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RESEARCH ON IRON CHLOROSIS OF POPLARS

by

Giuseppe FRISON, Naldo ANSELMI, Adriano BOCCONE
SAF/ENCC-Istituto di Sperimentazione per la Pioppicoltura
Casale Monferrato (Italy)

(Preliminary notes)

A B S T R A C T

Iron chlorosis had been reproduced in vegetation tanks and this has been the object of a series of research work in nurseries and poplar plantations.

The relative data of the chemical analysis of soil and leaf samples taken from nurseries and plantations with and without symptoms of iron chlorosis have been reported.

Treatments by leaf spraying and soil application of iron chelates were carried out to eliminate chlorosis in nurseries and poplar plantation. The results of leaf spraying were unsatisfactory whilst soil application gave impressive results.

CONTENTS

Page

1. Introduction 3

2. Experimental part 4

2.1 Symptomatology 4
2.2 Research in vegetation tanks 6
2.3 Research in nursery 8

2.3.1 Analysis of soil and leaves in nursery with and without iron chlorosis symptoms 10

2.3.2 Analysis of soil and leaves in nursery with iron chlorosis symptoms 11

2.4 Research in poplar plantations 15

2.4.1 Analysis of soil and leaves in poplar plantations with and without iron chlorosis symptoms 15

2.5 Results and Discussion 17

2.6 Cure treatment 23

2.6.1 Leaf spraying with iron chelates 24

2.6.1.1 In nursery 24
2.6.1.2 In poplar plantations 26

2.6.2 Soil application of iron chelates 27

2.6.2.1 In nursery 27
2.6.2.2 In poplar plantations 30

3. Conclusion 32

4. Bibliography 34

5. Summary 36

INTRODUCTION

The poplar grows naturally along rivers courses where soil depth, texture, fertility, pH and available soil moisture during the growing season are sufficient for excellent growth. In these sites the cultivation of poplar does not present any particular problems and it does not have any important signs of nutrition deficiency.

In Italy, where poplar cultivation plays an important part in the economy of the Country, besides bottomland sites, often compact, more calcareous and less deeper soils have been used.

In these sites the poplar does not always find adequate nutrients elements, therefore, shows symptoms of yellowing of the leaves which could lead, in more serious cases, to necrosis of the tissues, growth reduction and, sometimes, the plant dies.

Chlorosis is, aboveall, found in nurseries in various zones of the Po Valley and, in a weaker form, in Central -South Italy and it can cause considerable damage (loss of production from 20 to 40%).

Chlorosis has also spread in poplar groves in Friuli, around Mantova and particularly in Monferrato where, in the last ten years, the poplar is substituting grapevines in hilly zones which are well known as calcareous soils.

The exceptional process of yellowing has been noticed in Turkey too where in 1965-1968 J.E. COURTOIS conducted a research from which he pointed out the remarkable differences in phosphorated compounds between leaves with and without chlorosis. The accumulation of phytic acid in chlorotic leaves was particularly noticed and this blocked the iron necessary for the metabolism of leaves, especially for chlorophyll synthesis. In this way the connection between chlorosis and iron deficiency was pointed out.

The yellowing of leaves in poplar nurseries in Central and South Italy was also a subject of study (G. GIULIMONDI, 1972). In this study this phenomenon could probably be connected to water stagnancy in the soil on which the plant grows.

Actually, chlorotic symptoms have been observed in nurseries, which have a fairly good system of drainage, in various zones of the Po Valley since 1963. In one of these, precisely in Porto Mantovano (MN) during the fertilizing tests carried out in 1968-69, the yellowing of the young poplars, became intense due to the high quantity of phosphorous and nitrogen, both from sulphate and urea applied in fertilization trials (FRISON G., 1974).

The supposition that this was iron chlorosis was gradually confirmed but the foundation had to be proved.

For this reason, for about 10 years the Poplar Research Institute in Casale Monferrato has been conducting a series of researches to confirm this diagnosis and to study etiology, and to point out the methods for the prevention and, aboveall, the cure of the disease in question.

References to some pathologic aspects, such as alteration and damages caused in nurseries and the relative consequences on diseased material in plantation have been set out in another paper (ANSELMI N., FRISON G., BOCCONE A., 1982).

EXPERIMENTAL PART

2.1 Symptomatology

Iron chlorosis means the yellowing of leaves of plants which can be alleviated or eliminated by suitable iron compounds.

During the first stage, the iron deficiency is noticed on the leaves of the top part of the plant through an interveinal depigmentation, which tends to extend due to the persistence of the cause which originates this deficiency. The leaves then turn a whitish yellow which gradually spreads to the nervature starting from the finer ones. The older leaves, which existed before the start of the yellowing, may stay green because their iron is not transferred to younger or new leaves. Therefore on the same plant one can see yellow leaves on the top part of the plant and green ones on the lower part.

In more serious cases, the leaves dry around the borders and then fall. The plants without leaves deteriorate and, generally, die. Only in rare cases, they recover.

In poplar nurseries, iron deficiency can be found as early as in the first year, thus becoming very serious, or during the second year of vegetation. Even in the second case the results can be serious, in spite of the better growth of young poplars, due to the necrosis of the leader and top branches of the plant or, at least, due to poor lignification and dehydration.

Sometimes the disease attacks weaker plants, the suppressed ones, but often spreads in a uniform manner on extensive surfaces. It can appear during the spring season (May) or at the end of summer. When the disease appears too early during the vegetative season, the intensity is high or low depending on the climatic trend or interventions carried out at soil level (particularly irrigation).

It has been noticed that in nurseries, the coppicing and dense spacing increases chlorosis. This is probably due to the fact that because of the high production of biomass, the rhythm of absorption of the various nutrient elements is not adequately compensated by the rhythm with which the said elements in the soil solution are available. Eventual disequilibrium can easily be found.

The young poplars which have been seriously damaged in nurseries are not fit for transplanting. Those which have slighter attacks, i.e. without getting necrosis of the top part and side branches of the plant, show signs of chlorosis on new shoots which disappear quite fast as soon as the new roots start absorbing activities. This normally happens in June if there is no iron deficiency or presence of other factors which helps this disease in the soil.

Chlorosis can be noticed in poplar groves from the first or following years depending on the chlorotic power of the soil. It, sometimes, appears in 4 or 5 year old plants which, since then, grew exceptionally well. Whether the plants are affected slightly or intensely depends on environmental conditions and in more serious cases, the disease causes death of the plant in 2 or 3 years' time.

2.2 Research in vegetation tanks

Observations carried out in nursery and poplar plantations lead us to believe that the appearance of chlorosis could depend on the nature of the soil and on the climatic trend. Therefore, if certain environmental conditions are formed, these could reproduce chlorosis.

It was immediately noticed that the number of controlling factors should be reduced and, therefore, it was decided to operate under the same kind of weather conditions and limit the testing to only the main pedologic parameters.

Hence the idea of growing young poplars in vegetation tanks in 4 carefully-chosen different types of soil.

Accordingly 4 adjacent tanks were made - 12 m long, 1.50 m wide and 1.50 m deep.

The soils were chosen on the basis of their reaction (pH from sub-acid to subalkaline), carbonate contents (from free to calcareous in the first 50 cm) and the chlorosis power index (from 0 to 215) in layers highly interested in rhisosphere. In Tab. 1 also other characteristics of the soil used for testing, have been reported.

The variability of the pedologic parameters taken into consideration, not very ample from the practical point of view, have been regarded sufficient on the basis of direct observations conducted on the plants before removing the soil. In fact, it was noticed that the poplar did not show any symptoms of chlorosis in the first two types of soil whilst in the fourth type of soil, frequent iron deficiency was found.

On the bottom of the tank a layer of gravel, 10 cm deep was laid to facilitate the elimination of excess water and to be able to regulate the depth of the water table of about 140 cm from soil surface.

In each tank, a different type of soil was placed, respecting the order of layers present in fields to the depth of 1.40 m. During the vegetative season, periodic controls of soil water contents and rainfall were taken into account, and the soil was constantly irrigated to maintain the moisture in the soil above 50% of the field capacity content.

In each tank the cuttings were planted at a distance of 50 cm from one another in a single row.

Tests were conducted with 'I-214' clone during the first two years which did not give any results.

The young poplars grew extremely well in all four types of soil without any apparant differences.

Probably the transfer of soil from fields to tanks, which involved modification of its consistency, created ideal conditions of structure for all four types of soil. During the first two years the soil readjusted itself acquiring its natural conditions once again. This was also due to rain or irrigation effects. As we did not attain the expected results with the 'I-214', a local clone was chosen for the second test. This clone was taken from an area having subacid soil and it was formerly deduced that this clone could be more susceptible to calcareous chlorosis.

Therefore, the 'Pan' clone was chosen which is grown on its own by a private poplar cultivator, Mr. Ferrari of Alagna Lomellina, in a type of soil in which lime was often added by the proprietor to correct the acidity.

The course of the first year of vegetation was normal whilst in the Spring of the second year, the poplars of the fourth tank showed symptoms of chlorosis.

The chlorosis intensity kept on increasing during the vegetative season until necrosis set in on the leaves of the top part of the plants of about 30% of the young poplars.

Before the beginning of the third vegetative period, coppicing of the young plants in all four tanks was carried out. Whilst the stumps in the first three types of soil all sprouted normally, the ones in the fourth type of soil, which seriously suffered for iron chlorosis, all died.

The results of this experiment proved that this was due to calcareous chlorosis, better known as Iron Chlorosis.

In order to confirm this diagnosis, in July of the second vegetative season, leaves of five plants were sprayed using an acid solution of 0.1% ferrous sulphate. This produced some green spotting on chlorotic leaves, but uniform greening was not produced even after repeated sprayings. This outcome was sufficient enough to confirm the supposition that this was Iron Chlorosis.

