height growth of clones at Klarafalva in 1955-1959.

Clone No.	Year of observation					Total	Average	C.V. %
	1955	1956	1957	1958	1959			
	height in centimeters							
1.	174	248	272	202	230	1126	225	17
2.	153	205	256	186	230	1030	206	19
3.	173	231	267	205	240	1116	223	16
4.	80	150	185	127	190	732	146	31
5.	67	170	202	144	190	773	154	35
6.	90	179	252	179	160	860	172	34
7.	123	213	255	175	200	966	193	25
8.	115	201	229	189	180	914	182	23
9.	60	167	176	152	190	745	149	36
10.	124	195	122	159	170	770	154	20
11.	107	186	114	150	180	737	148	27
Total	1266	2145	2330	1868	2160	9769	888	
Average	116	195	212	170	196	888	177	

Table 16. Average height growth of clones at Korostarcsa in 1955-1959.

Clone No.	Year of observation					Total	Average	C.V. %
	1955	1956	1957	1958	1959			
	height in centimeters							
1.	175	226	203	208	202	1014	203	10
2.	189	214	201	200	186	990	198	6
3.	186	227	176	165	174	928	186	13
4.	121	167	158	121	167	734	147	16
5.	119	157	156	178	174	784	156	15
6.	120	207	180	147	168	822	164	20
7.	146	241	187	148	167	889	178	22
8.	140	213	177	181	202	913	183	15
9.	121	208	133	150	164	776	155	22
10.	130	184	140	169	174	797	159	15
11.	140	201	171	148	148	808	162	17
Total	1587	2245	1882	1815	1926	9455	859	
Average	144	204	171	165	175	859	172	



Fig· 12 Height growth of No· 10 clone at the different localities in 1955

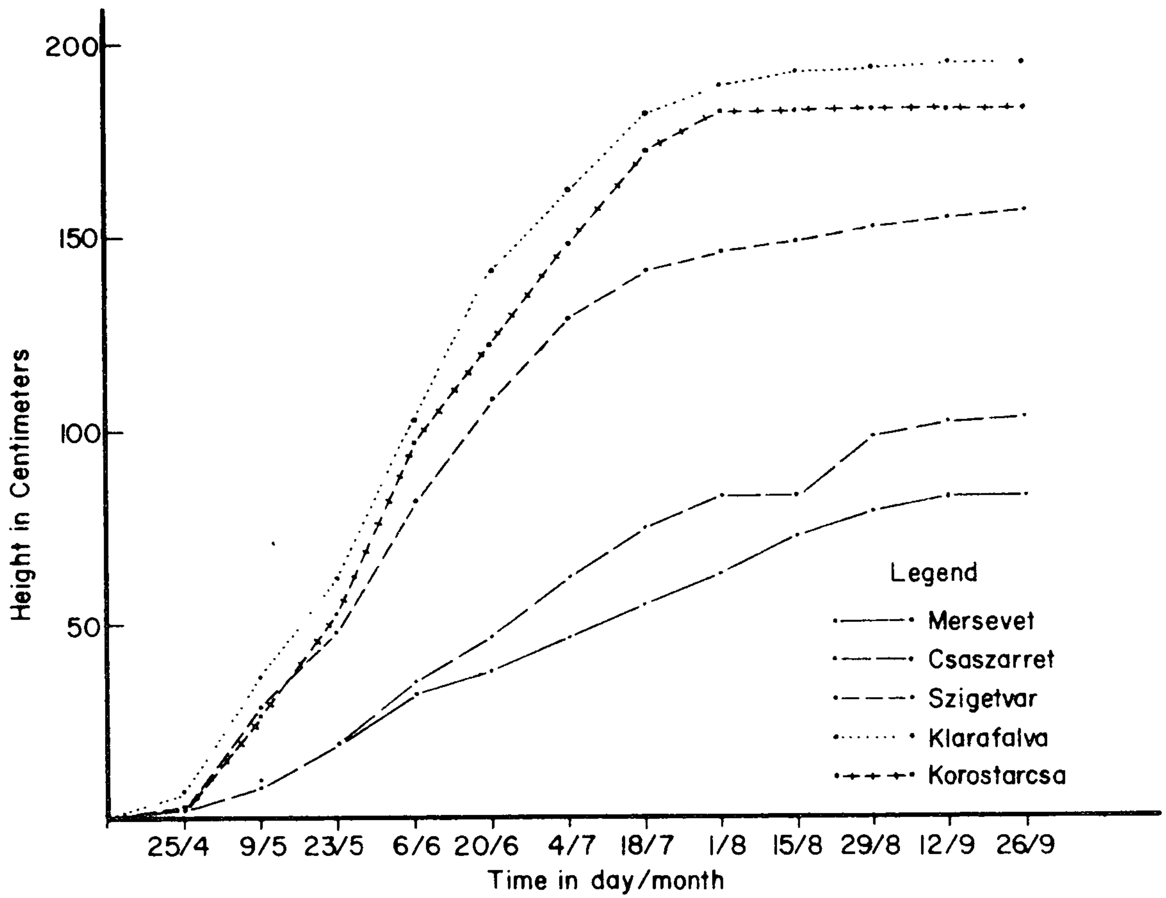


Fig. 13 Height growth of No. 10 clone at the different localities in 1956

The height growth patterns were different in 1955 and in 1956 (Figures 12 and 13).

No. 10 clone began to grow rather slowly in 1955. During this time the root system formed and after that a progressively faster growth took place from the middle of June to the end of July, after which the growth gradually slowed down. A second growing period occurred from August 10th to August 24th at the three localities where growth was fast (Szigetvar, Klarafalva, Korostarcsa). No second growing period occurred at the two localities where growth was slow (Csaszarret, Klarafalva).

Shoot elongation started early in 1956 and by August 1st approximately 80 per cent of the total height was achieved at the three fast-growth localities. The growth was so rapid in 1956 that clone No. 10 at Klarafalva reached the 100 cm. height by June 6th, instead of September 1st in 1955. The height growth gradually slowed down near the end of August and ceased at the middle of September. At the two slow-growth localities (Csaszarret and Mersevat) growth was gradual to the end of August, except at Csaszarret, where a second growing period occurred from August 15th to 29th.

Influence of Different Variables

An analysis of variance was made (Table 17) for five localities during five years and for eleven clones.

Table 17. Analysis of variance of average height growth at five localities during five years for eleven clones.

Source of Variation	Degrees of Freedom	Net Sum Squares	Mean Sum Squares	Variance Ratio (F)
Clone (C)	10	105,246	10,524	24.48 ++
Year (Y)	4	278,361	69,590	161.84 ++
Locality (L)	4	163,879	40,969	95.28 ++
C x L	40	47,729	1,193	2.77 ++
C x Y	40	21,874	546	1.27 N.S.
Y x L	16	159,834	9,989	23.24 ++
Residual	160	68,804	430	
Total	275	840,727		

++ significant at p = 0.01
N.S. not significant

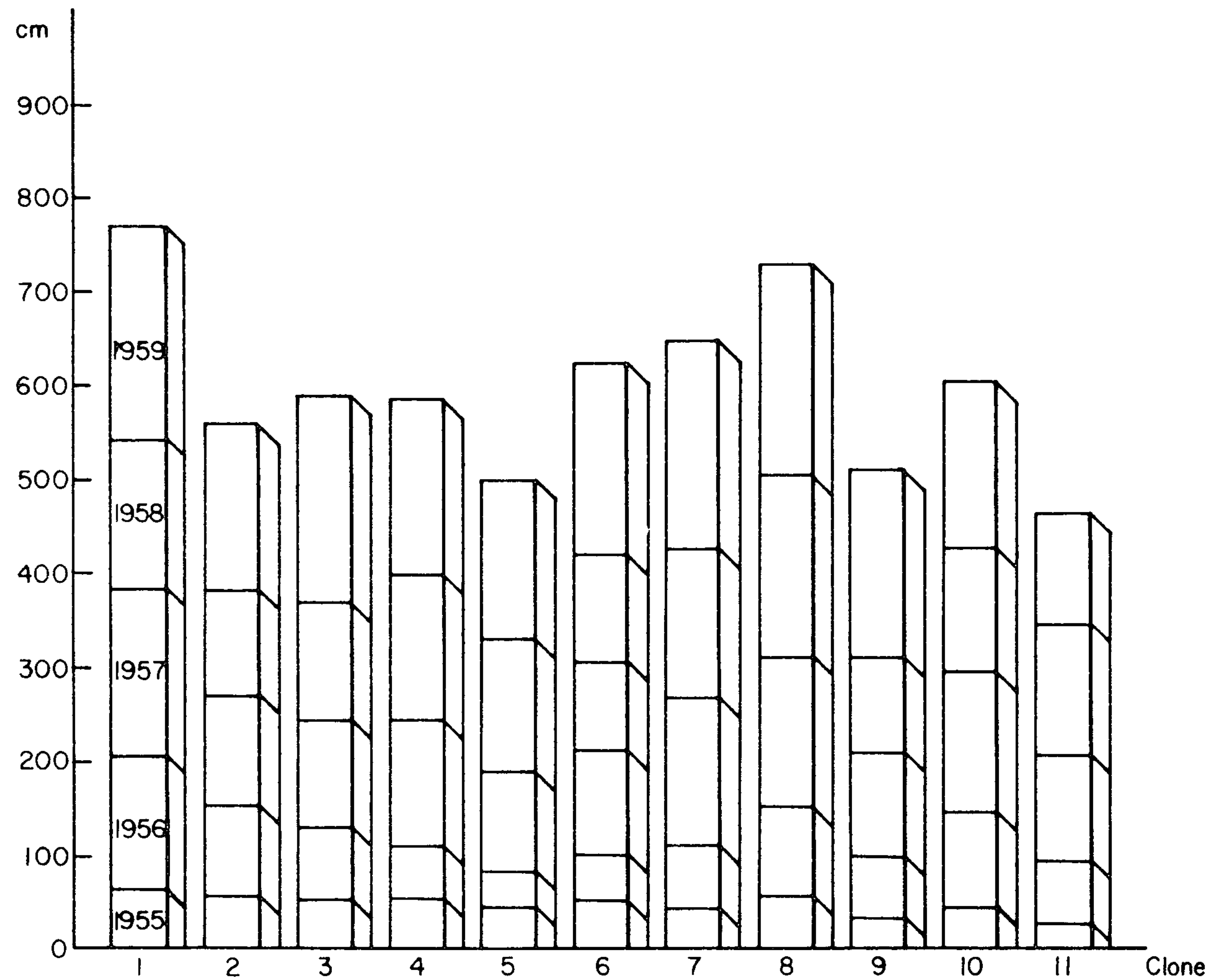
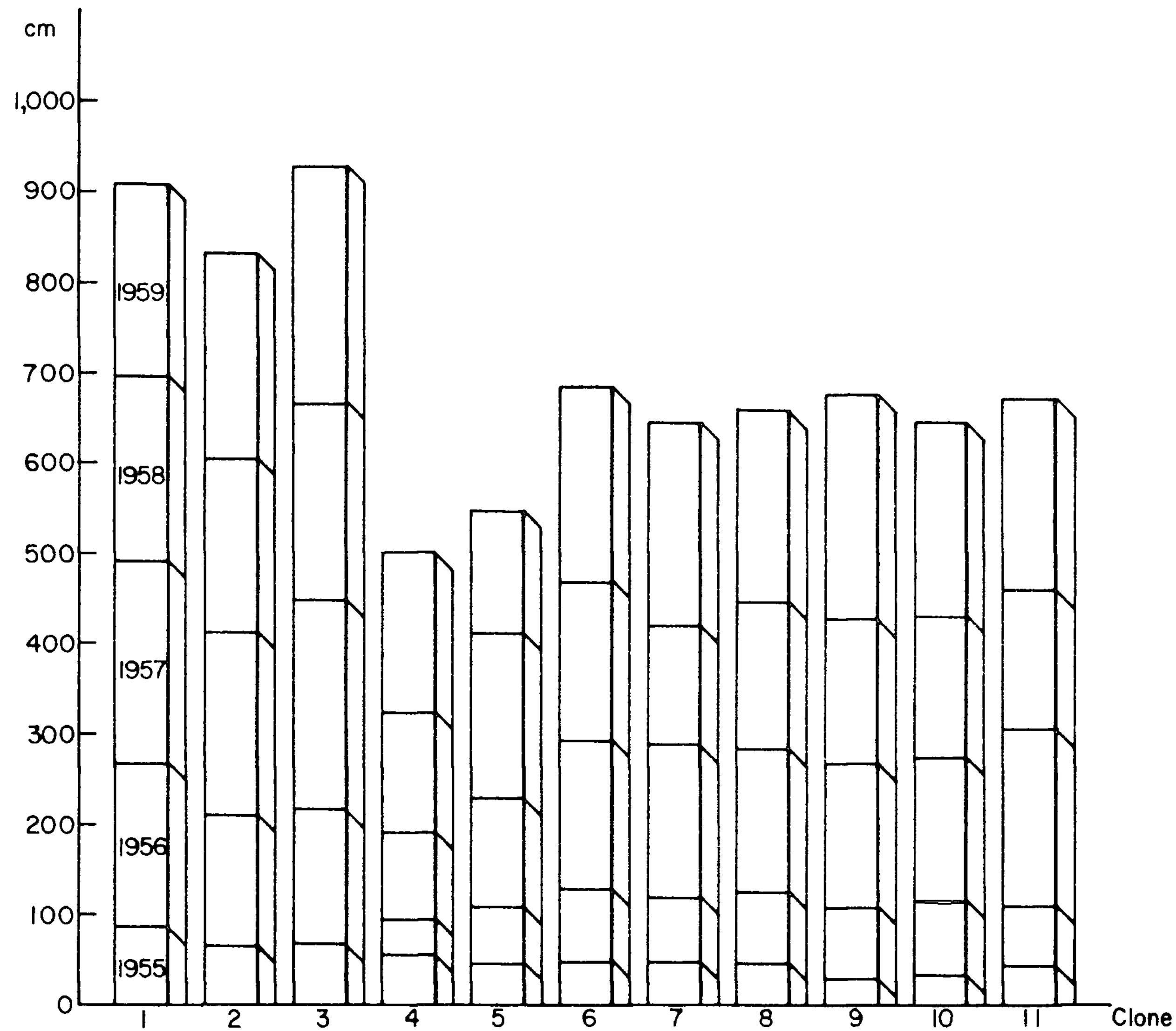
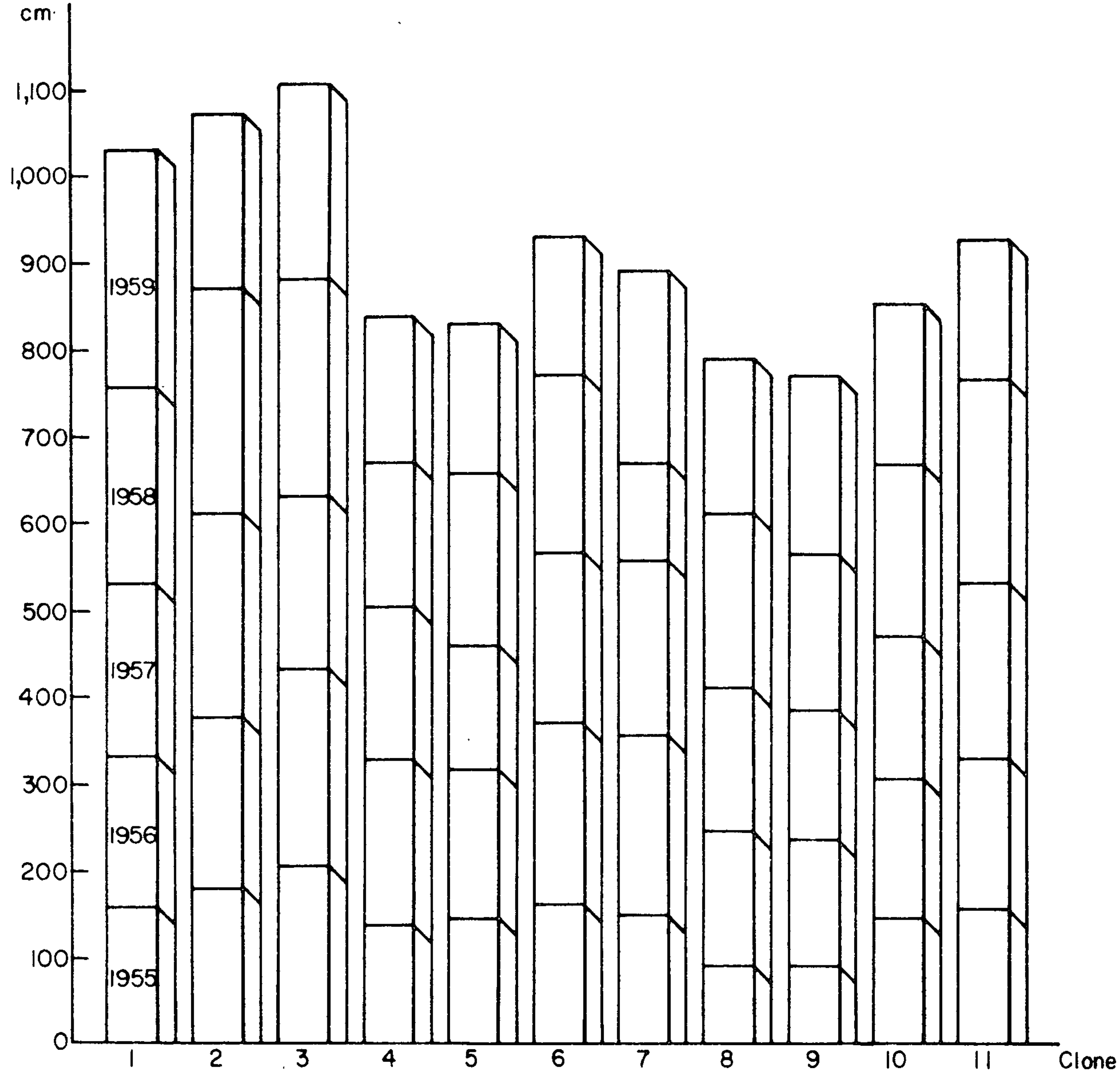


