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WORKSHOP REPORT

Graz and Casale Monferrato
September 19-25, 1990

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SHORT ROTATION FORESTRY IN ITALY: PAST EXPERIENCE AND PRESENT SITUATION

by

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ABSTRACT

A review of the results of the trials carried out in Italy dealing with SRIC plantation for the production of pulpwood size material, for chipboard and for fuel-wood has been reported here.

SRIC plantations have very high production capacity but demand intensive culture practice (weed control, pest and disease control, fertilization, irrigation, etc.), and clones particularly selected for fast juvenile growth, good résprouting ability, tolerance to narrow spacing and resistance to the main biotic adversities.

Twenty poplar clones out of 60 tested had very high yield or, in any case, significantly higher than 'I 214'. Very promising results have been obtained also with two willow clones.

The breeding programmes which are being carried out at present will certainly offer real possibilities to obtain, in the near future, new clones suitable for commercial SRIC plantations.

In fertile soil the yield of SRIC plantations range from 10 to 20 ODT/ha/year with 5-6 year rotation and spacing of 1,000-2,500 plants/ha.

Cultivation costs of SRIC plantations are very high and the price of wood material produced is very low, so the economic results obtained by a poplar plantation with a production of 15 ODT/ha/year are highly negative.

If a production of 20 ODT/ha/year turns out to be possible also on a large scale and not only in experimental tests, SRIC plantation would become interesting also from the economic point of view and could guarantee an adequate income to the planter.

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SHORT ROTATION FORESTRY IN ITALY: PAST EXPERIENCE AND PRESENT SITUATION

1. INTRODUCTION

1.1 General considerations

The increase in the demand for wooden raw material for the production of pulpwood and chipboard panels together with the more general problem of the energy crisis have pushed the researchers to examine in details the aspects of density and rotation of poplar-plantations to find cultivation techniques suitable for dense plantations (1,000 to 2,500 plants per hectar approx.) with very short rotations (5-6 years) to regenerate by coppicing for the production of pulpwood size material, for chipboard and for fuel-wood, as a renewable source of energy.

The woody biomass which can be obtained from these plantations is increasing, within certain limits, as the actual number of plants per surface unit increases (density).

However, it is necessary to stress the fact that, by increasing the density, the diameters of the tree trunks decrease, as well as the possible uses of the material produced. In good sites, with the above mentioned spacings and rotations, the trees obtained vary in size in fairly large ranges: diameter at breast height 10 to 20 cm, total height 15 to 20 m, fresh weight (trunk and branches) 100 to 200 kg each.

The logs with a diameter over 8-10 cm are suitable for pulpwood and the smaller ones for chipboards or as an energy source. On the other hand the commercial value decreases sharply from the first to the second assortment. It is therefore evident that should the density increase any further with the intent of increasing the yield, trunks of limited diameter would be produced, even if in shorter rotations, therefore suitable only for chipping or as fuel wood.

In view of the economic situation in Italy we believe it would be wiser to choose cultural models also able to ensure the production of pulpwood size material for which an established market is active.

These plantations have very high production capacities but demand intensive culture practices.

1.2 Production capacities

As already mentioned before, poplar-plantations with high density and short rotations give high production results. After coppicing, that is in the rotations following the first one, the production often increases because the stumps have a well-developed root system. The combination of high density, e.g. 1,000 plants/ha, with regeneration via coppicing permits to obtain in suitable sites and with rotations of 5 to 6 years a production of 10 to 20 tons/ha/year of oven-dry woody biomass.

Furthermore, the use of clones for monoclonal plantations permits to obtain lots of homogeneous material as to both the size of the trees and the physical and technological features of the wood produced. This aspect is very important for pulpwood industry material and is not negligible for chipboards (just think for instance of the percentage of bark, which varies according to the trunk diameter), while it is not so important for fuel wood.

1.3 Intensive culture practices

To obtain a production that meets the quality and quantity required by the industry it is necessary to cultivate poplar plantations by intensive culture practices, comparable with the ones adopted for the main agricultural crops, in all cultivation phases, namely:

- use of selected clones,
- planting stock selection and production,
- site selection and preparation,
- tending.

1.3.1 Use of selected clones

Short rotation intensive culture forestry implies the use of selected clones, particularly for:

- a very fast juvenile growth aiming to large production in short rotations;
- the tolerance to narrow spacing, to exploit the fertility of the soil as much as possible during the whole rotation;
- good sprouting abilities over several successive coppice rotations avoiding to replant, which is a very costly operation;
- resistance against diseases, particularly of leaves, such as *Melampsora* spp. and *Marssonina brunnea* and against insects, particularly *Phloeomyzus passerinii* in that the diffusion of these parasites is favoured by the particular micro-climatic conditions of very dense plantations;
- resistance to herbicides used for the control-weed of which, particularly during the first years after plantation and after coppicing, cause a strong competition for water and nutrients with the young plants or coppice shoots.

1.3.2 Planting stock selection

Well known among the materials used for SRIC forestry are cuttings, one-year-old plants with root or rootless, produced in common nurseries, and one-year-old unrooted shoots from coppice nurseries. The two-year-old plants are decidedly less suitable for this kind of plantation, especially in view of their high production costs and of the considerable planting expenses.

The care needed for the production, preparation and preservation of unrooted cutting and of plants (or shoots) is the same to be devoted to the material for nurseries and conventional poplar plantations respectively.

1.3.3 Site selection and preparation

To evaluate the site it is necessary to consider soil texture, depth, availability of water and nutrients and pH reaction.

For SRIC it is necessary to select a deep, medium texture soil with a high fertility and pH in the range of 5.5 to 7.5. The soil should be well drained and have good water reserves (water table accessible to roots) or be easy to irrigate during the growing season.

Cultivated land and bottom land are suitable, while easily flooded lands are to be avoided because of the damage water could cause to the culture the first year after planting or coppicing.

Cultivated lands are normally cleared and reasonably well drained and for their preparation they need only to be ploughed at the end of summer or even just before planting, physical soil conditions and weather permitting.

Fertilizing should correct any possible deficiencies of nutrients, almost always concerning nitrogen, but often also phosphorus and less frequently potassium. These last two nutrients are to be spread before ploughing, followed by disk harrowing to prevent weeds from growing again and to obtain a well-aired and finely crumbled soil, to improve the development of roots from cuttings or plants.

1.3.4 Planting

In the Po Valley the most suitable season to plant cuttings is mid February to March, but this period can be extended of 2-3 more weeks if the material is stocked in cold storage at a temperature of 2 to 3°C. To plant one-year-old poplars both the period from end of November to end of December and that from mid February to mid March are suitable to plant clones with a good rooting ability, while the latter is to be preferred for clones with any rooting difficulties (e.g. P. deltoides).

The one-year-old plants are inserted into holes 60 to 80 cm deep and 15 to 20 cm in diameter, digged by an auger driven by a tractor.

The cuttings of normal length (20 to 25 cm) are planted manually or with the machines used to plant cuttings in nurseries while the longest ones (50 cm) are inserted into holes digged by an auger driven by the tractor.

1.3 5 Tending

Weed control is very important. It includes herbicides and mechanical cultivation practices, using conventional cultivating equipment.

As to coppice with 5 to 6 years rotations, the most critical moments for weed control are the first and the second year after planting and after coppicing. The years after, a thicker canopy can shade out any serious competition from weeds.

Herbicides are used in pre-emergency, right after planting cuttings but before flushing.

For pre-emergency weeding good results are obtained with products made from trifularin+linuron (e.g. Neminfest, Siplen) against dicotyledons, adding other products made of alachlor (e.g. Lasso) or metolachlor (e.g. Dual) against graminaceous plants.

The herbicide is usually active 30 to 40 days. Afterwards, weed control is obtained by mechanical cultivation methods.

In the plantations established with one-year-old plants or shoots only a small area around the tree is treated where a normal harrow cannot manage. With chemical treatment good results have been obtained as follows:

- annual weeds have been treated with products containing paraquat (e.g. Gramoxone) or paraquat+MCPA (e.g. Erbisec) mixed with other products based on pendimethalin+linuron (e.g. Panter);
- in case of perennial and mixed species a first treatment has been administered based on paraquat+MCPA when weeds were growing and a second treatment containing:
  - 2.4D or MCPA in little volatile formulae (e.g. Weedone emulsamine) mixed with white oil in those soils where there are mainly wide-leaved weeds maybe adding Clopyralid (e.g. Cirtoxin) if there is any Cirsium;

. Dalapon+Oxyfluorfen (e.g. Multigoal) in case of perennial graminaceous plants;

. Glyfosate (e.g. Roundup) for an almost total and rather long lasting cleaning, particularly with largely diffused Artemisia, Solidago or anyway other weeds which are hard to control if the other herbicides are used;

- in case of infesting bushes (Rubus, Amorpha, Robinia, Clematis, etc.) a suspension of fosamine ammonium (e.g. Krenite) can be sprayed at the end of August.

As a precaution it is recommended to avoid any contact of the sprayed treatment with the green parts of the plant, particularly when hormon products are being used (such as Weedone, Erbisec, Cirtoxin and Roundup in particular). As far as doses are concerned, see ANSELMI (1981).

To destroy weeds between the rows disk harrows are used two or three times during the growing season according to the extent of the infestation and of the ability of weeds to recover.

Chemical weeding should be limited to the first two years and to a narrow stripe along the row, while mechanical weeding should be extended to all years and to all areas between rows.

During the second half of the first rotation and particularly during the rotations following coppicing it would be useful to compare the usual harrowing with mowing, a much simpler operation. A thick layer of leaves and other vegetable material on the ground should make it harder for weeds to sprout thus contributing to reduce the problem of weed control.

Other important aspects concern both making sure that the above mentioned herbicides are suitable for the newly selected clones and finding new chemical products in order to widen the range of products suitable for weeding in SRIC.

This Institute has recently ascertained, for example, fusilade (fluazifop-butyl), commonly used for weeding the cultures of a few poplar clones ('I 214' in particular), is decidedly toxic for the clone 'Lux' (P. deltoides). These data are extremely interesting and prove that no generalization can be made for herbicides, but constant tests are necessary before using them on a large scale.

Another practice which needs particular care is fertilizing. Apart from the basic fertilization before planting, a maintenance fertilization is useful to give the soil back the elements contained in the biomass removed from the field. In can be made once a year or every two years spreading about 50 to 60 kg/ha/year of N_2, P_2O_5 and K_2O. Soils with a low nitrogen percentage can be spread with larger quantities of this elements.

As far as irrigation is concerned, in the Po Valley there are usually long dry periods in July and August when, if the water table is not within root distance, it is necessary to irrigate the plantation with a total volume of about 150 mm water distributed twice or three times. How to distribute water will obviously depend on the site, on the available equipment and sources.

Particular attention is devoted to pesticide treatments particularly against bark and wood boring insects. The strategies for pest and disease control are the subject of chapter 3.2

2. TRIALS IN OUR ENVIRONMENT

This part of the report describes the trials carried out in Italy until now about clonal comparisons (poplar and willow clones), comparisons of different planting stocks, different spacings, researches about coppicing effect on the stump and finally drafting of volume and weight tables.

