EL CULTIVO DE ALAMOS Y SAUCES, COMPLEMENTO DE LA AGRICULTURA

POPLAR AND WILLOW GROWING IN COMBINATION WITH AGRICULTURE

LA CULTURE DES PEUPLIERS ET DES SAULES, COMPLEMENT DE L'AGRICULTURE

P O S S I B I L I T I E S O F P O P L A R C U L T I V A T I O N I N A C I D , S A L I N E A N D C A L C A R E O U S S O I L S

Giuseppe FRISON and Gianni FACCIOTTO

S.A.F., Istituto di Sperimentazione per la Pioppicoltura
Casale Monferrato, ITALIA

INVITED PAPER

Nota : La presente relazione è stata regolarmente presentata a questo convegno e illustra secondo programma ma, per uno spiacevole disguido, non è stata inserita negli ATTI.

19ª SESION DE LA COMISION INTERNACIONAL DEL ALAMO

19th SESSION OF THE INTERNATIONAL POPLAR COMMISSION

19ème SESSION DE LA COMMISSION INTERNATIONALE DU PEUPLIER

Zaragoza, 22-25 * IX * 1992

POSSIBILITIES OF POPLAR CULTIVATION IN ACID, SALINE AND CALCAREOUS SOILS

Giuseppe FRISON and Gianni FACCIOTTO

S.A.F., Istituto di Sperimentazione per la Pioppicoltura
Casale Monferrato, ITALIA

INTRODUCTION

In the past poplars in Italy were usually cultivated in alluvial soils of the Po valley along river beds and in agricultural areas with high inputs in terms of energy and money. Recently, attempts were made to spread poplar cultivation also to marginal areas, as for example the acid soils in the 'Baraggia', the saline soils along the coasts and the calcareous soils of the hills.

The most recent initiatives taken by the EC in the framework of the agro-forestal policy, which are adopted also in Italy as ministerial decrees, have opened interesting perspectives in the field of the productive afforestation in those areas set aside by agriculture. However, it should be kept in mind that the surface areas set aside are those less fertile of a farm and in this land a 'demanding' crop as the poplar is unlikely to be grown succesfully. Italian and EC incentives allow to overcome financial difficulties, but obstacles of ecological nature and of adaptability of the commercial clones to particular pedological situations often arise.

The knowledge acquired so far on poplar cultivation in marginal areas is very fragmentary as in the past the research activities regarding breeding and cultivation techniques aimed mainly at increasing the production and the profit in sites which were usual for poplar cultivation, devoting negligible means to the situations in which the culture was of minor importance. Therefore, the results achieved at present are quite contrasting as the same genetic pools and the same cultural techniques developed for poplar cultivation in fertile soils of the plain are used.

A similar approach should be discarded from the beginning as it does not take into account the poor production potentiality of marginal lands and the consequent need to reduce to minimum the preparation for the improvement of the site conditions and the cultural practices.

Awaiting the results which could be achieved by breeding, in a first indicative stage it was advisable to examine the behaviour in saline and calcareous soils of the clones under selection for classic poplar cultivation and of native and exotic poplar genotypes, introduced on the basis of ecological considerations.

As regards acid soils particular attention was paid to the opportunity of improving their reaction by liming and reintegrating their chemical fertility by mineral fertilizing.

As regards the cultural techniques adopted attempts were made in order to:

- reduce to minimum the preparation of the soil;
- use one-year old plants because of the lower cost, the transportation facility and their higher rooting ability;
- use most simplified techniques for the reduction of production costs.

The results of the trials described above will help the farmers make their choice on a concrete basis.

ACID SOILS

Characteristics

'Baragge', 'vaude', 'groane' are names referring to areas in the Provinces of Vercelli, Turin and Milan respectively where the soils named "ferretti" have characteristics which may vary from one site to another, mainly as a consequence of the litological nature of the substrate they originate from. The soils of the baragge in the area near Vercelli, particularly those situated between Buronzo and Lenta, derive from the weathering of materials which mostly consist of magnesium silicates. They are characterized by a very acid pH and a low content of nutrients.

The soil formation of these "ferretti" is characterized firstly by the washing away of the calcium and other alkaline bases and subsequently, when humic acids form and the environment becomes acid, leaching involves also the aluminium and iron sesquioxides which are swept away from the surface to the deeper horizons by meteoric waters.

The spontaneous vegetation growing in these soils is represented by an association of herbaceous plants and shrubs with not many species where the heath prevails (*Calluna vulgaris*). Among the arboreous species the chestnut (*Castanea sativa*), the oak (*Quercus robur*) and the black locust *(Robinia pseudo-acacia*) are present.

These soils have very low fertility and it is difficult to grow agricultural crops. Rice is widely grown though the production results are often economically not so important.

Towards the end of the Seventies also in marginal areas of this kind, where a regression of the agricultural crops took place, attempts were made to extend poplar cultivation. Taking advantage of this trend, an experimentation programme was started aiming at gathering useful data for the evaluation of the real possibilities of poplar cultivation, particularly in acid soils with high iron contents in the 'baraggia'. As no detailed information regarding the possibility of improving poplar cultivation in acid soils by fertilizing and liming are available, neither in Italian nor in Foreign literature, research in this field was considered necessary.

Materials and methods

In February 1981 a plantation was established at Buronzo, in the 'Baraggia', with a spacing of 6x5 m.

The soil preparation was limited to a superficial ploughing. Instead of deep ploughing a ripping 50-60 cm deep was carried out so that the soil of the inert layer was not brought to the surface.

One-year old plants from the nursery were compared with two-year old plants, both belonging to the same two clones (LUISA_AVANZO and CIMA), at that time considered to have a good adaptability to marginal soils and requiring no particular cultural practices. One-year old plants were cheaper and easier to handle than two-year old ones.

For the correction of soil acidity and the integration of fertility, fertilization and liming were carried out as described below.

Cultural practices consisted in a couple of diskings per year and control treatments against insect pests.

For the field trial a split plot design with 4 replications was adopted. The larger plots were assigned to the factor 'clone'; the plots to the factor 'plant age' and the sub-plots to the factor fertilizing and liming. Each sub-plot contained 25 plants (5 rows, 5 plants in each row), the 9 central plants were used for surveys.

For liming, calcium hydrated ($CaOH_2$) was used in the following doses kg/tree: 1,2 on 15.6.1981, 2 on 23.6.1982, 4 on 19.10.1984, 8 on 10.6.1986 and 10 on 18.6.1987.

Lime was always spread on the whole surface area and the doses used were increased on account of the plant age in order to avoid the burning of young roots.

Mineral fertilizers were distributed according to the following calendar:

02.06.1981	N-P-K 15-15-15 at a dosis of 1kg/tree
14.05.1982	N-P-K 11-22-16 at a dosis of 1kg/tree
24.06.1982	Urea 46% at a dosis of 0,250 kg/tree
17.10.1984	Mineral superphosphate 19-21% at a dosis of 2 kg/tree
	Potassium salt 40-42% at a dosis of 1 kg/tree
10.06.1986	N-P-K- 15-15-15 at a dosis of 3 kg/tree
16.06.1987	N-P-K- 15-15-15 at a dosis of 3 kg/tree

The fertilizers were spread only around the tree within a 1.2-metre radius during the first distribution, 2-metre radius during the second one and all over the surface area during the third one and in the following applications.

In order to study the influence of liming and fertilizing on the mineral contents of the soil and the nutrient content of the leaves, soil and leaf samples were taken on 11.7.1983, 22.7.1985, 15.7.1986, 10.8.1987.

To reduce work, the leaf and soil samplings were carried out only in 32 plots established with two-year old plants of both clones.

The leaves were taken from the middle part of the shoot on a branch at the second or third vegetation year.

The sample of each plot consisted of about 20 leaves per plant from the 6 central trees, in order to avoid edge effects.

The soil samples were taken in the layer corresponding to the first 30 cm in five different places of the surface area corresponding to the 6 plants from which the leaves were taken. In order to obtain a single sample for the analysis the five takings were mixed.

The effects of the corrective and fertilizing treatments were pointed out through mensuration surveys carried out at the end of each vegetative period.

Results

Tables 1, 2, 3 and 4 show the results of soil analysis while the results of leaf analysis are illustrated in tables 5, 6, 7 and 8.

The data concerning each individual clone are reported only if relevant differences were found.

From the statistical processing of the data deriving from the chemical analysis carried out on the sample taken in the four years mentioned, it could be observed that:

- on 11.7.1983 no significant effect on the soil chemical characteristics could be noted (pH and available nutrients) nor on the mineral contents in the leaves, which could be attributed to liming and fertilization (tables 1 and 5);
- on 22.7.1985 the influence of liming on the soil pH and on the exchangeable calcium content was evident and also the effect of fertilizing on available phosphorous and exchangeable potassium content could be noted (tab. 2). Nevertheless, both treatments seem to have no influence on the mineral contents in the leaves (tab. 6);
- on 15.7.1986 the effectiveness of liming on the soil pH and the exchangeable calcium was confirmed. The negative effect on the available iron content was also proved. The fertilization had a positive influence also on the contents of available phosphorous and exchangeable potassium (tab. 3). Liming had no influence on the mineral contents in the leaves and fertilizing caused a significant increase of the nitrogen and potassium contents. On the contrary, the supply of phosphorous caused no changes in the concentration of this element in the leaves (tab. 7);
- on 10.8.1987 the liming seemed to affect positively the soil pH and the exchangeable calcium content, whereas a negative effect was noted on the available iron content. The fertilization was effective on exchangeable potassium and available phosphorous content (tab. 4 and fig. 1). It should be pointed out that phosphorous fertilization positively affected the available P_2O_5 only if no liming was carried out. Besides making insoluble a part of the available iron, the slacked lime applied clearly blocked most of the P_2O_5 added by fertilizing. Liming affected ashes and calcium contents in the leaves taken at the same time as the soil samples, but it had no effect on the content of other nutrients. Fertilization increased significantly nitrogen and potassium contents and decreased magnesium content. A higher absorption of potassium corresponds to a lower concentration in magnesium. The phosphorous supply had no influence on its concentration in the leaves (tab. 8 and fig. 2).

The interaction at the first and second level between kind of treatment (fertilizing and corrective) and clone and plant age was not significant.

The difference among the abovementioned clones is significant only as regards the phosphorous content; the highest levels were recorded on the leaves of the clone CIMA.

The mensuration data gathered at the end of each vegetative period are reported in table 9.

The effect of the clone is significant during the first years (the average basal areas of the clone CIMA are larger than those of LUISA_AVANZO) but not significant in the following ones.

One-year old plants, having significantly smaller dimensions than two-year old plants at the establishment, were able to fill the gap within 3 years.

Liming did not affect tree growth significantly (expressed as basal area). On the contrary, fertilization had positive effects, statistically significant, particularly clear in the last 3 years (1985, '86, '87).

Since the beginning of the experimentation lime ($Ca(OH)_2$) was applied 5 different times (15.6.1981, 23.6.1982, 19.10.1984, 10.6.1986 and 18.6.1987) and in increasing doses (kg/tree 1,2; 2; 4; 8 and 10 respectively) in order to avoid the burning of young roots. A total amount of 8 t/ha was applied which raised the pH value (determined in KCl) of more than 1 unit.

It is noteworthy that the raising of more than one pH unit, (from 3,7 to about 5 as global response, corresponding to a pH effective response of about 5 and 6 respectively) did not affect tree growth. It was advisable not to raise the pH further. In fact, the amount of lime needed to raise the pH from 5 to 6 (as global reaction) would have been much higher than those used to bring the soil from pH 4 to 5 (always as global reaction). Furthermore, the high lime quantity necessary in this case would make the intervention too expensive, particularly if we take into account that the corrective action, as already referred in literature, lasts for a relatively short time period.

Total liming raised the pH significantly, increased the exchangeable calcium and magnesium contents, decreased the exchangeable iron and blocked most of the phosphorous added by fertilizing. Thus, the available phosphorous amount in the soil was so maintained constant. In the leaves liming had significant influence only on calcium content.

The quantity of fertilizer distributed during the period from 1981 to 1987 was equal to 614 kg/ha Nitrogen, 523 kg/ha P_2O_5 and 509 kg/ha K_2O, with ratios 1:0,85:0,83. On the whole, the fertilization significantly affected the growth of the stem at 1,30 m (expressed as basal area). Positive effects were found also in the previous years. However, the differences among fertilized and control trees exceeded the statistical threshold of significance only as a result of the cumulative effect of several vegetative periods.

Although no fertilization nor liming were repeated in the last three years, namely from 1988 to 1990, the differences among treatments were still highly significant. The annual increments had a marked decreasing trend: 72 cm^2/tree in 1988, 23,5 in 1989 and only 15 in 1990 (tab. 9). As problems arose also as regards the phytosanitary situation, the grower decided to fell the plantation at the end of 1990, that is 10 years after the establishment. During the felling operations dendrometric surveys were carried out (diameter, total height) in order to calculate the dendrometric volumes (total and up to a diameter of 10 cm at the top) for each treatment. The results of these surveys and the calculation of the volumes per ha, taking into account the trees present when the plantation was felled, are reported in table 10.

These data confirm the equivalence between one- and two-year old plants and the ineffectiveness of liming on yield (fig. 3 and 4).

On the other hand, the fertilization effect is still very clear with an increase of about 17% in comparison with the control plot not fertilized.

The lower production of the clone CIMA, compared to that of LUISA_AVANZO, agrees with the results obtained also under different pedological conditions.