Fig. 14 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Csaszarret



Fig· 15 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Mersevat



Fig· 16 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Szigetvar

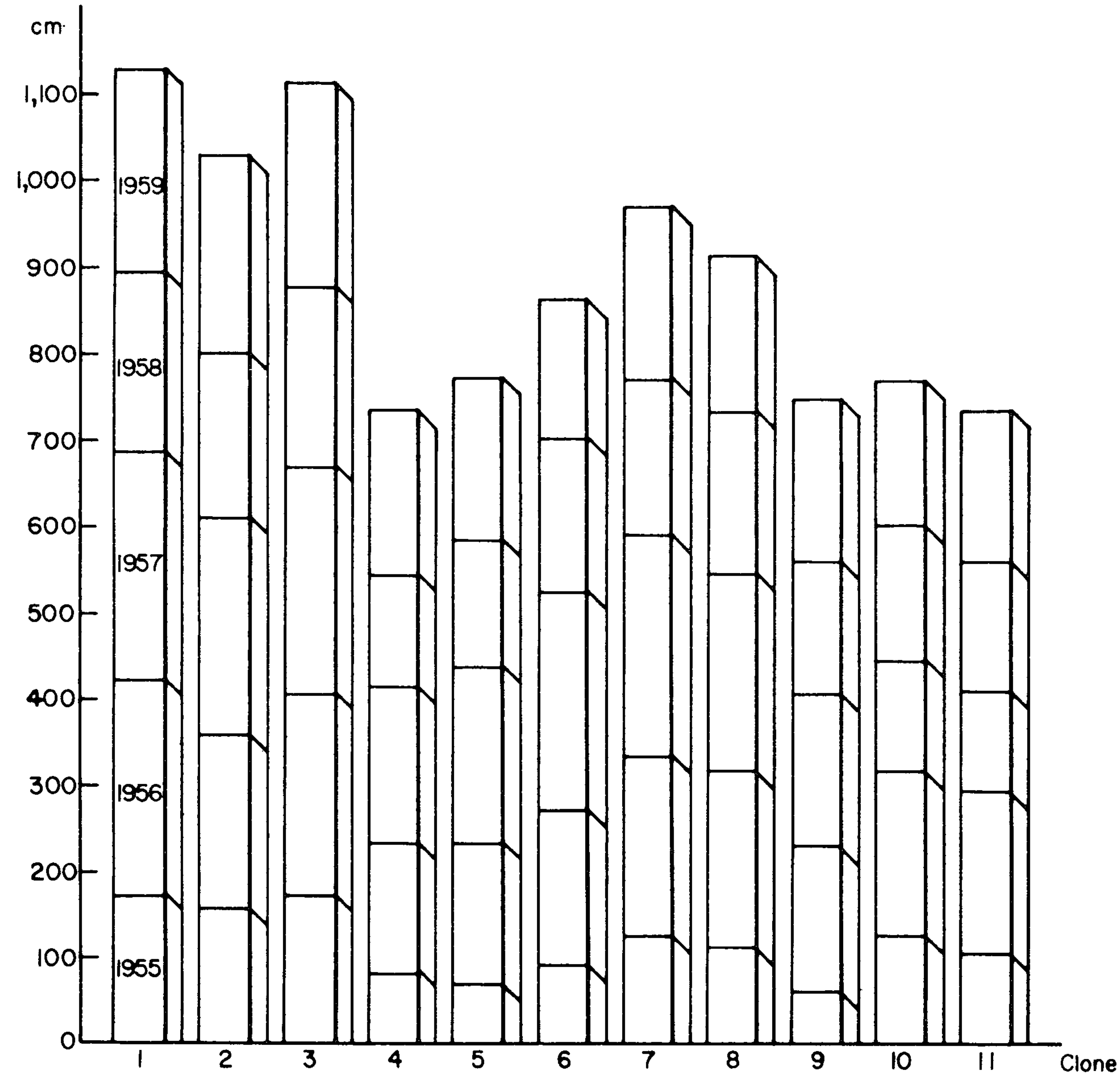


Fig. 17 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Klarafalva

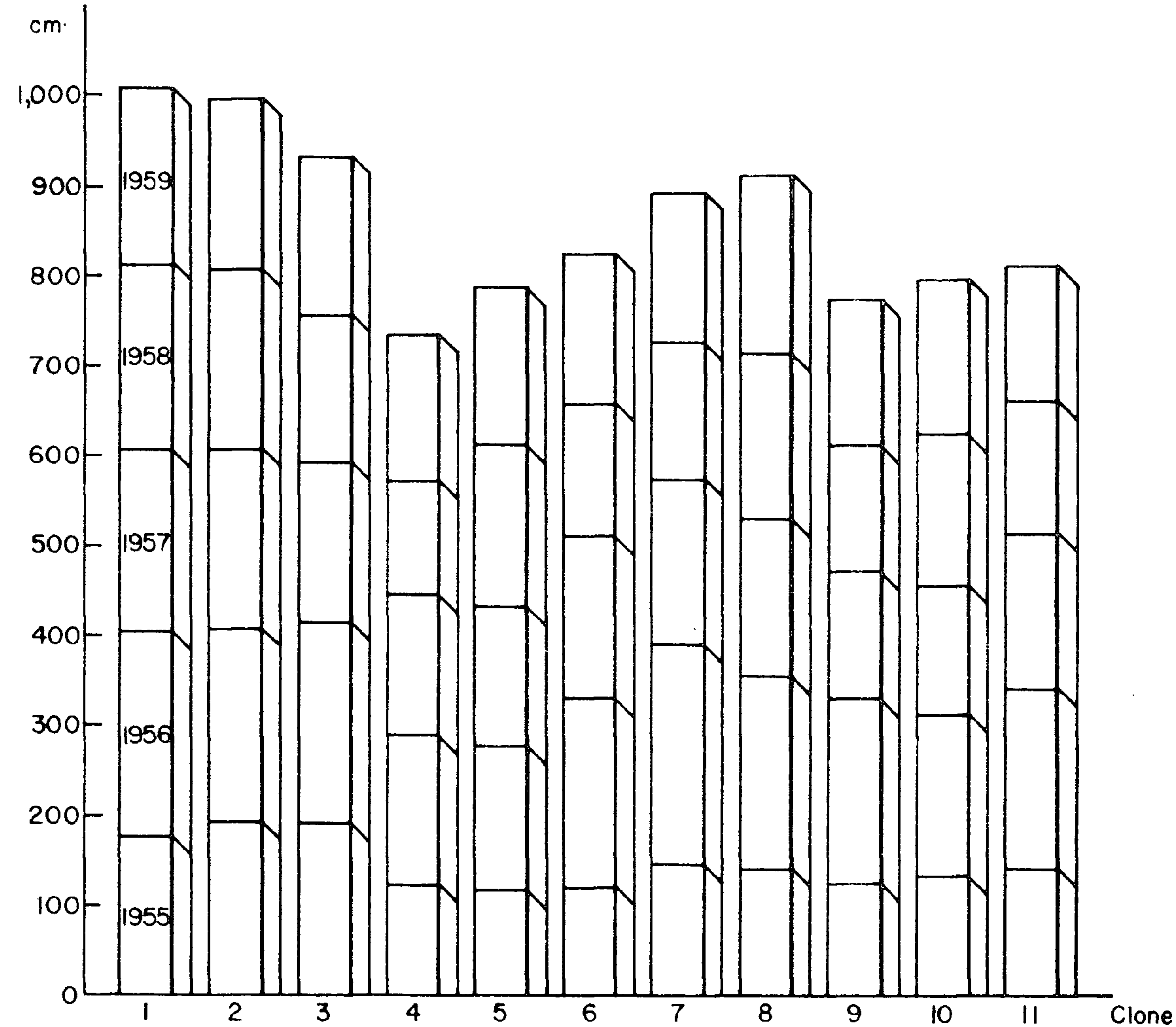


Fig. 18 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Korostarcsa

(a) Clone

Using the means of the clones from all localities for 1955-1959 to test the height differences and assuming No. 10 the clone used most commonly as control, the just significant difference was calculated. Table 18 shows that Number 1, 3, 2, 7, 8 and 6 are significantly taller than Number 10 clone, and Number 9, 5 and 4 are significantly shorter.

Table 18. Average yearly height growth of eleven different clones at five localities from 1955 to 1959.