While the clonal comparisons are carried out using 60 poplar clones and two willow clones all the other trials have been made exclusively with 'I 214' which is the most common cultivated clone in Italy.

2.1 Clonal comparisons

2.1.1 Comparisons between poplar clones

In Italy the genetic improvement of poplars has never aimed at the selection of clones suitable for high density plantations with short rotations for the production of biomass; therefore the most suitable clones can be chosen among the most interesting ones, particularly for their rapid growth and high resistance to the main biotic adversities, in the tests of the genotypes for conventional culture.

According to this criterion three plantations have been established, two of which in the Po Valley (Casale Monferrato), the former with 25 clones and the latter with 30, as well as one in Central Italy (Spello PG) with 14 clones.

The clones have been selected among the ones recorded in the RNCF (National Register Poplar Clones) and among those in advanced fase of selection.

Trials carried out in the Po Valley

For the first trial a two-year rotation has been chosen, in the second trial the rotation lasted six years.

Two-year rotation

The trial was carried out in Casale Monferrato at the Farm Mezzi annexed to the ISP (Poplar Research Institute) in Casale Monferrato using cuttings (30 cm long) of 25 clones, mainly P. x euramericana ('I 214', 'BL', 'Pan', 'Boccalari', 'Cappa Bigliona', 'Branagesi', 'Triplo', 'Luisa Avanzo', 'Cima', 'Carpaccio' already recorded in the RNCF and other experimental ones) and a small quantity of P. deltoides ('ECO 28', 'PE 4-68'). Some of these clones have been selected by ISP, others by the CSAF (Centre for Agricultural and Forestry Experimentation) in Rome or by private people; some were also introduced from abroad ('PE 35-67', 'PE 3-70', 'PE 4-68').

The characteristics of the soil used for this trial were typical of the area, with a sandy texture, pH = 7.6, a medium quantity of available phosphorus and exchangeable potassium. The soil was particularly poor in nitrogen and organic matter.

The cuttings were planted 50 cm apart in rows with a distance of 200 cm between rows adopting an experimental design of complete randomized blocks with 5 replications. In the first two-year rotation only one shoot per cutting was grown while in the second all the shoots were left. Coppicing level was 5 cm above ground.

Observations were carried out on the rooting ability of the cuttings, the diameter of the shoots and the weight of woody biomass produced in the first rotation. In the course of the second rotation observations are also being made in order to estimate resprouting ability and branching habit of the shoots. The percentage of bark has been determined on separate samples.

The data gathered during the first rotation are shown in table 1.

The cuttings rooting ability was extremely variable: over 80% for 9 clones, 60 to 80% for 14 clones, 42% for 'ECO 28' and 35% for the clone '35/64'. Generally speaking the cuttings of Euramerican clones rooted better than P. deltoides clones.

The diameter at breast height ranges from 2.5 to 7 cm. The production of wood, taking only the trunks into consideration, expressed as ODT/ha/year ranges from about 8 ('35/64', 'Boccalari') to 23.5 ('Bellotto') with a value of 13 for 'I 214'. The production increases by about 20% if branches are included.

The most productive clones in the first rotation proved to be so also in the second one without remarkable differences. Despite some mortality of the stumps after the first coppicing, ranging from 5 to 10% and limited to the stumps of the dominated plants, the production of the second rotation was higher than that of the first one, ranging from 10-15% for the less productive clones to 30-35% for the most productive ones.

Apart from productivity, also resprouting ability and branching habit have proved extremely variable. Having made no thinning (all the shoots were left on the stumps) the material produced has turned out to be much more heterogeneous than in the first rotation.

Tab. 1 - Casale Monferrato (AL). Survival of unrooted cuttings, fresh weight of stem and mean annual increment (MAI) of 25 poplar clones

Clone	Survival	Mean Fresh Weight		MAI
	%	Per plot (kg)	Per hectare (tons)	(ODT/ha/year)
35/64	35.20	89.42a	17.88	7.96
Boccalari 2	65.20	98.92ab	19.78	8.90
PE 35-67	75.20	121.96abc	24.39	11.22
130/51	75.60	123.44abc	24.69	11.23
Eco 28	42.80	124.56abc	24.91	10.96
Padovanino	65.20	127.00abc	25.40	11.43
NE 222	78.80	132.42 bc	26.48	12.04
Carpaccio	64.80	134.78 bc	26.96	12.40
Branagesi	88.80	136.04 bc	27.21	12.65
Tiepolo	77.60	145.30 cd	29.06	13.37
I 214	70.40	145.50 cd	29.10	13.10
Triplo	75.60	150.56 cde	30.11	13.40
Pacher	74.00	156.24 cde	31.25	14.06
Altichiero	77.60	158.12 cde	31.62	14.07
Cappa Bigliona	84.80	159.30 cde	31.86	14.34
Pan	86.00	161.50 cde	32.30	14.54
BL Costanzo	88.40	163.80 cdef	32.76	14.91
6/67	64.00	183.32 defg	36.64	16.87
Veneziano	78.00	192.44 efgh	38.49	18.09
Guardi	82.40	202.62 fghi	40.52	18.64
PE 3-70	77.60	202.66 fghi	40.53	18.44
Cima	86.00	208.74 ghi	41.77	19.21
Luisa Avanzo	85.20	228.90 hil	45.78	21.29
PE 4-68	85.60	239.08 il	47.82	22.00
Bellotto	94.00	252.90 l	50.58	23.52

The bark, which increases in percent as the diameter of stem decreases, represents about 20% of the fresh weight.

On the basis of these first observations, some clones seem much more interesting than 'I 214' with regard to SRIC especially 'Bellotto', 'L. Avanzo', 'Cima', 'PE 4-68'.

Six-year rotation

The trial (SEKAWIN and BISOFFI, 1985) has been carried out at the Farm Mezzi on a rather heterogeneous alluvial sandy-silt soil but anyway quite fertile.

The experimental design consisted of randomized complete blocks with 4 replications and 25 plants per plot.

The test included one clone of Populus alba ('I 58/57'), 5 of Populus deltoides ('Lux', 'PE 3-71', '104/69', 'PE 9-71', '35/66'), one hybrid of Populus deltoides x alba ('114/69'), 20 clones of Populus x euramericana ('Luisa Avanzo', '53/72', 'PE 24-62', 'Flevo', 'ECO 28', 'PE 62-71', '92/40', 'PI 8-70', 'PI 7-70', 'PI 6-70', '130/51', 'Cima', 'NE 222', 'Boccalari', 'Bellotto', 'Triplo', 'BL Costanzo', 'San Martino', 'PE 25-62', '10/71', '97/51', 'I 214'), one hybrid of Populus deltoides x maximowiczii ('Eridano') and one of Populus deltoides x (deltoides x trichocarpa) 33/72).

The clones 'Lux', 'Luisa Avanzo', 'Cima, 'Boccalari', 'Triplo', 'BL Costanzo', 'San Martino' and 'I 214' are commercial (registered in the RNCF) while all the others are experimental clones. Normal tending was adopted, treatments against burk and wood boring insects included, while no irrigation was applied.

Survival of the cuttings was observed at the end of the first year and girth at the breast height of all the trees was measured at the end of the third, fourth, fifth and sixth year of vegetation. The calculation of the basal area of each experimental unit, as the sum of the single basal areas of the living trees, was therefore possible.

The method adopted for the calculation of volumes was that of the single model tree, selecting for each clone the tree having the mean basal area. The scale of model trees was made for one meter long sections.

Specific gravity (fresh weight/fresh volume) was calculated by weighing cross sections of 2-4 dm^3 (taken from the stem one meter above ground level).

The same sections were dried in stove at 103-105°C to constant weight, so as to determine the basic density (dry weight/fresh volume). Finally, the dry weight was calculated multiplying the basic density by the volume.

The best survival was observed on all Euramerican hybrids, except 'Eridano' that is an hybrid of P. deltoides x maximowiczii. P. deltoides clones are in the lower positions of the ranking list. The best is 'Lux', with 85% of cuttings survival. P. alba clone is at the last but two position, although showing a fairly good survival for this species. Only the results of the two last clones of the list (table 2) were disappointing.

The clonal mean diameters of trees, taken at breast height, range from a minimum of 9-10 cm to a maximum of 15 cm. The corresponding mean heights range from 10 to 15 m.

Upon examination of the increment of basal area, it was observed that the current annual increment of almost all clones reaches the top at the fifth year, being lower than the mean annual increment already at the sixth year.

An exception to the above is constituted by 'I 214' reaching the top of the mean annual increment of basal area already at the fourth year, and by some P. deltoides ('35/66' and 'Lux' in particular) for which the current annual increment also at the sixth year remains higher than the mean annual increment. This is an amazing fact, given the broadcrowned form of these clones; the larger real spacing of the trees as consequence of a lower survival rate could be a reason.

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Sufficient data to indicate with certainty which is the most convenient rotation for this type of plantation are not available. We believe however that, although the height increment can still be remarkable after the sixth year, the mean annual increment of basal area is however destined to lower quite rapidly, due to the strong competition, in a short time: rotation of maximum volume production should therefore not go beyond 6 or 7 years for the most interesting clones.

On the basis of production results (table 2) it is interesting to note that there is a group of clones well fitted for a SRIC plantation. Among these clones the 'Luisa Avanzo' demonstrates to be quite flexible, with good production also when competition is extreme, at least in the environment conditions in which we have worked and with the adopted spacing and rotation. On the other hand, the statistical tests indicate a certain number of clones that are not significantly different from the preceeding one. Among these, another P. x euramericana clone selected by CSAF, 'Bellotto', a dutch clone, the 'Flevo', one selected by the ISP the '114/69', and two P. deltoides also belonging to ISP: the already known clone 'Lux' and the clone '35/66'.

Trial carried out in Central Italy

The test (MUGHINI and GRAS, 1984) was carried out in Spello (PG) at the Feccioli Farm, on alluvial soil, with silty-sand texture. The water table is near the surface during the dormancy period and decreases to 2-3 m in summer. The average annual precipitations, amounting to 840 mm, were concentrated in autumn-winter with a long summer drought (June-August).

The plantation was established in February 1978 utilizing cuttings (30 cm long) of 14 clones, 10 of which of P. deltoides ('Fierolo', '14/9', '2 Ken 8', 'S7C1', 'S7C2', 'S7C4', 'S7C5', 'S7C20', '1862', 'Spiado') and 4 P. x euramericana ('L. Avanzo', 'Schiavone', 'Tiepolo', 'I 214'), adopting 2 x 1.50 m spacing.

The clones were planted on the field arranged in complete randomized blocks with 4 replications. The test unit was constituted by a plot of 35 trees, on a surface of 105 m^2.