However, the results of the experiment did not mean that the 'Pan' clone was more susceptible than the 'I-214' to chlorosis for various reasons. In the first place, the basis of this test did not allow exact confrontations and, in the second place, because the soil had already been used for the 'I-214' clone in the previous two years before the 'Pan' clone. Thus, the soil did not have any fertilizing advantages.

As for the third type of soil, whilst there was no chlorosis in tank vegetation, yellowing of the leaves was found every now and then for short periods when the poplar was densely grown in the nursery (1.30 x 0.1 m) and coppiced.

Owing to this fact, the root density and the disequilibrium between the parts of the plant above the soil and the root system play an important part on the causes of iron chlorosis.

2.3 Research in nursery

The main purpose of this test is to compare a few characteristics of the soil and young poplars in nursery with and without symptoms of chlorosis. This test also intended to point out probable differences on soil and plant properties according to chlorosis intensity (0 = no chlorosis; 1 = slight chlorosis; 2 = intense chlorosis but without leaf necrosis; 3 = heavy chlorosis with leaf necrosis) of the young plants grown in adjacent areas in the same nursery.

For this purpose, 6 poplar nurseries - 'I-214' clone - in the second year of vegetation of which three had symptoms of chlorosis - 2 in Palazzolo dello Stella (UD) and 1 in Bigarello (MN) - and three which had no chlorosis - Giarole (AL), Rosasco (PV) and Casale Monferrato (AL) - , were taken into consideration.

From each nursery with symptoms of chlorosis and in the ambit of each class of intensity, 3 groups of about 50 Plants were singled out to obtain leaf and soil samples from each group.

The leaves were taken from the middle part of the more vigorous branches excluding the younger ones (6 from the top part of the branches) and the leaves on the lower part of the branches.

The soil was removed from two different points of the area where the plants were grown and the leaves were taken from the plants and mixed together, thus becoming into one sole sample. Only the Ap horizon with a variable thickness of 35 to 50 cm in which the major part of the roots are concentrated was taken into consideration. This was established through direct observations.

In nurseries without any symptoms of chlorosis, five soil samples and the same number of leaf samples were collected, obviously all from healthy plants, and the same method was followed.

The sampling of leaves and soil was carried out in July 1981.

After necessary preparation, the samples were forwarded to the SIGLA Laboratory in Tortona for chemical analysis.

The following analyses were conducted for the different types of soil: texture, pH, total and active carbonate, organic carbon, organic matter, total nitrogen, available P, exchangeable Ca, Mg and K , and available Fe.
The following analyses were conducted for leaves: Ash, N, P, K, Ca, Mg, Fe, Chlorophyll and Water Contents.

The results of the chemical analyses were then submitted for variance analysis.

A preliminary test was carried out in Bigarello (MN) in nurseries with symptoms of iron chlorosis which is referred to in a separate section (2.3.2.3).

2.3.1 Analysis of soil and leaves in nursery with and without iron chlorosis symptoms

2.3.1.1 Analysis of soil

On the basis of the data found in Tab. 2, regarding Ap horizon only, the soil in nursery with symptoms of iron chlorosis can be defined as loam, calcareous, of subalkaline reaction, averagely provided with organic matter (with a good C/N ratio) and total nitrogen, rich in calcium and exchangeable magnesium, slightly provided with available phosphorous and poor in exchangeable potassium - an exceptional fact for Bigarello.

The Ap horizon is on a remarkably thick calcareous layer and is more or less permeable.

In nurseries without symptoms of iron chlorosis, the texture of the soil is sandy, from neutral to subalkaline pH, poor in organic matter, total nitrogen and exchangeable potassium; completely without or very slightly provided with total and active carbonate, sufficiently provided with available phosphorous, well-provided with exchangeable calcium and tendentially poor in excangeable magnesium (particularly in Casale Monferrato).

Under the Ap layer, the percentage of sand increases even more and this usually leads to a decrease of the main nutrients.

From the average analytic data of the two groups (Tab. 2) it emerged that the soil in nurseries with symptoms of iron chlorosis with regard to the soil in the other group presents:

- higher silt and clay contents and, therefore, lower sand contents;
- much higher contents of exchangeable Ca and Mg;
- values significantly not different of exchangeable potassium, an exceptional factor for Bigarello and Casale which presents two extreme values (the soil in Bigarello is much richer);
- lower contents of available phosphorous.

As regards available iron in the soil in Ciarole and Rosasco, similar values to those of the soil in Bigarello and Palazzolo have been reported. Nevertheless, as the active carbonate and exchangeable calcium contents are higher in the soil in Bigarello and Palazzolo, the ratio in both CaO/Fe and C.P.I. are significantly superior. These two parameters are very important for the diagnosis of estimating chlorotic power in different types of soil.

2.3.1.2 Analysis of leaves

Leaves of poplars grown in nurseries with symptoms of chlorosis with respect to those grown in nurseries without chlorosis present (Tab. 3):

- higher contents of Ca and Mg
- lower contents of Fe and K
- no significantly different contents of ash, N and P
- higher ratio values of Ca/P and Ca/K and lower ratio of K/Mg.

Taking into consideration the total of all six nurseries, the correlation between the availability of nutrients of the soil and their concentration in leaves show:

- significant at N_2 ($r = -0.52$), at P ($r = 0.453$) and in Mg ($r = 0.65$)
- not significant in K ($r = 0.07$), in Ca ($r = 0.13$) and in Fe ($r = 0.17$).

2.3.2 Analysis of soil and leaves in nurseries with iron chlorosis symptoms

2.3.2.1 Soil analysis

In nurseries with symptoms of iron chlorosis, the soil analysis has been carefully examined comparing the analytic data of adjacent areas with different intensities of chlorosis. As three intensity levels have been taken into consideration in the two Palazzolo nurseries and four intensity levels at the Bigarello nurseries, the statistic analysis was made separately for these two places.

Palazzolo dello Stella (Nursery A and B)

In spite of the different growth of plants, there were no obvious differences as far as the spreading and the intensity of yellowing was concerned in the two nurseries during sampling; but when the analytic data of the soil of these two nurseries was confronted, considerable differences were found. It can be affirmed that the soil in nursery A where the plants were smaller with respect to those in nursery B showed values (Tab. 4 and 5):

- significantly higher in gravel, sand (coarse and fine), organic carbon and, therefore, organic matter, total N_2, available phosphorus, exchangeable magnesium, C.P.I. and CaO/Fe ratio;
- significantly lower in total and active carbonate, pH and available iron;
- not significantly different in exchangeable calcium and potassium and in C/N ratio.

The only characteristic found in soil of adjacent areas with different chlorotic intensities was at granulometry level where there were high contents of sand and, therefore, low contents of silt and clay. Here, serious symptoms of chlorosis were found. For all other pedologic parameters taken into consideration, the differences are not significant at 5% level.

Bigarello

No significant differences were found, in pedologic parameters taken into consideration, in adjacent areas with different chlorotic intensity (Tab. 6). This includes active $CaCO_3$, exchangeable calcium and magnesium and available iron. Only the C.P.I. ratio are lower, even if not significantly, in areas without symptoms of iron chlorosis.

2.3.2.2 Analysis of leaves

What was done for the soil was also done for the leaves. The tests were thoroughly examined confronting the analytic data to adjacent areas with different chlorotic intensities. A statistic analysis was conducted in each place, elaborating together the data of the two nurseries in Palazzolo dello Stella.

Palazzolo dello Stella

The poplar leaves in nursery A with respect to those in nursery B show (Tab. 7 and 8):

- significantly lower contents of water and calcium
- no significantly different contents of chlorophyll (a, b and total), N, P, K, Mg and Fe
- a lower ratio Ca/P
- Ca/K and K/Mg ratio not significantly different.

In both nurseries, with the increase of chlorotic symptoms in leaves, the contents of ash, Ca, Mg, K and Ca/P ratio also increased significantly whilst the contents of chlorophyll (a, b and total) decreased significantly. The contents of N, P, Fe and Ca/K and K/Mg ratio did not vary.

Bigarello

With the increase of chlorotic intensity, the contents of water, ash, P, K and Mg increased whilst the contents of chlorophyll (a, b and total), Fe, and Ca/P and Ca/K ratio decreased. The contents of N, Ca, and K/Mg ratio did not vary particularly (Tab. 9 and 10).

2.3.2.3 In Bigarello, during the second half of August in the summer of 1975, symptoms of chlorosis, although slight and without any serious consequences on the growth, were found in one-year old plants of 'I-214' clone in nurseries. Iron chlorosis reappeared in more serious forms in the second vegetative year starting from June 1976.

Due to the considerable spreading of chlorosis, it was considered necessary to conduct a test on 12 soil profiles to find out possible macroscopic differences at pedologic level in adjacent areas with and without iron chlorosis.

Soil samples were taken from each profile paying attention to the different layers on which the pH value and total carbonate content were determined. Even the active calcium carbonate content was determined for the Ap horizon.

The presence of water was reported at a depth of about 1 m in most of the profiles. Normally the water table is much deeper and the fact that it was found higher is due to the irrigation carried out with great quantities of flowing water not controlled.

From analytic data the soil of loam texture, turned out calcareous with subalkaline reaction which decidedly tended to increase deeper (Tab. 11).

The thickness of the Ap horizon varied from 35 to 55 cm depending on the fields and has high active $CaCO_3$ contents which varies from 8 to 17.5%, but without a clear correlation with the intensity of chlorotic symptoms.

This shows that after having only considered a few pedologic parameters (pH, total carbonate, active $CaCO_3$, thickness of the layer mostly explored by roots, depth of the water table), it is not sufficient enough to point out the different behaviour of plants from one area to another at the same nursery. The soil should be examined more carefully taking into consideration many other parameters, particularly the one regarding the availability of microelements and the water and CO_2 content variations.

Some interesting elements were found through leaf tests which were separately taken from healthly and chlorotic plants of 'I-214' clone. The essential elements, which were of considerable interest for the research in question, were determined (Tab. 12).