Height in centimeters	971	934	896	807	799	784	733	722	697	686	677
Clone number	+ 1	+ 3	+ 2	+ 7	+ 8	+ 6	10	11	+ 9	+ 5	+ 4

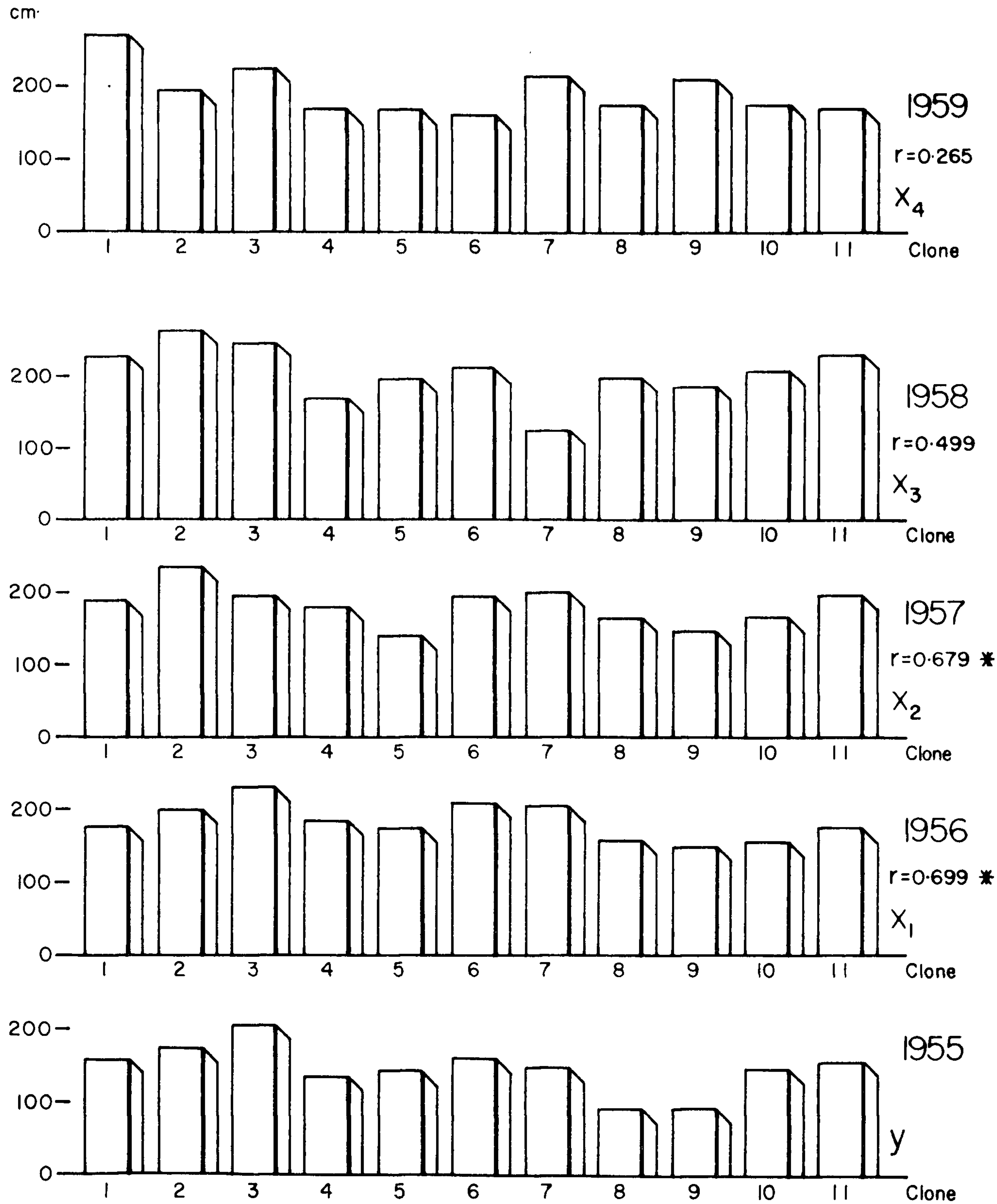
+ = significantly different from Number 10 clones as control
jsd = 29

Number 1 clone is the tallest with 971 cm. It produced shoots that were 32 percent longer than Number 10 clone, which was only 733 cm. high.

(b) Year

The height growth are shown from year to year in Tables 12-16, and in Figs. 14-19.

The average height growths from 1955 to 1959 were respectively 504, 757, 869, 853, and 973 centimeters. The just-significant range was calculated (jsr = 24) and the following significant differences were observed. The years 1955, 1956 and 1959 were significantly different from all the other years. The years 1957 and 1958 did not differ from each other, but differed significantly from 1955, 1956 and from 1959. Differences in the first two years may be explainable by the age of the stump. During willow cultivation, the one-year-old shoot is the end product, and the shoots were cut off every year. The root systems were intact and on the average it took two years to establish a well developed root system. No significant difference occurred during the third and fourth year, but in the fifth year the height growth was taller and differed significantly from that of the previous years. In addition to the age of stump, environmental factors are important. In a preliminary study, the relationship between height measurements from year to year were evaluated at one locality,



Fig· 19 Height growth of different clones from 1955 to 1959 at Szigetvar (r = 0·576 at 5 % level)

Szigetvar. The average height of the first year was chosen as the dependent variable and heights for the consecutive years were the independent variables. Simple correlation coefficients (r) were calculated. The annual growth in height of different clones are presented separately in Figure 19. Only the second- and third-year height growths are correlated with those of the first, fourth, and fifth years. The first-year result, even in this highly homogeneous population, did not show correlation among the years at Szigetvar.

In the calculations of simple correlation coefficients for all localities, all years and all clones (Table 21) the first-year growth was highly correlated with growth of the second, third and fourth years, but no significant correlation existed between growth in the first and growth in the fifth year.

(c) Locality

The highly significant differences between localities were tested assuming Szigetvar, the most important locality for willow plantations, as the control. Using the average yearly height growth (Table 19), Csaszarret and Mersevat produced significantly less than Szigetvar, and no significant difference existed between Szigetvar and the remaining localities.

Table 19. Average yearly height growth at the different localities.

Locality	Csaszarret	Mersevat	Szigetvar	Klarafalva	Korostarcsa
Average height in centimeter	119 +	140 +	182	178	172

+ = significantly different from Szigetvar as control
jsd = 11

The differences are mainly due to the slow establishment of the willow plantation at Csaszarret and at Mersevat. The eleven clones could produce 180 centimeters growth in average height during one year. Szigetvar, Klarafalva and Korostarcsa reached this limit at the end of the second growing season, but Mersevat and most clones at Csaszarret exceeded this height only at the end of the fifth growing season. Among the localities the height growth was greatest at Mersevat in 1959 with 215 centimeters.

The slow establishment explains the highly significant differences in the interactions.

In a supplementary analysis (Table 20) components of variance were calculated for clone, year, and locality, and for their interactions to determine the relative amounts of variation from each source.

Table 20. Analysis of components of variance for height growth.

Source of Variation	Degrees of Freedom	Mean Sum Squares	Values of Components
Clone (C)	10	10,524	S_C^2 = 368
Year (Y)	4	69,590	S_Y^2 = 1082
Locality(L)	4	40,969	S_L^2 = 549
C x L	40	1,193	S_{CL}^2 = 153
C x Y	40	546	S_{CY}^2 = 23
Y x L	14	9,989	S_{YL}^2 = 868
Residual	160	430	S_O^2 = 430

c = 11, y = 5, l = 5.

The highest component is related to the year, which includes 31 percent of the total variation; locality has 16 percent and the lowest component of variance is the clone with 11 percent.

The component of variance for clone would occur if the other two factors (year and locality) were held constant. This value is entirely due to genotype and because vegetative propagation was used includes the components of variance from additive genetic, dominance, and epistasis sources. In this case the heritability may be used in its broad sense, and the value for height growth is about 11 per cent, in the combined calculation. Because the heritability is composed of two components, the effect of the genes and the effect of the environment, it is possible to change the numerical value for heritability by changing the environmental effect. In this case the high value of year and locality would be reduced considerably by calculating the heritability value for one locality in one specific year.

<u>Use of Height Growth to Estimate Serveral Variables</u>

Simple correlation coefficients were calculated for Table 21. The dependent variable (Y) was the average height growth for each clone at each locality from 1955 to 1959 and the independent variables

(x_1 to x_{12}) were:

x_1 = total height of five years growth for each locality

x_2 = clone number from 1 to 11

x_3 to x_{10} include the average height growth for each clone at each locality for one to several years.

x_3 = 1955 height

x_4 = 1956 height

x_5 = 1957 height

x_6 = 1958 height

x_7 = 1959 height

x_8 = 1955 plus 1956 height

x_9 = 1955 plus 1956 plus 1957 heights

x_{10} = 1955 plus 1956 plus 1957 plus 1958 heights.

Table 21. Simple correlation coefficients of average height, weight and volume of different clones and localities during 1955-1959.

Variable													
X_1 on	1.000	.005	.773 ++	.841 ++	.448 ++	.303 +	.195	.834 ++	.784 ++	.748 ++	.761 ++	.764 ++	.679 ++
X_2		1.000	.279 +	.213	.381 ++	.281 +	.373 ++	.250	.317 ++	.331 +	.297 +	.324 +	.386 ++
X_3			1.000	.886 ++	.518 ++	.556 ++	.043	.965 ++	.914 ++	.908 ++	.845 ++	.837 ++	.860 ++
X_4				1.000	.637 ++	.448 ++	.013	.976 ++	.959 ++	.926 ++	.854 ++	.863 ++	.882 ++
X_5					1.000	.562 ++	.399 ++	.601 ++	.772 ++	.794 ++	.644 ++	.675 ++	.833 ++
X_6						1.000	.270	.512 ++	.568 ++	.705 ++	.520 ++	.502 ++	.724 ++
X_7							1.000	.028	.094	.145	.041	.075	.325 +
X_8								1.000	.966 ++	.945 ++	.875 ++	.876 ++	.898 ++
X_9									1.000	.980 ++	.882 ++	.892 ++	.955 ++
X_{10}										1.000	.874 ++	.880 ++	.983 ++
X_{11}											1.000	.991 ++	.843 ++
X_{12}												1.000	.855
Y	.679 ++	.386 ++	.860 ++	.882 ++	.833 ++	.724 ++	.325 ++	.898 ++	.955 ++	.983 ++	.843 ++	.855 ++	1.000

++ = highly significant at p = .01 (.354)

\+ = significant at p = .05 (.273)

x_{11} = the average weight for each clone at each locality from 1955 to 1958 in 100 kilograms/hectare (Tables 23 and 24).

x_{12} = the average volume for each clone at each locality from 1955 to 1958 in cubic meters/hectare.

The dependent variable shows highly significant correlations with all variables except one, 1959 height growth (x_7), in which case the correlation is just significant with an r of .325. The highest correlation exists as .983 between Y and x_{10}. As might be expected good correlations exists between x_5, the average height growth in 1957, and each of the remaining variables. Correlations in all cases are highly significant, with the highest .833 on Y, and the lowest .381 on x_2. In this case the correlation with clone number (x_2) has no meaning, although it is statistically significant.

The simple correlation coefficients were calculated separately for each locality and in Table 22 the highest and lowest correlations are shown for the different localities.

Table 22. The highest and lowest correlation coefficients of average height, weight and volume of different clones during 1955-1959.

Variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	Y
Csaszarret													
Highest Y	.341	.377	.755++	.726+	.957++	.627+	.784++	.800++	.928++	.956++	.558	.668+	1.0
Lowest X_7	.407	.421	.585	.414	.648+	.261	1.0	.499	.601	.567	.145	.293	.784++
Mersevat													
Highest Y	.048	.511	.763++	.945++	.945++	.818++	.752++	.921++	.931++	.979++	.963++	.965++	1.0
Lowest$_7$	.013	.058	.335	.546	.743++	.392	1.0	.504	.589	.601	.651+	.684+	.752++
Szigetvar													
Highest Y	.163	.635+	.881++	.754++	.801++	.668+	.476	.865++	.902++	.956++	.769++	.749++	1.0
Lowest$_7$	.046	.495	.207	.148	.187	.100	1.0	.190	.202	.195	.069	.142	.476
Klarafalva													
Highest Y	.332	.702+	.880++	.900++	.832++	.917++	.800++	.906++	.995++	.993++	.645+	.692+	1.0
Lowest X_5	.576	.776++	.496	.562	1.0	.733+	.590	.534	.852++	.841++	.464	.612+	.832++
Korostarcsa													
Highest Y	.027	.585	.886++	.716+	.837++	.786++	.700+	.892++	.932++	.990++	.538	.607+	1.0
Lowest X_7	.361	.532	.441	.243	.473	.772++	1.0	.383	.439	.592	.297	.391	.700+

++ highly significant at p = .01 (.735)
+ significant at p = .05 (.602)

The best correlation at each locality occurred with Y on the remaining variables, and the lowest correlation appeared at four out of five localities with X_7, the average height growth in 1959. At the fifth locality X_5, the average height in 1957, was least correlated with the other variables.

The results confirm the conclusions of the combined analysis. Average height growth for five years has the best correlation with yearly heights, volume and weight (1955-1958) in these basket-willow plantations. Among the individual years, the third (1957) has the best correlation with the other variables, followed by the first, second and fourth years. The lowest correlation occurred between the fifth-year height-growth and the other variables.