Tab. 2 - Casale Monferrato (AL). Survival of unrooted cuttings, volume, specific gravity, basic density, fresh and dry weight of the stem and mean annual increment (MAI) of 30 poplar clones

Clone	Survival %	Volume (m^3/ha)	Specific gravity	Fresh weight (t/ha)	Basic density	Dry weight (t/ha)	MAI (ODT/ha/year)
Luisa Avanzo	91	238	0.90	186.8	0.34	81.0	13.50
Flevo	98	208	0.74	176.2	0.37	76.8	12.80
114/69	95	199	0.74	176.1	0.36	71.6	11.93
35/66	77	238	0.81	161.1	0.30	71.4	11.90
Lux	85	186	0.85	159.5	0.38	70.5	11.75
Bellotto	94	199	0.78	154.9	0.34	67.5	11.25
Triplo	93	168	0.82	137.5	0.33	55.4	9.23
NE 222	93	161	0.85	131.6	0.34	54.7	9.12
104/69	69	155	0.80	128.7	0.35	54.2	9.03
PE 9-71	79	156	0.80	124.6	0.34	53.0	8.83
PE 26-62	87	145	0.83	111.5	0.34	49.1	8.18
Cima	95	134	0.74	110.5	0.35	47.0	7.83
BL Costanzo	90	135	0.75	108.4	0.33	44.7	7.45
PI 6-70	91	128	0.73	98.8	0.34	43.4	7.23
S. Martino	70	149	0.76	98.7	0.29	43.3	7.22
PE 3-71	79	122	0.78	95.5	0.35	42.8	7.13
ECO 28	53	116	0.81	94.2	0.35	40.7	6.78
Eridano	96	130	0.80	92.7	0.31	40.3	6.72
10/71	90	110	0.80	87.9	0.34	37.3	6.22
PI 7-70	98	116	0.87	83.7	0.32	37.1	6.18
53-72	88	109	0.76	83.1	0.33	36.1	6.02
33/72	39	96	0.89	78.0	0.37	35.6	5.93
130/51	97	98	0.79	77.6	0.34	33.5	5.58
97/51	91	84	0.78	76.8	0.36	30.4	5.07
PE 62-71	94	88	0.75	67.7	0.34	29.8	4.97
PI 8-70	84	90	0.68	65.4	0.31	28.0	4.67
I 214	97	96	0.85	64.5	0.29	27.9	4.65
Boccalari	92	76	0.76	64.1	0 35	26.8	4.47
92/40	87	76	0.74	56.6	0.35	26.6	4.43
58/57	67	66	0.65	42.9	0.29	19.1	3.18

Normal tending was applied (treatments against bark and wood boring insects included) while irrigation was limited to the first year after plantation in order to favour the rooting of the cuttings.

From the third to the sixth year, at the end of the growing season, all plants were measured to record circumferences at breast height. At the end of the sixth year the trees were cut down.

20 model trees per clone were sampled in order to determine the real volume; the height increments of the last 4 years were also recorded. On a sub-sample of 5 trees per clone the stem analysis was carried out in order to calculate the variations of form factors from the third to the sixth year. The basic density was determined on cross sections of the trunks. The form factors were used for calculating the volumes of the trees in the last 4 years of growth. Plot volumes were calculated utilizing the regression of volume of model trees on their circumference. The biomass (ODT/ha/year) was determined multiplying basic density by volume.

Mean diameters at breast height range from 7.8 cm for the less productive clone to 10.3 cm for the most productive one and the corresponding heights range from 10.2 to 13.6 m.

Table 3 shows data concerning the mean and current increments (m^3/ha) from the third to the sixth year after plantation and the biomass produced (ODT/ha/year).

These data taken as a whole make evident that there is a high variability among clones and that some of them are very interesting as regards biomass production in SRIC plantations ('S7C2', '14/9', '2 Ken 8', 'Luisa Avanzo'). In spite of long dry summer periods, interrupted by irrigation only during the first year, yields of these clones can be considered as remarkable (from 9.33 to 10.7 ODT/ha/year).

Tab. 3 - Spello (PG). Volume (m^3/ha) of mean annual increment (i_m), current increment (i_c) from 3rd to 6th year of planting and mean annual increment (MAI) as dry weight (ODT/ha/year) of 14 poplar clones

Clone	Year of installation 3rd	4th		5th		6th		MAI
	i_m	i_c	i_m	i_c	i_m	i_c	i_m	(ODT/ha/year)
S7C2	12.384	47.823	21.244	45.773	26.150	36.822	27.928	10.70
14/9	9.882	43.505	18.288	52.161	25.063	34.163	26.579	9.94
Luisa Avanzo	9.861	44.455	18.509	46.878	24.183	33.228	25.691	9.33
2 KEN 8	10.888	48.050	20.179	43.992	24.941	27.126	25.308	9.82
S7C1	9.384	38.265	16.605	38.675	21.019	29.002	22.350	8.47
S7C20	9.463	40.474	17.216	40.271	21.827	24.555	22.282	9.16
Fierolo	8.013	42.441	16.620	40.669	21.430	25.921	22.180	8.05
Tiepolo	9.733	39.513	17.178	36.215	20.985	27.121	22.007	8.85
1862	7.580	38.327	15.267	39.750	20.163	28.136	21.492	7.59
I 214	7.387	31.853	13.503	35.605	17.924	38.953	21.430	6.56
S7C15	8.487	33.091	14.638	29.618	17.634	26.472	19.107	7.59
Spiado	6.643	31.399	12.832	35.293	17.324	27.569	19.033	7.48
S7C4	7.384	28.367	12.630	29.460	15.996	24.402	17.397	7.64
Schiavone	7.005	24.712	11.432	17.636	12.672	19.781	13.857	5.29

2.1.2 Comparison between poplar and willow clones

As shown by the tests which have been previously illustrated, there are at present various poplar clones, belonging both to the Euramerican group and to P. deltoides, that are able - in SRIC plantations - to yield wood masses higher than those produced by 'I 214'. Compared with this clone, according to AVANZO (1974), even within P. nigra breeding offers the possibility of increasing biomass yield by approx. 12% for each generation. As a matter of fact, some clones such as 'N369', 'Jean Pourtet' and 'Brisighella', have a very rapid juvenile growth.

As regards the biomass production, results as good as those given by poplars can also be reached with willows. According to a preliminary report (MAY, 1982), clones of Salix alba can yield a biomass up to 85% higher than 'I 214'.

It is evident that within both Salicaceae there are remarkable potentials. It is therefore extremely interesting to verify in practice which are in our environment the real possibilities of both genera by comparing some of the most promising clones of each one.

To this purpose some tests have already been started and the present paper reports the results of the test which is at present the most advanced.

The test was started in February 1984 comparing eight poplar clones with two willow clones. Among poplars one Euramerican clone ('Luisa Avanzo'), one P. deltoides ('Fierolo'), one hybrid P. deltoides x P. maximowiczii ('Eridano'), all of them belonging to Italian selections and four interamerican clones selected in Belgium. The interamerican clones were obtained by hybridization of P. trichocarpa 'Fritzi Pauley' x P. deltoides 'Missouri' (clones 69.042/1, 69.042/2, 69.043/1 and 69.043/3).

Among willows, two clones of Salix alba were chosen (SI 59-62 and SI 12-64), both selected by ISP.

In order to avoid irrigation, which is always a very expensive operation, a soil with good natural water supply has been chosen. It was in fact characterized by a permanent water table ranging, during the growing season, between 50 and 80 cm. Texture was sandy-silt, pH 7.5 and medium level of nutritive elements.

Grass weeds are mainly represented by the following species that can be found with decreasing density: Artemisia vulgaris, Astragalus glyciphillus, Lythrum salicaria, Rumex acetosella, Urtica urens and by other ones that are sporadically found.

The plantation was established by using one-year-old unrooted shoots from coppice nursery, put 0.80 m deep and at spacing 3 x 2.50 m.

As test design randomized blocks with 4 replications were adopted. The test unit was represented by a plot of 8 rows of 8 trees each, for a total of 64 trees and a surface of 480 sq.m.

Tending consisted yearly of three disking of the soil and antiparasitical treatments against burk and wood boring insects (Cryptorhynchus and Saperda in particular).

Trees of the inner part of the plot were measured to record yearly heights and circumferences from the end of 1985 to 1988. During the winter between 1988 and 1989 (at the end of the fifth year) coppicing was carried out; in such occasion, in order to evaluate the wood mass production, two average trees (with mean basal area) were singled out for each plot and utilized as model trees.

Each model tree was weighted at fresh condition considering separately the stem (topped at 4 cm of diameter), the top and the side branches.

The mean data of the two model trees per plot were subjected to the variance analysis. The fresh weight per ha was calculated multiplying the number of trees per plot by the weight of the average tree. Dry weight was evaluated by determining the humidity on stem samples.

Survival, observed at the end of the first growing season, was 92% for 'Luisa Avanzo', 95% for 'Fierolo', 'Eridano', '69.042/1', '69.042/2' and '69.042/3', and 99% for the clone '69.043/1' and for the two willow clones.

In the course of 1986 and 1987 the mortality rate was almost total for the trees of clone '69.043/3' and approx. 29% for those of clone '69.042/1', due to attacks of rots at the collar caused by an unidentified pathological agent. Clone '69.043/3' was eliminated from the statistical tests.

Height growth was very remarkable for all clones with yearly increments ranging from a minimum of 2.20 m to a maximum of 4.70 m, according to year and to clone. Poplar clones 'Luisa Avanzo' and '69.042/2' were the highest after five years, over 20 m, and all the others, including willows, reached heights ranging from 16 to 17.30 m. Mean diameters, ranging from 13 to 17.9 cm, confirm that the two highest poplar clones are superior and that the other poplar and willow clones are equivalent (table 4).

'Luisa Avanzo' appears in the first position also as regards the mean fresh weight (184 kg), followed by clone '69.042/2' (160 kg) and by 'Fierolo' (150 kg). Willow clones show values that are slightly higher than those of the other poplar clones (table 4).

The ranking appears almost unchanged also as regards the effective production, expressed both in fresh weight of stems, tops and branches, and in dry weight (table 5).

In fact, willows production can be very interesting (13.5 and 15.8 ODT/ha/year) if we consider that the two tested clones are not the most productive ones among those already selected by ISP.

Tab. 4 - Motta dei Conti (VC). Diameter at breast height, height and fresh weight per tree split in stem (till 4 cm of diameter), stem-top (less than 4 cm of diameter) and side branches of 6 poplar clones and 2 willow clones

Clone	Diameter at m 1.30 (cm)	Total height (m)	Mean fresh weight per tree (in kg) Stem >Ø cm 4	Stem-top <Ø cm 4	Side branches	Total
Poplars						
L. Avanzo	17.30A	20.11A	154.94A	1.41 CD	28.31A	184.66A
69.042/2	16.00AB	20.03A	136.25AB	1.76AB	22.50ABC	160.51AB
Fierolo	16.08AB	18.28 B	121.25 BC	1.11 DE	27.81AB	150.17 B
69.042/1	14.34 CD	17.37 BC	96.56 D	1.90A	13.96 D	112.42 C
Eridano	14.06 D	17.36 BC	88.88 D	1.61ABC	20.75 BCD	111.23 C
69.043/1	13.68 D	17.59 BC	90.38 D	1.56 BC	15.88 CD	107.82 C
Willows						
SI 12-64	15.63 BC	17.00 C	104.69 CD	1.31 CDE	26.75AB	132.75 BC
SI 59-62	13.79 D	16.05 D	91.88 D	1.07 E	23.63AB	116.57 C
Mean	15.11	17.97	110.60	1.47	22.45	134.52

Tab. 5 - Motta dei Conti (VC). Production expressed as fresh weight per hectare split in stem (till 4 cm of diameter), stem-top (less than 4 cm of diameter) and mean annual increment as oven dry weight of 6 poplar clones and 2 willow clones

Clone	Fresh weight (t/ha)				MAI
	Stem > Ø cm 4	Stem-top < Ø cm 4	Side branches	Total	(ODT/ha/year)
Poplars					
69.042/2	177.25A	2.29A	29.26ABC	208.81A	19.21
Luisa Avanzo	171.80A	1.57 B	31.28AB	204.66A	18.42
Fierolo	149.44AB	1.36 B	34.29A	185.09AB	16.29
69.042/1	94.14 C	1.81AB	14.02 D	109.97 D	10.23
69.043/1	113.17 BC	1.97AB	19.84 CD	134.98 CD	12.28
Eridano	93.76 C	1.59 B	21.69 BCD	170.04 D	10.30
Willows					
SI 12-64	138.52AB	1.73AB	35.35A	175.60ABC	15.80
SI 59-62	120.19 BC	1.40 B	30.90AB	152.48 BCD	13.57
Mean	132.28	1.71	27.08	161.08	14.51

2.2 Comparison of different types of stock planting material

As it has already been said, cuttings (at variable lenghts), one-year-old plants and two-year-old plants are the types of planting stock utilized in Italy.