Discussion

Though clones with high potencialities and soils poor in nutrients were used, the yield is fairly low (about 100 m^3/ha of exploitable woody mass, up to 10 cm girth at the top) and the yield increases resulting from fertilizing are fairly low (less than 20% in volume compared to the control plot not fertilized).

However, it should be borne in mind that the survey was carried out in the 'Baraggia' near Vercelli in compact soils whose acid origin is connected with the oxidation of iron compounds. Under these conditions though liming had positive effects on the correction of soil acidity, it did not affect tree growth. By liming the response was brought from pH 4 to pH 5 (determination in KCl) corresponding to pH over 5 and 6 respectively for determinations in H_2O (effective acidity).

In acid soils with a pH value lower than 6 the microorganism activity is fairly limited and the nitrogen and phosphorous requirements are very high because of the little decomposition of organic matter and the insolubilization of phosphorous.

Consequently, a positive effect was expected also on tree growth as a result of pH raising from 5 to 6. Actually, liming blocked the availability of the phosphorous added by fertilizing. The same phenomenon, though less evident, was observed also for potassium. The fertilization effect proved to be totally independent from liming and this clearly suggests that the woody increment was caused mainly by the dressing of nitrogen.

On the whole, the woody increment due to fertilization is fairly low. The fertilizer efficacy, presumably about 17 m^3/ha of exploitable woody mass, was limited by the soil compact texture in the deep layers which negatively influenced the movement of water. In fact, the presence of water in the surface was often observed after precipitations and was due to the slow penetration of water into the soil. In order to reduce the negative effects of stagnation soil tillage and gathering towards rows were often carried out, so that the soil level increased in the zones around the roots and decreased in the zones far from roots and water could be removed from the zone where roots were concentrated.

As regards economics, it should be pointed out that the production increments achieved by fertilizing are enough to cover only part of the costs.

The results show that these marginal lands set aside by agriculture because of their low economic interest are unlikely to be exploited by intensive poplar cultivation, particularly if we take into account that costs are much higher due to the soil preparation necessary for the improvement of site conditions. In this regard cultural practices should be carried out without restrictions.

SALINE SOILS

Introduction

Saline soils in Italy are situated along the Adriatic coast (e.g. in the Province of Ferrara) and the Tyrrenian coast (e.g. in the Province of Pisa), in the Apulian 'Tavogliere', in the Sibari plain, in the Capitanata and in Sicily. Some of these lands, those in the internal areas, have a constitutional salinity due to the presence of soluble salts in the forming rocks. However, for most coastal lands salinity results from the nearness to the sea. Here the chloride amount is higher than the sulphate amount, whereas in the internal areas the situation is opposite.

In the last decades serious and sometimes very severe cases were often reported of toxic effects on poplars caused by excess salts in the soil, particularly in the areas of the Adriatic and Tyrrenian coast. These are low lands located mainly under sea level. In the past these lands were flooded by brackish waters because of depression. In these soils salinity usually depends on the movement of underground waters rich in soluble salts which accumulate in the absence of a deep percolation which would help remove soluble salts. The clay texture blocks this process.

Poplar cultivation in these soils would be a good technical solution. However, for a realistic evaluation of this possibility it is necessary to closely examinate the soil salinity level tolerated by poplars without any growth and yield decrease and any loss in the dynamics of the salinity levels.

To this purpose a trial was carried out in the period 1987-1989, after carefully choosing clones and site.

Materials and methods

It was fairly easy to chose the poplar clones to be used. In fact, a group of clones was used, which, on the basis of surveys carried out in experimental poplar stands along the Romea road near Contarina (RO), were supposed to be tolerant of soil salinity. 47 euro-american hybrids belong to this group. They were obtained from artificial crosses using *P.deltoides* clones selected from seed, which come from Vicksburg (Mississippi), 33° 18' lat North, and from Stoneville (Mississippi), 33° lat North, as mothers and from *P.nigra* clones collected in different areas in Central-Southern Italy, in Turkey, Greece and in Toulouse (France) as fathers. Two euro-american clones (I-214 and LUISA_AVANZO) and one *P.alba* clone (VILLAFRANCA), the only one of this species included in the National Register of Forest Species, were used as control clones.

After preliminary observations, a field was choosen situated at Vaccolino (FE) in front of the "Valle Bertuzzi". By 'Valle' is meant a brackish water basin usually embanked. These basins are located along the Adriatic coast in Veneto or in Emilia Romagna. On the basis of previous investigations on the growth rate of herbaceous crops, the salinity gradient of the soil was supposed to be uniformly increasing from one side the other one of the field.

The area was divided into 9 blocks 20 m wide and with a decreasing length from 240 to 80 m bordering on the Valle. Each block included 4 rows along which two-tree plots of the clones under testing were arrayed. *P.alba* was expected to have a higher adaptability than euro-american clones. Therefore, a network of 87 two-tree plots was set up on the whole stand using two-year old plants of the clone VILLAFRANCA. A series of reference points for the other clones was thus formed in areas not very different from each other as regards their salt concentration.

The two-tree plots of the other clones were completely randomized with 24 replications for each clone.

Two-year old plants taken from a two-year old nursery were planted during the period from 21st to 28th March 1988. They were put into planting holes at most 80 cm deep in order to allow young roots to spread, at least at the beginning stage, to the surface layers where salinity had lower tenors. During the establishment the water table was 1.50 m deep with variations of about 50 cm. Therefore, it can be assumed that no plants in the planting hole came into direct contact with groundwater.

Results

Observations on soil analysis

A first series of soil samples was taken in June 1987 in order to get a first impression of the soil salinity characteristics before deciding on its utilization for the experiment. These analysis showed (tab. 11) that salinity varied fairly regularly from minimum values not toxic (samples 1 and 2) to medium values toxic (samples 3 and 4) to maximum values injurious (samples 5 and 6), moving from the farest to the nearest zone bordering on the Valle Bertuzzi, facing the sea.

In the same year a second series of soil samples was taken in August. A distinction was made between surface layer (30 cm) and underneath layer (30-60 cm). Soil texture, response and lime content were analysed. The soil had a loam sandy texture with subalkaline response and on the average calcareous in both layers (tab. 12).

During the establishment water samples from the water table were taken from a series of 15 pits uniformly distributed on the whole field surface area. Chloride concentration in the water and pH were determined. Also chloride concentration in the water increases fairly regularly as a consequence of the nearness to the Valle's influence (tab.13).

This clearly suggests that soil salinity results from the infiltration of brackish water of the Valle allowed by the soil permeability due to the loam sandy texture.

Another series of samples, allotted over on a network including 20 points, was taken on 13.7.1988 when the suffering symptoms, that is leaf necrosis, sprout or even plant death, were already evident on two-year old plants.

On the basis of the symptomatology, the area was divided into 4 sectors: A=healthy trees, B=suffering trees, C=very suffering trees, D=dead trees.

Four to six soil samples were taken from each sector and the following parameters were analysed: pH, conductibility, chlorides, sulphates, C.S.C., exchangeable Na, K, Ca, available P_2O_5, N, organic carbon and organic matter. Some of the results are reported in fig. 5.

The conductibility varies from 230 to 338 μS/cm for the soil where healthy trees were present, from 450 to 683 μS/cm in the sector containing suffering trees, from 500 to 1045 μS/cm where trees were suffering and from 658 to 1183 μS in the last zone where dead trees were present.

The contents of Na_2O in the same sectors vary from 284 to 531, 660-783, 732-1464, 874-1946 ppm respectively. The differences in conductibility and sodium content between the two sectors containing very suffering and dead trees are fairly small.

A last taking of samples was carried out on 8.6.1989. Soil samples from the surface layer and from the groundwater level were taken. The water samples were also taken from the groundwater.

The pits for sample taking were digged in all the sectors few meters far from the zone where samples were previously taken.

Figure 6 gives the results of the analysis of soil samples, whereas Figure 7 those of the groundwater analysis.

In the zone with healthy trees the Na_2O content in the soil varies from 0,073% to 0,12% in the surface layer and from 0,34% to 0,43 % in the deeper layer; the conductibility varies from 330 to 560 μS/cm in the surface layer and from 960 to 1450 μS/cm in the deeper layer respectively.

In the zones with suffering trees the Na_2O concentration is always above 0,1 % in the surface layer and above 0,4 % in the deeper layer. Where there are very suffering or dead trees the concentration exceeds 0,2 % also in the surface layer.

Also in groundwater the sodium content has a trend increasing from the zones with healthy trees towards the zones with suffering, very suffering and dead trees.

The Na_2O content in groundwater varies from 0,086% to 0,21% in the areas with healthy trees, from 0.19% to 0,28% in the areas where trees are suffering and raise from 0,94% to 2,31% in the zones where trees are very suffering or dead (fig. 7).

Comparing sodium concentration in the soil with that of water, it can be observed that the ratios vary in the different areas of the field: in the zones with healthy trees, that is with a lower alkaline concentration, the values are higher in soil than in water, whereas in the areas with dead or very suffering trees, that is with a much higher saline concentration, the values are higher in water than in soil. The reason for this is to be searched in the low absorption capacity of the soil, poor in colloids, because of its loam-sandy texture. It is well-known that the sodium amount absorbed by the soil depends on the availability of the colloids present.

In all the profiles the sodium concentration is higher in the deeper layers than in the surface layers. This is due to the fact that the leaching of meteoric water is more intense in the above layer, as salinity results from the raising of groundwater under capillarity in the dry periods. During dry summers, in the zones of the field where the saline concentration is higher crystals of carbonates and alkali sulphates occurred in the surface.

Observations on plant behaviour

A survey was carried out at the end of April 1988. Almost all the plants of all the clones had sprouted. Only about ten clones, included the *P.alba* clone, had a survival rate which did not exceed 75% of the planting stock.

The mortality rate surveyed at that time should be attributed to accidental reasons or factors not related to the soil salinity, as the plant roots, just developing, had not yet reached a sufficient functionality towards absorption. At the end of May leaf necrosis occurred which could be attributed to the toxicity resulting from excess salts. On 13.7.1988 a survey was carried out and the results are reported in table 17. At that time the field surface area was divided into 4 zones on account of the symptomatology already evident: A, B, C, D. In each of them surveys were carried out separately.

As shown in table 14, the total mortality rate was about 9% in the A zone, where the rooted plants were healthy and vigorous, 40% in the B zone, where the surviving plants had large necrotic areas on the leaves, 65% in the C zone, where some plants had foliar necrosis and dead sprouts and in some cases also their stem was dead. In the D zone, where spontaneous vegetation was absent, the mortality rate was 100%.

On 8.6.1989 the situation surveyed was worsened in the C zone where the mortality rate exceeded 95% and the few survived plants seemed very suffering. The sanitary situation had worsened also in the B zone, where the mortality rate had reached 75% and no plant still alive appeared uninjured: on the contrary, in the A zone the mortality rate had settled at about 10% and the survived plants appeared healthy and vigorous (fig. 8).

These results suggest that among the clones compared there are no levels of tolerance of soil salinity significantly different. However, the most surprising data is that *P.alba*, represented by the clone VILLAFRANCA, did not prove more resistant than euro-american clones.

Discussion

In evaluating the limits of salinity as regards the tree tolerance, it should be taken into account that in the field there are dynamic and not static conditions. In fact, if we consider that the water content in the soil varies in the time as a result of different evaporation and precipitation ratios in the different horizons, it can be assumed that the vertical distribution of salinity changes with different rhythm day by day. Consequently, the salt concentration of a certain horizon is not constant at all. This clearly suggests that the maximum limit of soil salinity compatible with the crop tolerance cannot be determined if the concentration varies considerably as a result of the water movements in the soil.

Furthermore, it should be pointed out that the toxicity level depends on the salt concentration in the solution in which the soil is soaked with reference to the crop vegetative period. The data collected show that young plants of euro-american clones show toxicity symptoms during the rooting stage or just after transplanting also at concentrations of sodium chloride lower than 1 per 1000 and surely die when salinity exceeds this tenor. On the contrary, adult plants have a wider tolerance interval. For example, according to our experience mature stands (I-214) can be irrigated at long intervals using water containing 0.2-0.3% of sodium chlorides with no consequent evident damages. The tolerance limit varies also on account of soil texture: it is lower in sandy soils, higher in clay soils.

However, these limits are abundantly exceeded by common agricultural crops. This indicates that the possibility of using saline soils for euramerican poplar clones cultivation is fairly limited.

CALCAREOUS SOILS

As a result of the spreading of poplar cultivation from its natural habitat to ex-agricultural lands where the soils are less deep, less soft and more calcareous a physiological disorder due to iron deficiency frequently occurred. Typical symptoms were leaf yellowing, subsequent necrosis and, in most severe cases, growth inhibition .

In former studies we dealt with the factors causing the frequency and intensity increase of the physiopathy and in particular its care and prevention. In this regard the tests carried out show that iron chlorosis of poplars in nursery can be effectively treated via roots with Sequestrene 138 Fe (EDDHA) at a dosis of 3 g/m^2 or with similar products. The treatment cost weighs about 5% upon the average price of saplings and is therefore bearable.

Treatments in plantation proved to be equally efficaceous. However, the cost is exorbitant because of the higher dosis required and the low value of the material produced.

In order to solve the problem of iron chlorosis in poplar plantations, we took other factors into account, as for example the choice of a site having a tolerable active limestone amount, the choice of most tolerant clones and the application of preventive agronomic methods.

In order to develop a method for the evaluation of the suitability of calcareous soils for poplar cultivation without any risk of iron chlorosis, a preliminary trial was carried out and followed by specific investigations.