The chlorotic leaves compared to the healthy ones showed average contents:

- significantly higher of water, ash, calcium and zinc
- significantly lower in iron
- higher, but not significantly, in P, K and Na
- lower, but not significantly, in Mn.

The Ca/P ratio was significantly much higher in chlorotic leaves than in the healthy ones. No significant differences between chlorotic leaves and healthy ones was found in the Ca/K and K/Mg ratio.

The most interesting data were certainly the high contents of Ca and Zn and the low contents of Fe found in yellow leaves as compared to the green ones.

2.4 Research in poplar plantations

2.4.1 Analysis of soil and leaves in poplar plantations with and without iron chlorosis symptoms

Soil tests conducted in nurseries with symptoms of iron chlorosis in Palazzolo dello Stella and Bigarello pointed out that at the most common pedologic parameters taken into consideration, there are no established differences in adjacent areas with different chlorotic intensities. It must, therefore, be taken into consideration that chlorosis is the result of actions due to numerous factors and their interactions from which we have only partly learnt their specific roles.

In the first place, when what we know is very limited, before entering into analytic details on small adjacent areas where plants show symptoms of different chlorotic intensity, it seemed more opportune to confront on an analytic basis, more extensive areas where very intense chlorotic symptoms exist compared to other areas where there is no chlorosis.

Following this line two poplar cultivation farms in San Giorgio Monferrato (Baldovina Farm) and in Mede Lomellina (Valle Verde Farm) were chosen. The first farm showed symptoms of chlorosis whilst the second had none. All four classes of chlorosis intensity (0,1,2,3) existed in the first farm.

In both farms, with poplar plantations - 'I-214' clone - from 3-6 years old a series of soil sampling was carried out only on the Ap layer, about 50 cm thick, in which most of the absorbing roots are concentrated.

In San Giorgio, 20 equally divided soil samples were taken in areas with different chlorotic intensity. In Mede, 15 soil samples were taken, obviously all from areas with healthy plants.

A sample of leaves and a branch, about halfway of the crown, were taken from plants around the area from where the soil was drawn as sample.

The chemical analysis of the soil, leaves and branch was done at the SIGLA Laboratory in Tortona.

The results of this analysis were studied along with the variance analysis comparing the data of Mede to those of San Giorgio, independently from iron chlorosis intensity.

2.4.1.1 Analysis of soil

The soil in San Giorgio compared to that in Mede Lomellina shows contents (Tab. 13):

- significantly higher of total carbonate, active $CaCO_3$, exchangeable calcium, magnesium and potassium and available boron;
- significantly lower of iron, manganese and available molybdenum
- not significantly different of total nitrogen, organic matter and available phosphorous

The index of chlorosis power results in an average of 386 in the San Giorgio soil and 15 for the soil in Mede. Even the ratio CaO/Fe is much more higher in the first soil than in the second (662 against 123).

2.4.1.2 Analysis of the leaves

The leaves on the plants in San Giorgio, with respect to those in Mede show contents (Tab. 14):

- significantly higher of ash, silica, potassium, calcium and boron
- significantly lower of phosphorous and magnesium.
- not significantly different in nitrogen, iron and manganese.

The ratios Ca/P, K/Mg and Ca/K result, in average, higher in leaves of the plants in San Giorgio than those in Mede Lomellina but not statistically significant in the last one.

2.4.1.3 Analysis of branches

The branches of the plants in San Giorgio with respect to those in Mede Lomellina show contents (Tab. 15):

- significantly higher of silica and calcium
- significantly lower of iron, phosphorous, manganese and boron
- not significantly different of ash, nitrogen, potassium and magnesium.

In this case, all three ratios Ca/P, Ca/K and K/Mg are higher in branches of plants in San Giorgio than those in Mede Lomellina.

2.5 Results and Discussion

The confrontation of analytic data of soil in nurseries with chlorosis as regards those in healthy nurseries have given significant results. The first type shows higher contents of silt and clay, organic carbon (and, therefore, organic matter), total and active carbonate, total nitrogen and exchangeable CaO and MgO. The contents are lower of available P_2O_5. As regards available K and Fe, there is a complete difference between the two groups of soil, but in the internal parts of each one of these soils there is a strong variability.

In soils where poplars show chlorotic symptoms compared to those with healthy poplars, higher contents of total and active carbonate, exchangeable CaO, MgO and K_2O and available B, and lower contents of Fe, Mn and available Mo were found.

Both the Chlorosis Power Index and the CaO/Fe ratio are much more higher in calcareous soils than in soils where poplars do not have any chlorotic symptoms.

Leaf analysis supplied elements of considerable interest. In nurseries with symptoms of chlorosis higher contents of water, Ca and Mg were recorded whilst there were lower contents of Fe and, in some cases, even of phosphorous.

In poplar plantations with chlorosis, significantly higher contents of ash, silica, calcium, potassium and boron were recorded whilst there were significantly lower contents of phosphorous and iron, even if not too significant at 5% level.

In these poplar plantations even branches had been analysed and the results showed higher contents of silica and calcium and lower contents of iron and phosphorous in plantations with symptoms of chlorosis.

In leaves of older plants growing on calcareous soils, the Ca/P and Ca/K ratios are always higher whilst the K/Mg ratio is higher in poplar plantations and lower in nurseries. One must remember that according to the connection of the various nutrient elements, particular importance is given to the age of sample leaves which had been valued at 30 days for nurseries and 60 for poplar plantations. Therefore, the values of data recorded only once do not give a definite idea of the biochemical dynamism of the nutrients taken into consideration.

Comparing the mineral contents of the soil to those of plants, it appears that:

- in nurseries with chlorosis compared to those without chlorosis:
  - calcium and magnesium contents are high in both soil and leaves
  - iron contents are averagely lower in both soil and leaves
  - N_2 and potassium are higher in soils but less in leaves (but not significant at 5% level for nitrogen)
  - phosphorous appears less higher in both soil and leaves (in the latter not significantly at 5% level)

- in poplar plantations with chlorosis compared to those without chlorosis:

  . calcium contents are high in soil, leaves and branches

  . iron contents are lower in soil, branches and leaves (in the latter not significantly at 5% level)

  . potassium is high in both soil and leaves

  . magnesium and phosphorous is higher in soil but lower in leaves

  . nitrogen does not present any difference in soil or plant samples.

However, the comparison between nurseries and poplar plantations were hindered due to the fact that younger leaves were taken from nurseries. As known, in young leaves, which are physiologically more active, N_2 and phosphorous contents are higher and calcium contents are lower.

In any case, in both types of plantations where there were symptoms of Fe deficiency, besides a high active calcium carbonate contents in the soil, a much higher contents of calcium at both soil and plant levels and low iron contents in plants, were recorded.

This datum is very important because this favours the validity of the Chlorosis Power Index (C.P.I.) and the CaO/Fe ratio for the valuation of chlorotic power in the soil.

At this stage, it is interesting to explain the significance of the differences verified at the considered parameter levels.

In nursery soils with chlorotic symptoms, the highest percentage of the finest soil grain assumes a particular significance because silt represents the mayor part of active calcium and clay is a component which plays an important role in many chemical and physical processes of the soil.

In tested soils, active calcium carbonate on the whole was significantly correlated ($r = 0.665$, $P = 0.01$) to total carbonate.

As known, the determination of total carbonate does not establish a sufficient element to value the chlorotic power of the soil, although in the past it was claimed that total carbonate caused Fe deficiency.

The knowledge of active calcium carbonate is very important, but on its own does not allow definate characteristics of the soil in question. Its determination becomes certain also taking into consideration available iron not separately, but together with active calcium carbonate (C.P.I.) and exchangeable calcium (CaO/Fe).

As organic matter was found in greater quantities in nurseries with chlorosis, it is considered that its well-known positive functions of forming water-soluble iron chelates did not prevale against its negative effects. In fact, the organic matter, in cause of its transformation, could have increased the production of carbon dioxide which could have caused an increase of the concentration of carbonate and bicarbonate ions (CO_3^{--}, HCO_3^-). This can lead to a diminution of available iron (BROWN J.C., 1961). It is also possible that the greater concentration of magnesium could have decomposed organic iron chelates, particularly iron-fulvic, which forms in the soil spontaneously, taking away, from the plant, the possibility of using this natural source of soluble iron.

The high concentration of calcium is considered one of the major causes of iron chlorosis. Its action reveals the insolubility of iron compounds favouring the oxidation of iron ions to less active iron ions and their consequent fixation in compounds at low biological activity (ROTINI O.T., 1957).

The major contents of total N_2 in calcareous soils did not mean a higher concentration of the same element in leaves. A positive correlation could be expected considering the fact that in calcareous soil mineralization is very active. Therefore, the total N_2 content should appear a fairly approximate value of the level of available N_2. The negative correlation can also

been interpretated as one of the effects of iron chlorosis which can be noticed by a depressive action on proteic synthesis. On the other hand, chlorosis effects, due to high levels of nitrogen in soils have already been pointed out. Even with poplars in nurseries, the intensification of chlorosis was found due to strong nitrogen fertilizing doses, 200/ Kg/ha/year of fertilizing units, in calcareous soils (FRISON G., 1974).

The meccanism of the action is still not completely clear. It is possible that owing to the high doses of nitrogen, the growth of young poplars is strongly enhanced and therefore, the demand of iron proportionally increases. Instead iron availability in calcareous soils is limited. In this way there could be a nutritional disequilibrium between nitrogen and iron.

Phosphorous and potassium contents in the examined samples of soil do not offer any reasons to explain their role in the manifestation of iron chlorosis.

Clay contents play an important role because of its influence on the physical characteristics of soils, so much so that if one considers that the Ap horizon is on a calcareous layer in which there is, sometimes, a lot of sand, but often the finer fraction prevails, and this limits the permeability. In fact, the importance of drainage problems is well-known in the manifestation of chlorosis both for its negative action on root respiration and the accumulation of carbon dioxide.