A test carried out in Pomposa (FE) (FRISON, 1984), on a sandy soil of low fertility, with clone 'I 214', adopting a spacing of 2.50 x 1.60 m, demonstrated that at the end of the fifth year the cuttings (approx. 50 cm long) yielded 370 q/ha, one-year-old plants 807 q/ha and the two-year-old ones 1,008 q/ha, taking into consideration both the stems and the branches topped at 4 cm of diameter. Production expressed in biomass is approx. 3.5, 7.5 and 9 ODT/ha/year for cuttings, one-year-old plants and two-year-old plants respectively.

On the basis of the practical experience acquired so far, we can state that in fertile soil the productive differences among the three types of planting stock material tend to decrease; however, one-year-old plants are always definitely better than cuttings, owing to the fact that the short cycle does not allow the smaller starting stock to recover, unless making rotation longer. On the contrary, the productive differences between one-year and two-year-old plants drastically decrease and often disappear.

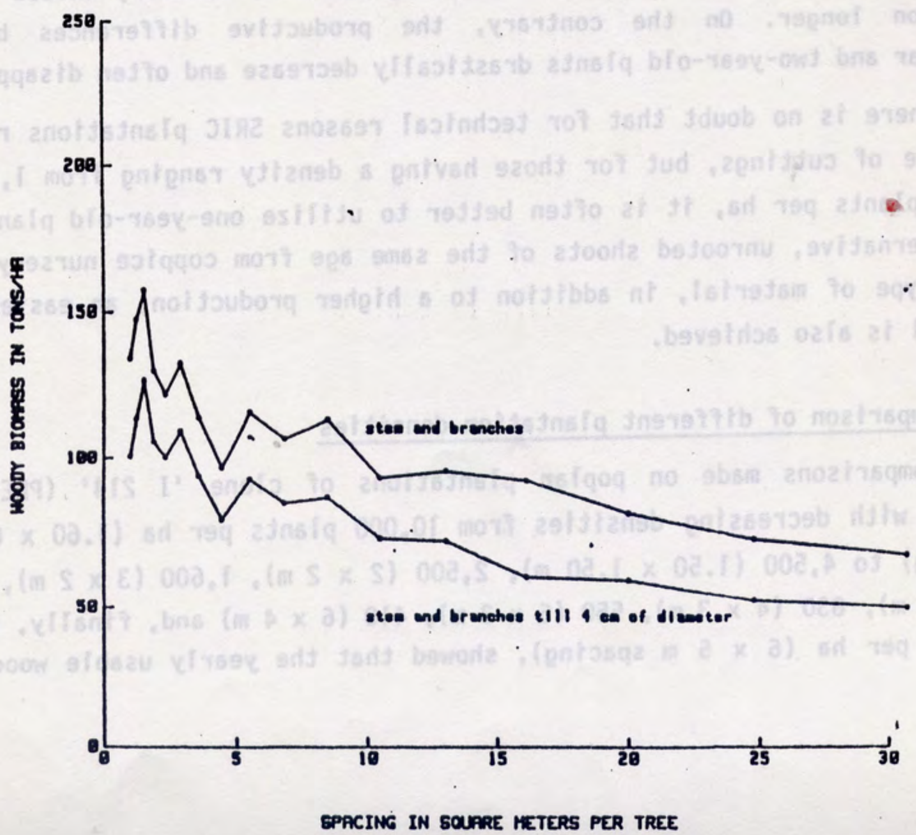
There is no doubt that for technical reasons SRIC plantations request the use of cuttings, but for those having a density ranging from 1,000 to 2,500 plants per ha, it is often better to utilize one-year-old plants or, in alternative, unrooted shoots of the same age from coppice nursery. With this type of material, in addition to a higher production, an easier weed control is also achieved.

2.3 Comparison of different plantation densities

Comparisons made on poplar plantations of clone 'I 214' (PREVOSTO, 1974), with decreasing densities from 10,000 plants per ha (1.60 x 0.60 m spacing) to 4,500 (1.50 x 1.50 m), 2,500 (2 x 2 m), 1,600 (3 x 2 m), 1,100 (3 x 3 m), 830 (4 x 3 m), 550 (6 x 3 m), 410 (6 x 4 m) and, finally, to 330 plants per ha (6 x 5 m spacing), showed that the yearly usable wood mass produced decreases when spacing is increasing but, at the same time, the percentages of utilizable wood mass in the most valued assortments increases.

The results of a series of spacing tests carried in plantations where cuttings were set at 18 increasing distances, on divergent rows, following Nelder scheme, represent a proof of the above as regards the yields. The available area for each tree was ranging from 0.807 to 30.75 m^2 (figure 1). With a six-year rotation the production, including stem and branches topped at 4 cm of diameter, was sharply decreasing when density was reduced. With a density of 6,500 trees per ha production totalled 19.65 kg/sq.m., equal to 196.5 t/ha, and lowered to 12.7 kg/sq.m., equal to 127 t/ha, with a density of 2,770 trees per ha. Production expressed in biomass is of approx. 14.5 and 9.5 ODT/ha/year respectively.

Figure 1 - Variation of production related to spacing in a trial carried out with Nelder design



It is interesting to note that production changes moderately from the density of 2,770 trees per ha (3.61 m^2 per tree) to the density of 1,176 trees per ha (8.50 m^2 per tree) (figure 1). This result is quite important from the practical point of view as it allows to operate practically in a sufficiently wide spacing range. For example, the density of 2,770 trees per ha can be obtained with 3 x 1.20 m spacing and that of 1,176 trees per ha with 3 x 2.80 m spacing. It is not by chance the choice of 3 m spacing within the rows, which allows, among other things, to employ the most common cultivating machinary. The possibility of changing the spacing within the row from 1.20 m to 2.80 m without significant production losses, allows to use clones with different requirements or to achieve production of logs with various diameters, increasing when spacing becomes greater. In fact, going from the first to the second distance the mean diameter per tree at breast height, six years after plantation, ranges, on average, from approx. 10 to approx. 15 cm, with an increase from 20 to 70% of wood suitable for the paper industry.

2.4 Effects of coppicing

Coppicing is carried out in order to avoid replanting (always very expensive), making profit of the capacity of stumps to resprout. Vigour and longevity of stumps are very important for the adoption of this technique. These aspects were studied in plantations of clone 'I 214' adopting annual or multiannual rotations.

2.4.1 Annual rotation

The test was carried out in Casale Monferrato in a plantation of the clone 'I 214', cuttings (20 cm long) were planted with a spacing of 1.30 x 0.20 m.

The soil was sandy, of sub-alkaline reaction, with a moderate amount of total limestone and nutritive elements and poor in organic matter.

Every year cultural cares consisting in 2 or 3 harrowings, 3 or 4 irrigations and maintenance fertilizing (75 kg/ha of N_2, 75 of P_2O_5 and 75 of K_2O every year) were carried out.

Coppicing was carried out every year between the end of February and the first days of March, 5 cm above ground level.

Data were collected concerning stump mortality rate and the wood mass obtained. The percentage of wood and bark on separate samples was also calculated. The data are reported in table 6.

The shoots had an average height of 2.50-3.00 m and an average diameter (measured at 0.5 m above ground) of 1.40-1.76 cm. The bark was about 28-30%.

Biomass, which was 8.10 ODT/ha in the first year, increased steadily and to a considerable extent in successive rotations, touching a ceiling of 14.92 ODT/h in the fourth one, and then fell off until it returned to the levels of the first rotation at the ninth or tenth one.

Stump mortality rate increased progressively until it reached 84% by the end of the tenth year. This is a rather high value which may be partly attributed to the very dense spacing and frequency of coppicing. In spite of this, productivity is maintained at quite high values.

The greater number of shoots on surviving stump or their vigorous conditions has certainly an influence on these values.

At the same time, a similar test was carried out on an adjacent plot where the soil was impoverished before plantation with a two-year crop of <u>Sorghum</u> and never manured or fertilized during the test period of ten years. In order to furtherly deprive the soil, poplar leaves were collected and removed just as they were falling in the course of the growing season.

Under this situation stump mortality was more or less similar to the mortality rate observed in the adjacent plot.

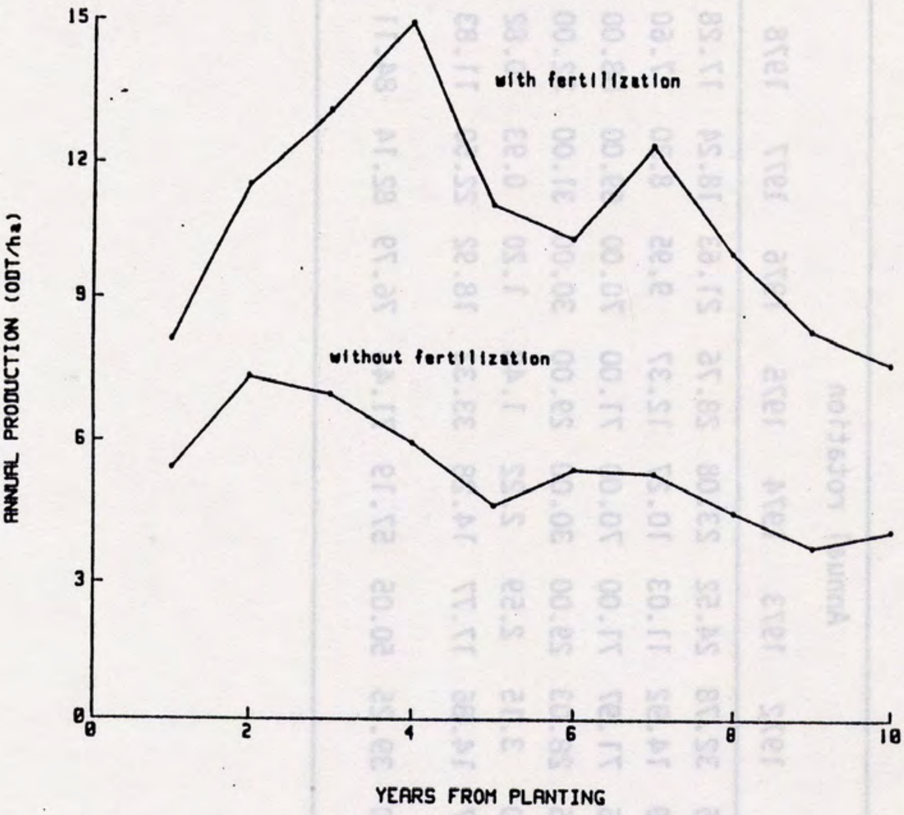
Comparing the two curves (figure 2) the effect of the soil fertility on the productivity taken as a whole is evident, as well as on stump vigour. In fact, while in the most fertile soil productivity increased progressively after each yearly coppicing for four years, productivity of the depleted soil increased only after the first coppicing, taking up a decreasing trend thereafter.