In the preliminary trial 12 sites were chosen situated in the hills of Monferrato, in the Province of Mantova, Piacenza and Ferrara where poplars were damaged by chlorosis. In these plantations, established with I-214, soil samples were taken from the Ap layer and the physical-chemical analysis illustrated in table 15 were carried out.

Through the analysis of analytical data, particularly of the content of active lime, exchangeable calcium, available phosphorous and iron, attempts were made to find out a possible analogy as regards the above parameters among the soils considered, all having a high chlorosis power index. These data indicate that in poplar stands where I-214 was suffering from iron chlorosis, soils had the following characteristics:

- from a minimum of 50% to a minimum of 85% of fine particles (silt+clay)
- from a minimum of 4400 ppm to a maximum of 6600 ppm of exchangeable calcium
- from a minimum of 16 ppm to a maximum of 65 ppm of available iron

As regards the extent of damage a remarkable clonal variability can be observed. For instance, at San Salvatore about 50% of the trees (clone I-214) were damaged during the rotation, whereas at Camino, where the clone BL_COSTANZO was damaged, the mortality rate of I-214 was insignificant and trees were affected only by intense yellowing.

In the soils at Fossadello and San Savino, containing higher amounts of available iron, (175 and 112 ppm respectively) symptoms of iron chlorosis appeared only on less tolerant clones, particularly ERIDANO.

A very different behaviour was observed in nursery and in plantation. In the Province of Mantova and Piacenza, for instance, whereas in nursery iron chlorosis severely affected also I-214, in plantation the physiopathy occurred only on the most sensible clones and just 5-6 years after the establishment.

As regards the occurrence of iron chlorosis the distribution and density of roots and the water balance of the soil are likely to play an important role.

Therefore, threshold levels for the parameters considered cannot be easily determined. However, clay soils containing more than 7-8% active lime, 5000-6000 ppm of exchangeable CaO, 45-50 ppm of available P_2O_5 and less than 50-60 ppm of available iron can be considered at risk, at least for clones with an average tolerance of lime chlorosis.

In the specific trial a very small area in Monferrato was considered and within this area a randomized sampling of the plantations was carried out. In each stand soil samples were taken and the presence (or absence) and intensity of chlorosis were recorded. As the euro-american clone I-214 prevails (32 out of 38), the genetic variability can be excluded. Attempts were made to identify the factors responsible for the physiopathy in a fairly extended area at risk. Furthermore, the frequence and the incidence of the soil potencialities for poplar cultivation were surveyed.

The plantations were established using one- and two-year old plants from nursery and the cultural practices carried out are a little less intensive than in the plain.

Materials and methods

In the 124 plantations, where the inventory was carried out (work which is being concluded), a randomized undersampling was carried out in 38 stands for pedological surveys.

The survey was carried out in June 1990. For each site the following factors were considered, as are reported in table 19:

- profile (name)
- locality
- position on the landscape
- slope
- exposure
- tree age
- clone
- number of plants
- average girth of the 15 plants contained in a 3-row plot (5 plants in each row). In the center of the plot a pedological pit was digged.

Pits with a different depth were digged with a grab bucket excavator from a minimum of 50 cm to a maximum of 140 cm in the most representative zone of the poplar stand.

During the survey in the field the description of the profile was made taking into account the following factors:

- depth: determined on the basis of the presence and distribution of roots;
- presence or absence of skeleton, that is solid matter between 2 mm and 60 cm;
- colour by means of Munsell chart;
- structure
- streacks for the survey of phenomena of chemical-physical alteration in the soil;
- hardened horizons, represented by the layers impenetrable by roots;
- clefts, which indicate typical phenomena affecting soils with high contents of expansible clays;
- drainage, for the evaluation of water downflow from the profile surface horizons to the deeper ones.

Soil samples were taken from each layer which seemed to have different characteristics from the other, particularly as regards colour, but also texture, structure and so on.

On account of the practical purposes of the survey it was advisable to consider only emorganic horizons which were grouped as Ap and b horizons in order to simplify.

By Ap is meant the cultivation horizon influenced by ploughings and any other anthropic intervention. It should be considered that those lands cultivated with poplars were previously cultivated with wineyards and other agricultural crops.

The C horizon, still not interested by soil formation, was not sampled.

Organic horizons were not taken into account because of the low accumulation of organic residuals and the low content of organic matter observed during field surveys and laboratory analysis.

The preparation of soil samples and the methods adopted for soil analysis are those suggested by the SISS (Italian Society of Soil Science).

Only analysis of soil texture, reaction (pH in H_2O) and lime content were carried out.

As regards lime content, the total carbonates and the active lime contents were determined on account of the frequent occurrence of severe phenomena of leaf yellowing on the plants in the hills caused by iron deficiency which may be correlated with to excess active lime. The frequence and intensity of the physiopathy was surveyed during the summer.

Results

The results of the survey were examined and attempts were made to correlate site and profile characteristics with the growth rate of the 15 plants measured at the time of sample taking.

As regards the position on the landscape it can be affirmed that about 12% of poplar plantations is situated on the hill top, 58% on the slope and 30% in bottom lands. The slope was about 20%, with a maximum of 40%. Most plantations were facing north and only a few were facing south.

A detailed examination of the influence of site characteristics on the success is not possible, as the data gathered (tab. 16) are quite heterogeneous as regards both clone and plant age. However, some general conclusions can be drawn. On the whole, productive results are better in bottom lands (than in slope and top), except some seldom cases. In the slopes plantations usually have an evident growth trend increasing from upper to the lower part particularly in case of higher slopes where a few meters (less than 10) are enough to determine differences in growth evident both in height and in girth.

These growth changes can be correlated with opposite variations affecting the soil profile depth and consequently its water supply.

For the slopes also exposure plays an important role because of the variations it causes towards soil temperature.

For example, it was observed that in the slopes facing north compared to all the others young plants root with difficulty during cold springs. The soil, particularly in case its water content is high, keeps cold for a longer time period, thus delaying the rooting of saplings in comparison with sprouting and causing difficulties as regards survival.

From the profile analysis it can be observed that 8 of them are not very deep, that is 50-60 cm at maximum. The sub-soil is formed by a thick lime layer that cannot be penetrated by roots. Under these situations growth is very limited, as shown in the scheme below.

Profile n.	Girth cm	Years after establishment
3	44	11
6	32	6
10	68	11
13	46	8
20	36	8
29	63	8

The data refer to I-214 and other euro-american clones (profile n. 10). For profile n. 8 growth could not be evaluated as the tree is only one-year old.

Also profiles n. 2, 4, 9, 12, 27, 28, 31, 32, 33, 34 which at a depth of over 50-60 cm have a total lime content of above 30% up to 55% are considered superficial. Only few roots penetrate into these horizons. Girth growth in these soils is the following one:

Profile n.	Girth cm	Years after establishment
2	66.9	8
4	77.7	11
9	68	7
12	52	6
27	67.5	8
28	55	11
31	94	9
32	52.6	12
33	41.9	6
34	66.7	9

The values are quite low, except for profile n. 31 where, on the contrary, growth is fairly good. However, this is a bottom land situation where the water balance is fairly good.

Particularly low is the growth rate referring to profile n. 32 where lime content is very high (about 60%) also in the surface.

Profiles n. 1, 16, 19, 23, 24, 25 and 30 seem less superficial. However, a high percentage of active lime is present, particularly in 6 of them (from 9 to 13%).

In all the seven sites plants show evident symptoms of chlorosis, except those referring to profile 30 where only the first surface layer 40 cm deep shows an excess of active lime.

A good growth rate was observed in site n. 16, situated on the top, and in site n. 24, stretching from the slope to the bottom, whereas it is low in all the other sites (tab. 19).

In the last 12 sites (n. 5, 7, 14, 15, 17, 18, 21, 26, 35, 36, 37 and 38) the profile analysis does not indicate the limits represented by limited depth or excess active lime. Notwithstanding, in some of them (n. 7, 14, 26 and 38) growth rate is low and in others (n. 5, 15, 18, 21, 35, 36 and 38) is slight. In sites n. 11 and 22 poplar plantations were felled just before carrying out pedological surveys.

The subject can be further investigated through the analysis of the data concerning soil texture, soil response and the contents of active lime in the soil.

As regards pH no particular observation could be made, as all the values fall within the limits of the sub-alkaline reaction.

On the basis of the texture of the samples taken from the most superficial layer (down to 40-60 cm) soils can be grouped into the following classes (tab. 17):

- loamy sand (profiles n. 5, 6, 13)
- loam (profiles n. 7, 34, 35, 37)
- loam sandy clay (profiles n. 8, 9, 14, 33)
- silty clay loam (profiles n. 1, 3, 10)
- loam clay (profiles n. 2, 4, 12, 15, 16, 17, 19, 21, 23, 25, 26, 29, 30, 31, 32)
- silty clay (profiles n. 18, 22)
- clay (profiles n. 11, 20, 24, 27, 28, 36, 38).

In many profiles in the layers below the first one texture does not vary considerably and in some of them the clay percentage increases.

In soils with loamy sand texture (n. 5, 6 and 13) no drainage problems arise. The tenor of active lime is very high in sites n. 6 and 13 (7.75% and 10.75% respectively) and fairly low in site n. 5 (equal to 2.65 from 0 to 45 cm and 4.13 from 45 to 90 cm). Iron deficiency affects plants with different degrees of severity in all the three sites.

In the 4 sites with loam texture drainage problems may arise resulting also from orography, as the surface layer lies on a layer with a more fine texture (silty clay loam). The amount of active lime is very low in site n. 7 (0.75%) and in site n. 35 (0.14%) where no chlorosis symptoms occur, whereas it is very high in site n. 34 which is affected by chlorosis symptoms. The amount of active lime is very low in site n. 37 (0.1%) where chlorosis symptoms are evident. The clone is BL_COSTANZO which is much more sensible to chlorosis than I-214.

In the four sites with loam sandy clay texture situated in the upper or middle part of the slope, drainage is favoured by slope. Chlorosis did not affect site n. 8 which had a low active lime content. However, slight symptoms were observed in sites n. 9 and 14 and they were very severe in site n. 33 where the active lime content was about 11-12%.

In the three sites with a silty clay-loam texture no drainage problems arose and the active lime amount was very high. Chlorosis severely affected the first two sites, whereas no symptoms could be noted in the third one in spite of the high content of active lime. Tree growth was limited because of the little depth of the profile and the position on the slope.

In the 15 sites with loam clay texture situated on the slope, some in the middle part and some on the top or in the lower part, no serious drainage problems arose.

Iron chlorosis occurred in all three sites with intense symptoms, except in the three sites n. 15, 17 and 26 which had the lowest contents of active lime. In the poplar stands located in these sites the physiopathy occurred only on few trees and was not intense.

The two sites with silty clay texture (18 and 22) had no particular drainage problems and are not affected by iron chlorosis: the content of active lime reached high values (10%) only in the surface layer of the first site and average values in the second one. (5.3%).

However, it should be noticed that both stations were situated in bottom land where the soil is deeper.

The seven sites with clay texture had all a certain slope which facilitated the removal of excess water, thus avoiding backwater. Five of them showed excess of active lime and on the plants chlorotic symptoms were evident. The physiopathy also affected the trees of the two sites n. 36 and 38 which were not very calcareous. However, here the active layer of the soil was not very deep.

Some of the seven sites with clay soil were situated on the hill top (n. 11 and 36), others in the upper (n. 20 and 28) or lower (n. 24, 27 and 38) part of the slope and hence they were not affected by drainage problems.

Some soils (n. 20, 24 and 27) had excess of active lime (from 7 to 10%) and severe chlorotic symptoms were evident. Other soils had average (n. 11 and 38) and low (n. 28 and 36) contents of active lime and trees showed evident symptoms probably due to the limited profile depth (n. 28) or to the high clay content (n. 38) which were likely to hinder the expansion of roots.

These observations suggest that no evident correlation exists between texture and active lime content. This is also proved by the calculation of the correlation coefficient, equal to 0.274, which was obtained correlating the percentage silt+clay with the content of active lime. The value of the correlation coefficient is not significant, as it is too low.

It is also evident that no clear correlation exists between content of active lime and intensity of iron chlorosis. As already known, the physiopathy cannot be explained only on the basis of the amount of active lime. Other factors have to be taken into account, such as profile depth and layer texture which play an important role on the water and air balance and consequently on the expansion and functionality of roots, thus affecting nutritional balances.

Damages caused by iron chlorosis are the more or less intense yellowing of leaves on a more or less wide part of the tree with a consequent influence on growth rate which is not likely to be determined (as for instance in stand n. 1, 3, 6, 13, 14, 16, 17, 19, 20, 21, 23, 24, 25, 26, 27, 29, 36, 37, 38). In some cases some trees died (as for instance in stand n. 2, 5, 12, 31, 32, 34) with evident influences on yield.

As regards water balance it should be noted that the area surveyed from the phytoclimatic point of view is placed in the *Castanetum* , an area where annual average precipitations are about 700 mm, characterized by two minimum (summer and winter) and two maximum (spring and autumn) values. In the dry periods during the summer the occurrence of fissures is likely to be observed 5-6 cm wide and deeper than the Ap layer in soils with a more fine texture , as particularly in the slopes a water table does not exist that could influence under capillarity the soil moisture in the surface layers. On the contrary, in the rainy periods soils with a fine texture are satured with water and cannot be entered by machines for long time periods. Very humid and dry periods alternate causing unfavourable conditions for a regular tree growth.