The results of the analysis of soils at nurseries with iron chlorosis in Palazzolo dello Stella and in Bigarello show, contrary to what was expected, that the singular parameters taken into consideration such as total and active carbonate, pH, total nitrogen, available pH, exchangeable Ca and Mg and available iron, are not correlated to the intensity of chlorosis. Only the C.P.I. varies, but not significantly, with an intenseness of yellowing. On the inside of each class of chlorosis intensity at soil level, a considerable variability exists. Therefore the differences in intensity classes as compared to each pedologic parameter should be very high to reach a significant level. The number of soil samples, for examination, could have been increased but these had to be limited due to expenses. It is not very easy to take soil samples which are actually rapresentative when the variability of soil is very high.

On the other hand, it is not generally true that significant differences may exist in each one of the soil parameters, taken into consideration, in adjacent areas in which there are plants with serious symptoms of chlorosis and others with slight chlorosis or quite healthy trees. This is because there are many factors with high level chlorotic power in the said soils. Furthermore, among these various factors, interactions are also quite possible.

It is fairly probable that even in soils, with plants having intensity class 0, where high chlorotic factors are also found and, therefore, symptoms of chlorosis could be caused by slightly varying the said factors, including climatic ones.

In fact, during sampling at the Palazzolo dello Stella nurseries, which are spread over a surface of about 10 ha, chlorosis was found practically all over and we were unable to find plants with completely green leaves to enable us to consider them totally healthy. It was possible that they could have been found 2 weeks earlier or even 2 weeks later, depending on the variation of soil conditions.

It is not certain that some important parameters have been overlooked in this research, such as the variation of water contents in the soil and the concentration CO_2 in the root zone.

From researches it was found that particular importance had been given to the fixation of CO_2 at root level with the possibility that with each mole of fixed CO_2 corresponds the freeing of a mole of inorganic phosphate which was held responsible for the precipation of iron (RHOADS S.W. and WALLACE A., 1960).

But even if soil analysis did not point out the significant differences, leaf analysis supplied far more indicative results.

In all three nurseries with iron deficiency, contents of ash, K and Mg in leaves increased with the rising of chlorosis intensity. In the two Palazzolo nurseries contents of Ca had also increased but not of P.

On the contrary, in the Bigarello nursery contents of P had increased but not of Ca. On the whole, Ca contents were much higher in leaves of plants in Palazzolo whilst P contents were much higher of plants in Bigarello. Therefore, there could only be a correlation of chlorosis intensity at determined concentration and determined ratios between Ca and P elements.

2.6. Cure treatment

In the last few years a considerable intensification of iron chlorosis has been found. This physiologic trouble causes very serious damages in both nurseries and poplar plantations.

Iron deficiency has been found in nurseries at different places along the Po Valley: from Piacenza to Ferrara and from Mantova to Udine in heavy and calcareous agricultural soils. It has also been found in poplar plantations in vast plain areas in Friuli, Mantova and Verona, in hilly land where the poplar has only recently been introduced, as in Monferrato where the soil is well-known as being calcareous.

Among the reasons that have caused the increase of frequency and intensity of iron chlorosis and besides the widely spread growth of poplars in not very deep, heavier and more calcareous soils, as compared to those of their typical natural hábitat, the following points must be included:

- the replacement of simple fertilizers, which also contain iron, with complete fertilizers characterized by a remarkable degree of purity
- unavailable mature manure which leads to the major use of organic matter and green manure with a high C/N ratio
- the execution of deeper ploughing, which is possible with more powerful tractors. The deep ploughing mixes the soil well bringing the layers of carbonate accumulated deep in the soil, to the surface
- the accumulation of micronutrients in the soil, particularly Zn and Mn, through massive antiparasitic treatments
- the frequent use of heavy doses of nitrogen and phosphate fertilizers

- heavy irrigation of clayey soils, often using water, rich in bicarbonate.

After examining the various causes listed above, it can easily be deduced that with the intervention of an agronomic order, the attenuation of the manifestation of this phenomenon could be useful. It must be noted that such a choice, which can be positive and, in any case, convenient, shows results after a long period of time whilst the gravity of the situation demands - particularly in nurseries - effective remedies which have immediate results. Consequently, a series of treatment tests by leaf spraying and soil application with iron chelates, in nurseries and poplar plantations, are necessary.

2.6.1 Leaf spraying with iron chelates

2.6.1.1 In nursery

A first set of test series in 1976 with Quelacros 56 and a second set of test series in 1982 with Sequestrene 330 Fe (DTPA) was carried out.

In 1976, these tests were carried out:

- in Bigarello (MN) in a nursery at its second year of vegetation of 'I-214' and 'Pan' clones
- in Palazzolo dello Stella (UD) in a nursery at its second year of vegetation of 'I-214', 'Pan', and 'Luisa Avanzo' clones and in densely-spaced, coppiced nursery (S_1R_2) of 'I-214' clone.

In Bigarello, the yellowing appeared in August 1975, with fairly slight intensity, but it reappeared in May 1976 more seriously. In Palazzolo dello Stella, symptoms of chlorosis were noticed at the beginning of the second vegetative season (May 1976) without any obvious differences in plants belonging to the abovementioned clones but with a fairly strong intensity in all.

In both places, leaf spraying was carried out using 20 hl/ha of a watery solution with 0.1% Quelacros-56 adding a wetting agent.

The spraying was carried out on 10/6, 15/6, 21/6 and 30/6/1976 in Bigarello and on 11/6, 16/6, 21/6 and 1/7/1976 in Palazzolo dello Stella.

After the third spraying, the leaves turned green on most of the plants, but not completely. There were isolated spots on the surface of the leaves. After about 15 days and after the fourth spraying, particularly towards the end of July, the effect of the treatments were not sufficient enough to avoid an intensity of chlorosis, which had become particularly serious in new leaves. This was also due to the concurrence of rainfall and heavy irrigation.

It was noted that leaf spraying has a fairly labile effect. Therefore weekly spraying is necessary for the whole vegetative season which needs considerable work and money.

In 1982 tests were carried out:

- In Migliaro (FE) in a coppiced, densely-spaced nursery (S_1R_2) of 'Luisa Avanzo', 'Bellini' and 'Bellotto' clones
- In Sarmato (PC) in a nursery during its second vegetative year of 'Luisa Avanzo' clone
- In Palazzolo dello Stella (UD) in a nursery during its second vegetative year - clone 'Cima'.

In all three places, chlorosis was noticed at the end of May. In the beginning, the intensity was slight and became more and more intense until the end of July. Then the intensity decreased during August on plants which were less seriously stricken. This was observed on plants which had not been sprayed.

The treatments were carried out by spraying the leaves with 12 to 20/hl/ha, depending on the L.A.I. of the plants to be sprayed, with a watery solution of Sequestrene-330 FE (DTPA) at 0.125% adding a wetting agent.

The spraying was carried out:

- at Migliaro on 14/6, 21/6, 28/6, 5/7, 12/7, 19/7, 26/7, 2/8 and 9/8/1982
- at Sarmato on 2/7, 8/7, 16/7, 22/7, 30/7, 6/8, 13/8 and 20/8/1982
- at Palazzolo dello Stella on 15/6, 22/6, 29/6, 6/7 and 13/7/1982.

The leaves began to turn green between the second and the third spraying. This was found as small spots on leaf surfaces. The leaves continued to turn more and more green with the number of spray treatment, but not completely and neither did the new leaves grow green. This was probably because of poor penetration and translocation of used chelates through poplar leaves.

Even though there was a certain improvement after 6 to 9 treatments, it was not valid enough from a practical point of view, considering the work and cost involved.

2.6.1.2 <u>In poplar plantations</u>

A series of tests were carried out in poplar plantations - 'I-214' clone - in summer 1976, the second year after planting, in San Giorgio Monferrato (AL) and the fourth year after planting in Torsa di Tolmasson (UD).

The treatment was carried out spraying leaves with 20 hl/ha of a solution with 0.1% Quelacros adding a wetting agent on 12/6, 17/6, 22/6 and 2/7/1976 in Torsa di Tolmasson and on 15/6, 22/6, 2/7 and 10/7/1976 in San Giorgio Monferrato.

About 100 plants were sprayed at each of the two abovementioned places. These plants were specifically chosen because they had symptoms of serious chlorosis. The same number of plants with symptoms of the same intensity were not treated (control).

As in the nurseries, even in plantations the leaves turned green only in small spots. In any case, the four treatments carried out did not give any satisfactory results, especially from a practical point of view.

2.6.2 Soil application of iron chelates

2.6.2.1 In nurseries

The alternative treatment was application of iron chelates in soils. The only problem here was to choose the best method of application.

In order to do this, the method of trickle irrigation seemed suitable both for distributing water and the dosage of products to be administered.

Three tests were carried out during the vegetative season in 1982, each on a surface of about two ha, in nurseries with chlorotic symptoms found in areas with fairly different pedoclimatic characteristics:

- in Sarmato (PC) - 'Luisa Avanzo' clone
- in Migliaro (FE) - various clones
- in Bigarello (MN) - 'I-214' and 'Luisa Avanzo' clones.

A nursery in its second vegetative year was chosen in Sarmato (S_2R_2), partly coppiced at the end of the first year. No evident symptoms were found during the first vegetative year. Chlorosis appeared in May of the second year tending to increase following irrigation or rainfall and decreased during the hot and dry season.

Nurseries, in their second year of vegetation (S_2R_2), including commercial clones ('Luisa Avanzo' and 'Bellini') and experimental clones ('Bellotto' and 'Guariento') were chosen in Migliaro. Even in this case chlorosis was found starting from June of the second vegetative year tending strongly to intensify or alleviate depending on the abovementioned factors.

Both nurseries were divided in four parts of which two were treated with Sequestrene-138 Fe (EDDHA), using trickle irrigation system and the other two were irrigated in the same manner but without adding iron chelates to the water.

A pipeline was placed along each row of young poplars with emitters fixed 1 m from one another distributing 4/l/h.