This result demonstrates that in order to reach a good productivity and to maintain it at a high level the choice of good fertility sites is crucial.

Tab. 6 - Production expressed in fresh and dry weight (tons per hectar), wood and bark percentage and mortality of the stump in a poplar coppiced stand with annual rotation (clone 'I 214')

Parameters	Year of plantation 1969	Annual rotation 1970	1971	1972	1973	1974	1975	1976	1977	1978
Fresh weight (t/ha/year)	18.01	25.80	29.75	32.78	24.52	23.08	28.76	21.63	18.24	17.28
MAI (ODT/ha/year)	8.10	11.48	13.09	14.92	11.03	10.27	12.37	9.95	8.30	7.60
Wood (%)	68.82	70.68	73.25	71.97	71.00	70.00	71.00	70.00	69.00	68.00
Bark (%)	31.18	29.36	28.75	28.03	29.00	30.00	29.00	30.00	31.00	32.00
Tree stump per m^2	5.18	4.44	3.70	3.15	2.59	2.22	1.48	1.20	0.93	0.82
Mortality in each year (%)	-	14.28	16.67	14.86	17.77	14.28	33.33	18.92	22.50	11.83
Mortality in respect to the initial number of the stumps (%)	-	14.30	28.60	39.25	50.05	57.19	71.46	76.79	82.14	84.11

Figure 2 - Effects of annual coppicing on production in sandy soil with and without addition of mineral fertilizers (spacing 1.30 x 0.20 m)



2.4.2 3-6 year rotation

Here we briefly illustrate the results obtained (tab. 7) in five plantations with the clone 'I 214', established with the aim of producing material for chipboard, paper industries and biomass in areas of Northern Italy (Casale Monferrato) and in Central Italy (Bagni di Tivoli-Rome and Spello-Perugia).

Two plantations, the first with a spacing of 3 x 2 m and the second of 2 x 2 m, were established in Casale Monferrato, Farm Mezzi, utilizing 2-year old nursery stock. The soil is a sandy one, of subalkaline reaction, averagely rich in nutritive elements and poor in organic matter. Cultural cares consisted of two or three diskings each year, irrigation and maintenance fertilization.

Tab. 7 - Production of the poplar clone 'I 214' in various coppiced stands with 3-6 years rotation

Characteristics	Casale Monferrato Trial 1 3 x 2	Trial 2 2 x 2	Bagni di T. Trial 3 1 x 1.50	Spello Trial 4 3 x 2		Trial 5 3 x 1
Type of stock planting material	2-year old saplings		Cuttings	2-year old saplings		Cuttings
1st Coppicing						
Rotation in years	4	1	3	3		4
Wood production (m^3/ha)	130.50	-	63.000	39.90		52.40
Mean annual increment (ODT/ha/year)	8.77	-	6.30	4.08		3.93
Density (Kg/dm^3)	0.27	-	0.30	0.31		0.30
Survival (%)	88.23	90.00	-	94.00		88.80
2nd Coppicing						
Rotation in years	6	3	5	3	5	5
Wood production (m^3/ha)						
1 shoot per stump	223.00	130.00				
2 shoots per stump	217.55	-	-	-	-	-
2 shoots per stump			178.00	60.75	126.50	118.50
Mean annual increment (ODT/ha/year)						
1 shoot per stump	10.40	12.20				
2 shoots per stump	10.15	-	-	-	-	-
2 shoots per stump			10.68	6.07	7.05	7.18
Mortality of stump (%)	20.00	10.00	7.25	-	13.78	7.31
3rd Coppicing						
Rotation in years	-	-	-	5	3	-
Wood production (m^3/ha)	-	-	-	129.50	26.40	-
Mean annual increment (ODT/ha/year)	-	-	-	7.77	2.64	-

In the 3 x 2 m plantation the first coppicing was carried out at the end of the fourth year and yielded a mass of 130 m^3/ha, corresponding to 8.77 ODT/ha/year. The second coppicing was carried out 6 years after and yielded a wood mass of 223 m^3/ha with only one shoot left per stump and of 217 m^3/ha with two shoots, corresponding to 10.40 and 10.15 ODT/ha/year respectively.

In the 2 x 2 m plantation, the first coppicing was carried out, for unforeseen circumstances, right after the first year; the wood mass has not been held in account as it was, naturally, extremely small. The second coppicing was carried out after three years and yielded a wood mass of 130 m^3/ha, corresponding to 12.20 ODT/ha/year.

At Bagni di Tivoli (GIORDANO, 1974), at the Farm Cesurni, 40 cm long cuttings were planted at a distance of 1 x 0.50 m. Subsequently the trees were thinned and the distance increased to 1 x 1 m. The first coppicing, for the production of material for chipboard, was carried out at the end of the third year and yielded 6.30 ODT/ha/year. The second coppicing was carried out after 5 years (for the production of material for paper), and the production was 10.68 ODT/ha/year.

At Spello, at the Farm Feccioli, a plantation was established in 1968 with two-year old plants, set at a distance of 3 x 2 m. The first coppicing, carried out at the end of the third year, produced 4.08 ODT/ha/year. The second one was carried out on one part of the plantation after three years and after five years on the rest. In the first case it yielded 6.07 ODT/ha/year and in the second 7.05 ODT/ha/year. The third coppicing on the whole plantation was carried out in 1979, that is, the first part after 5 years and the second after 3 from the last coppicing, yielding 7.77 and 2.64 ODT/ha/year respectively.

Finally, again at Spello, a plantation was established directly with 40 cm long cuttings set at a distance of 3 x 1 m. In the first rotation (4 years) the biomass produced was 3.93 ODT/ha/year and in the second (5 years) 7.11 ODT/ha/year.

From these data taken as a whole, we note that production is always higher in the second as compared to the first rotation and, in general, in Northern than in Central Italy. Viceversa, stump mortality rate is higher in Northern Italy (tab. 7).

2.5 Volume and weight tables

Volume and weight double entry tables were prepared only for 'I 214' in order to evaluate volume, fresh and dry weight of the stems produced in SRIC plantations, separating the material produced at the end of the first rotation from that produced in the following rotations after coppicing.

To evaluate the wood mass yielded at the end of the first rotation, the tables were based upon 51 model trees grown in a poplar plantation located at Motta dei Conti (VC) with 3 x 2.50 m spacing, cut down at six-year of age.

Some tables allow to evaluate the volume of the stem up to 4 cm of diameter, of the whole stem and of stem and branches altogether on the basis of the diameter at breast height and of the tree height. Other tables permit to evaluate the volume of the stem up to the diameter of 4 cm on the basis of the diameter at breast height and of the height of the stem up to the diameter of 4 cm (h 4), the volume of the stem up to the diameter of 7 cm on the basis of the diameter and of the height of the stem up to the diameter of 7 cm (h 7), and, finally, the volume of the stem up to the diameter of 10 cm on the basis of the diameter and of the height of the stem up to the diameter of 10 cm (h 10).

As many other tables were prepared for the evaluation of fresh weight and of dry weight.

In addition to these tables, a double entry timber heights table of trees topped at 4 cm, 7 cm and 10 cm, according to the diameter at breast height and to the tree heights, was also prepared.

To evaluate the wood mass yielded in the rotations following the first one, tables were made with the same standard and with the same subdivision adopted for the preceeding ones, on the basis of 156 model trees of three coppices of 3, 4 and 6-year age from the first felling and with spacing of 2 x 2, 2 x 2 and 3 x 2 m respectively, cultivated in Casale Monferrato. Only one shoot per stump was grown; all the other sprouts were removed at the end of the first year of growth after coppicing.

Obviously these tables can be used only for trees of 'I 214'. Weight tables, in particular, as they do not take into account the specific gravity, a parameter variable according to both clone and site, can only be applied to plantations grown in environmental conditions similar to those of the poplar plantations from which the tables have been obtained (local table).

With the above limitations, the tables are suitable for evaluating, beyond the total volume and fresh weight of the stand wood biomass also those of the assortments for the paper industry (10 cm diameter at the top) and for chipboard (from 10 to 4 cm diameter at the top).

For example (table 8) a tree of 'I 214', 15 cm diameter at breast height, has a total height of 19 m and stem length of 9 m (up to 10 cm diameter at the top), of 13 m (up to 7 cm) and of 15.7 m (up to 4 cm). The fresh weight of the stem will be approx. 85 kg (up to 10 cm), 97 kg (up to 7 cm), 104 kg (up to 4 cm) and 122 kg considering stem and side branches as a whole. The wood quota for paper industry is equal to 70% with respect to the total weight (stem plus branches). This quota increases to 80% for trees of 20 cm diameter at breast height and decreases to approx. 20% for trees with 10 cm diameter.

3. OTHER RESEARCH AREAS

3.1 Breeding and selection for biomass

Considering the present situation of the small-size wood market, poplar and willow biomass does not have and is not likely to have in the near future a specific breeding programme.

Tab. 8 - Motta dei Conti (VC). Mean height and fresh weight per poplar tree of cm 10, 15 and 20 of diameter at breast height. Clone 'I 214', spacing m 3 x 2.5

Parameters	Diameter at breast height (cm) 10	15	20
Height (m)			
till Ø cm 10	1.5	9.0	13.0
till Ø cm 7	6.7	13.0	15.8
till Ø cm 4	11.0	15.7	18.0
Total	15.0	19.0	21.0
Fresh weight (kg/tree)			
till Ø cm 10	-	85.0	175.0
till Ø cm 7	31.0	97.0	189.0
till Ø cm 4	38.5	104.0	193.0
Total (stem)	40.5	105.5	195.0
Total (stem + branches)	46.5	122.0	227.0
Volume (dm^3/tree)			
till Ø cm 10	-	129.0	278.0
till Ø cm 7	44.6	150.0	296.0
till Ø cm 4	55.5	156.0	300.5
Total (stem)	57.5	157.5	302.5
Total (stem + branches)	65.6	177.5	334.0

3. OTHER RESEARCH AREAS

3.1 Breeding and selection for biomass

Considering the present situation of the small-size wood market, poplar and willow biomass does not have and is not likely to have in the near future a specific breeding programme.