In the areas on slopes, particularly near the watershed, the surface layers satured with precipitation waters often slide down onto the calcareous layer and cause slides. In some cases farmers decide to grow poplars in order to reduce the phenomenon as they take into account the protective action of poplar roots. Nevertheless, under such conditions also the poplar is faced with difficulties as regards the delopment of a root system suitable for this purpose.

Discussion

It can be affirmed that the main factors affecting tree growth in the calcareous soils in the hills are the little depth of the profile, the excess active lime, the high clay content, the low water availability during the summer and their interaction.

Chlorosis is widespread and occurs with different degrees of severity ranging from leaf yellowing, sometimes only temporary, in spring when rainfalls are heavy, to persisting yellowing followed by leaf necrosis and, in most severe cases, by tree death.

Because of the high soil heterogeneity, mortality usually does not affect wide areas but groups of trees. Thus, only a part of the poplar stand is damaged. In most severe cases this part can reach 30% of the total surface area.

As regards yields mean annual increments of about 10 m^3/ha/year can be obtained. To this purpose, although cultural models are less extensive than those typical for poplar cultivation in the Po valley, considerable available funds are necessary for the establishment and the management, especially during the initial years. Therefore, it can be assumed that with the clones available at the moment and the techniques actually used, poplar cultivation is not profitable in the calcareous soil on the slopes of the hills of Monferrato.

CONCLUSIONS

Among the commercial clones selectected for poplar cultivation in the Po valley with the intensive cultural models adopted in acid soils in the 'Baraggia' and in calcareous soils in the hills of Monferrato yields of 10 m^3/ha/year of exploitable woody mass (upto ∅ of 10 cm at the top) were obtained.

On the basis of these results poplar cultivation cannot be justified by economic expectations. Poplar cultivation is rather connected with the necessity of using lands for which there is no other good alternative.

Under these conditions the grower must reduce to minimum both costs and works for the improvement of site conditions necessary in acid soils (liming and fertilization) as well as in calcareous soils in the hills (distribution of organic fertilizers for the prevention of iron deficiency). The only possibility is thus the selection of suitable micro-sites, where the stand can be established with rough preparation interventions.

If we follow this logic forecasting methods for the evaluation of site suitability must be developed. Furthermore, the possibility of using simplified cultural models must be evaluated. Clones with a higher adaptability to edaphic conditions and less potentialities, in comparison with the classic ones used for poplar cultivation in the plain, will be used.

Potential possibilities certainly exist. Forecasting techniques can be further improved and the potentialities of use of soils can be evaluated very precisely. It is possible to simplify cultural models: it was observed that one-year old plant yields are equal to those of two-year old plants, whereas the production and establishment costs required are lower. Soil diskings can be reduced and carried out only in the first stage of the rotation. The genetic variability is very wide and selection and breeding open up a series of interesting perspectives. In this regard, very promising results were obtained for non-calcareous or fairly calcareous soils in the hills in Emilia (Salsomaggiore) with inter-american clones.

The possibilities for saline soils are not so good because of the little adaptability to salinity of the poplar clones tested, including the clone VILLAFRANCA belonging to the species of *P. alba*. However, further investigations on this subject are advisable.

Furthermore, it is worth reminding that substantial incentives to the spread of poplar cultivation in marginal lands can derive from the application of EC initiatives, as for example those regarding the 'set aside' of agricultural lands and the contribution given for their afforestation.

Summary

In order to evaluate the real possibilities of using marginal lands with intensive poplar cultivation, investigations were carried out on acid soils of the 'Baraggia' near Vercelli, calcareous soils in the hills of Monferrato and saline soils along the Adriatic coast. The results of the experimentation show that soils of this kind are not always likely to be conveniently exploited with intensive poplar cultivation.

Particularly, acidity correction by liming, besides being very expensive, is not very effective for a long time and the pH raising alone cannot increase yield. Liming must always be combined with mineral fertilization and the cost of both operations added together exceeds the profit resulting from yield increase.

In the slope lands in the hills, which are not very deep and have excess lime, yield is on average fairly low (less than 10 m^3/year) and it is sometimes reduced by one third because of the incidence of iron chlorosis caused by excess lime. It is not economically convenient to carry out curative treatments with iron chelates and the possibilities of alternative interventions, for example with agronomic methods, are limited because of their low and slow effectiveness.

The solution to these problems is to be searched in genetics. The selection of clones more resistant to iron deficiency and the adoption of a different cultural model which is characterized by less intensive interventions.

In the soils with a high salt concentration poplar cultivation is limited because of the little resistance of euro-american hybrids to salinity. Most tested clones do not tolerate maximum sodium concentrations equal to 1 per 1000, thus showing a lower tolerance than crop trees.

Key words: poplar cultivation, acid soils, saline soils, hill calcareous soils

Resumé

Pour évaluer les possibilités réelles de l'utilisation de sols marginaux avec la culture du peuplier, des essais ont été effectuées en particulier sur des sols acides de la Baraggia Vercellese, des sols calcaires de colline du Monferrate et des sols salins du littoral adriatique. Les résultats de l'expérimentation démontrent que les sols de ce type ne peuvent pas être systématiquement mis en valeur par la culture intensive du peuplier. En particulier, la correction de l'acidité par chaulage a - à part son prix élevé - une efficacité limitée dans le temps et la simple élevation de la valeur du pH ne suffit pas pour accroître la production. La chaulage doit toujours être accompagnée de fumure minérale et le coût des deux traitements sommés dépasse le bénéfice obtenu avec l'augmentation de production.

Dans les sols de colline en pente, peu profonds, avec un excès de calcaire actif, la production est en moyenne plutôt faible (moins de 10 m^3/an) et est souvent encore réduite parfois même d'un tiers par effet de la chlorose ferrique. Dans ces sols il n'est pas rentable d'effectuer des traitements curatifs à base de chélates de fer et les possibilités d'interventions alternatives, par des méthodes agronomiques par exemple, sont limitées à cause de la lenteur et de la faiblesse de leur efficacité.

La solution de ces problèmes doit être recherchée sur le plan génétique en sélectionnant des clones plus résistants à la carence de fer et en adoptant une stratégie culturale diverse qui, tout en prévoyant des interventions bien coordonnées, soit caractérisée par un moindre degré d'intensité.

Dans les sols ayant une concentration saline élevée la culture du peuplier se heurte à des limitations importantes vue la faible résistance des hybrides euro-américains à la salinité. La plus grande partie des clones supporte des concentrations maximales de sodium de 1 pour mille et démontrent une tolérance inférieure à celle des plants agraires de grande culture.

Mots clef: populiculture, sols acides, sols salins, sols calcaires de colline

BIBLIOGRAPHY

ANDERSON W.B., 1982 - Diagnosis and correction of iron deficiency in field crops - an overview. Journal of Plant nutrition, 5(4-7) 785-795.

ARRU G., PREVOSTO M., 1981 - Gli aspetti economici e sociali della pioppicoltura in collina. "Giornata Nazionale del Pioppo e 3a Giornata Regionale del Pioppo". 16 maggio, Rovigo.

AVANZO E., FRISON G., 1979 - La pioppicoltura in collina e in montagna. Agricoltura Ricerca, II (3) 15-18.

AVELLANEDA M., NIJENSOHN L. , 1961 - Toxicidad salina en alamo y sauce alamo. Instituto de Suelos y Riego Facultad de Ciencias Agrarias. Univ. Nac. de Cuyo, Mendoza (Argentina).

BORELLI M., CHIARABAGLIO P.M., COALOA D., FRISON G. - Aspetti tecnici ed economici della pioppicoltura nelle aree collinari del Monferrato (to be printed).

CAPPELLI M., 1964 - Ricerche sugli effetti della salinità in un pioppeto del Basso Veneto. Monti e Boschi, XV, n. 6, 27-41.

FRISON G., 1984 - Scelta del clone e tecniche colturali in pioppicoltura. Quaderni C.I.P.A. n. 9, 1-57.

FRISON G., 1986 - Prove di cura della clorosi ferrica del pioppo. L'Informatore Agrario, XLII (48) 65-72.

FRISON G., ANSELMI N., BOCCONE A., 1982 - Research on iron chlorosis of poplars. FAO/CIP/DIS, XXIII Meeting, Casale Monferrato, September 6-10, 1982.

GIULIMONDI G., 1972 - Fenomeni di ingiallimento del pioppo in vivaio. Cellulosa e Carta, XXIII, 7, 7-15.

GRUZDEV D.M., 1959 - "Influence of soil salinity on the growth of oak and other species in the irrigated regions of Azerbaijan" in F.A. vol. 21 n. 1.

HOCHBERG M., LAHAV N., 1976 - Soluble iron in several soils fertilized by Sequestrene 138 Fe. Agrochimica, XX (2-3) 213-221.

HOLMES R.S., BROWN J.C., 1955 - Chelates as correctives for chlorosis. Soil Science, 80: 167-179.

PRINCIPI P., 1956 - I terreni salsi in Italia. L'Italia Agricola, 8, 542-553.

ROMANO E., ROVELLI F., 1966 - Conduttività elettrica e salinità nelle indagini idropedologiche. L'Irrigazione IV (4) 29-43.

SCHIERL R., KREUTZER K., 1991 - Effects of liming in a Norway spruce stand (*Picea abies* L.) Karst. Fertilizer Research, 27: 39-47.

SEKAWIN M., 1979 - Prospettive ed esperienze di pioppicoltura in terreni marginali. Cellulosa e Carta, XXX (1) 3-16.

SPIECKER H., 1991 - Liming, nitrogen and phosphorus fertilization on the annual volume increment of Norway spruce stands on long-term permanent plots in South Western Germany. Fertilizer Research, 27:87-93.

TERRASSON D., DEBOISSE G., LEMOINE M., DUVAL H., 1991 - Intéret des saules et des peupliers pour le boisment des marais dessechés de l'ouest (to be printed).

WALLACE A., 1966 - Ten years of iron EDDHA in correcting iron chlorosis in plants. Current topics in Plant Nutrition. Univ. of Calif., Los Angeles, 1-2.

Casale Monferrato, May 27, 1992

Tab. 1 - Buronzo. Physical and chemical characteristics of soil samples taken on 11.7.1983

Characteristics	Control	Liming	Liming and fertilization	Fertilization	F Value
Skeleton	1.57	2.60	1.96	1.23	0.21n.s.
Texture					
Coarse sand (2-0.2 mm) %	5.94	5.08	4.41	6.45	0.39n.s.
Fine sand (0.2-0.02 mm) %	53.34	56.28	50.32	50.60	1.94n.s.
Silt (0.02-0,002 mm) %	28,76	27,45	32,62	29,82	2.15n.s.
Clay (<0.002 mm) %	11,96	11.20	12.65	13.12	0.32n.s.
Reaction					
pH (H_2O)	4.66	4.88	5.02	4.46	2.77n.s.
Organic carbon %	1.12	1.03	1.06	1.11	0.40n.s.
Organic matter (C x 1.724) %	1.93	1.78	1.83	1.93	0.39n.s.
Total carbonate %	absent	absent	absent	absent	-
N_2 (Kjeldahl) %	1.10	1.02	1.02	1.06	0.47n.s.
Available P_2O_5 p.p.m.	50.75	33.50	51.63	34.50	0.66n.s.
Exchangeable K_2O p.p.m.	54.25	44.50	54.12	52.25	0.65n.s.
Exchangeable CaO p.p.m.	631.50	666.75	857.38	445.00	2.32n.s.
Exchangeable MgO p.p.m.	172.00	139.00	218.00	84.25	0.70n.s.
Available Fe p.p.m.	160.00	117.00	122.00	133.00	1.53n.s.
Available Mn p.p.m.	8.16	6.85	9.07	7.75	0.18n.s.
Available Cu p.p.m.	0.62	0.60	0.56	0.65	0.71n.s.
Available Zn p.p.m.	2.94	1.18	1.76	1.50	1.70n.s.
Available B p.p.m.	0.31	0.31	0.31	0.30	0.007n.s.
C/N	10.18	10.10	10.43	10.49	-

n.s. = not significant

Tab. 2 - Buronzo. Chemical characteristics of soil samples taken on 22.7.1985 around the 6 central plants of each plot established with 2-year old poplars

Characteristics	Control	Liming	Liming and fertilization	Fertilization	F Value
Reaction					
pH (H_2O)	4.87	5.27	5.73	4.83	4.05+
pH (KCl)	3.53	3.99	4.56	3.62	7.42++
Organic carbon %	1.29	1.05	1.28	1.26	1.23n.s.
Organic matter (C x 1.724) %	2.22	1.81	2.21	2.17	-
Total carbonate %	absent	absent	absent	absent	-
N_2 (Kjeldahl) %	0.11	0.09	0.11	0.11	1.32n.s.
Available P_2O_5 p.p.m.	43.00	47.00	63.00	72.00	10.3++
Exchangeable K_2O p.p.m.	68.00	63.00	104.00	125.00	3.13+
Exchangeable CaO p.p.m.	643.00	896.00	1.093.00	644.00	3.60+
Exchangeable MgO p.p.m.	84.00	167.00	256.00	98.00	2.87n.s.
Available Fe p.p.m.	149.00	104.00	76.00	130.00	2.42n.s.

n.s. = not significant
+ = significant at P = 0.05
++ = significant at O = 0,01

Tab. 3 - Buronzo. Chemical characteristics of soil samples taken on 15.7.1986 around the 6 central plants of each plot established with 2-year old poplars