An experimental nursery was used in Bigarello where tests for spacing, irrigation methods (trickle or sprinkle) and coppicing of 'I-214' and 'Luisa Avanzo' clones are being carried out.

The young trees in this nursery had been coppiced at the end of the first vegetative period (1981). During this time, starting from August, together with heavy rainfall, intense symptoms of chlorosis was found on the 'Luisa Avanzo' clone and on more densely-spaced plants.

During the second vegetative period (1982), the first after coppicing, chlorosis became more serious and following this, no difference was found in spacing or in the different clones.

As the young poplars were placed in groups of four rows, the pipeline were placed between the first and second row and between the third and fourth row of each group.

The nursery was divided into eight big blocks of which four were trickle-irrigated and four were sprinkle-irrigated. The chelate treatment was carried out in the four trickle-irrigated blocks. In all eight blocks whether trickle or sprinkle-irrigated, when chelate treatment was first started, most of the young poplars were seriously damaged due to iron chlorosis which had prevented growth (intensity class 3).

The object of this test is to find out whether the use of chelates helps to cure chlorosis and consequently stimulate growth - aside from chlorosis intensity - or whether there is a limit beyond which the pathologic state becomes irreversible.

The treatment was carried out applying Sequestrene-138 Fe (EDDHA) by trickle irrigation system in doses of 3 g/m^2 within three weeks time (Tab. 16).

Sequestrene-138 was chosen because EDDHA is a very strong chelatic agent and it is suitable for very calcareous soils. This agent is known for its remarkable persistency if it is not leached away from the rhizosphera.

With regard to the method of application of chelates, a basic Sequestrene solution was prepared (about 5 Kg melted in 300 litres of water) which was then injected by means of a pump into the pipelines in 2 hours. As 50 m^3 of water was administered during that time, the concentration of the product in the solution which came out from the emitters was 100 p.p.m.

At the Sarmato nursery, where the application started on July 3, the leaves immediately turned green only after 6 days after the beginning of the treatment with chelates. The treated plants improved very quickly and in an excellent manner and started to grow vigorously once again. The effect was first noticed on the leaves at the top of the plant and this confirms that the iron moves in an acropetal direction and, successively to the other leaves on the top branches. On the lower and side branches, the yellowing persisted longer tending to diminish but without disappearing completely.

The effect of this treatment was decisive even on the growth. In fact the young poplars treated, on August 23 were averagely 60 cm higher than those irrigated with the same quantity of water but without Sequestrene. There was a slight improvement, aboveall in plants with slight intensity of chlorosis of young poplars, not treated (control), in August.

At the Migliaro nursery the effects after treatment appeared obvious but not as impressive as in Sarmato. This could be attributed to the fact that at this nursery, treatment began on August 4, more than a month later, and that the yellowing of the plants, not treated, decreased noticeably.

The fact that the yellowing of the young controlled trees decreased more in Migliaro than in Sarmato is partly due to the soft water used for irrigation purposes. In fact the bicarbonate contents in the water in Sarmato was found to be averagely higher than in Migliaro (g per 100 litres of water = 30 in Sarmato and 11.3 in Migliaro).

In Bigarello where the treatment started with a delay, on July 26, the effects were positive in an unequivocal manner but with differencies in the ambit of certain plots due to various chlorotic intensities. Treatments carried out on plants with chlorotic intensity - class 3 - were less effective. This shows that when iron deficiency is very serious, higher doses of iron chelates should be used. It must be mentioned here that the young poplars in Bigarello had already suffered damages due to a very heavy hailstorm which took place on June 13, 1982 which had split stems and ruined leaves. In spite of this it was surprising to note the positive effects of the treatment.

Treatment through soil application with Sequestrene-138 Fe (EDDHA) has proved positive at all the three abovementioned farms, and also others.

It has also been proved, with positive results, the soil application of iron chelates in granules.

2.6.2.2 <u>In poplar plantations</u>

Tests were carried out on a plantation situated on the hills near San Giorgio Monferrato on 8-year old plantations of 10-year old trees - 'BL Costanzo' and 'I-214' clones.

For this purpose 20 plants of the first clone and 10 plants of the second clone were chosen. All these plants had symptoms of iron chlorosis (intensity class 3). Half of them were treated and the other half no. The product was administered watering the soil around the trees within a radius of 2 m with a solution of Sequestrene138 Fe in quantities and concentrations as reported on Tab. 17.

It was necessary to use elevated volumes of water and high quantities of product to water the entire profiled soil which was explored by roots due to the fact that the said plants had suffered from iron deficiency for some years.

In this way it was necessary to establish whether iron chlorosis was curable until the trees had some life in them or whether at a certain intensity level this became irreversible. The results of treatment were absolutely excellent in spite of the delayed treatment and in spite of the advanced age of the plants and the seriousness of the deficiency. The leaves turned green much more slowly than in nurseries but fairly fast considering the fact that this took place within a month and also considering the fact that the product had been administered much later. In the middle of August the new leaves were completely green and the old chlorotic intensity (class 3) came down to class 1 or 0. In the meantime, the leaves of trees which were not treated maintained class 3 chlorotic intensity.

Even though treatments with iron chelates are quite expensive in poplar plantations, they are comparatively low in nurseries (less than 100 lire per young poplar). In any case, these treatments have confirmed that we are dealing with iron chlorosis.

3. CONCLUSION

With the diffusion of poplar cultivation from its natural habitats to ex-agricultural soils which are not very deep, with heavy texture and more calcareous, even more frequent manifestations of a physiologic trouble can be seen with the yellowing of leaves followed by necrosis and prevention of growth in more serious cases.

Chlorosis had been induced by growing poplars in vegetation tanks containing soils which had comparatively high active carbonate and low available iron. Leaf treatment with iron sulphates on plants with chlorosis allowed us to identify the cause of the phenomenon in Fe deficiency.

Leaf application of iron chelates (Sequestrene 330 Fe (DTPA) and Quelacros-56) proved unsatisfactory from a practical point of view, because the spraying only partly effected leaf surface and this persisted for a very short time.

Recent tests have proved that iron chlorosis in poplar nurseries can be cured with very good results by soil application with Sequestrene 138 Fe (EDDHA), in doses of about 3 g/m^2. Consequently, we feel that chlorosis is caused because of an insufficient availability of iron in the rhizosphere.

On trees with chlorosis, both green leaves (on lower part of the tree) and chlorotic leaves (on the top part of the tree) are found. This means that no transfer of active iron exists from older leaves to younger ones. Therefore, in such a situation, the mobility of iron had been blocked also in plants. Soil application helps to turn the leaves green on the top part of the tree first and gradually even the others, but not so successfully on the lower branches which are less active.

On the basis of the above points, it can be affirmed that among the causes of iron chlorosis of the poplar there are some that maintain a low concentration of available iron in soils or prevent root absorption and others that do not allow the mobility and utilization in the internal parts of the tree.

In any case, the rising of this phenomenon is enhanced by the physiologic state of the plant which, in turn, is a result of certain pedoclimatic factors (low temperature, heavy rainfall, water table and inadequate soil) and other agronomical factors (such as highly-dense plantations, coppicing, untimely contributions of organic matter, excessive nitrogen and phosphate fertilizers).

To be in a position to carefully examine the nature of this phenomenon, a series of analysis were carried out on soil and leaf samples both in nurseries and poplar plantations with or without symptoms of iron chlorosis.

Comparing the data of the adjacent areas of nurseries with chlorosis, no significant correlation was found between the yellowing intensity class and the pedologic parameter level taken into consideration. Only the C.P.I. increases with the increase of chlorotic intensity.

Comparing the data relative to nurseries and poplar plantations with and without the yellowing phenomenon, the results show that soils with chlorotic power have higher contents of silt and clay, total and active carbonate, exchangeable Ca , Mg and K , and lower contents of available iron. Consequently, the C.P.I. and CaO/Fe ratio are much higher. Leaves of chlorotic plants show high contents of Ash, Ca and low contents of chlorophyll, dry matter and Fe. The Ca/P and Ca/K ratios are much higher.

From all the data gathered, it is certain that the physiologic trouble is due to iron deficiency. As we are now certain that we are dealing with iron chlorosis and the products used in trials are quite expensive, it should be easier to find alternative products which are not so expensive but just as effective.

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SUMMARY

With the diffusion of poplar cultivation from its natural habitats to ex-agricultural soils which are not very deep, having heavier texture and are more calcareous, even more frequent manifestations of a physiologic trouble can be seen with the yellowing of leaves followed by necrosis and prevention of growth, in more serious cases.

Chlorosis had been induced by growing young poplars in vegetation tanks containing soils which had comparatively high active carbonate contents and low available iron contents. Leaf treatment with iron sulphate of trees with chlorosis confirmed the supposition that it was actually iron chlorosis.

A series of analysis were carried out on soil and leaf samples taken from nurseries and poplar plantations with and without yellowing symptoms. These analyses pointed out that soils with chlorotic power presented high contents of silt and clay, total and active carbonate, exchangeable Ca , Mg and K, and low contents of available iron. Consequently, the C.P.I. and CaO/Fe ratio are much higher. Leaves of chlorotic trees show higher contents of Ash and Ca, and lower contents of chlorophyll, dry matter and Fe and the Ca/P and Ca/K ratios are much higher.

In adjacent areas of nurseries with chlorosis, no significant correlation between yellowing intensity and the levels of pedologic parameters taken into consideration, have been found; only the C.P.I. increased with chlorosis intensity.

The results of the tests showed that iron chlorosis in poplars can be alleviated with excellent results through soil application with Sequestrene 138 Fe (EDDHA) in doses of about 3 g/m^2 in nurseries but in higher doses in poplar plantations.

As the diagnosis is now certain, less expensive and effective remedies are far more easier to find. Even the agronomic kinds can be taken into consideration.