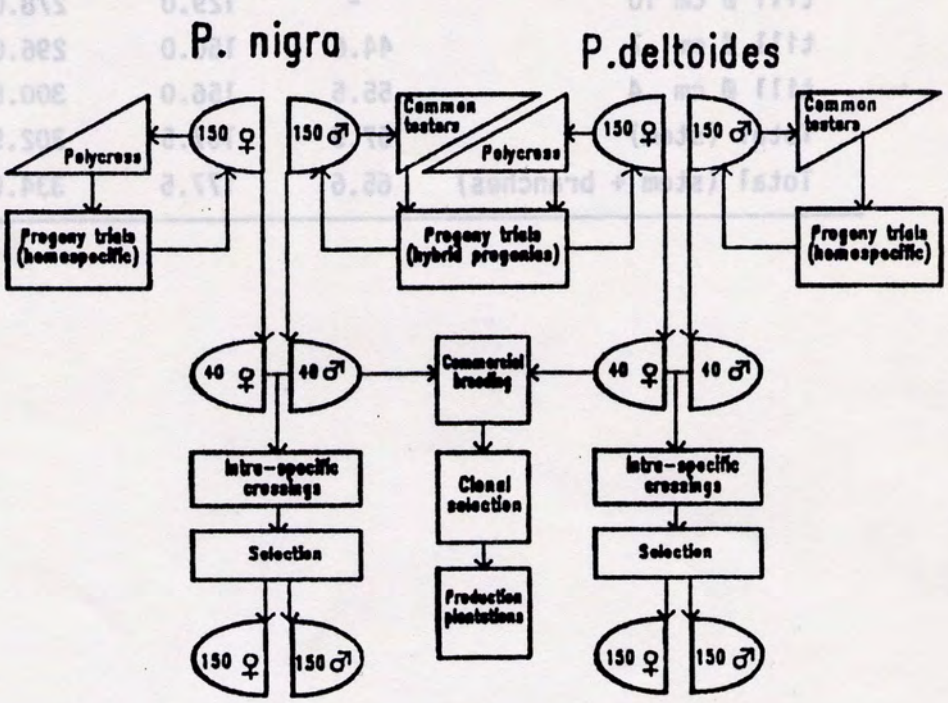
However, the existing breeding projects dedicated to the improvement of poplars and willows as big-size trees for the sawmills and for the plywood industry satisfy to a fair degree also the possible demands of biomass production.

Juvenile growth, with particular regard to the nursery stage, is one of the traits that is being improved, partly because it is fairly well correlated with growth in stands, and partly because of its intrinsic importance. On the other hand, normal rotation in Italy is around ten years, with a tendency to decrease, and consequently, even big-size trees can be considered still in their juvenile phase. This last fact is probably the main reason why one usually has the same ranking of clones in short-rotation narrow-spaced clonal trials as in ten-year-rotation wide-spaced experiments.

3.1.1 Breeding strategies

Our breeding strategies have been discussed on several occasion (AVANZO et al., 1985; BISOFFI, 1989) and will be briefly summarized here (see figure 3).

Figure 3 - Flow-chart of the current breeding programme for the improvement of P. x euramericana



The programme is based on what should have been a Reciprocal Recurrent Selection (RRS) of P. deltoides and P. nigra for the improvement of their hybrid, but is actually a Semi-RRS due to the incompatibility between the male P. deltoides and the female P. nigra.

The starting point was represented by a partially selected population of P. deltoides from a wide range of latitudes in the USA and an unimproved sample of Italian P. nigra resources.

The whole breeding cycle is divided into two generations. In the first one all the individuals are crossed (interspecifically where possible) and then progeny-tested in a series of two-year nurseries in order to be rated according to their General Combining Ability (GCA). In the second generation the best general combiners are crossed intra-specifically in order to have a recombination of genes. The best individuals selected within these last families will be the starting point of a second cycle.

All the individuals in the progeny trials, besides producing information about their parents, are also clonally selected.

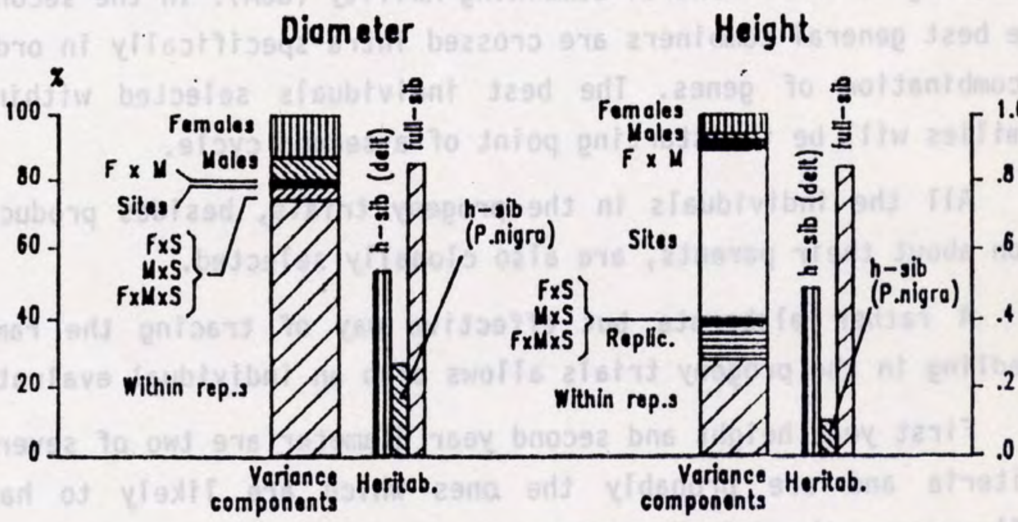
A rather elaborate but effective way of tracing the ramets of each seedling in the progeny trials allows also an individual evaluation.

First year height and second year diameter are two of several selection criteria and are probably the ones which are likely to have a strong influence on the value of clones to be used in biomass plantations. Within the framework of the crossings for the evaluation of P. nigra males, in which each male was mated with a set of six P. deltoides females (common testers), we were able to analyze two subsets of the families which fitted either into a 4x20 complete factorial or into a 5(x10) hierarchical mating design. The trials were replicated in two places, situated at either end of the poplar cultivated area of Northern Italy.

For a detailed discussion of the results see BISOFFI (1989); the main points will be outlined hereafter.

a) Variance partitioning in the factorial design (see table 9 and figure 4) shows that additive components (female and male effects) are larger than non-additive components (female x male interaction). Consequently, a breeding strategy aiming at exploiting GCA is more suited than one based on Specific Combining Ability (SCA), at least in the short run.

Figure 4 - Variance components and heritabilities of 1st year height and 2nd year diameter estimated in a 4 x 20 factorial mating between P. deltoides and P. nigra



b) The female component (P. deltoides) is larger than the male one (P. nigra) for both traits. In plain words this means that the performance of a progeny depends more on which the mother was than the father and that it is P. deltoides parents that we must look for if we want to improve the juvenile growth rate of P. x euramericana.

c) The interaction between genetic components and site is negligible even in the case of height growth, for which the site variance component is very large. This is a very lucky outcome since it means that a single-population strategy can be adopted for the breeding needs of Northern Italy and there is no need to have separate breeding programmes for different regions.

Tab. 9 - P. deltoides x P. nigra factorial mating. Estimated genetic parameters

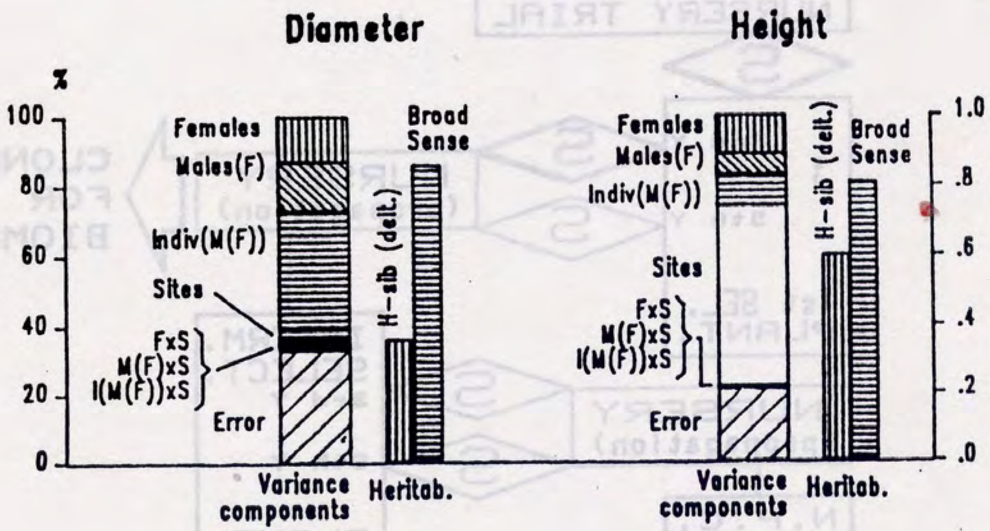
Variance components %	Height (m) (first year)	Diameter (mm) (second year)
Females	6.6	13.7
Males	1.4	7.0
FxM	3.3	1.0
Sites	49.5	.9
FxS	.1	3.3
MxS	.0	.6
FxMxS	.2	.0
Replications	10.6	.0
Within plots	28.3	73.5
Mean	331	44.3
σ^2 (phen fam.)	702	53.7
$h^2_{HS(f)}$	.49	.54
$h^2_{HS(m)}$	.10	.27
h^2_{FS}	.84	.85

Tab. 10 - <u>P. deltoides</u> x <u>P. nigra</u> hierarchical mating. Estimated genetic parameters

Variance components %	Height (m) (first year)	Diameter (mm) (second year)
Females	11.0	12.7
Males (in Females)	4.9	14.5
Individuals (in FM)	9.1	34.4
Sites	52.8	2.0
SxF	.2	.0
SxM(F)	.8	2.3
SxI(M(F))	.0	1.6
Error	21.1	32.8
Mean	334	46.4
σ^2 (phen. fam.)	1127	78.5
σ^2 (phen. ind.)	1897	165.1
$h^2_{HS(f)}$	.60	.36
h^2_{bs}	.81	.86

d) The individual-within-family variance component is rather large as can be seen from table 10 and figure 5 which refer to the hierarchical subset in which each individual in a family was replicated twice in each of the two places. We can deduce the expected genetic gain from family selection by calculating the product of heritability and selection differential under different selection hypotheses. For instance, if we selected the best 25% of the families our gain would be about 8.5% of the mean for height and 17.7% for diameter. If we applied a selection rate of 1 in 100 to the individuals (which is quite realistic considering how large the progenies can be), the gain would be 26.5% of the mean for height and 59.7% for diameter. Consequently, even though in the long run a breeding programme is certainly needed in order to guarantee a continuity of genetic progress over time, in the short run the potential of clonal selection is enormous.