Characteristics	Control	Liming	Liming and fertilization	Fertilization	F Value
Reaction pH (KCl)	4.28	5.07	4.98	4.06	22.26++
Organic carbon %	1.33	1.24	1.33	1.41	0.46n.s.
Organic matter (C x 1.724) %	2.29	2.14	2.29	2.43	-
Total carbonate %	absent	absent	absent	absent	-
N_2 (Kjeldahl) %	0.11	0.10	0.12	0.12	1.12n.s.
Available P_2O_5 p.p.m.	24.00	16.00	74.00	108.00	14.53++
Exchangeable K_2O p.p.m.	47.00	54.00	97.00	135.00	10.71++
Exchangeable CaO p.p.m.	583.00	762.00	991.00	463.00	6.43++
Exchangeable MgO p.p.m.	125.00	93.00	144.00	62.00	0.84n.s.
Available Fe p.p.m.	116.00	69.00	53.00	115.00	5.21n.s.

n.s. = not significant
++ = significant at O = 0,01

Tab. 4 - Buronzo. Chemical characteristics of soil samples taken on 10.8.1987 around the 6 central plants of each plot established with 2-year old poplars

Characteristics	Control	Liming	Liming and fertilization	Fertilization	F Value
Reaction pH (KCl)	3.81	4.94	4.78	3.70	44.63++
Organic carbon %	1.38	1.19	1.29	1.37	2.09n.s.
Organic matter (C x 1.724) %	2.38	2.05	2.22	2.36	-
Total carbonate %	absent	absent	absent	absent	-
N_2 (Kjeldahl) %	0.12	0.10	0.12	0.12	1.64n.s.
Available P_2O_5 p.p.m.	26.88	20.00	28.63	40.50	7.38++
Exchangeable K_2O p.p.m.	38.50	36.88	48.00	57.63	6.50++
Exchangeable CaO p.p.m.	592.50	875.00	911.30	418.80	9.82++
Exchangeable MgO p.p.m.	125.63	181.0	173.0	50.38	2.15n.s.
Available Fe p.p.m.	121.88	51.88	59.00	108.63	12.58++

n.s. = not significant
++ = significant at p = 0,01

Tab. 5 - Buronzo. Nutrient contents in leaf samples from the 6 central plants of each plot on 11.7.1983

Nutrient (% of dry matter)	Control	Liming	Liming and fertilization	Fertilization	F value
Ashes	4.99	4.82	5.07	4.35	1.47n.s.
Nitrogen	1.95	1.77	1.88	1.78	0.66n.s.
Phosphorous	0.15	0.14	0.18	0.14	1.44n.s.
Potassium	0.65	0.68	0.68	0.65	0.66n.s.
Calcium	0.76	0.79	0.77	0.66	1.53n.s.
Magnesium	0.44	0.41	0.42	0.38	0.86n.s.
Iron (p.p.m.)	153.00	146.00	127.00	137.00	0.52n.s.
Manganese (p.p.m.)	118.00	108.00	103.00	127.00	0.56n.s.
Copper (p.p.m.)	7.75	8.25	7.84	7.65	0.24n.s.
Boron (p.p.m.)	21.75	25.25	24.88	22.00	0.81n.s.

n.s. = non significant

Tab. 6 - Buronzo. Nutrient contents in leaf samples taken from the 6 central plants of each plot on 22.7.1985

Nutrient (% of dry matter)	Control	Liming	Liming and fertilization	Fertilization	F value
Ashes	5.25	4.96	5.39	5.10	0.84n.s.
Nitrogen	2.02	1.82	2.06	1.94	1.30n.s.
Phosphorous	0.19	0.16	0.20	0.19	0.84n.s.
Potassium	0.91	0.86	0.98	1.04	0.85n.s.
Calcium	0.80	0.79	0.82	0.73	0.53n.s.
Magnesium	0.51	0.46	0.48	0.44	1.30n.s.
Iron (p.p.m.)	100.00	107.00	83.00	100.00	0.99n.s.

n.s. = not significant

Tab. 7 - Buronzo. Nutrient contents in leaf samples taken from the 6 central plants of each plot on 15.7.1986

Nutrient (% of dry matter)	Control	Liming	Liming and fertilization	Fertilization	F value
Ashes	6.34	6.35	7.20	6.95	2.71n.s.
Nitrogen	2.15	2.07	2.77	2.47	6.33++
Phosphorous	0.18	0.16	0.20	0.18	1.54n.s.
Potassium	0.81	0.86	1.09	1.16	5.79++
Calcium	0.98	1.13	1.18	1.03	2.80n.s.
Magnesium	0.58	0.51	0.53	0.52	2.23n.s.
Iron (p.p.m.)	125.00	115.00	90.00	90.00	0.97n.s.

n.s. = not significant
++ = significant at P = 0,01

Tab. 8 - Buronzo. Nutrient contents of leaf samples taken from the 6 central plants of each plot on 10.8.198

	Ashes	N	P	K	Ca	Mg	Fe (p.p.m.)
			Nutrient (% of dry matter)				
LUISA AVANZO							
Control	5.78	2.55	0.23	0.79	0.85	0.52	78.75
Liming	6.79	2.51	0.21	0.86	1.77	0.53	84.00
Liming and fertilization	6.80	2.77	0.22	1.10	0.98	0.48	81.50
Fertilization	5.57	2.89	0.21	1.02	0.70	0.43	74.00
CIMA							
Control	5.94	2.61	0.22	0.75	0.92	0.55	91.50
Liming	6.37	2.53	0.27	0.71	1.16	0.59	80.50
Liming and fertilization	6.33	3.11	0.26	0.90	1.08	0.47	92.00
Fertilization	5.99	2.92	0.25	0.10	0.81	0.45	79.25
GENERAL AVERAGE	6.19	2.74	0.23	0.90	0.96	0.50	82.69
CLONE AVERAGE							
LUISA AVANZO	6.23	2.68	0.22	0.94	0.93	0.49	79.56
CIMA	6.16	2.79	0.24	0.84	0.99	0.51	85.81
AVERAGE TREATMENT							
Control	5.86	2.58	0.23	0.77	0.88	0.53	85.13
Liming	6.58	2.52	0.23	0.78	1.17	0.56	82.25
Liming and Fertilization	6.56	2.94	0.24	1.00	1.03	0.47	86.75
Fertilization	5.78	2.91	0.22	1.01	0.76	0.44	76.63
F VALUE							
Clone (C)	1.01n.s.	0.80n.s.	20.84+	8.36n.s.	4.58n.s.	1.22n.s.	0.53n.s.
Treatment (T)	2.71n.s.	6.11++	0.60n.s.	6.32++	5.80++	3.25+	0.62n.s.
Interaction (C x T)	0.69n.s.	0.72n.s.	1.03n.s.	0.66n.s.	0.14n.s.	0.23n.s.	0.41n.s.

n.s. = not significant
\+ = significant at P = 0.05
++ = significant at P = 0.01

Tab. 9 - BURONZO (VC). Surveys carried out at 1.30 m from ground of the average basal area per plant (cm^2)

Clone	Age of saplings (years)	Treatment	Date of surveys										
			1.6.81	25.11.81	27.9.82	20.9.83	28.9.84	2.10.85	3.10.86	31.11.87	17.5.1989	18.11.1989	28.8.1990
LUISA_AVANZO	1	Control	2.61	5.14	23.32	61.83	118.70	179.19	251.57	297.74	363.58	387.49	395.04
		Liming	2.80	5.08	22.46	56.96	110.62	167.42	240.68	298.09	370.57	400.96	412.44
		Lim.+fert.	2.53	7.16	26.71	63.12	121.65	194.02	283.35	361.12	438.52	472.93	486.45
		Fertilization	2.71	6.82	26.90	63.15	117.37	186.05	273.99	346.33	427.31	455.43	478.78
		Average	2.66	6.05	24.85	61.26	117.08	181.67	262.39	325.82	400.00	429.20	443.18
	2	Control	9.32	12.94	36.40	68.93	118.89	171.06	234.42	285.48	350.58	371.90	377.45
		Liming	9.60	12.02	32.06	67.76	128.94	177.62	259.81	324.33	399.51	426.44	440.61
		Lim.+fert.	9.41	13.82	34.73	66.01	116.71	183.30	274.63	346.82	426.09	455.83	478.84
		Fertilization	9.14	13.52	37.20	68.25	116.88	197.19	275.00	343.84	426.63	459.37	461.89
		Average	9.37	13.07	35.10	67.74	120.35	182.29	260.96	325.24	400.70	428.38	439.70
CIMA	1	Control	3.23	5.79	23.39	53.85	100.94	148.73	206.48	243.32	313.43	328.83	340.11
		Liming	3.39	6.27	25.68	59.79	114.73	169.67	229.01	278.92	347.49	369.86	380.40
		Lim.+fert.	3.05	8.26	31.60	69.33	118.53	181.34	254.11	312.92	379.57	400.28	425.58
		Fertilization	2.97	10.34	38.09	76.85	133.39	194.16	275.72	332.49	410.59	429.18	454.55
		Average	3.16	7.66	29.69	67.45	116.90	173.49	241.33	291.91	362.77	382.04	400.16
	2	Control	9.70	11.96	33.13	67.39	123.18	181.94	249.28	290.36	360.71	375.87	388.80
		Liming	9.98	12.76	35.04	69.90	125.48	184.20	242.11	284.58	356.96	373.77	387.00
		Lim.+fert.	9.55	17.65	47.17	88.15	146.24	211.47	285.86	331.78	398.01	419.26	433.82
		Fertilization	9.14	15.66	46.75	87.56	144.20	210.69	290.02	340.58	407.45	426.67	449.29
		Average	9.59	14.51	40.52	78.25	134.77	197.08	266.82	311.82	380.78	398.89	414.73
Clone average													
LUISA_AVANZO			6.01a*	9.56a	29.97a	64.50a	118.72a	181.98a	261.68a	325.53a	400.35a	428.79a	441.41a
CIMA			6.37a	11.08b	35.10b	71.60a	125.83a	185.28a	254.07a	301.87a	371.79a	390.46a	407.44a
Sapling age average													
1-yr. nursery			2.91a	8.86a	27.27a	64.36a	116.99a	177.58a	251.86a	308.87a	381.33a	405.62a	421.67a
2-yr. nursery			9.48b	13.79b	37.81b	73.00a	127.56a	189.69a	263.89a	318.53a	390.81a	413.64a	427.21a
Treatment average													
Control			6.22a	8.96a	29.06a	63.00a	115.43a	170.24a	235.43a	279.35a	347.07a	366.02a	375.35a
Liming			6.44a	9.03a	28.81a	63.60a	119.94a	173.98a	242.90a	296.48a	368.63a	392.76a	405.11a
Lim.+fert.			6.14a	11.72a	35.05b	71.65b	125.78b	192.53a	274.49b	338.16b	410.55b	437.07b	456.17b
Fertilization			5.99a	11.59a	37.24b	73.95b	127.96b	197.02a	278.68b	340.81b	417.99b	442.66b	461.13b
GENERAL AVERAGE			6.19	10.32	32.54	68.05	122.28	183.63	257.88	313.70	386.07	409.63	424.44

*Figures of the same group with the same letter are not statistically different.

Tab. 10 - Buronzo. Effects of liming and fertilization of acid soil on the production of poplar plantations with a 10-year rotation

Clone	Age of saplings (years)	Treatment	Circumf. at 1.30 m from ground level (cm)	Total height (m)	Total volume (f+r) (m^3/plant)	Total volume upto 10 cm Ø (m^3/plant)	Number of trees per ha	Total volume upto 10 cm (m^3/ha)
LUISA_AVANZO	1	Control	69.99	20.83	0.389	0.332	283	94.04
		Liming	71.40	21.15	0.411	0.351	262	92.08
		Lim.+fertiliz.	77.93	22.50	0.520	0.448	286	128.12
		Fertilization	77.35	22.39	0.510	0.439	283	124.18
		Average	74.17	21.72	0.458	0.392	279	109.60
	2	Control	68.61	20.44	0.367	0.313	295	92.27
		Liming	74.21	21.05	0.443	0.379	289	109.44
		Lim.+fertiliz.	77.22	21.50	0.490	0.420	283	118.82
		Fertilization	75.56	21.24	0.464	0.396	295	116.98
		Average	73.90	21.06	0.441	0.377	291	109.38
CIMA	1	Control	65.17	19.43	0.316	0.267	286	76.29
		Liming	68.87	20.09	0.365	0.310	289	89.57
		Lim.+fertiliz.	72.86	20.76	0.422	0.360	258	92.81
		Fertilization	75.27	21.15	0.458	0.392	243	95.19
		Average	70.54	20.36	0.405	0.332	269	88.46
	2	Control	69.54	20.85	0.384	0.328	289	94.83
		Liming	69.28	20.83	0.381	0.325	292	94.99
		Lim.+fertiliz.	73.55	21.27	0.440	0.377	258	97.17
		Fertilization	74.81	21.41	0.457	0.392	268	104.97
		Average	71.82	21.09	0.415	0.356	277	97.99
Clone average								
LUISA_AVANZO			74.03	21.39	0.449	0.385	285	109.49
CIMA			71.18	20.72	0.410	0.344	273	93.22
Sapling age average								
1 yr. nursery			72.35	21.04	0.431	0.362	274	99.03
2 yr. nursery			72.86	21.07	0.428	0.366	284	103.68
Treatment average								
Control			68.33a	20.39a	0.364a	0.310a	288a	89.36
Liming			70.94a	20.78ab	0.400a	0.341a	283a	96.52
Lim.+fertiliz.			75.41b	21.51b	0.468b	0.401b	271a	109.23
Fertilization			75.75b	21.55b	0.472b	0.405b	272a	110.31
GENERAL AVERAGE			72.60	21.06	0.430	0.365	279	101.35