Résumé

Avec l'expansion de la populiculture de son habitat naturel à des terrains ex-agraires moins profonds, plus lourds et plus calcaires, on a pu observer des manifestations de plus en plus fréquentes d'un trouble physiologique se manifestant par le jaunissement des feuilles suivi de nécrose et, dans les cas les plus graves, par l'arrêt de l'accroissement. Le phénomène avait été diagnostiqué comme chlorose ferrique.

Le trouble a été reproduit en élevant des plants de peuplier dans des caisses de végétation sur terrain relativement riche en calcaire actif et pauvre en fer assimilable. Des traitements foliaires avec sulfate de fer, effectués sur les plantes attaquéés, ont permis de confirmer l'hypothése qu'il s'agissait réellement de chlorose ferrique.

De successives séries d'analyses d'échantillons de terrain et de feuilles, prélevés soit dans les pépinières soit dans les peuplements présentant et non de phénomènes de jaunissement, ont mis en évidence que les terrains ayant pouvoir chlorosant ont des teneurs plus élevées en limon et en argile, en calcaire total et actif, en Ca , Mg et K échangeables et une teneur plus faible en Fe assimilable. Par conséquent, l'indice du pouvoir chlorosant (I.P.C.) et le rapport CaO/Fe résultent bien plus élevés. Les feuilles des plantes chlorotiques ont des contenus plus hauts en cendres et en Ca et plus bas en chlorophylle, en matière sèche et en Fe, et des rapports Ca/P et Ca/K plus élevés.

Au sein des pépinières présentant des manifestations de chlorose, on n'a pas encore trouvé une corrélation significative entre l'intensité du jaunissement et les niveaux des paramètres pédelogiques considérés. C'est seulement l'I.P.C. qui augmente avec l'intensité de la chlorose.

Les essais conduits ont démontré que la chlorose ferrique du peuplier peut être soignée avec des résultats sensationnels à l'aide de traitements par voie racinaire avec le Sequestrene 138 .Fe (EDDHA) aux doses de 3 g/m^2 environ en pépinière mais plus élevées en plantation.

Puisque la diagnose est désormais certaine, il résulte plus facile de chercher des rémèdes moins coûteux et en même temps efficaces, parmi lesquels aussi ceux d'ordre agronomique.

TABLE 1 - MECHANICAL AND CHEMICAL CHARACTERISTICS OF 4 TYPES OF SOIL USED IN VEGETATION TANKS TO REPRODUCE SYMPTOMS OF IRON CHLOROSIS ON YOUNG POPLARS

Characteristics	Soil No. 1		2		3		4	
Depth (cm)	0 - 25	25 -50	0 - 25	25 - 50	0 - 25	25 - 50	0 - 25	25 - 50
Coarse sand (2-0,2 mm) %	2.73	2.44	10.26	16.98	1.92	1.67	8.69	7.90
Fine sand (0,2-0,02 mm) %	76.77	76.06	64,24	52.02	81.08	85.33	40.81	38.10
Silt (0,02-0,002 mm) %	12.50	14.50	19.50	22.50	13.00	11,00	35.00	35.00
Clay (<0,002 mm) %	8.00	7,00	6,00	8.50	4.00	2,00	15.50	19,00
pH	6.28	6.25	6.35	6.35	7.35	7.35	7.30	7.78
Total carbonate %	0	0	0	0	4.35	5.00	6.50	12.19
Active $CaCO_3$ (Drouineau) %	0,38	0.25	0	0	0.50	0.50	4,87	5.50
Total nitrogen (Kjeldahl) %	0.906	1,016	1.312	0.776	0.859	0.467	2,081	0.551
Organic carbon (Walkley and Block) %	0,27	0,21	0.42	0,23	0.33	0.18	1.20	1.05
Organic matter (C x 1,724) %	0.47	0.36	0.72	0.47	0.57	0.31	2.06	1,81
Total P_2O_5 (Ferrari) %	1.05	1,14	1,11	1.10	2.16	1.85	2,42	2.59
Available K_2O (Dirks and Scheffer) p.p.m.	19.7	1,8	26.4	3.4	24.0	10,0	57.5	14.4
Available Fe p.p.m.	32.00	28.00	75.00	83.00	105.00	120.00	17.00	16.00
Chlorosis Power Index (C.P.I.)	0	0	0	0	0.45	0.45	168	215

$$C.P.I. = \frac{CaCO_3 \text{ (active \%)}}{(Fe)^2 \text{(avail. p.p.m.)}} \times 10^4$$ (By JUSTE C., POUGET R., 1972)

TABLE 2 - CHARACTERISTICS OF DIFFERENT TYPES OF SOIL OF POPLAR NURSERIES WITH AND WITHOUT IRON CHLOROSIS

Characteristics	Nurseries with symptoms of iron chlorosis				Nurseries without symptoms of iron chlorosis				Values at F
	Palazzolo dello Stella A	Palazzolo dello Stella B	Bigarello	Average	Giarole	Rosasco	Casale Monf.	Average	
Gravel %	21.64	7.18	0.42	8.80	0.17	0,14	0.34	0.22	14,44++
Coarse sand %	19.81	13.08	2.49	10.86	18.75	34.46	20.16	25.33	10.39++
Fine sand %	33.53	44.30	37.02	38.16	55,28	49.98	65.62	57.22	11.10++
Silt %	33.64	30.97	42.51	36.39	18,79	12,18	10.19	12.94	52,71++
Clay %	13.02	11.65	17.98	14.60	7.18	3.38	4.03	4.51	51,22++
pH	7.62	7.73	7.64	7.66	6.88	6.95	7.68	6.39	69.51++
Organic carbon (C) %	1.324	0.894	1.215	1.152	0.720	0.708	0.644	0.686	15.45++
Organic matter (C x 1,724) %	2.28	1.54	2.09	1.99	1.24	1.22	1.11	1,18	15.45++
C/N	10.56	9.72	10.20	10,16	9.78	9.96	10.72	10,21	1.12 n.s.
Total carbonate %	8.69	23.94	21.84	18.53	0.00	0.42	5.74	2.37	23.40++
Active $CaCO_3$ (Drouineau) %	1.39	4.06	11.08	6.07	0.00	0.16	0.84	0.38	41.40++
Total nitrogen (Kjeldahl) %	0.125	0.092	0.119	0,113	0.074	0.074	0.060	0.069	15.10++
Available P_2O_5 (Ferrari) p.p.m.	110.1	67.0	62.8	78.3	149.0	190.2	143.4	162,7	14,1++
Exchangeable K_2O p.p.m.	98.8	103.5	209.9	144.7	105.3	112.2	78.6	97.7	13.7++
Exchangeable CaO p.p.m.	2773	2997	5111	3777	1328	1110	1241	1211	87.1++
Exchangeable MgO p.p.m.	610	311	445	454	122	135	40	95	21.6++
Available Fe p.p.m.	8.0	25.8	31.4	22,7	17.0	24.4	120.3	59.6	83.9++
CaO/Fe	355	174	171	227	79	53	10	43	18.7++
C.P.I.	213	105	137	150	0	3	0,6	1,4	6.9++

++ significant at 1% level

n.s. not significant

TABLE 3 - ASH AND NUTRIENT ELEMENT CONTENTS IN LEAVES OF YOUNG POPLARS GROWN IN NURSERIES WITH AND WITHOUT SYMPTOMS OF IRON CHLOROSIS

	Dry matter							Ratio		
	Ash (%)	N_2 (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (p.p.m.)	Ca/P	Ca/K	K/Mg
Nurseries with symptoms of iron chlorosis										
Palazzolo dello Stella										
Nursery A	8.54	3.779	0.391	1.783	1.678	0.419	71.6	4.36	0.96	4.30
Nursery B	9.42	3.918	0.358	1.832	1.856	0.407	63.0	5.31	1.02	4.57
Bigarello	9.15	3.663	0.416	2.082	1.594	0.440	52,1	3.99	0.82	4.83
Average	9.05	3.774	0.391	1.918	1.698	0.424	61.20	4.50	0.92	4.59
Nurseries without symptoms of iron chlorosis										
Giarole	8.66	3.880	0.455	2.240	1.297	0.273	77.33	2.88	0.58	8.20
Rosasco	9.61	4.112	0.480	2.610	1.340	0.278	97.40	2.79	0.51	9.47
Casale Monferrato	9.63	4.050	0.431	2.582	1.442	0.238	83.40	3.361	0.56	10.88
Average	9.40	4.035	0.455	2.514	1.369	0.261	87.39	3.03	0.55	9.72
Values at F	1.23n.s.	2.51n.s.	3.46n.s.	6.27+	6.29+	18.44++	10.05++	6.81+	11.21++	57.56++

n.s. not significant
\+ significant at 5% level
++ significant at 1% level

TAB. 4 - CHARACTERISTICS OF SOIL IN POPLAR NURSERIES WITH SYMPTOMS OF IRON CHLOROSIS

Intensity of chlorosis	Gravel (%)	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	pH	Organic carbon (%)	Organic matter (C x 1.724) (%)	C/N
Nursery A 1 (slight)	17.30	18.20	33.22	35.23	13.35	7.60	1.327	2.287	10.15
2 (intense)	20.03	16.34	33.22	36.10	14.34	7.58	1.420	2.448	10.56
3 (serious)	27.60	24.88	34.15	29.59	11.37	7.78	1.227	2.115	10.97
Nursery B 1 (slight)	4.83	9.58	39.11	37.15	14.15	7.75	0.960	1.655	9.80
2 (intense)	6.43	10.71	47.17	30.65	11.45	7.76	0.847	1.459	9.54
3 (serious)	10.10	18.94	46.94	25.11	9.34	7.68	0.877	1.511	9.83
Average-nurseries									
A	21.64	19.81	33.53	33.64	13.02	7.62	1.324	2.283	10.56
B	7.12	13.08	44.41	30.97	11.65	7.73	0.894	1.542	9.72
Values at F	9.84++	3.85+	4.44+	1.25n.s.	3.31n.s.	6.95+	15.23++	15.23++	2.53n.s.
Average-Intensity of chlorosis									
1 (slight)	11.07	13.89	36.17	36.19	13.75	7.67	1.143	1.971	9.98
2 (intense)	13.23	13.53	40.19	33.38	12.89	7.67	1.133	1.854	10.05
3 (serious)	18.85	21.91	40.55	27.35	10.36	7.68	1.052	1.813	10.40
Values at F	1.0n.s.	2.55n.s.	0.30n.s.	4.77+	7.27++	0.04n.s.	0.28n.s.	0.28n.s.	0.25n.s.
General average	14.38	16.44	38.97	32.31	12.33	7.68	1.109	1.913	10.14

n.s. not significant
\+ significant at 5% level
++ significant at 1% level.