Weight Measurements

At the end of the growing season the sprouts were cut off at the soil surface and their weights were measured in kilograms. The sprouts were separated (Table 23 and Fig. 11) into three parts, those from the middle of the block, those from the surrounding part of the blocks near the vacant separation strips and those sprouts which were actually measured for height growth during the growing season.

Table 23. Weight measurements of different clones at Mersevat at the end of the first growing season.*

Clone number	Weight in kilogram of the sprouts from			Total
	middle	surrounding	measured	
	part of the block			
1.	4.60	5.76	1.52	11.88
2.	3.20	3.87	0.89	7.96
3.	2.15	3.24	0.81	6.20
4.	1.15	1.49	0.42	3.06
5.	1.14	1.26	0.32	2.72
6.	1.02	1.48	0.34	2.84
7.	1.00	1.58	0.44	3.02
8.	1.04	1.54	0.32	2.90
9.	0.71	1.04	0.26	2.01
10.	0.96	1.46	0.25	2.67
11.	1.18	2.14	0.49	3.81
Total	18.15	24.86	6.06	49.07

*Number of ramets: 88 in the middle, 62 in the surrounding and 20 in the measured part of the block.

From these measurements the weights of sprouts were calculated for the individual ramets (Table 24).

Table 24. Weight of sprouts on individual ramets at Mersevat at the end of the first growing season.

Clone number	Weight in gramm of the sprouts from			Total
	middle	surrounding	measured	
	part of the block			
1.	57.50 +	92.90	76.00 +	226.40
2.	40.00 +	62.41	44.50 +	146.91
3.	26.87 +	52.25	40.50 +	119.62
4.	14.37 +	24.03	21.00	59.40
5.	14.36	20.32	16.00	50.68
6.	12.75 +	23.87	17.00	53.62
7.	12.50 +	25.48	22.00	59.98
8.	13.00 +	24.84	16.00 +	53.84
9.	8.87	16.77	13.00	38.64
10.	12.00 +	23.54	12.50 +	48.04
11.	14.75 +	34.52	24.50 +	73.77
Total	226.97	400.93	303.00	930.90

+ differs significantly from the surrounding value.

Analysis of variance (Table 25) was carried out, and significant differences were found for clone and position.

Table 25. Analysis of variance for the weight of sprouts on the individual ramet.

Source of Variation	Degrees of Freedom	Net Sum Squares	Mean Sum Squares	Variance Ratio (F)
Clone	10	11,026.7	1,102.6	48.31 ++
Position	2	1,382.8	691.4	30.29 ++
Residual	20	456.5	22.8	
Total	32	12,866.0		

++ highly significant at p = .01

$jsd_C = 4.25$ $jsd_p = 8.15$

Assuming that the edge position is control, the weight of the shoots of the individual ramets in the middle part differs significantly in classes No. 1, 2, 3, 4, 6, 7, 8, 10, and 11. No significant difference exists for No. 5 and 9 clones. This means that the most of the clones are adapted to express more variation when the environment is favorable. Only No. 5 and No. 9 clones are more stable, i.e. less effected by the environment. This may mean that No. 5 and No. 9 clones have an above average heritability value for stability of growth in that particular environment.

The difference between the weight of the ramets in the surround and the measured part is significant for clones 1, 2, 3, 8, 10 and 11. No significant difference exists for clones 4, 5, 6, 7, and 9. Part of the reason for this is that the group of twenty measured ramets included four ramets which were in the surrounding strip, and the weight of these shoots may have raised the weight of the measured ramets. This suggests that clones 1, 2, 3, 8, 10 and 11 are affected very much by environment. Their heritability value may be less than No. 4, 5, 6, 7 and 9 clones. However, since capacity to respond favourably to more favourable environment may also be considered an inherited factor, the results of this analysis may simply mean that clones 4, 5, 6, 7 and 9 are more stable in growth characteristics.

The coefficient of variation or relative standard deviation confirms this result (Tables 12-16). The coefficient is large when the standard deviation is large or when the mean is small. The coefficient of variation is the largest at each locality for No. 9 clone. The average yearly height growth (Table 18) also follows more or less this pattern ranking of which is based only on one year's observation at one locality.

Other Variables under Study in Hungary

(a) Meteorological Observations

At the time when the plantation was carried out, a small meteorological station was set up to record the microclimatic differences at each locality, close to the randomized block. Daily maximum-minimum and average temperature in degrees Centigrade and precipitation in millimeters were recorded. These data were compared and completed with the data of the nearest suitable meteorological station.

(b) Form of Sprouts

Ten sprouts from each clone were sent to the University of Sopron from Szigetvar in November 1955 to study the form of sprouts. One 10-millimeter section was cut from the center of each 30 cm. portion and the bark-wood-pith diameter was measured. Examples of these observations are shown in Table 4.

(c) Cellulose Content

Forests comprise only 13.5 percent of the total land area of Hungary. Conifers occupy only 5.4 percent of the total forest. One third of the coniferous stands are spruce, the most valuable wood for the manufacture of pulp. The yearly paper requirements of Hungary are about 80,000 tons of which around 75 percent is imported. All materials, even reeds or straw, which have considerable amounts of cellulose are important. For basket making, usually only the thinner sprouts, less than 15 millimeters in diameter, are suitable. The thicker ones are partly used as sticks to strengthen the basket. Larger sticks combined with the insect-attacked and hail-damaged sprouts comprise 20-25 percent of the yearly production. Of the yearly production of 8,240 tons in 1955, about 1,500-2,000 tons were not strictly suitable for basket making. To evaluate use of this part of the production for pulp the cellulose contents of the 11 different clones were determined on laboratory scale by using Scharrer's method (Table 26).

Table 26. Cellulose content and average height growth of different clones at Szigetvar.

Clone number	Cellulose content per cent	Average height growth centimeter
1.	47	206
2.	46	213
3.	42	221
4.	47	167
5.	44	165
6.	44	186
7.	47	178
8.	43	157
9.	49	154
10.	45	170

r significant at p = .05 (.632)

Although the highest cellulose content (49%) occurred in Clone 9, which has the lowest height growth (154 cm.) and the lowest cellulose content (42%) appeared in Clone 3 which has the largest average height (213 cm.) growth, the correlation coefficient (r = 0.041) does not show any degree of association between the two variables.

Brundl (1957) mentioned that large-scale experiment in two industries proved the usability of willow for pulp; using the sulphate process the cooking time was shorter for willow shoots than for poplar, but further studies have not been undertaken.

(d) Spacing Experiment

In order to determine the most effective spacing for basket-willow cultivation, an experiment was set up at Szigetvar in 1955. Only Clone 10 was planted, in a four by four Latin square design, and the spacings of 50 x 10, 50 x 20, 50 x 30 and 80 x 10 centimeters were used. The size of the block was 10 by 10 meters.

(e) Fertilizing Experiment

In a study of the effect of fertilizers, nitrogen, phosphorous and potassium were applied in four different levels at Szigetvar in 1955. A four by four Latin square design was used with Clone 10 at a spacing of 50 by 30 centimeters. The size of the block was 10 by 10 meters.

CONCLUSIONS

The principal problem found in the improvement program is to determine the best clones for basket making. The best clones are defined as those which have th most rapid height growth rate and volume production.

Whether selecting or hybridizing, the improver must know the characteristics and the extent of the currently used populations. An inventory of the native and exotic Salix clones was carried out systematically as a prerequisite to obtaining the material necessary for evaluating the different clones within the country. In general forest tree improvement, the biological limitations, the high cost and long wait for results, all tend to reduce the fact-finding efficiency of this traditional approach. In the basket willow improvement work, the end product is the one year old shoot and in this case the limitation of the long waiting time is reduced considerably. The high cost during the hybridization may be reduced by utilizing the detached branches. Because of its fast growing characteristics, the one year rotation, and its relatively easy hybridization, Pauley called Populus "the guinea pig of forest tree breeding". Willow, which possesses these characteristics to an even greater degree, may be called "the fruitfly of forest tree breeding".

From this very incomplete survey the following conclusions may be deduced:

1. On the one year old willow shoots foliar dimorphism exists.
2. The late leaf characteristics are distinguishable on many of the described clones, but in a few cases the identification is extremely difficult.
3. The vegetative characteristics combined with the flower characteristics are the most useful method to identify the different clones.
4. The development of sexual organs on detached branches in water culture makes it possible to do the cross pollination in greenhouse conditions.

5. The seed maturation starts four weeks after pollination and ends eight weeks after pollination.

6. The germination of Salix seed is very rapid and starts after the second hour. A "standing up" process is necessary to get a viable seedling. This process takes two days in certain environments.

7. Early planting is necessary to obtain good rooting of Salix.

8. Compatibility in bud grafting appears to be a clonal characteristic.

9. Number 1 clone produced 32 percent longer shoots than the most commonly used number 10 clone.

10. Locality Szigetvar showed the highest yearly height growth, but the other two fast growing localities are not significantly different from Szigetvar. Csaszarret and Mersevat localities need four years to establish a uniform height growth, but on the other three localities the height growth is uniform after the second year.

11. Average height growth for five years has the best correlation with yearly height, volume and weight. The same high correlations exist between the third year and the remaining variables.

12. Numbers 4, 5, 6, 7 and 9 clones are more stable in growth characteristics and they are less affected by environment than the remaining clones.

Bibliography

For convenience it has been considered desirable to include here references to various scattered papers dealing more or less directly with the subject of the thesis and generally related to the Salicaceae family.

The English, French, German and Latin articles have the original titles. The Polish, Russian, Serbian and Spanish articles were collected from the Centralized Title Service and they are in English. The Hungarian was freely translated.