Tab. 11 -Vaccolino (FE). Results of the chemical analysis carried out on 6 soil samples (surface layer) taken in June 1987

Determination	Sample n. 1	2	3	4	5	6
Reaction pH (H_2O)	7,45	8,05	7,28	7,59	7,18	7,32
Chlorides (such as Cl^-) (mg/kg)	481	378	1230	1385	2271	2313
Sulfates (such as SO_4^{--}) (mg/kg)	151	63	147	66	170	76
Salinity (meq/100 gr)	1,91	1,70	5,61	5,33	8,68	8,30
Conductibility (µS/cm) - upto saturation	3,760	3,750	10,000	9,350	15,400	13,600
- upto ratio 1:5	650	660	1,920	1,860	2,990	2,830

Tab. 12 - Vaccolino (FE). Results of the analysis regarding soil samples taken in August 1987 from the surface layer (a = cm 0-30) and the underlying layer (b = cm 30-60)

Characteristics	Sample n. 1 a	1 b	2 a	2 b	3 a	3 b	4 a	4 b	5 a	5 b	6 a	6 b
Skeleton	absent		absent		absent		absent		absent		absent	
Texture												
Coarse sand %	0,60	0,43	0,24	0,26	0,39	0,48	0,67	0,60	0,34	0,56	0,64	0,44
Fine sand %	52,25	48,87	53,86	59,34	58,06	57,52	60,38	55,93	56,67	53,13	55,33	49,88
Silt %	29,15	31,25	24,65	24,05	24,95	25,15	23,30	26,13	26,14	28,13	27,18	30,24
Clay %	18,00	19,45	21,25	16,35	16,60	16,90	15,65	17,34	16,85	18,15	16,85	19,44
Total carbonate %	17,42	16,81	18,13	18,15	17,64	18,17	17,60	17,42	17,72	17,42	18,00	17,64
Active lime %	3,75	4,12	4,25	4,00	3,75	4,12	3,87	4,00	4,25	4,00	3,75	4,25
Reaction												
pH (H_2O)	8,00	8,30	8,00	7,95	8,20	8,35	8,20	8,10	7,95	8,15	8,25	8,30

Tab. 13 - Vaccolino (FE). Results of the chemical analysis carried out on water samples taken on 21.3.1988

Sample n.	Depth cm	Chlorides ppm	pH
1	130	710	8,03
2	130	852	8,70
3	110	887	8,40
4	150	958	8,15
5	130	1171	8,53
6	120	1313	8,35
7	150	1600	7,80
8	150	2485	8,55
9	100	3000	8,20
10	170	3550	7,38
11	160	5325	7,40
12	160	7100	8,00
13	100	7100	8,05
14	100	7100	7,75
15	100	7810	7,47

Tab. 14 - Vaccolino (FE). Percentage of surviving plants taken on 13.7.1988 in areas with different concentrations of salina

Clone	% of surviving plants Zone A	Zone B	Zone C	Zone D
SPE 017	100.00	50.00	37.50	0
SPE 018	75.00	75.00	50.00	0
SPE 029	100.00	100.00	50.00	0
SPE 031	90.00	50.00	50.00	0
SPE 032	88.89	75.00	25.00	0
SPE 033	100.00	75.00	-	0
SPE 036	100.00	0.00	50.00	0
SPE 061	100.00	25.00	66.67	0
SPE 063	75.00	66.67	16.67	0
SPE 068	83.33	50.00	37.50	0
SPE 070	100.00	50.00	0.00	0
SPE 076	100.00	-	25.00	0
SPE 077	100.00	0.00	0.00	0
SPE 092	100.00	50.00	-	0
SPE 098	100.00	75.00	0.00	0
SPE 110	100.00	0.00	30.00	0
SPE 115	100.00	100.00	0.00	0
SPE 116	87.50	50.00	16.67	0
SPE 125	100.00	75.00	25.00	0
SPE 127	80.00	62.500	33.33	0
SPE 129	100.00	33.33	75.00	0
SPE 131	100.00	100.00	62.50	0
SPE 138	100.00	100.00	50.00	0
SPE 139	100.00	-	33.33	0
SPE 142	100.00	75.00	0.00	0
SPE 144	100.00	-	0.00	0
SPE 165	100.00	50.00	-	0
SPE 170	83.33	100.00	0.00	0
SPE 171	50.00	50.00	50.00	0
SPE 172	100.00	25.00	66.67	0
SPE 174	87.50	75.00	50.00	0
SPE 176	75.00	-	16.67	0
SPE 188	100.00	25.00	0.00	0
SPE 196	100.00	-	0.00	0
SPE 205	100.00	33.33	50.00	0
SPE 216	100.00	100.00	100.00	0
SPE 217	50.00	0.00	-	0
SPE 222	83.33	100.00	-	0
SPE 232	75.00	100.00	66.67	0
SPE 249	80.00	100.00	0.00	0
SPE 252	100.00	100.00	50.00	0
SPE 256	90.00	66.67	57.14	0
SPE 260	100.00	60.00	16.67	0
SPE 262	75.00	50.00	33.33	0
SPE 272	-	66.67	100.00	0
SPE 273	100.00	42.85	100.00	0
SPE 283	100.00	60.00	25.00	0
LUISA_AVANZO	100.00	50.00	25.00	0
VILLAFRANCA	71.42	62.50	0.00	0
I-214	96.67	72.73	27.27	0
Average	91.77	60.61	34.84	0

Tab. 15 - Chemical and physical characteristics of soil taken in poplar stands showing signs of iron chlorosis

Physical and chemical determination		Hills of Monferrato			Province of Piacenza			Province of Mantova			Province of Ferrara		
		Camino	Rosignano	San Salvatore	Sarmato	Fossa-dello	San Savino	Marcaria	Castel-dario	Bancale	Migliaro	Cona	Miglia-rino
Skeleton	%	0.0	0.7	2.5	0.00	0.20	0.00	2.50	1.20	0.5	2.10	0.00	0.20
Texture of fine soil													
Coarse sand	%	2.1	2.0	2.6	2.10	0.80	2.80	2.70	8.30	18.30	0.60	0.40	0.70
Fine sand	%	35.4	36.5	39.8	18.80	39.40	35.20	43.70	57.50	47.20	14.80	36.60	34.70
Silt	%	44.0	46.3	44.2	37.15	37.80	40.20	37.30	25.00	23.50	58.90	48.50	49.30
Clay	%	18.5	15.2	13.4	41.95	22.00	21.80	16.30	9.20	11.00	25.70	14.50	15.30
pH	%	7.65	7.82	7.89	7.60	7.83	7.70	7.77	7.78	7.78	7.90	7.72	7.75
Organic carbon	%	1.15	0.97	0.58	1.63	1.35	1.02	1.24	0.90	0.93	1.34	1.43	1.17
Nitrogen	%	0.13	0.09	0.06	0.14	0.13	0.10	0.12	0.08	0.09	0.12	0.14	0.11
P_2O_5 available	ppm	45.00	60.00	47.00	117.37	83.00	173.00	152.00	167.00	89.00	139.00	110.00	141.00
K_2O exchangeable	ppm	98.00	170.00	90.00	110.00	148.00	133.00	118.00	103.00	90.00	172.00	137.00	125.00
CaO exchangebale	ppm	5200.00	4970.00	4580.00	6665.00	4620.00	4305.00	4410.00	4515.00	4130.00	4790.00	5775.00	4970.00
MgO exchangeable	ppm	267.00	320.00	180.00	568.00	295.00	344.00	432.00	340.00	253.00	1025.00	514.00	647.00
Total carbonate	%	15.1	10.7	22.0	10.41	16.70	12.80	10.10	16.10	17.00	7.20	10.50	7.20
Active lime	%	11.4	6.9	10.6	7.24	8.90	7.00	6.00	4.10	3.90	6.20	5.10	4.20
Iron available	ppm	65.00	57.00	61.00	63.06	175.00	112.00	16.00	15.00	18.00	43.00	22.00	16.00
Manganese available	ppm	12.00	4.00	1.60	4.56	0.90	3.10	3.00	2.10	1.30	2.00	1.60	0.80
Copper available	ppm	1.00	19.40	6.10	1.46	4.10	2.10	10.50	1.10	1.60	1.00	2.10	1.50
Zinc available	ppm	1.30	1.80	1.10	1.10	1.40	1.20	2.90	0.70	1.00	0.90	0.80	0.50
Boron available	ppm	0.58	0.36	0.74	0.62	0.62	0.49	1.12	0.54	0.62	1.56	0.93	1.00

Tab. 16 - Characteristics of the sites and the poplar stands subject to soil sampling

Profile n°	Record n°	Locality	Position*	Slope %	Exposure	Age (year)	Clone	N° plants	Average girth (cm)
1	230	Vestodina j	S	25	North	12	Eur.	215	70,53
2	230	Vestodina k	S	23	North	8	214	789	66,93
3	230	Vestodina ci	TSB	-	North	11	214	100	43,93
4	230	Vestodina c2	TSB	31	North	11	214	147	77,73
5	230	Vestodina d	B	-	North	7	214	454	65,13
6	230	Vestodina a	S	25	North	6	214	68	32,86
7	329	Stevani e	B	14	West	11	214	264	59,20
8	329	Stevani f	B	14	West	1	214	192	9,00
9	344	Stevani d	S	21	West	7	214	530	68,07
10	306	Ottiglio a	S	20	East	11	Eur.	146	68,13
11	-	Salabue	Poplar stand cut down						
12	243	Castel. M. e	S	28	N.-East	6	BL	180	52,14
13	323	Alfiano N. e	B	-	-	8	214	260	45,87
14	323	Alfiano N. al	S	40	East	8	214	338	52,20
15	323	Alfiano N. d	S	29	East	7	BL	173	59,73
16	319	Zanco a	T	-	-	12	214	58	96,80
17	319	Zanco g	T	-	-	3	Eur.	180	37,07
18	319	Zanco i	T	-	-	7	214	128	57,53
19	267	Villadeati b	S	12	S.-East	7	214	197	66,27
20	267	Villadeati f	S	16	South	8	214	65	36,13
21	267	Villadeati a	S	23	N.-West	7	214	85	60,64
22	348	Fontanina o	Poplar stand cut down						96,67
23	184	Cicengo b	B	-	-	6	214	120	55,33
24	184	Cicengo c	S-B	19	West	11	214	197	91,20
25	184	Cicengo d	S-B	17	West	7	214	462	62,60
26	160	Cerrina j	S	16	N.-East	9	214	604	65,00
27	21	Moncestino a	S	28	N.-East	8	214	156	83,13
28	46	Micengo a	S	23	West	11	214	150	55,07
29	162	Montaldo a	S	21	N.-East	8	214	82	63,47
30	162	Montaldo c	S	-	-	7	214	194	52,40
31	165	Serralunga t	S	-	-	9	214	105	94,40
32	165	Serralunga v	S	-	-	12	214	87	51,60
33	165	Serralunga n	S-B	9	North	6	214	467	41,87
34	165	Serralunga w	S	34	North	9	BL	122	66,71
35	98	Pontestura j	B	-	-	14	214	92	96,33
36	98	Pontestura i	T	-	-	7	BL	82	62,00
37	98	Pontestura i	S	12	North	9	BL	156	76,20
38	123	Quarti a	S	20	North	12	214	780	63,87

* S = slope; T = top; B = bottom

Tab. 17 - Physical and chemical analysis of soil taken from poplar stands situated around the hills of Monferrato in May 1990

Profile	Depth	Texture				pH	Limestone	
		Coarse sand	Fine sand	Silt	Clay		Total	Active
n.	cm	%	%	%	%	(H_2O)	%	%
1	0-40	1.67	16.78	45.15	36.60	7.45	18.75	6.13
	40-100	3.63	16.02	44.30	35.55	7.70	25.28	9.38
2	0-60	0.80	20.60	44.35	34.25	7.65	23.09	8.88
	60-120	1.05	14.90	42.40	34.05	8.00	42.45	10.88
3	0-50	0.47	11.88	58.35	29.30	7.80	48.80	12.38
4	0-40	0.69	26.36	35.90	37.05	7.55	13.96	3.63
	40-80	1.20	24.00	27.75	47.05	7.80	25.23	8.13
	80-120	1.16	17.69	50.75	30.40	7.65	33.55	10.50
5	0-45	0.89	83.36	4.30	11.45	7.65	7.82	2.63
	45-90	0.58	82.42	8.30	8.70	7.40	5.67	4.13
	90-130	0.22	41.23	39.70	18.95	7.80	0.10	0.75
6	0-50	1.59	83.31	2.70	12.40	7.55	29.63	7.75
7	0.50	1.41	42.04	49.00	7.55	7.05	0.10	0.75
	50-100	2.15	47.40	22.05	28.40	7.55	0.10	0.88
8	0-60	8.72	37.43	21.10	32.75	7.20	0.10	0.88
9	0.80	2.76	52.19	20.95	24.10	7.40	7.42	2.88
	80-120	1.55	44.00	25.05	29.40	7.40	32.23	10.13
10	0-60	1.48	16.07	45.85	36.10	7.05	39.63	10.88
11	0-40	2.32	23.18	30.00	44.50	7.30	11.78	5.25
	40-130	4.85	18.25	29.80	47.10	7.30	5.67	4.63
12	0-75	1.57	20.63	38.75	39.05	7.40	37.46	10.75
	75-130	0.69	18.36	38.70	42.35	7.70	34.84	12.00
13	0-80	32.45	32.00	31.80	3.75	7.30	36.59	10.75
14	0-50	35.48	26.82	22.90	24.80	7.40	12.21	4.13
	55-100	38.33	20.27	19.15	22.25	7.70	1.32	1.00
15	0-40	8.40	31.12	28.85	36.55	7.20	0.10	0.50
	40-85	8.27	29.08	23.60	39.05	7.25	0.10	0.50
16	0-60	1.47	21.88	42.70	33.25	7.40	20.91	6.03
	60-110	1.90	27.70	37.65	32.75	7.40	11.91	5.50