Figure 5 - Variance components and heritabilities of 1st year height and 2nd year diameter estimated in a 5 (x 10) hierarchical mating between <u>P. deltoides</u> and <u>P. nigra</u>

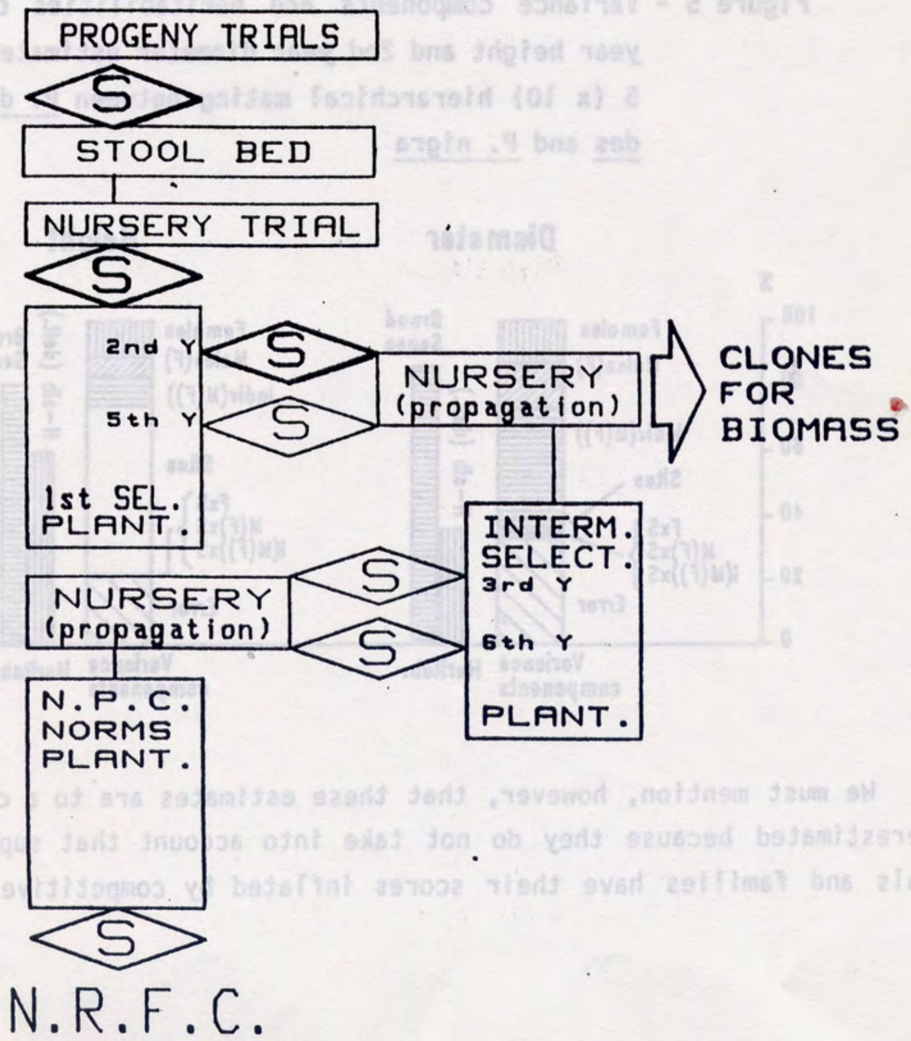


We must mention, however, that these estimates are to a certain extent overestimated because they do not take into account that superior individuals and families have their scores inflated by competitive success over average neighbours. The abovementioned estimates are thus to be seen as the upper limits that the parameters can attain.

3.1.2 Clonal selection

Here again the selection of clones for biomass is a by-product of the main job of finding the best clones for conventional culture. The process is graphically represented in figure 6; it consists of a series of stages; at each stage selection (i.e. a reduction in number) of clones is carried out, based on different traits and criteria according to the number of clones available and the number of ramets per ortet.

Figure 6 - Selection of clones for biomass: relationship with the main selection programme for big-size poplars



Following selection in the progeny-trial nurseries, each individual is vegetatively propagated in a stool-bed for one or two years. As soon as at least 50 cuttings per clones become available, three nurseries are set up in places that represent distinct poplar areas. The number of clones at this stage is in the range of a few hundreds; a minimum of three replications of five-cuttings-in-a-row plots per locality are employed, with a systematic arrangement of controls to separate the plots, provide a check for local fertility and a base of comparison for susceptibility to Marssonina brunnea. Resistance to this disease, growth, crown form and branching habit are the traits that are considered at this stage.

Clonal selection at this stage is usually carried out by means of Principal Component Analysis (PCA). Clonal average values for each trait and locality are treated as variables, clones as cases. Two or three PC's, which usually account for over 80% of the variance, are easily identified. Case scores are calculated and then plotted over the PC's and are then taken as the effective selection criteria.

Selected clones are then planted in a number of plantations. Due to limited availability of stock per clone and their still rather large number (from several tens to more than a hundred) small plots (one or two trees) are employed, with either incomplete block designs or even with complete randomization and symmetrically located controls (a type of 'augmented design').

A first evaluation is carried out at the second or third year (fourth or fifth from cutting); early growth in the stand after covariance adjustment with planting stock dimension, apical dominance, and branching habit are the main selective traits.

At this stage the paths of selection for biomass and for conventional culture part away. The stress is upon form-related traits for the latter, on growth for the former. Clones for conventional culture undergo a new series of plantations and laboratory as well as field tests.

Biomass clones are evaluated for their ability to resprout after coppicing, for their tolerance to dense spacing, for their wood density and so on in ad hoc trials.

3.1.3 Willows

At present there is no interest whatsoever in willow wood for industrial uses in Italy. Willows are considered a weed by poplar growers and are supported only by environmentally concerned groups because they represent the main riparian species along the over-exploited banks of the northern rivers.

The ISP, however, still keeps an eye on this genus: Salix, with its astonishing genetic diversity, is considered a sort of last resource in case of catastrophic events involving poplars. The work carried out in the past (May, 1982) was directed at broadening the genetic reserves and at testing clones in narrow-spaced plantations. The research, while showing the limits of willows as potential substitutes for poplars in conventional culture (namely weak apical dominance and too many epicormic branches), also demonstrated that willows can be a very good choice for biomass plantations.

With respect to poplars, willows usually display a higher juvenile growth rate (in the first 3-4 years from cutting), and a higher rooting ability. Several clones are available that can reach an average d.b.h. of 60 mm in two years with 1 m^2 per tree on good soils.

Breeding is now focused on Salix alba, the main European tree species. In the case of willows too, the main efforts are directed at improving the species for conventional culture, in case they should be needed as substitutes for poplars. Monocormic crown, limited number of branches, wide branch angle, and limited production of epicormics are the main goals of breeding. Fortunately, all these traits display a very large genetic variability and willows are therefore a very promising breeding material.

As far as breeding programmes are concerned, we recently started a screening of our reserves of S. alba which are the result of surveys in Italy and Eastern Europe carried out in the past decades. This screening, performed in three dense plantations (2x2 m), ended with the selection of 24 individuals, half of them females, half males, which will be the starting point of a crossing programme beginning in 1991. As an appendix to the main programme, also interspecific hybridization will be investigated, always using S. alba as one of the partners and Asiatic willow species as the other one.

The first goal of the programme will be an estimation of the genetic parameters for several traits, in order to optimize breeding efforts and predict genetic gains.

As with poplars, clones for biomass will be selected among the best growing in a juvenile phase.

3.2 Pathological and entomological risks

Productivity of plantations for biomass production can be affected in a remarkable measure by several biotic adversities. Their harmful effect is strictly connected to the peculiar characteristics of cultivation and microclimatic conditions of plantations, as well as to the destination of the wood material produced.

High density of plantation and the resulting humid microclimate are favourable to parasites proliferation, such as the Woolly Poplar Aphid (Phloeomyzus passerinii) and the scales (Diaspis pentagona, Chionaspis salicis, Quadraspidiotus spp.), which are able to compromise vitality of cortical tissues and therefore survival of the young shoots. Humid environment is also suitable to defoliators such as Phyllodecta vitellinae and to foliar fungi such as Melampsora spp., the attacks of which will result in important production losses.

Coppicing allows the establishment on stumps of a great population of harmful bark and wood boring insects among which the most important ones are the European Goat Moth (Cossus cossus) and Poplar Clearwing Borer (Paranthrene tabaniformis), that are attracted by the healing tissues and cause a remarkable weakening of the tree, the Large Poplar Borer (Saperda carcharias), that causes a similar damage, and the Poplar and Willow Borer (Cryptorhynchus lapathi), that is to be considered the most fearful one for the gravity of damages on young stems. The delicate shoots developped after coppicing are moreover the favourite food by Melasoma populi, the defoliations of which can be important enough in consideration of the delicate vegetative phase of the tree.

If the culture is aimed at the production of material of adequate dimensions for use in the paper industry, also the Poplar Shoot Borer (Gypsonoma aceriana), which is constantly present at high population levels, can cause appreciable damages, preventing development of the leader where a witches broom, formed by smaller twigs, will take its place.

There are finally numerous parasites able to damage the poplar independently from the final use of the crop. Among these we can mention the bark and wood boring insects Agrilus suvorovi populneus and Melanophila picta, frequently found on trees suffering from water stress, and the defoliators Hyphantria cunea and Byctiscus spp. Also Marssonina brunnea and Venturia populina fungi, in the climate conditions of the Po Valley, can cause repeated defoliations on the most sensitive clones.

Phytosanitary control in plantations for biomass production cause a number of problems (not only for economic reasons) mainly due to the culture characteristics themselves. The high density prevents an easy operation of machines and a satisfactory distribution of chemical products both on the stem and on the crown. In addition, bark and wood boring insects living in the stumps are unlikely to be reached by the insecticides and are therefore able to reinfest the crop itself as well as the adjacent poplar plantations grown as high forest, where they can seriously damage their quality.

Measures against the other parasites mentioned above are economically and technically impossible; it is therefore advisable to try to limit damages by carefully choosing the planting site and by carrying out, where possible, adequate tending in order to maintain the trees in a sufficiently vigorous condition, so that they can better endure the attacks.

The use of resistant poplar species and clones can be of great help to control biotic adversities. To this purpose, Populus alba, among indigenous poplars, shows a very high resistance to the Woolly Poplar Aphid and to several foliar diseases, as well as a good tolerance against bark and wood boring insects (DELPLANQUE et al., 1986); among exotic species, Populus deltoides is generally resistant to the Aphid and to Marssonina brunnea. Among the hybrids, those of P. deltoides x Populus trichocarpa and x Populus ciliata give higher guaranties of resistance against P. passerinii and M. brunnea with respect to the hybrids P. deltoides x P. nigra, among which it is still possible to select some interesting clones.

3.3 Removal of nutrients from the soil

On the basis of tests carried out on plantations of clone 'I 214', we can state that the quantity of nutrients removed from the soil depends essentially on the percentage of bark and therefore varies according to the dimensions of the stems which, in turn, are depending on densities and rotations adopted. For example, a ton of leafless biomass can contain the following quantities of nutrients:

Density	Rotation	Nutrients (kg/ODT)			
(trees/ha)	(years)	N_2	P_2O_5	K_2O	CaO
75,000	1	6.9	3.1	5.2	9.0
10,000	2	5.6	2.1	4.2	7.5
277	13	1.6	0.7	2.4	5.7

We can reasonably expect that for density of 1,000-2,500 trees per ha and rotations of 5-6 years, quantities of nutrients removed are intermediate among those given in the above table for densities of 10,000 and 277 trees per ha. This means that for these plantations a ton of woody biomass (at dry condition) should contain approx. 3.5 kg of nitrogen, 1.5 of P_2O_5, 3.5 of K_2O and 6.5 of CaO.