Abbreviation of Journal Titles

A.K. = A Kert

B.K. = Botanikai Kozlemenyek

B.L. = Boraszati Lapok

Bu. = Buvar

B.Z. = Botanische Zentralblatt

E. = Az Erdo

E.K. = Erdeszeti Kutatasok

E.k. = Erdeszeti Kiserletek

Ell. = Ellenor

E.L. = Erdeszeti Lapok

E.T. = Elet es Tudomany

E.U. = Erdeszeti Ujsag

F.E. = Foldmivelesi Erdekeink

F.K. = Foldrajzi Kozlemenyek

G.T. = Gazdasagi Tanacsado

H. = Herba

H.M. = Hasznos Mulattato

K. = Koztelek

Kg. = Kerteszgazda

K.L. = Kerteszeti Lapok

K.Sz. = Kerteszeti Szemle

Kt. = Kerteszet

M.B.L. = Magyar Botanikai Lapok

M.D.D.G. = Mitteilungen der Deutschen Dendrologischen Gesellschaft

M.e. = Magyar Erdesz

M.E. = Magyar Erdo

M.K. = Magyar Kertesz

M.m. = Magyar Meh

M.M. = Magyar Mukertesz

M.N. = Magyarorszag es a Nagyvilag

N.K. = Nep Kertesze

O.B.Z. = Osterreichische Botanische Zeitschrift

O.K.T.K. = Orszagos Kozepiskolai Tanaregylet Kozlonye

P.N.L. = Pallas Nagy Lexikona

T. = Termeszet

T.B. = Termeszetbarat

T.F. = Termeszetrajzi Fuzetek

T.G. = Tiszantuli Gazdak

T.Gy. = Tudomanyos Gyujtemeny

T.K. = Termeszettudomanyi Kozlony

V.U. = Vasarnapi Ujsag

Abbreviations Indicating Original Language

(e) English

(f) French

(g) German

(h) Hungarian

(l) Latin

(p) Polish

(r) Russian

(s) Spanish

(serb) Serbian

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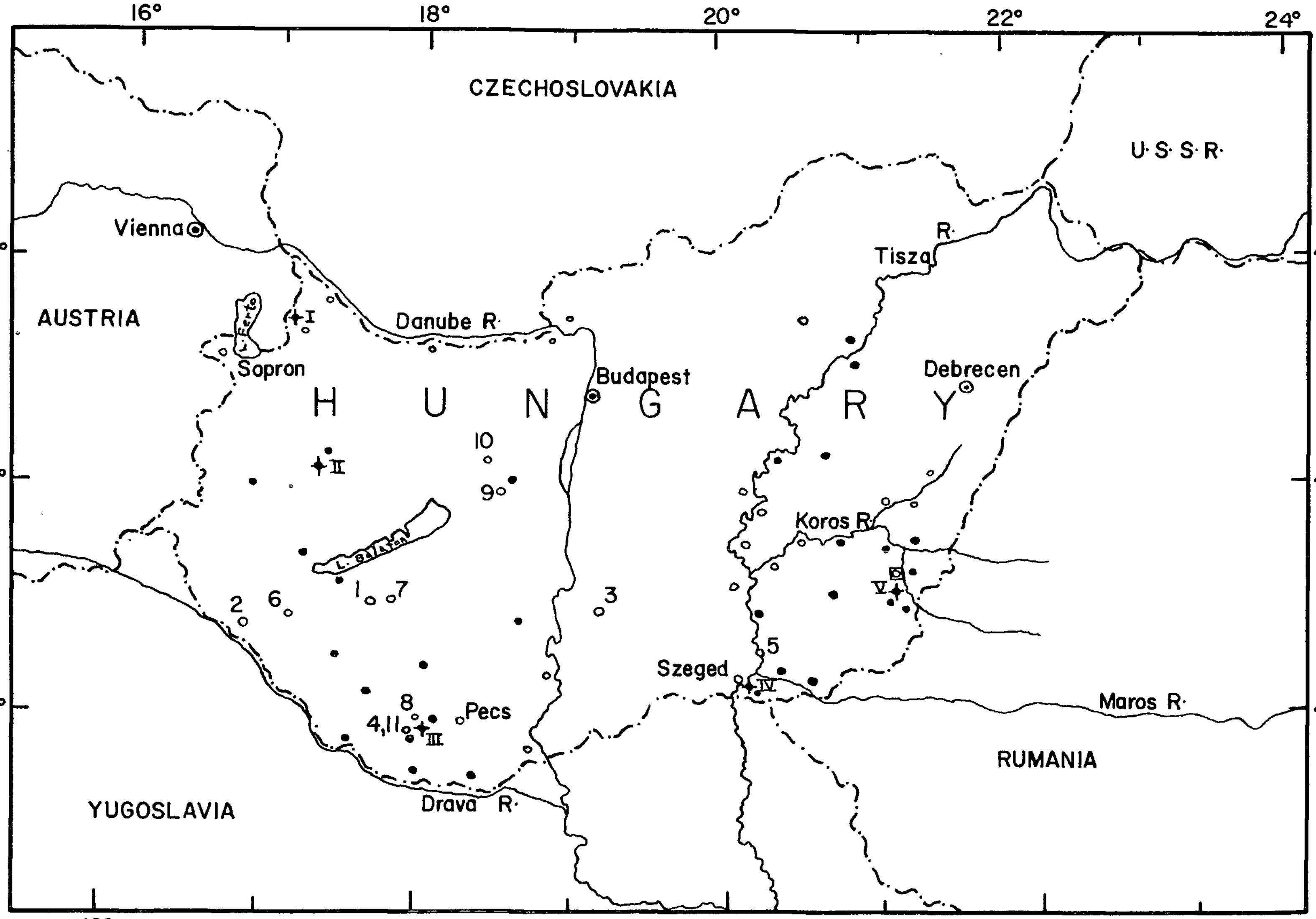


Fig. 1 Range of basket willow growing in Hungary

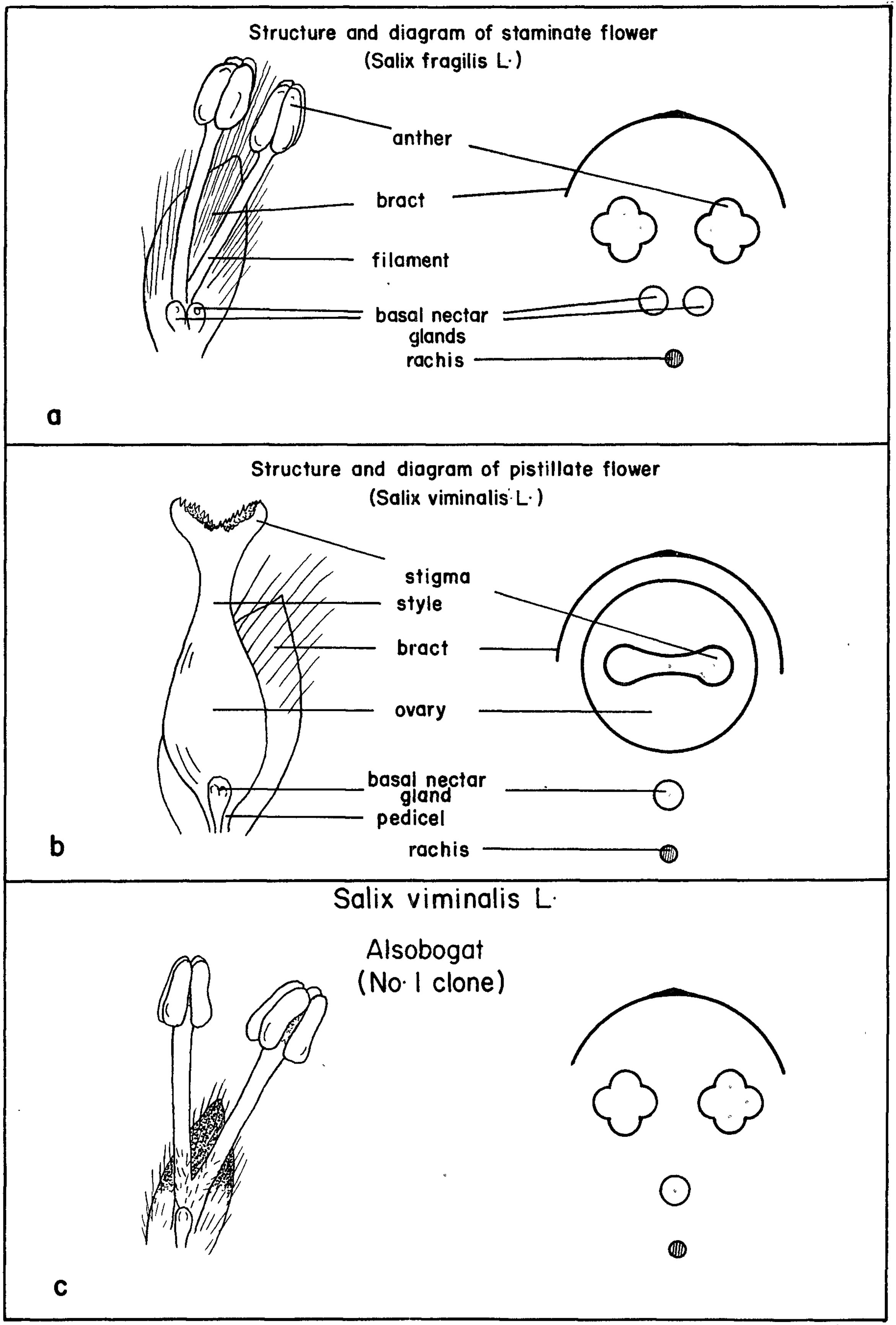
- • Localities in which basket willows are grown commercially
- o Localities in which basket willows are grown successfully
- ⊠ Locality in which baskets are made

1—11 Localities from which the clones were collected for experiment

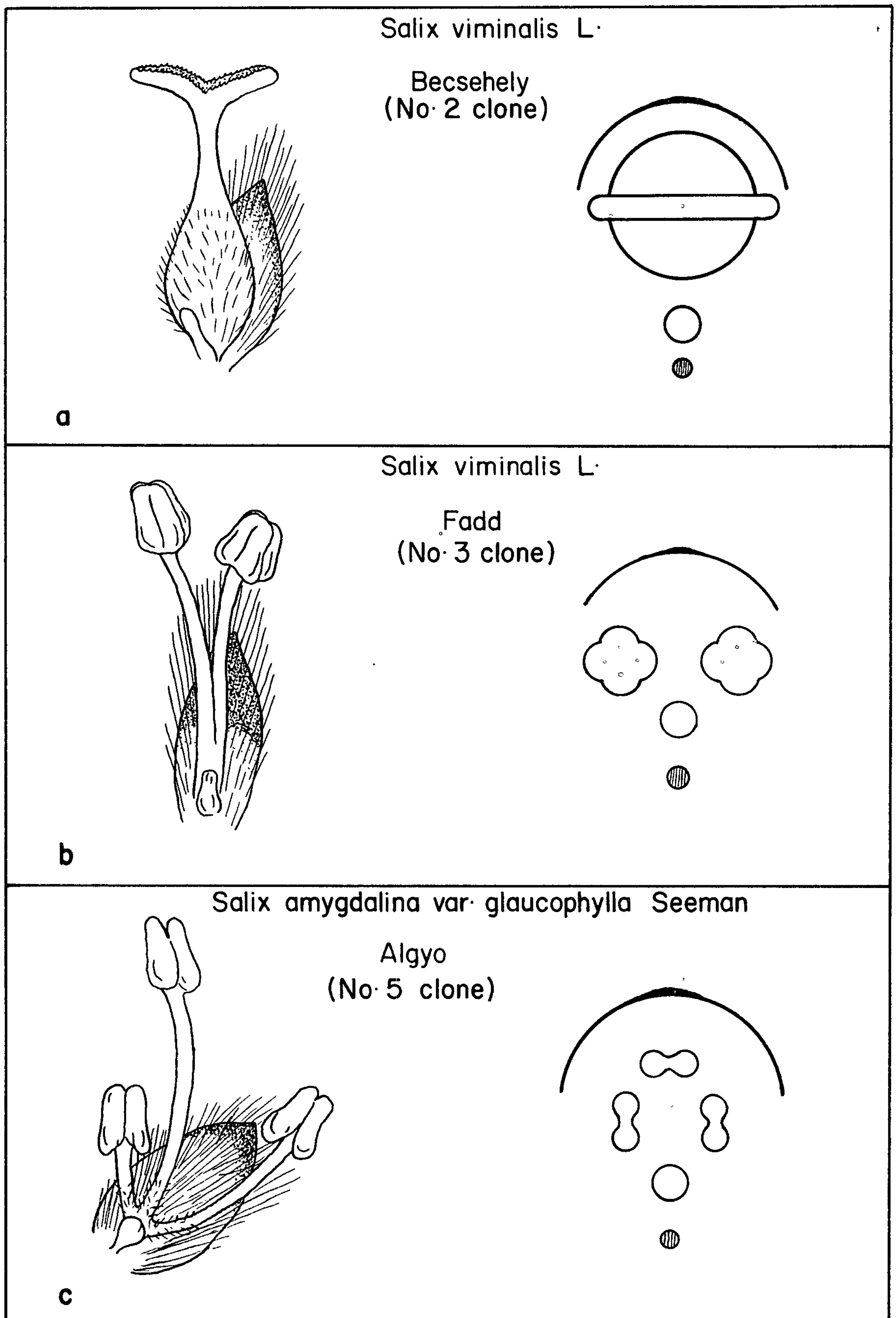
I—V Localities in which experimental plots were set up

0 25 50 75 100
miles

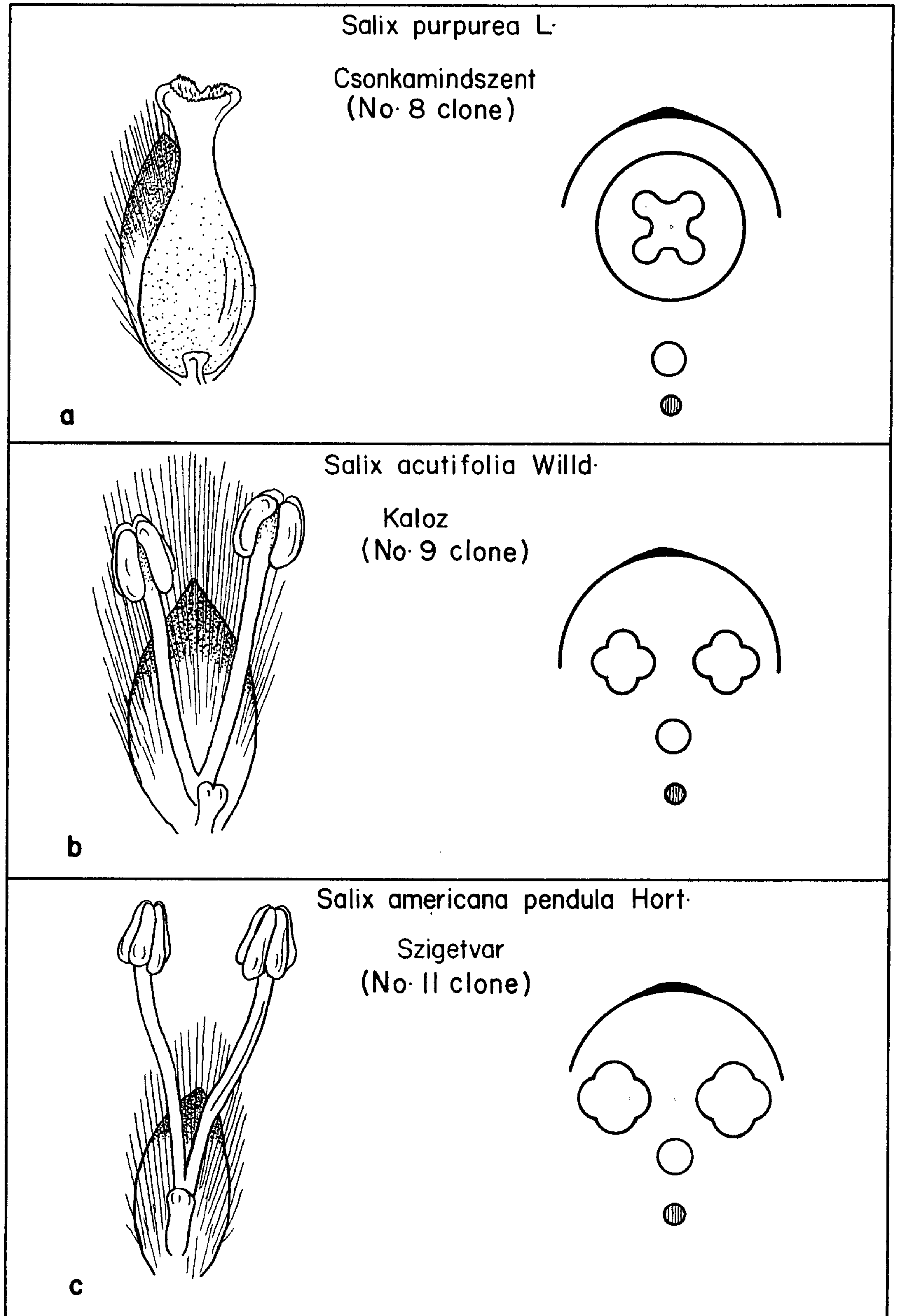
• ÷ 100 hectares ÷ 2·47 acres



Fig·2 Structure and diagram of a/staminate flower, b/pistillate flower, c/Salix viminalis L· (No·I clone)