TAB 5 - CHEMICAL CHARACTERISTICS OF SOIL IN POPLAR NURSERIES WITH SYMPTOMS OF IRON CHLOROSIS

Intensity of chlorosis		Carbonate Total (%)	Carbonate Active (%)	Total N_2 (Kjeldahl) (%)	P_2O_5 avail. (p.p.m.)	K_2O exch. (p.p.m.)	CaO exch. (p.p.m.)	MgO exch. (p.p.m.)	Fe avail. (p.p.m.)	CaO/Fe	CPI
Nursery A	1 (slight)	10.50	1.63	0.131	109	116	2979	634	8.9	343	184
	2 (intense)	4.80	1.10	0.135	115	95	2879	723	7.0	414	222
	3 (serious)	10.77	1.43	0.111	106	85	2463	577	8.1	309	232
Nursery B	1 (slight)	21.43	4.37	0.098	61	109	3333	326	28.6	173	80
	2 (intense)	28.80	5.87	0.088	61	97	2770	258	38.1	75	41
	3 (serious)	21.60	1.93	0.089	80	104	2890	349	10.7	274	193
Average-nursery											
A		8.69	1.39	0.125	110	99	2774	645	8.0	355	213
B		23.94	4.06	0.092	67	104	2998	311	25.8	174	105
Values at F		21.98++	15.96++	11.98++	25.1++	0.24n.s.	0.79n.s.	13.3++	17.6++	17.2++	5.3+
Average-Intensity of chlorosis											
	1 (slight)	15.97	3.00	0.114	85	113	3156	480	18.8	258	132
	2 (intense)	16.80	3.48	0.112	88	96	2825	491	22.6	245	131
	3 (serious)	16.18	1.68	0.100	93	95	2677	463	9.4	291	212
Values at F.		0.02n.s.	2.60n.s.	0.83n.s.	0.3n.s.	1.5n.s.	1.27n.s.	0.03n.s.	3.4n.s.	0.4n.s.	1.32n.s.
General average		16.32	2.72	0.109	89	101	2886	478	17.0	265	159

n.s. not significant
\+ significant at 5% level
++ significant at 1% level

TAB. 6 - CHARACTERISTICS OF SOIL IN POPLAR NURSERY IN BIGARELLO WITH SYMPTOMS OF IRON CHLOROSIS

Characteristics	Intensity of chlorosis 0 (no signs)	1 (slight)	2 (intense)	3 (serious)	Values at F	Average
Gravel %	0.67	0.40	0.17	0.43	0.81n.s.	0.42
Coarse sand %	2.38	2.71	2.70	2.15	1.22n.s.	2.49
Fine sand %	38.21	35.50	38.89	35.49	0.48n.s.	37.02
Silt %	43.23	42.04	41.61	43.15	0.37n.s.	42.51
Clay %	16.18	19.75	16.80	19.21	1.39n.s.	17.98
pH	7.64	7.67	7.59	7.65	1.40n.s.	7.64
Organic carbon (C) %	1.27	1.33	1.02	1.24	1.92n.s.	1.21
Organic matter (C x 1.724) %	2.20	2.29	1.75	2.14	1.92n.s.	2.09
C/N	10.14	10.31	9.91	10.44	0.83n.s.	10.20
Total carbonate %	23.84	14.13	25.67	23.73	3.98n.s.	21.84
Active $CaCO_3$ (Drouineau) %	11.13	8.43	12.60	12.17	0.99n.s.	11.08
Total nitrogen (Kjeldahl) %	0.126	0.129	0.102	0.120	1.10n.s.	0.119
Available P_2O_5 (Ferrari) p.p.m.	46.3	76.3	45.0	83.7	2.02n.s.	62.8
Exchangeable K_2O p.p.m.	182	239	170	250	0.89n.s.	210
Exchangeable CaO p.p.m.	4889	5639	4882	5034	1.61n.s.	5111
Exchangeable MgO p.p.m.	424	504	400	452	1.16n.s.	445
Available Fe p.p.m.	35.8	30.2	30.2	29.4	0.52n.s.	31.4
CaO/Fe	137	194	163	190	0.63n.s.	171
Chlorosis Power Index (C.P.I.)	87	101	164	194	0.75n.s.	137

n.s. not significant

TABLE 7 - VARIATIONS IN WATER, DRY SUBSTANCES, ASH AND CHLOROPHYLL CONTENTS IN POPLAR LEAVES IN CONNECTION WITH THE INTENSITY OF CHLOROSIS

Nurseries in Palazzolo dello Stella (UD)

Chlorosis intensity		Dry matter (%f.w.)	Moisture (%d.w.)	Ash (%d.m.)	Chlorophyll a (p.p.m. of fresh weight)	b	total
Nursery A	1 (slight)	27.12	268.73	7.31	331	679	1044
	2 (intense)	26.20	281.65	8.48	180	437	617
	3 (serious)	24.26	312.26	9.77	115	172	286
Nursery B	1 (slight)	26.57	276.34	8.02	285	680	965
	2 (intense)	24.19	313.24	9.20	247	529	776
	3 (serious)	23.43	326.81	11.04	106	213	318
Average-nurseries							
A		25.80	287.55	8.54	209	429	649
B		24.66	305.50	9.42	212	474	686
Values at F		5.97++	5.97++	9.33++	0.03n.s.	0.82n.s.	0.26n.s.
Average-Intensity of chlorosis							
	1 (slight)	26.84	272.54	7.69	308	680	1004
	2 (intense)	25.15	297.50	8.84	213	483	696
	3 (serious)	23.84	319.54	10.40	110	192	302
Values at F		13.67++	13.67++	30.03++	30.03++	32.6++	30.8++
General average		25.22	296.52	8.98	210	452	668

n.s. not significant
++ significant at 1% level

TAB. 8 - ASH AND NUTRIENT CONTENTS OF POPLAR LEAVES GROWN IN NURSERIES WITH SYMPTOMS OF IRON CHLOROSIS

Chlorosis intensity		Dry matter Ash (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (p.p.m.)	Ratio Ca/P	Ca/K	K/Mg
Nursery A	1 (slight)	7.37	3.840	0.419	1.587	1.383	0.360	76.7	3.3	0.9	4.5
	2 (intense)	8.48	3.623	0.340	1.680	1.723	0.443	66.0	5.2	1.1	3.8
	3 (serious)	9.77	3.873	0.415	2.083	1.887	0.453	72.0	4.6	0.9	4.6
Nursery B	1 (slight)	8.02	3.803	0.374	1.613	1.513	0.350	63.3	4.1	0.9	4.6
	2 (intense)	9.20	3.907	0.321	1.730	1.920	0.373	57.0	6.2	1.1	4.7
	3 (serious)	11.04	4.043	0.379	2.153	2.133	0.497	68.7	5.7	1.0	4.4
Average-nurseries											
	A	8.54	3.779	0.391	1.783	1.678	0.419	71.6	4.4	1.0	4.3
	B	9.42	3.918	0.358	1.832	1.856	0.407	63.0	5.3	1.0	4.6
Values at F		9.33++	2.94n.s.	3.57n.s.	0.22n.s.	6.52++	0.46n.s.	2.53n.s.	5.4+	0.7n.s.	0.5n.s.
Average-Intensity of chlorosis											
	1 (slight)	7.69	3.822	0.396	1.600	1.448	0.355	70.0	3.7	0.9	4.5
	2 (intense)	8.84	3.765	0.330	1.705	1.842	0.408	61.5	5.7	1.1	4.3
	3 (serious)	10.40	3.958	0.397	2.118	2.010	0.475	70.3	5.1	0.9	4.5
Values at F		30.0++	2.0n.s.	6.23+	9.53++	22.8++	14.73++	1.2n.s.	8.8++	2.6n.s.	0.2n.s.
General average		8.98	3.848	0.375	1.808	1.767	0.413	67.3	4.8	1.0	4.4

n.s. not significant
\+ significant at 5% level
++ significant at 1% level

TAB. 9 - VARIATION OF WATER, DRY MATTER, ASH AND CHLOROPHYLL CONTENTS OF POPLAR LEAVES IN CONNECTION WITH CHLOROSIS INTENSITY NURSERY IN BIGARELLO (MN)

Chlorosis Intensity	Dry matter (%f.w.)	Moisture (%d.w.)	Ash (%d.m.)	Chlorophyll a (p.p.m. of fresh weight)	b	Total
0 (no chlorosis)	28.66	248.95	8.44	470	943	1414
1 (slight)	28.21	254.51	8.31	329	703	1035
2 (intense)	25.78	287.94	9.32	185	306	491
3 (serious)	24.51	308.03	10.53	98	173	265
General average	26.68	274.86	9.15	270	531	801
Values at F	13.85++	13.85++	5.50+	30.9++	17.25++	22.44++

\+ significant at 5% level
++ significant at 1% level

TAB. 10 - ASH AND NUTRIENT CONTENTS OF POPLAR LEAVES GROWN IN NURSERIES WITH SYMPTOMS OF IRON CHLOROSIS IN BIGARELLO (MN)