Tab. 17 - Physical and chemical analysis of soil taken from poplar stands situated around the hills of Monferrato in May 1990

Profile	Depth	Texture				pH	Limestone	
		Coarse sand	Fine sand	Silt	Clay		Total	Active
n.	cm	%	%	%	%	(H_2O)	%	%
17	0-70	1.07	29.13	36.30	33.50	7.30	5.67	2.50
	70-120	0.63	33.87	31.20	34.30	7.50	0.88	0.63
18	0-55	0.71	6.19	49.70	43.40	7.40	38.36	10.00
	55-110	1.91	29.84	37.65	30.60	7.80	10.46	4.25
19	0-50	4.59	25.71	37.30	32.40	7.60	24.84	9.53
	50-100	4.53	25.47	34.10	35.90	7.60	26.30	9.50
20	0-40	1.60	18.35	30.75	49.25	7.40	22.67	10.50
21	0-60	2.33	27.77	43.70	30.20	7.30	17.00	6.63
	60-110	5.41	28.94	36.00	22.65	7.50	20.92	6.63
22	0-45	0.79	11.16	45.95	42.10	7.60	17.00	5.30
	45-120	0.25	12.00	38.90	48.85	8.00	19.70	4.88
23	0-50	1.82	20.43	45.40	32.35	7.60	27.00	9.63
	50-110	2.00	19.05	44.75	34.20	7.50	22.65	9.50
24	0-60	1.37	17.53	35.55	45.55	7.30	19.61	9.30
	60-100	1.79	17.76	35.50	44.95	7.60	19.61	9.00
25	0-55	1.26	22.94	43.00	32.80	7.80	25.71	10.30
	55-120	5.29	17.66	44.20	32.85	7.85	21.78	12.75
26	0-50	7.46	23.54	36.75	32.25	7.05	1.75	1.25
	50-120	7.52	24.03	27.45	41.00	7.20	0.44	0.88
27	0-40	1.85	31.20	24.40	42.55	7.40	32.62	8.75
	40-80	1.36	28.44	36.50	33.90	7.40	34.42	7.75
	80-110	0.70	26.85	28.95	43.50	7.50	0.67	2.13
28	0-40	1.40	17.95	35.75	44.90	7.30	10.90	1.75
	40-100	1.26	20.39	39.05	39.30	7.60	34.92	7.00
29	0-35	1.61	19.34	44.05	35.00	7.45	21.78	6.50
30	0-40	3.79	19.36	42.15	34.70	7.65	32.33	10.38
	40-110	1.28	13.02	34.15	51.55	8.00	4.80	2.75
31	0-50	2.72	26.30	38.18	32.80	7.80	23.09	12.15
	50-120	7.41	30.19	33.10	28.80	7.55	55.75	13.00
32	0-20	4.60	31.24	34.90	29.50	7.45	59.25	12.00
	20-100	3.39	35.36	31.75	30.20	7.65	48.40	11.63
33	0-60	5.90	41.04	22.85	30.20	7.30	47.05	11.38
	60-120	2.93	25.62	36.45	35.00	7.40	54.88	12.38
34	0-40	7.24	36.20	29.05	27.50	7.40	51.42	11.75
	40-110	5.68	26.37	37.25	30.70	7.45	48.80	12.00
35	0-50	1.98	44.37	31.20	22.45	7.20	0.44	0.14
	50-100	1.69	42.35	28.10	27.85	7.60	0.00	0.13

Tab. 17 - Physical and chemical analysis of soil taken from poplar stands situated around the hills of Monferrato in May 1990

Profile	Depth	Texture				pH	Limestone	
		Coarse sand	Fine sand	Silt	Clay		Total	Active
n.	cm	%	%	%	%	(H_2O)	%	%
36	0-40	1.46	22.64	34.25	41.65	7.30	13.50	0.34
	40-100	0.35	25.85	27.85	45.95	7.40	0.88	0.21
37	0-30	1.74	46.41	26.55	25.30	7.00	0.10	0.10
	30-110	0.46	47.59	27.00	24.95	7.45	0.10	0.10
38	0-35	0.79	28.36	21.85	49.00	7.20	20.03	3.25
	35-100	0.07	50.68	24.25	25.00	7.20	4.96	2.50

Fig. 1 - Influence of liming and fertilization on nutrient contents of soil

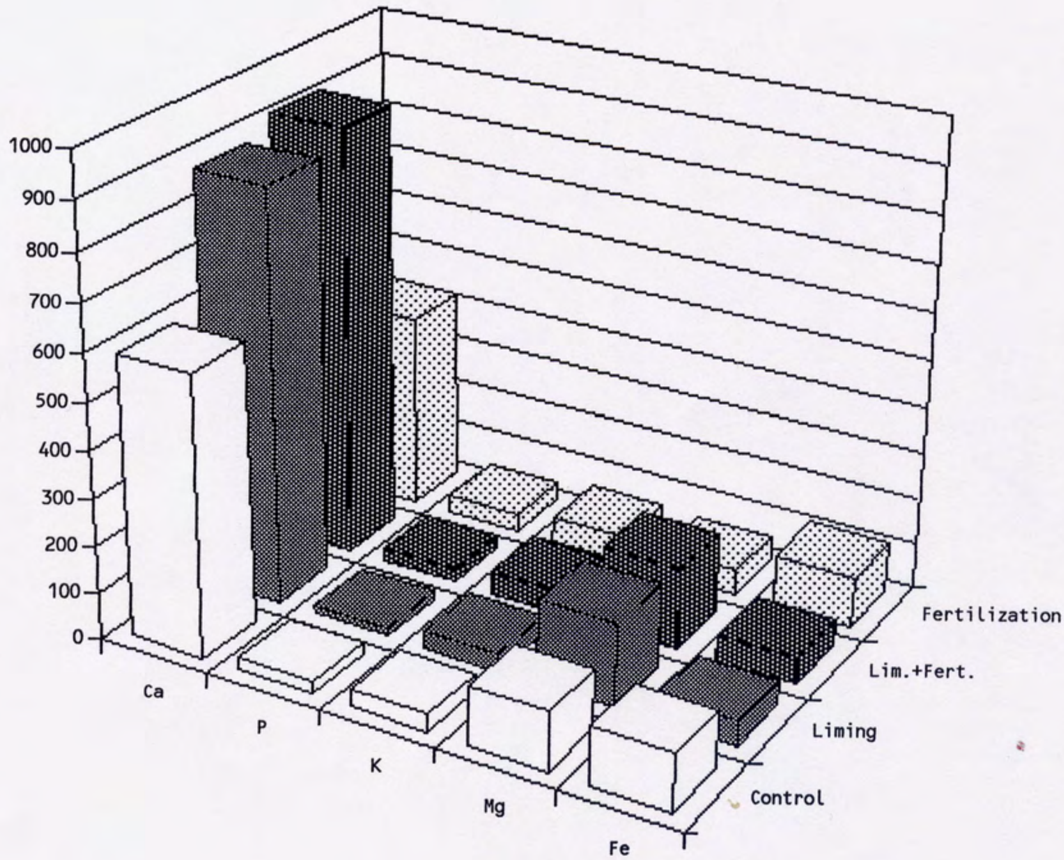

Fig. 2 - Influence of liming and fertilization on nutrient content of leaves (% d.w.)

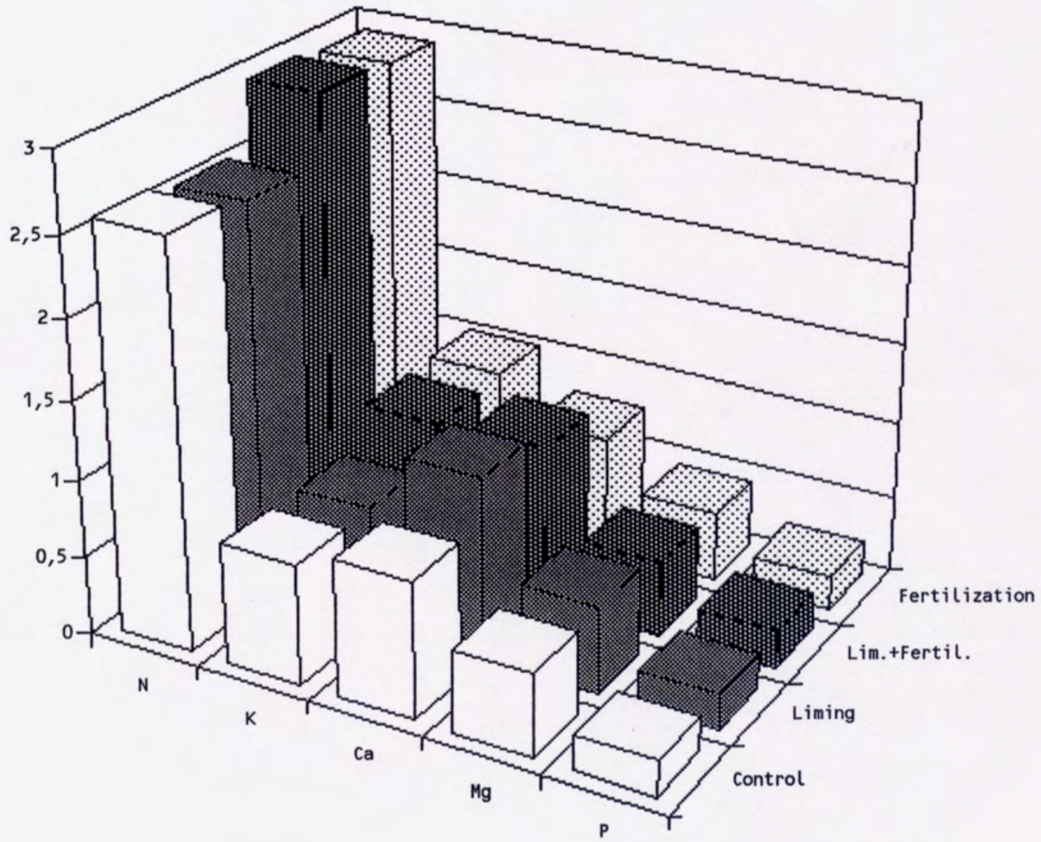

Fig. 3 -Influence of liming and fertilization on the growth (basal area cm2/tree) of 1-year old sapling of the clone L.Avanzo