Fig· 3 Structure and diagram of a/Salix viminalis L· (No· 2 clone), b/Salix viminalis L· (No· 3 clone), c/Salix amygdalina var· glaucophylla Seeman (No· 5 clone)



Fig· 4 Structure and diagram of a/ Salix purpurea L· (No· 8 clone), b/ Salix acutifolia Willd· (No· 9 clone), c/ Salix americana pendula Hort· (No· 11 clone)

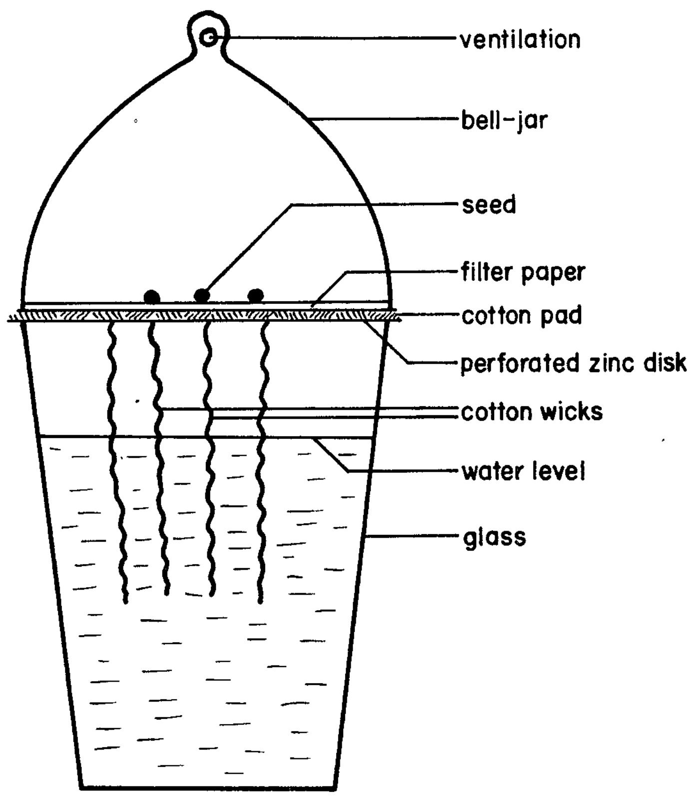
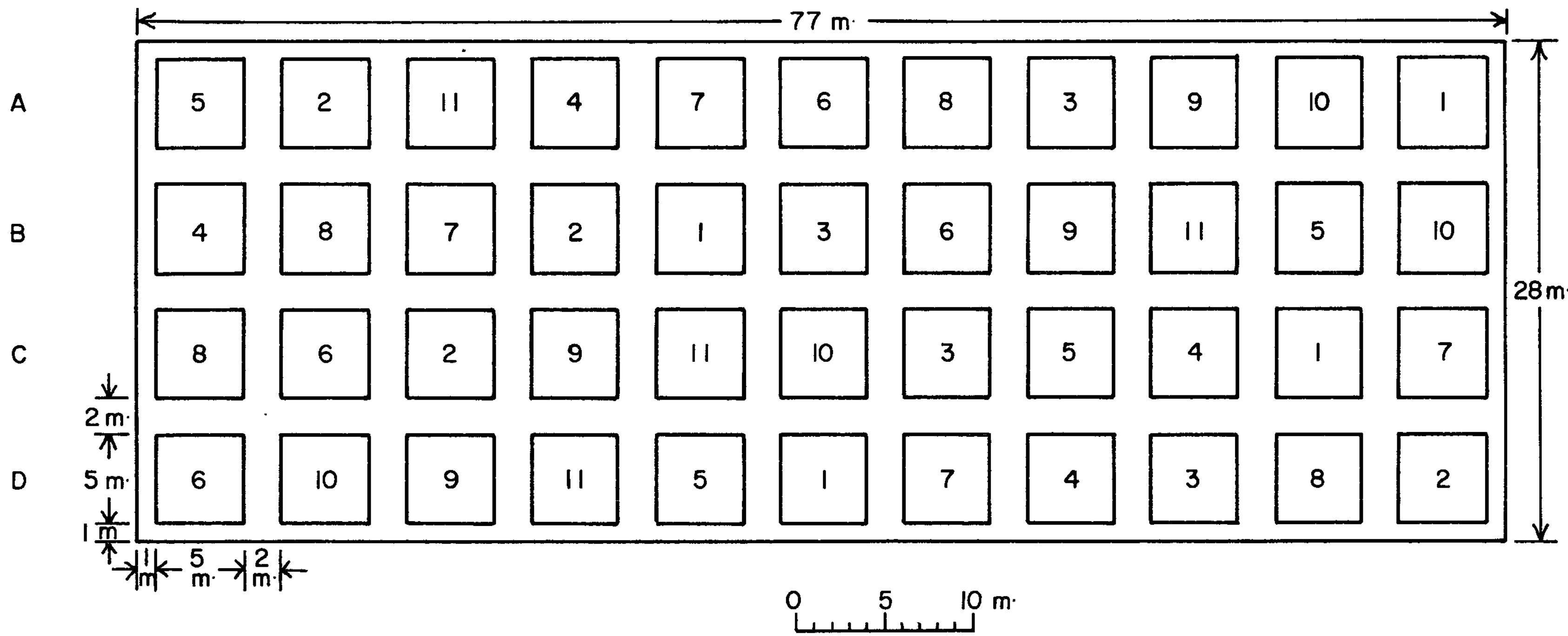


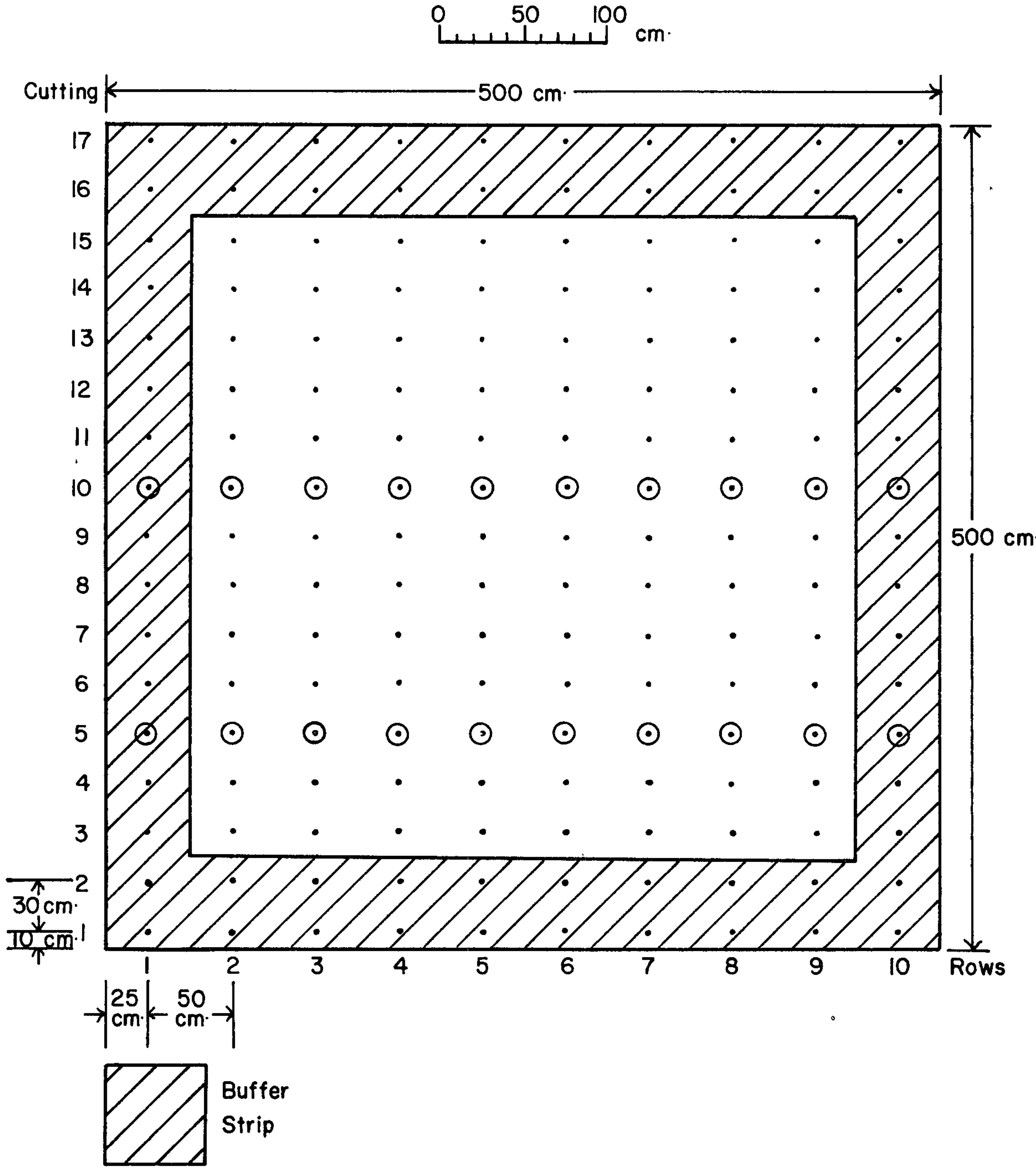
Fig. 8 Individual Jacobson Germinator



I — II Different Clones

A — D Replications

Fig· 10 Plantation layout of randomized block design at the five different localities