Chlorosis Intensity	Dry matter							Ratio		
	Ash (%)	N_2 (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (p.p.m.)	Ca/P	Ca/K	K/Mg
0 (no chlorosis)	8.44	3.400	0.352	1.600	1.727	0.400	75.0	4.9	1.1	4.0
1 (slight)	8.31	3.323	0.347	1.817	1.527	0.397	44.3	4.4	0.9	4.7
2 (intense)	9.32	3.740	0.447	2.137	1.607	0.467	39.7	3.6	0.8	4.6
3 (serious)	10.53	4.190	0.519	2.777	1.517	0.463	49.3	3.0	0.6	6.1
Values at F	5.50+	3.87n.s.	7.27+	6.40+	1.58n.s.	8.09+	5.1+	18.9++	5.6+	1.8n.s.
Average	9.15	3.663	0.416	2.082	1.594	0.432	52.1	4.0	0.8	4.8

n.s. not significant
\+ significant at 5% level
++ significant at 1% level

TABLE 11 - A FEW CHARACTERISTICS OF SOIL IN POPLAR NURSERIES IN BIGARELLO (MN) WITH SYMPTOMS OF IRON CHLOROSIS

Profile No	Depth (cm)	pH (H_2O)	Carbonate (%) total	Carbonate (%) active	Chlorosis intensity (*)	Depth of water table (cm)
1	0 - 34	8.15	13.3	8.5	1	100
	34 - 100	8.44	58.2			
2	0 - 50	7.60	20.0	9.7	2	>100
	50 - 100	8.30	62.2			
3	0 - 40	7.60	26.4	12.3	2	100
	40 - 100	8.30	60.4			
4	0 - 55	8.05	20.1	9.5	3	100
	55 - 100	8.28	73.8			
5	0 - 35	8.17	26.7	11.8	0	100
	35 - 100	8.35	73.4			
6	0 - 50	8.15	28.1	10.6	0	95
	50 - 100	8.35	58.2			
7	0 - 40	8.17	38.0	16.5	1	>100
	40 - 100	8.35	69.0			
8	0 - 40	8.15	35.0	9.6	0	100
	40 - 100	8.25	58.0			
9	0 - 40	8.07	14.1	7.9	2	>100
	40 - 100	8.25	68.4			
10	0 - 40	8.05	15.3	10.3	2	100
	40 - 100	8.15	60.2			
11	0 - 50	8.15	48.3	17.5	2	> 80
	50 - 80	8.30	65.8			
	80 - 100	8.40	57.0			
12	0 - 40	8.07	29.4	12.6	2	90
	40 - 90	8.15	31.2			
	90 - 110	8.25	55.5			

(*) 0 = no chlorosis; 1 = slight chlorosis; 2 = intense chlorosis; 3 = serious chlorosis

TAB. 12 - NUTRIENT CONTENTS OF POPLAR LEAVES GROWN IN NURSERIES IN BIGARELLO WITH SYMPTOMS OF IRON CHLOROSIS

Parameters (dry matter)		Green leaves	Chlorotic leaves (intensity 2)	Values at F
Water contents	%	178.47	212.50	5.19++
Ash	%	8.57	9.60	22.85++
N_2	%	3.658	3.913	1.27n.s.
P	%	0.235	0.239	0.05n.s.
K	%	1.490	1.694	0.79n.s.
Na	%	0.0125	0.0190	1.34n.s.
Ca	%	1.465	1.866	4.54+
Mg	%	0.277	0.348	1.42n.s.
Fe	p.p.m.	86.25	57.33	19.51++
Mn	p.p.m.	90.75	81.00	0.26n.s.
Cu	p.p.m.	9.84	9.83	0.00n.s.
Zn	p.p.m.	27.12	37.25	7.59++
Ca/P		7.04	8.90	3.74+
Ca/K		1.06	1.11	1.16n.s.
K/Mg		5.94	5.11	3.19n.s.

n.s. not significant
\+ significant at 5% level
++ significant at 1% level

TAB. 13 - CHEMICAL CHARACTERISTICS OF SOIL DRAWN FROM POPLAR PLANTATIONS WITH (SAN GIORGIO) AND WITHOUT (MEDE LOMELLINA) SYMPTOMS OF IRON CHLOROSIS

Characteristics	Poplar plantations with symptoms of iron chlorosis	Poplar plantations without symptoms of iron chlorosis	Values at F
pH	7.54	7.48	0.62n.s.
Total carbonate %	13.70	4.08	15.32++
Active $CaCO_3$ (Drouineau) %	9.02	1.03	52.93++
Total nitrogen (Kjeldahl) %	0.102	0.102	0.00n.s.
Organic carbon (Walkley and Block) %	0.98	1.14	2.74n.s.
Organic matter (C x 1,724) %	1.69	1.97	2.74n.s.
C/N	9.74	12.01	10.26++
Exchangeable K_2O p.p.m.	278	64	48.61++
Available P_2O_5 p.p.m.	98	58	2.61n.s.
Available Fe p.p.m.	18	44	23.59++
Available Mn p.p.m.	1.7	8.0	48.27++
Exchangeable CaO p.p.m.	10467	4273	91.34++
Exchangeable MgO	912	630	5.06+
Available Mo p.p.m.	0.167	0.500	32.97++
Available B p.p.m.	0.250	0.127	11.59++
CaO/Fe	662	123	43.85++
C.P.I.	386	15	28.06++

n.s. not significant
\+ significant at 5% level
++ significant at 1% level

TAB. 14 - NUTRIENT CONTENTS OF LEAVES TAKEN FROM POPLAR PLANTATIONS WITH (SAN GIORGIO) AND WITHOUT (MEDE LOMELLINA) SYMPTOMS OF IRON CHLOROSIS

Parameters (dry matter)		Poplar plantations with symptoms of iron chlorosis	Poplar plantations without symptoms of iron chlorosis	Values at F
Ash	%	16.70	10.88	52.46++
SiO_2	%	3.837	1.839	53.46++
N_2	%	2.203	2.101	0.77n.s.
P	%	0.154	0.215	28.09++
K	%	1.489	1.022	20.70++
Ca	%	4.474	2.619	43.66++
Mg	%	0.496	0.574	4.35+
Fe	p.p.m.	216	228	0.45n.s.
Mn	p.p.m.	152	149	0.02n.s.
B	p.p.m.	60	25	13.93++
Ca/P		30.3	12.4	47.50++
Ca/K		3.2	2.8	0.99n.s.
K/Mg		3.2	1.8	15.9++

n.s. not significant
\+ significant at 5% level
++ significant at 1% level

TAB. 15 - NUTRIENT CONTENTS IN BRANCHES TAKEN FROM POPLAR PLANTATIONS WITH (SAN GIORGIO) AND WITHOUT (MEDE LOMELLINA) SYMPTOMS OF IRON CHLOROSIS

Parameters (dry matter)		Poplar plantations with symptoms of iron chlorosis	Poplar plantations without symptoms of iron chlorosis	Values at F
Ash	%	5.94	5.40	1.26n.s.
SiO_2	%	0.044	0.028	6.08+
N_2	%	0.962	1.009	0.71n.s.
P	%	0.122	0.149	7.87++
K	%	0.630	0.572	1.92n.s.
Ca	%	1.981	1.452	10.83++
Mg	%	0.187	0.211	2.46n.s.
Fe	p.p.m.	45	72	30.27++
Mn	p.p.m.	23	30	6.66+
B	p.p.m.	16.1	23.5	12.34++
Ca/P		16.68	10.15	16.59++
Ca/K		3.28	2.58	4.75+
K/Mg		3.44	2.79	7.67++

n.s. not significant
\+ significant at 5% level
++ significant at 1% level

TAB. 16 - CALENDAR OF TREATMENTS AND QUANTITIES OF SEQUESTRENE 138 Fe (EDDHA) DISTRIBUTED per ha IN POPLAR NURSERIES WITH IRON CHLOROSIS SYMPTOMS BY TRICKLE IRRIGATION

Sarmato (PC)		Migliaro (FE)		Bigarello (MN)	
Date of administration	Quantity (Kg)	Date of administration	Quantity (Kg)	Date of administration	Quantity (Kg)
3.7.82	4*	4.8.82	5	26.7.82	5
6.7.82	4	6.8.82	5	28.7.82	5
7.7.82	7	9.8.82	5	30.7.82	5
8.7.82	7	11.8.82	5	2.8.82	5
9.7.82**	7	13.8.82	5	4.8.82	5
14.7.82	1	16.8.82**	1	11.8.82**	1
16.7.82	1	18.8.82	1	19.8.82	1
19.7.82	1	20.8.82	1		
27.7.82	1	23.8.82	1		
		25.8.82	1		
Total	33	Total	30	Total	27

*The concentration of Sequestrene 138 Fe solution that come out of emitters was about 100 p.p.m. in the first five treatments and about 20 p.p.m. in the following onces.

**On dates marked by asterisks, the leaves had already turned green in all the nurseries. In Sarmato it was quite impressive.

TAB. 17 - CALENDAR OF TREATMENTS AND THE QUANTITIES OF SEQUESTRENE 138 Fe (EDDHA) DISTRIBUTED TO 8-YEAR OLD POPLAR PLANTS OF CLONE 'BL COSTANZO' (MELI ZONE) AND CLONE 'I-214' (FORNELLO ZONE) WITH SERIOUS IRON CHLOROSIS SYMPTOMS IN SAN GIORGIO MONFERRATO (AL)

Date of administration	Quantity of Sequestrene (Kg)	Quantity of water (hl)	Treated plants (No)	Treated zone
	Meli zone - Clone 'BL Costanzo'			
16.7.82	2	15	10	r m 2*
19.7.82	1	15	10	"
9.8.82	1	15	10	"
13.8.82	1	15	10	"
	Fornello zone - Clone 'I-214'			
19.7.82	1	15	5	r m 2
9.8.82	1	15	5	"

On July 27 the leaves had already started to turn green in both zones and this was impressively obvious on August 17 on plants of clone 'BL Costanzo'

*r m 2 = radius of 2 m around the trees.