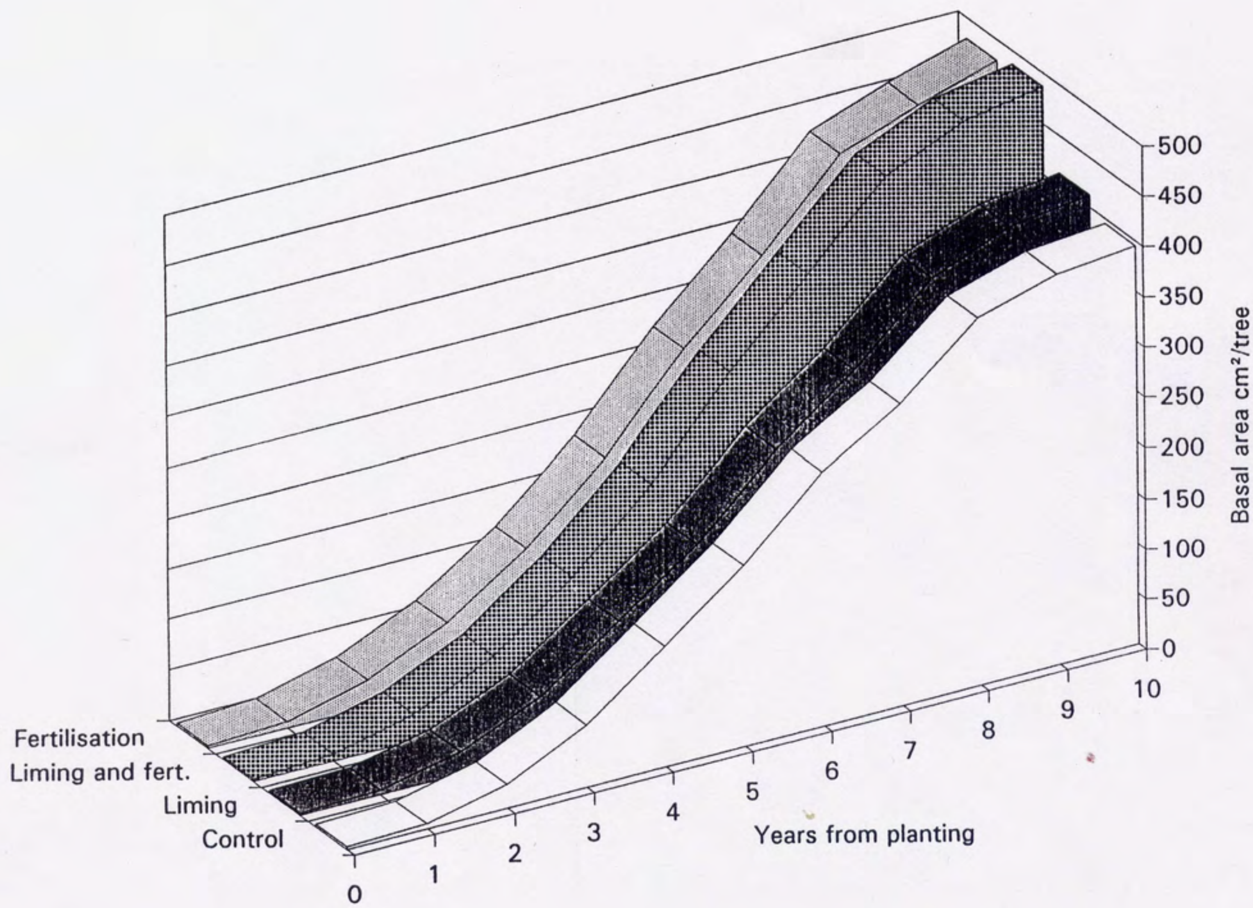

Fig. 4 - Total volume (m3/ha) apto 10 cm of diameter

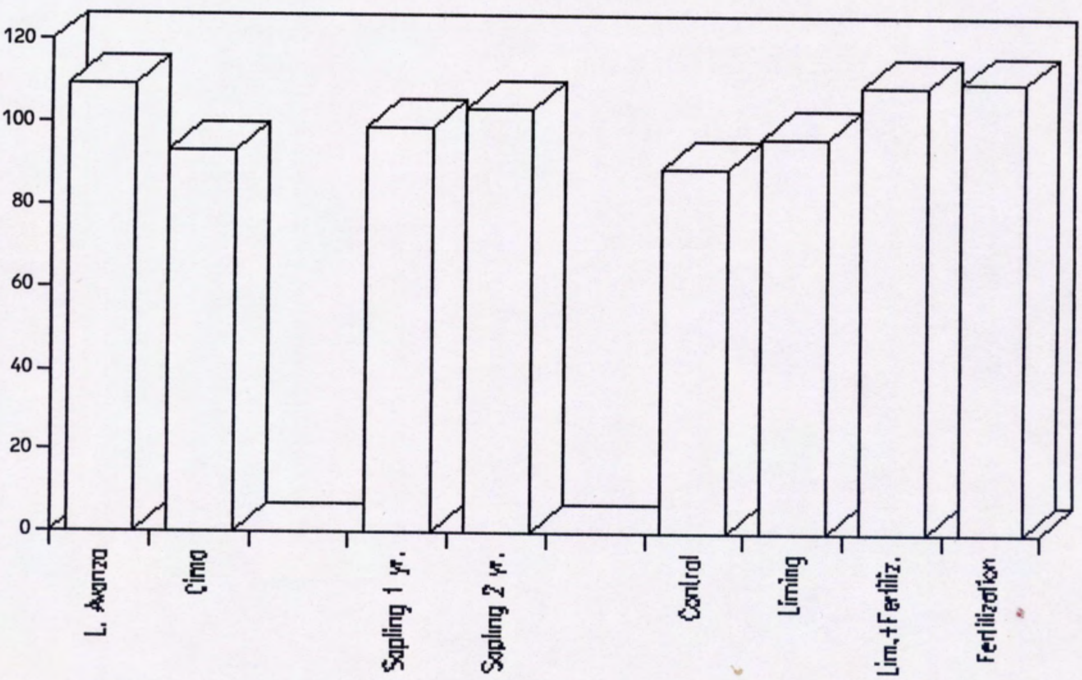

Fig. 5 - Exchangeable Na2O and Conductibility on soil samples taken on 13.7.1988

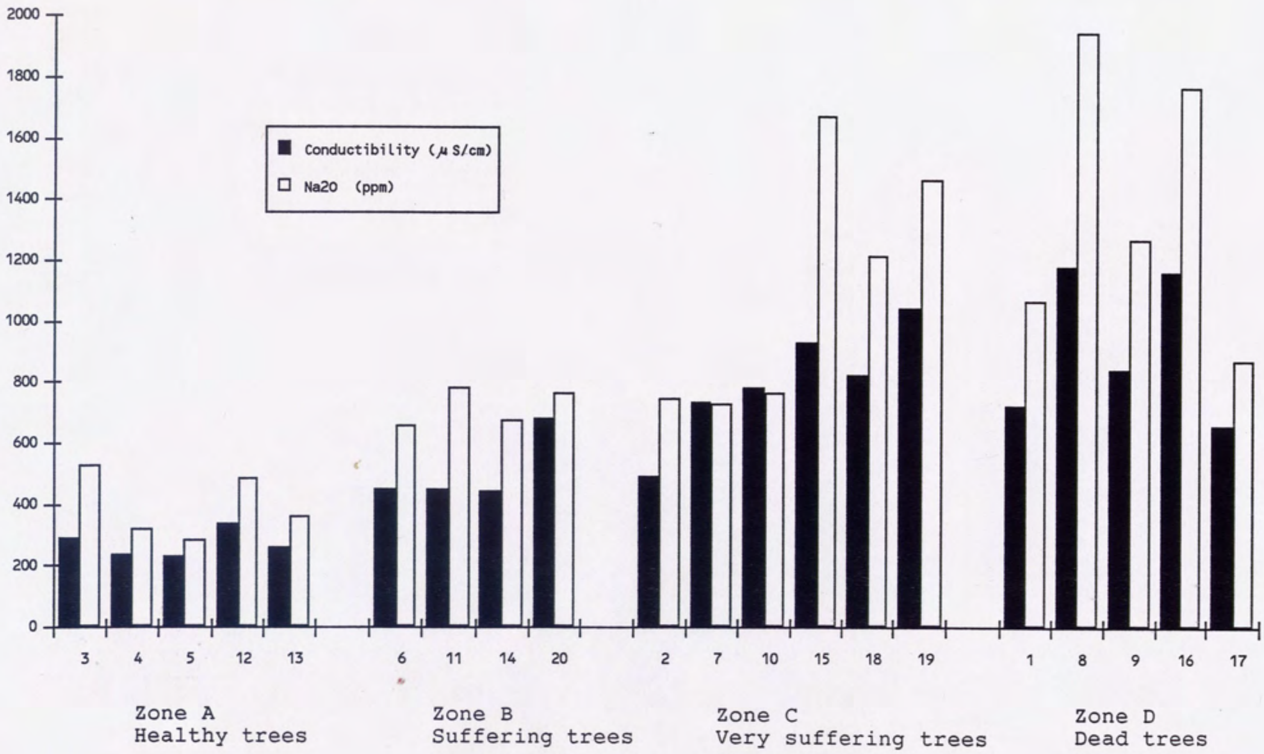

Fig. 6 - Content of Na2O and soluble salts in samples of water taken from water table on 8.6.1989

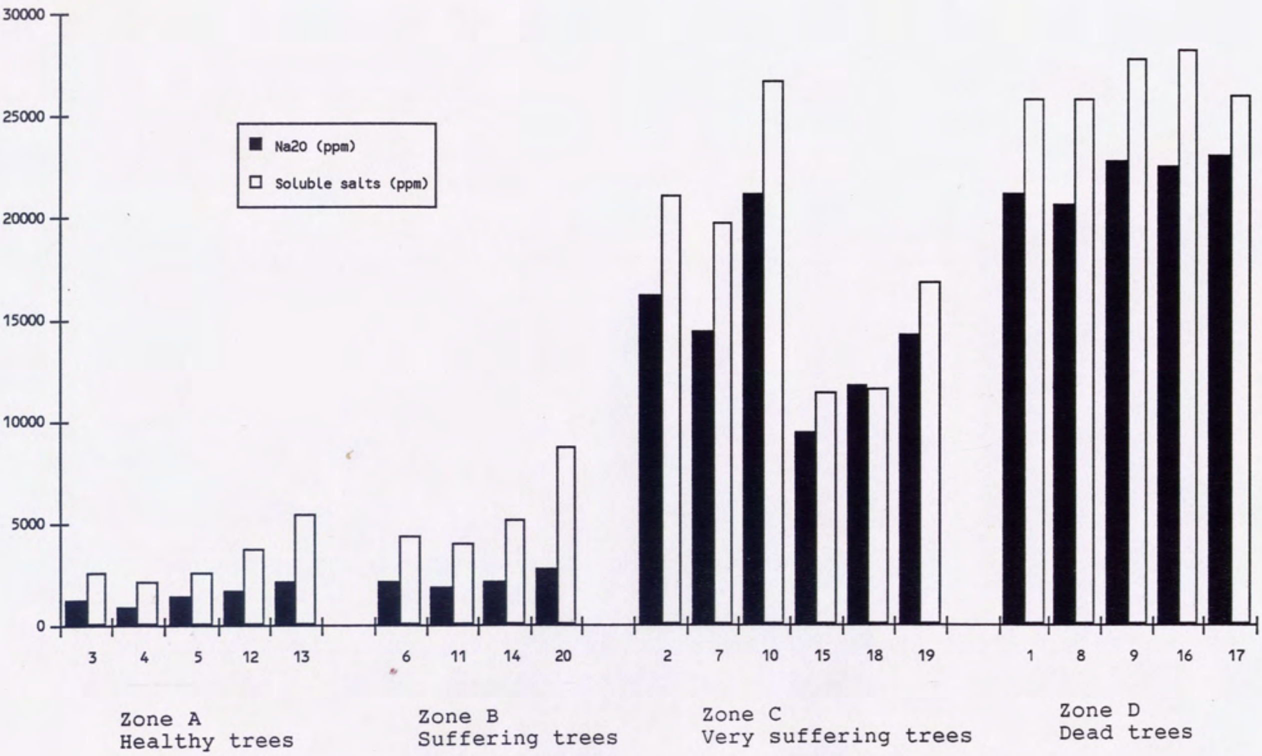

Fig. 7 - Exchangeable Na2O (ppm) on soil samples taken on 8.6.1989

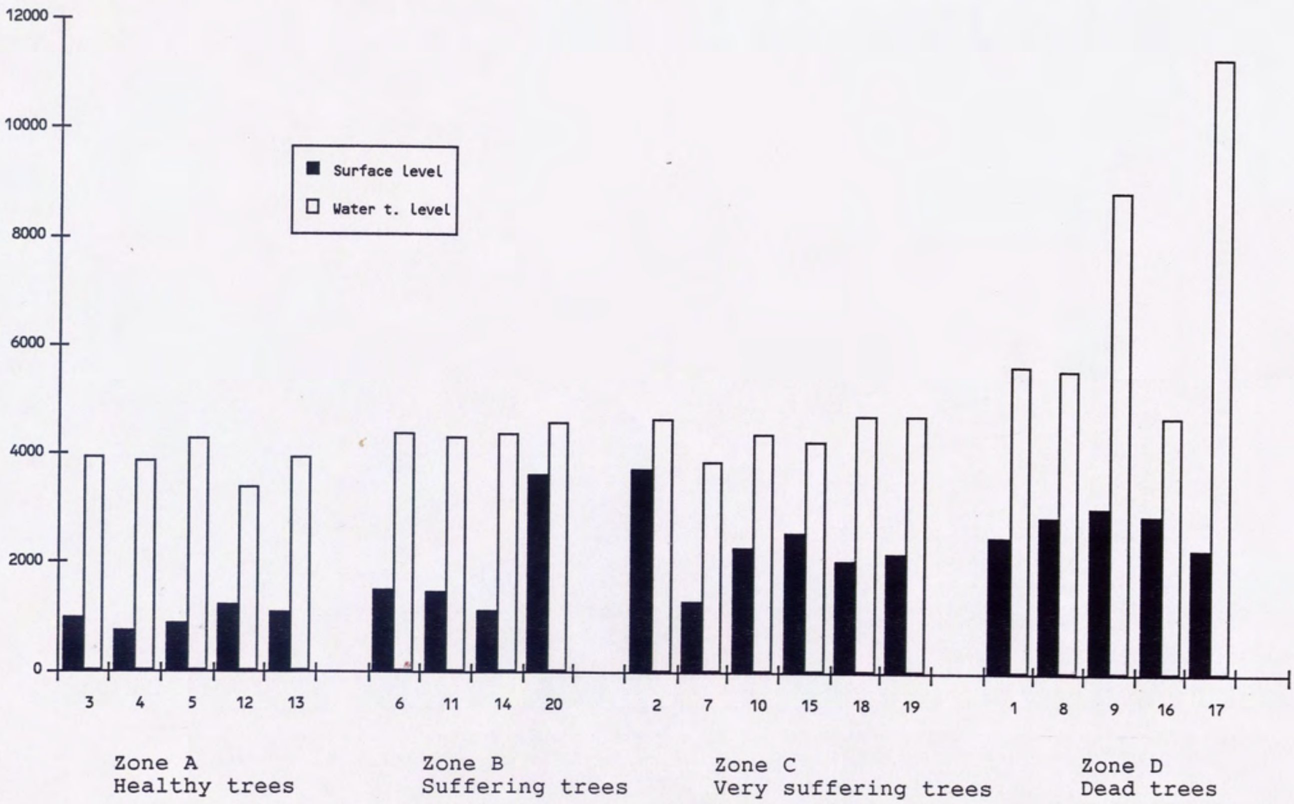

Fig. 8 - Total mortality rate (%)