Fig· 11 Spacing arrangement inside a block

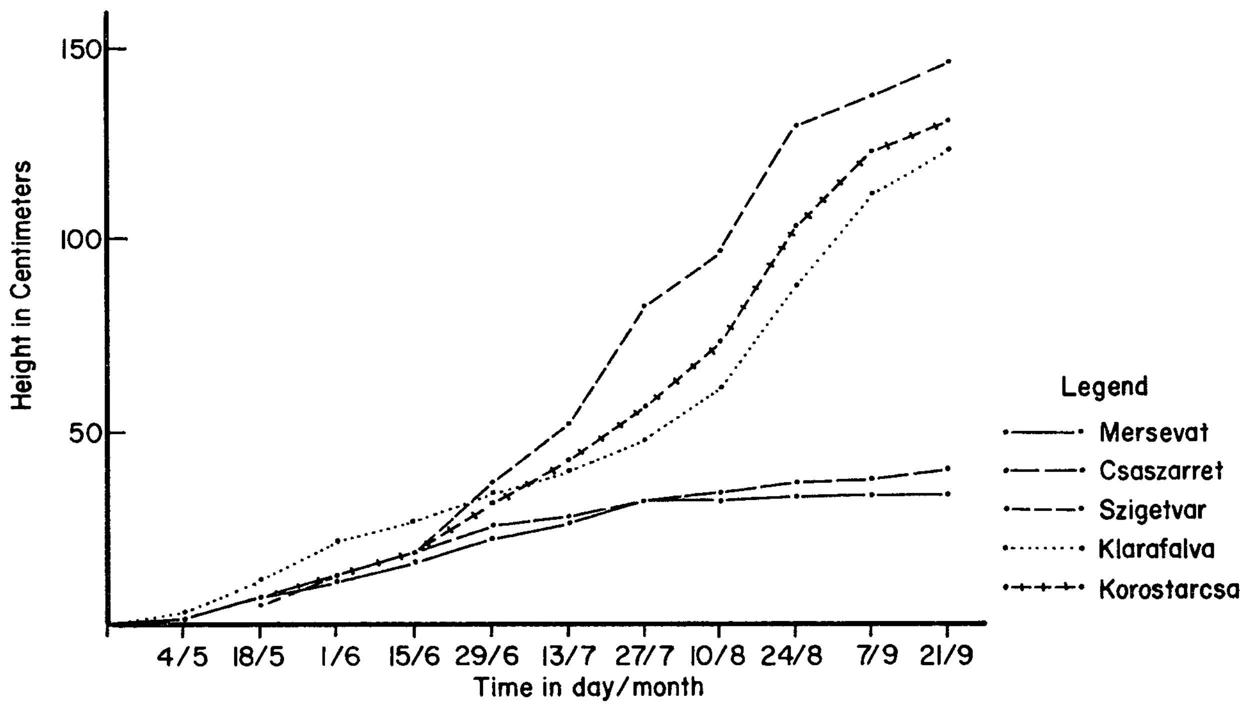


Fig. 12 Height growth of No. 10 clone at the different localities in 1955

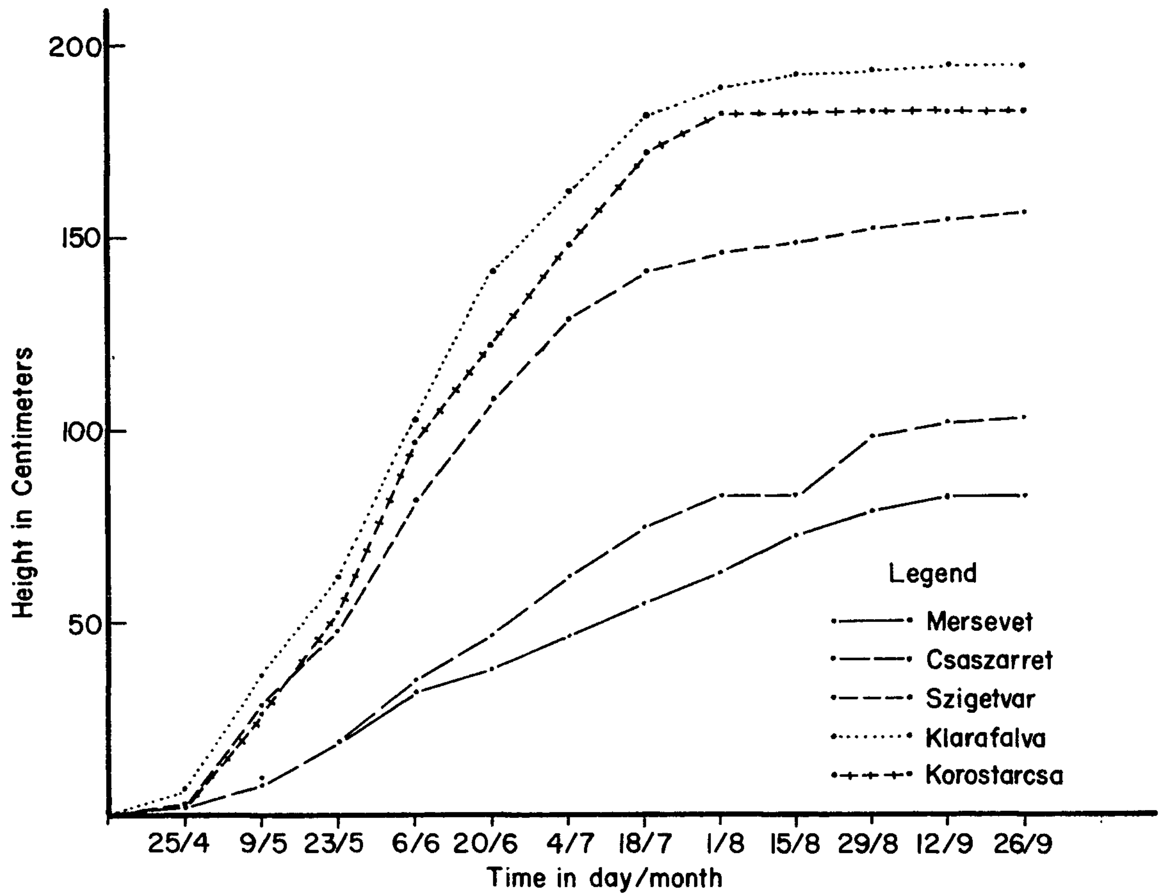


Fig. 13 Height growth of No. 10 clone at the different localities in 1956

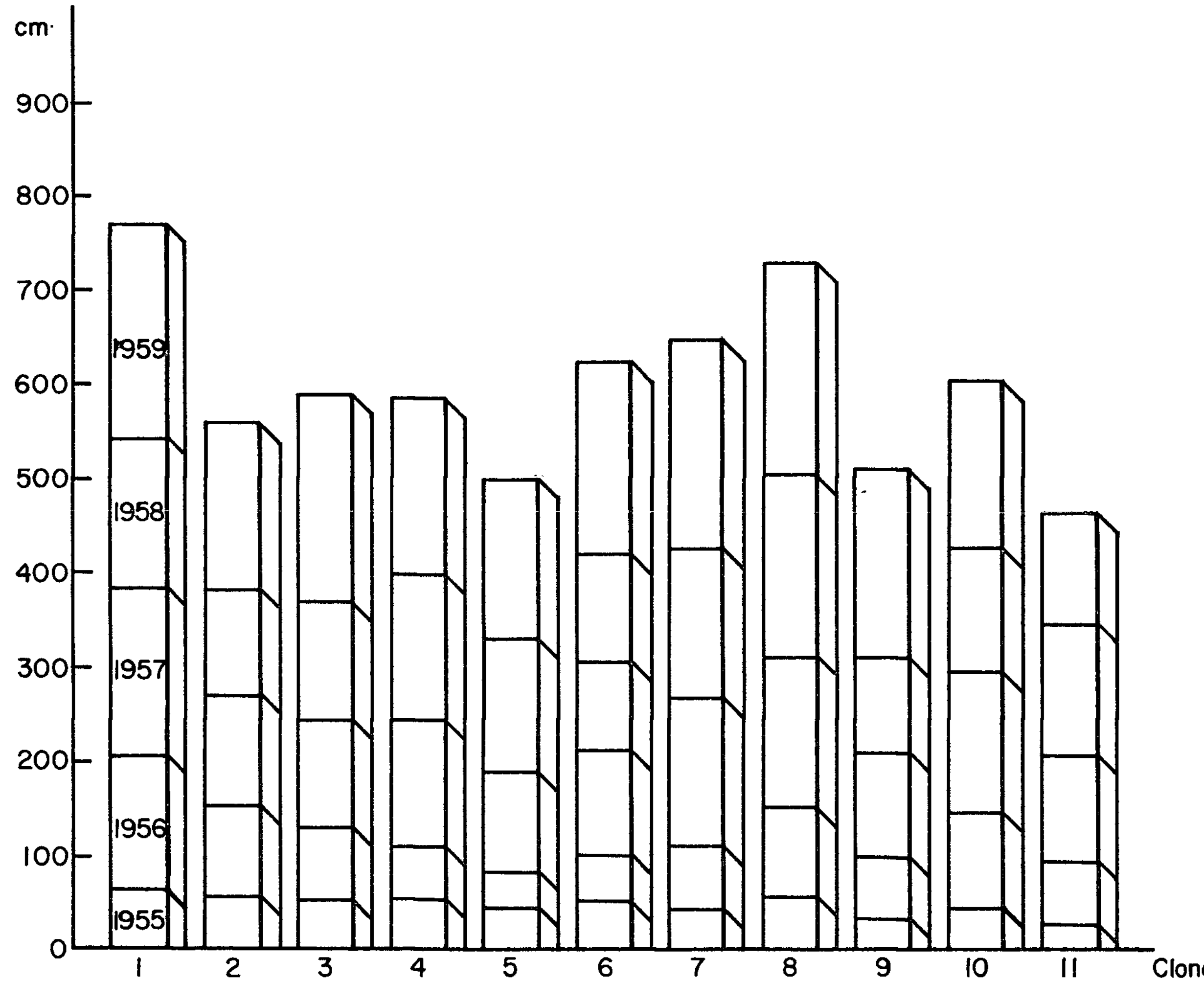


Fig. 14 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Csaszarret

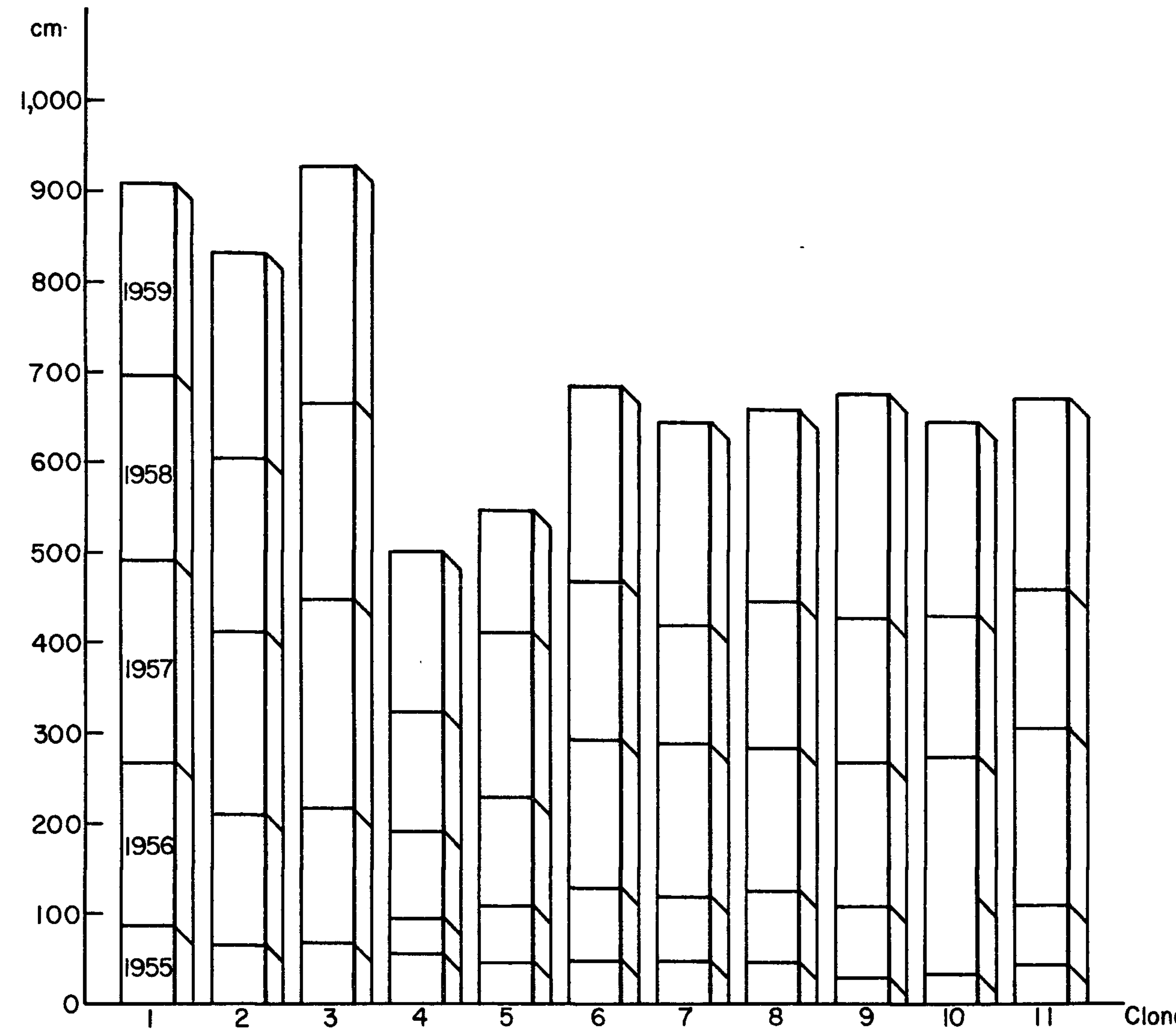
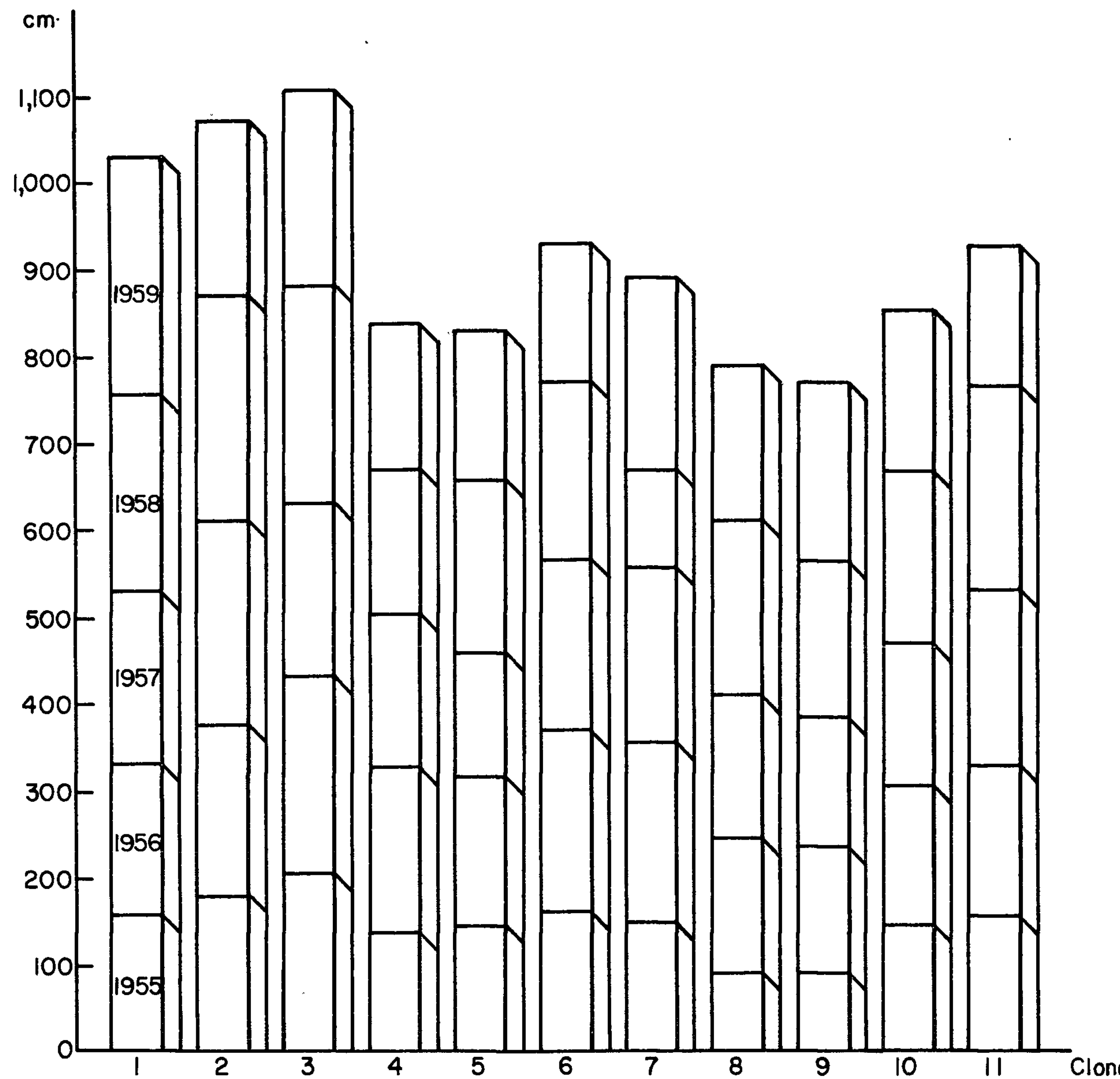