These data can be of help for an approximate definition of the maintenance fertilization needed by SRIC plantations. Obviously, it is necessary to verify them because the quantities of nutrients removed from the soil can vary as a function of the soil fertility and of the clone requirements.

4. TECHNICAL-ECONOMICAL PERSPECTIVES

For the time being it is rather complex to evaluate the economic chances of a poplar culture aimed at producing material of small dimensions in short rotations. It is in fact difficult to foresee what reaction is expected from the industrial converting system against a good that would be offered to the market in a substantially different way from what has been made so far. On the basis of the most commonly adopted cultivation models, that are strictly answering the requirements of the market, the assortments destined to the manufacture of pulp for paper production or chipboard can be considered as "by-products" of an activity aimed mainly at the production of timber suitable for veneer industry (BORELLI, 1989). The economic features of these materials would presumably take different aspects in case they were placed on the market as real "products"; in this case remuneration chances of poplar tree planters would probably change as a result of an activity specifically aimed at the production of small-size material.

It is obviously difficult to estimate, in absence of similar reference systems, the real importance of these aspects; however, it is worth trying to examine at least the market possibilities to absorb these products, on the basis of available data (R.E.S.S., 1984) concerning the wood consumption of industries manufacturing paper pulp and chipboard.

If we take into account only industries producing mechanical pulp, where poplar wood consumption reaches significant values, we can observe how strongly we are depending upon foreign supply: in fact, we import 204,000 tons out of the approx. 416,000 tons that are used. As the most important reason for these industries to import timber is the unsufficient level of home production and not the price competition, it is likely that we have sufficiently large chances to place suitable poplar material of internal production.

The situation of chipboard industries is completely different: in this case poplar wood, representing a little more than 50% of the total consumption (924,000 tons), comes almost exclusively (869,000 tons) from home supply. However, it is interesting to observe that round wood represents 55% of this value, while the remaining quota comes, as discard of manufacture, from other converting industries. It is probably within this consumption quota that it will be possible to sell round material produced for the purpose, provided the price is competitive.

If we examine table 11, drawn on the basis of the above mentioned research, it is possible to observe a substantial homogeneity in the way poplar wood assortments are distributed according to classes of purchase price. The use of chips and residues could be explained by an unsufficient quantity of logs rather than by an economic convenience.

Tab. 11 - Market price of wood in Italy in 1981 by type, assortment and price class. Case frequency in census of industries

	Conifers			Poplars			Other broad-leaved trees			Total
	L	C	R	L	C	R	L	C	R	
(lire/ton)	n.	n.	n.	n.	n.	n.	n.	n.	n.	n.
40,000	1	1	1	1	-	1	2	1	-	8
40-50,000	3	-	3	9	3	6	4	1	3	32
50-60,000	5	5	9	14	10	9	5	5	3	65
60,000	-	-	3	4	3	2	2	-	1	15
Total	**9**	**6**	**16**	**28**	**16**	**18**	**13**	**7**	**7**	**120**

LEGEND: L = Logs; C = Chips; R = Residues
SOURCE: R.E.S.S., 1984

Taking the above considerations into account, we believe that there are real chances to place poplar material of low dimensions belonging from SRIC cultivations on the market; 500-600,000 tons per year could be the maximum quantity. Assuming an average production at end of rotation of approx. 150 ton/ha, this means, in terms of areas, that we need approx. 3,600 ha to be yearly felled and therefore, should the production planning be set in rotations of 6 years, to cover an area of at least 21,000 ha.

These are enormous figures for the Italian poplar cultivation reality, especially if we consider the present unfavourable conjuncture that caused, in the last ten years, a continous contraction of plantations (5,200 ha in 1989 in the Po Valley). It is therefore evident that only a high profit of these crops can give impulse to important investments, especially with respect to competing of offer which, due to their need of irrigated soil of good fertility, would necessarily arise a competitive situation. Besides, these conditions make it economically impractical to destine the plantations to the production of fuel wood.

It is therefore necessary to examine the cost-benefit ratio of this particular cultivation model. This is particularly complex in absence of reference points as regards not only the intensity of tending to be carried out but also the choice of the rate of interest as well as the sale price of the final product that would have to answer different expectations compared with those of a traditional offer system.

The values used in the following balance scheme (table 12) are referred to well known situations of poplar farms in the Po Valley; therefore, the results obtained thereof have to be considered as merely indicative.

The table clearly shows that the economic results obtained by a poplar plantation destined to produce in a short period material of low dimensions are highly negative, especially because of the high planting costs. Even if these costs were drastically reduced in the successive cycles as a result of coppicing, poplar tree planters would have to support a heavy liability, difficult to be covered. The use of cuttings would certainly reduce the costs, but a similar reduction would also occur to production.

Tab. 12 - Cultivation costs (in thousands of lire) of one hectare of narrow-spaced poplar plantation

List of cost	Year 1°	2°	3°	4°	5°	6°
Site preparation	300					
Lay-out and hole-digging	500					
Stock purchase (L. 2,200 each)	2,860					
Delivery and planting	800					
Mechanical weed control	270	270	270	270	270	270
Chemical weed control	70	70				
Irrigation	450	300	300	300	300	300
Pest and disease control	50	130	130			
Fertilization	150		120		120	
TOTAL	5,450	770	820	570	690	570
CAPITAL AND COMPOUND INTEREST (1) (r = 0.07)	7,644	1,009	1,004	653	738	570

TOTAL COST (escluding fiscal costs, maintenance and caretaking expenses, land benefits): L. 11,618,000

TOTAL PRODUCTION: 150 tons

AVERAGE VALUE: 50,000 L./ton

TOTAL INCOME: 7,500,000 Lire

(1) In the simple hypothesis that costs are realized at the end of each year

Only in the best sites, with yields of approx. 270 ton/ha, will it be possible to have positive annual land revenues than can be estimated around 500,000 and 1,000,000 thousand lire per ha at the end of the first and second rotation respectively.

These economic estimates, although only indicative, do not allow to reach a optimistic conclusion on the possibilities of developping the proposed cultivation models on a large scale. In fact, against a substantially favourable expectation as regards the placing of final product is a reduced or even more likely a negative profitability of these productive systems; they are therefore practically unproposable in the present market situation of poplar wood. A possible overcoming of the unfavourable conjuncture that brought to a remarkable decrease of the price level, although expected for the next years, will be destined to rapidly exhaust unless the structure of the offer system and the relations between this system and the compartment of enterprises for the first converting are modified at the same time. To this purpose the establishment of inter-professional agreements between producers and users could guarantee to the former the product placing and a minimum level of sale prices; such level would have to be, on one hand, sufficiently high to guarantee an income that can be compared to that of other primary activities and, on the other hand, to the income of similar raw materials, but produced with different systems, in order to be competitive on the marketplace. For the time being, the margin separating these two values is so high to make it very hard to foresee a positive future for the development of SRIC models on large areas.

5. CONCLUSIONS

The experiments illustrated in this report demonstrate that the productive possibilities of SRIC are very high but that it is necessary to adopt intensive cultivation models, to utilize fertile soils and to employ suitable clones.

On the basis of results obtained it is evident that in order to produce logs of sufficient commercial value the following cultivation model is required:

- use of one-year-old plants or shoots from nurseries or coppices;
- densities ranging from approx. 1,000 to 2,500 trees per ha;
- rotations of 5-6 years with renewal by coppicing;
- control of natural vegetation both by herbicides and by mechanical means;
- phytosanitary protection;
- irrigation;
- fertilization.

As far as the choice of the clone is concerned, among the sixty clones tested - all of which were originally selected for traditional poplar cultivation - about twenty had very high yields or, in any case, significantly higher than 'I 214'. Ten of these clones are Euramerican ('Luisa Avanzo', 'Cima', 'Guardi', 'Bellotto', 'Flevo', 'PI 6-70', 'S. Martino', 'BL Costanzo', 'Pan', 'NE 222'), nine belong to P. deltoides ('Fierolo', 'Lux', 'PE 3-70', 'PE 4-68', '35/66', '2 Ken 8', '14/9', '6/67', 'S7C2') and one is interamerican ('69.042/2').

This does not mean, however, that all twenty of these clones are suitable for SRIC plantations; some of them could be excluded due to phytosanitary problems which are certainly aggravated in this type of plantations. As an example, among Euramerican clones, 'Cima' is very sensitive to Melampsora, 'BL Costanzo' and 'Pan' are sensitive to Marssonina brunnea, Melampsora and Phloeomyzus passerinii: the micro-climatic conditions created by the high density are ideal for the spread of these adversities and therefore large scale cultivation in SRIC plantations of said clones cannot be easily proposable. The same clones, as well as others such as 'Luisa Avanzo' and 'Bellotto', are very sensitive to water stress that favour the diffusion of parasite bark diseases (Dothichiza populea) and of physiopathologies ('brown spots'), with negative effects on the vitality of stumps, even if the risk of severe stress decreases when plantations are established in fertile, deep, irrigated or water-rich soils.

Among P. deltoides clones (or clones having morphologic characteristics attributable to this species) those with high susceptibility to Poplar Mosaic Virus (PMV) are not to be trusted: coppicing emphazises the effects of the disease with negative results on vigour and survival of coppices.

'San Martino' and 'Lux' are highly sensitive. For other clones of this group further research is needed before stating their fitness for biomass coppices.

Interamerican clone '69.042/2' appeared to be quite promising, being sufficiently resistant to Marssonina brunnea and to Melampsora: its suitability to coppicing, however, should still be carefully examined; in the only case observed so far, shoots developed from stumps after coppicing had an almost horizontal growth. Should this characteristic be confirmed, its utilization would be impossible as they would not allow the operation of machines.

Apart from these risks, that need to be carefully considered, yields of approx. 20 ODT/ha/year can be obtained in a first rotation of five years.

If these productive levels turn out to be possible also on large scale and not only in experimental tests, SRIC plantations become interesting also from the economic point of view and can guarantee an adequate income to the planter.

There is undoubtedly the possibility to select in a near future other fast growing clones having parasite resistance equal or even higher the best ones tested so far, also taking into consideration that the most productive clones in SRIC are the fastest growing among the clones selected for conventional poplar cultivation. Among the clones that are in an advanced selection phase, Euramerican clones (i.e.: 'SPE 275', 'SPE 104') of P. deltoides (i.e.: 'S7C8', '1-13-13-2') and even of P. nigra ('Brisighella', 'N369') could be available in a short period of time for the SRIC. Also some clones of P. alba seem to be promising, especially in the far southern environments.

There are good chances also for the willow. Various clones of Salix alba have already been singled out: rapid growing, excellent rooting and good sprouting ability. In our conditions a limit could be represented by their low tolerance to soils rich in active lime, rather common in the Po Valley, a tolerance that decreases after coppicing.

The breeding programs which are being carried out at present will certainly offer real possibilities on the matter. We can reasonably expect that within a short period of time at least ten poplar clones and the same number of willow clones for commercial SRIC plantations for biomass will be available.

Keeping a large range of species and clones is necessary to allow the establishment of a mosaic of monoclonal plantations of limited extension with the aim of reducing phytopathologic risks which are always very high in the Italian environmental conditions.

In any case, it is clear that the solution of technical problems will not be enough to ensure the success of this type of plantation; only the market and therefore the economic profitability will decide the success or the failure of plantations for biomass production.

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