Fig. 15 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Mersevat



Fig· 16 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Szigetvar

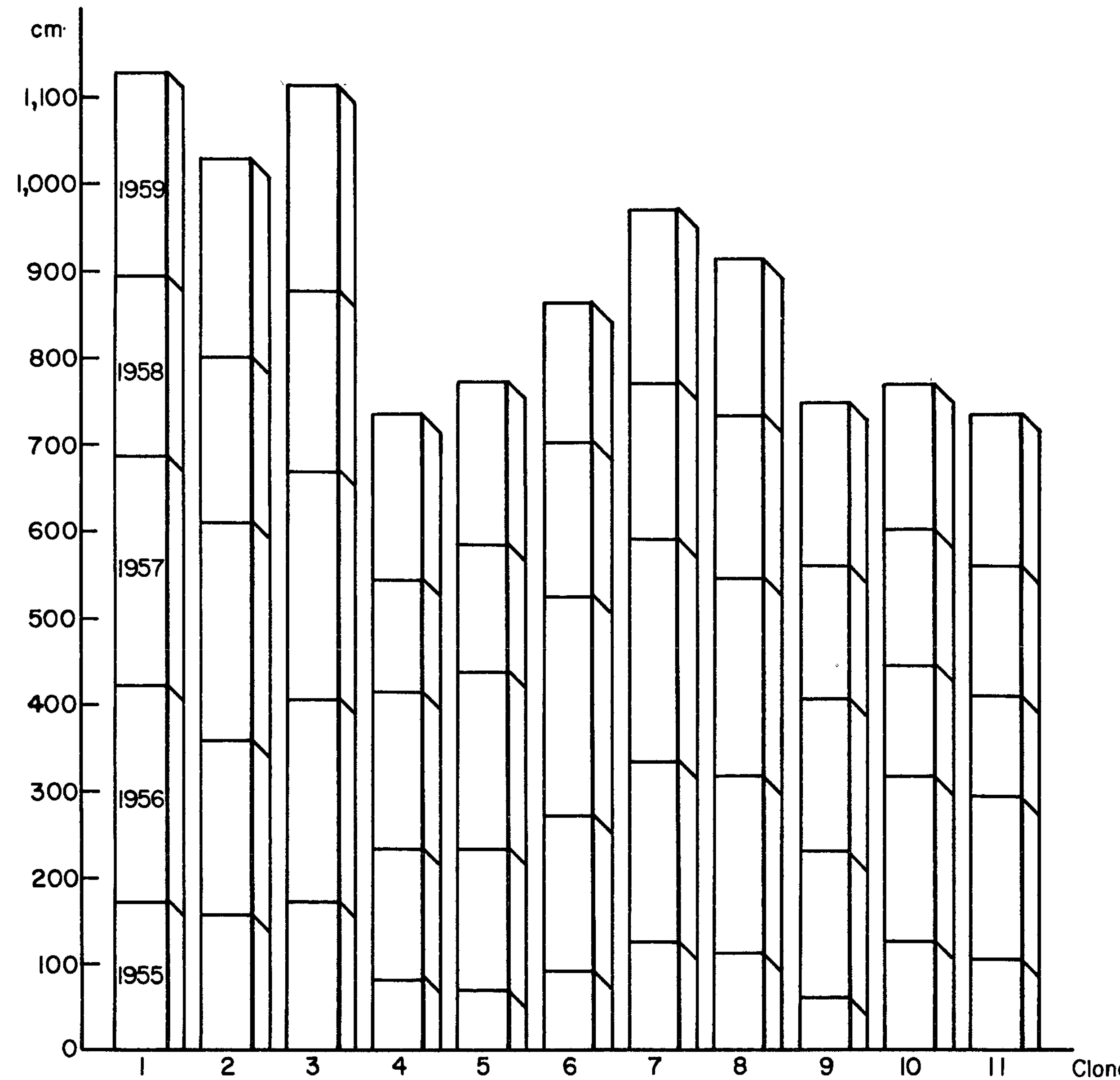


Fig. 17 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Klarafalva

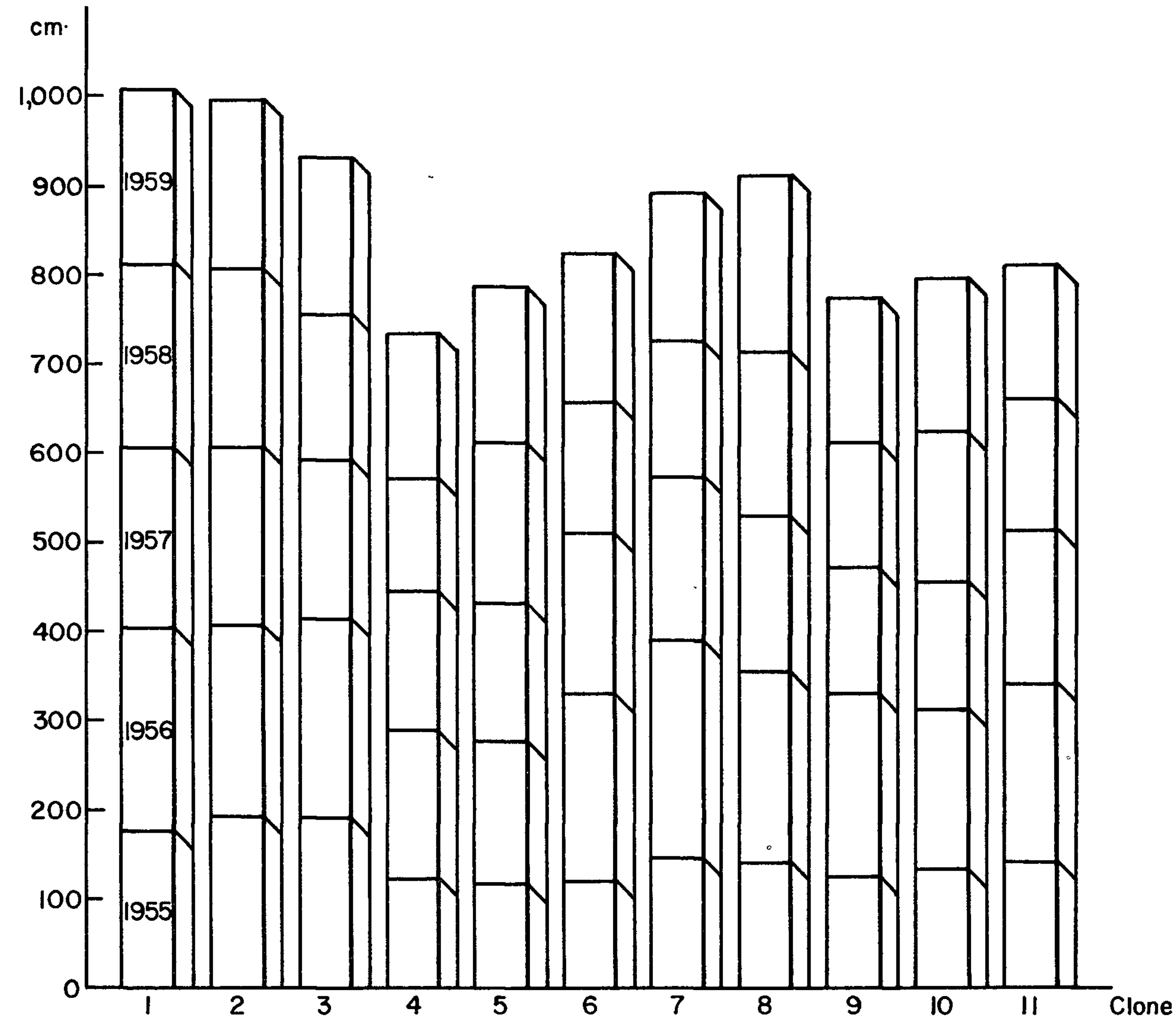
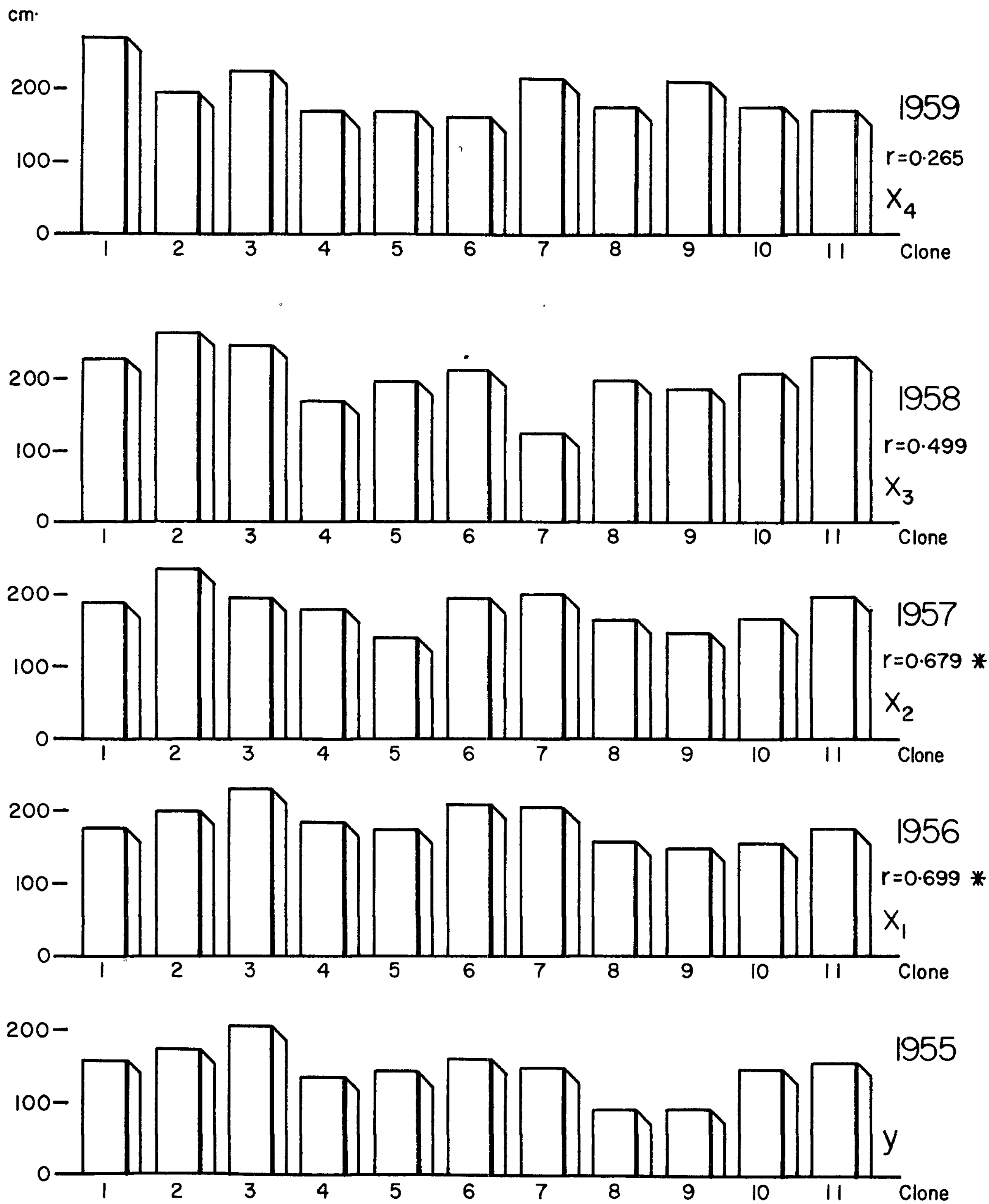


Fig. 18 Cumulative frequency bars of height growth of different clones from 1955 to 1959 at Korostarcsa



Fig· 19 **Height growth of different clones from 1955 to 1959 at Szigetvar (r = 0·576 at 5 % level)**