CERCOSPORA LEAF SPOT: INTEGRATED CONTROL IN NORTHERN ITALY

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ABSTRACT

Cercospora leaf spot (CLS) is the major disease of sugar beet in northern Italy; it seriously affects about 160,000 hectars. Losses due to the fungus are generally very severe even if they change with the environmental conditions, the cultural practices and the harvest period. To control the disease and minimize the losses for both growers and industries, strategies based on an integrated use of resistant sugar beet varieties and fungicide sprays were developed in the last ten years.

The aim of integrated control is to increase both sugar yield and quality of beets, to reduce the number of treatments and to decrease the risk of resistance of the fungal strains to the active ingredients. The sugar beet varieties performing high yields in Italy show a weak or medium level of resistance to CLS; this resistance level guarantees a sufficient disease control for the first harvesting period, while it must be integrated with a suitable scheduling of fungicide sprays in the late period of harvesting.

Some protection guidelines based on the start of treatments, number of sprays and the alternate use of active ingredients were developed. Two main types of integrated strategies are actually in use, developed by the National Technical Committee (grower's associations and factories), and by the Emilia-Romagna Region, the latter targeted to the farms following rules for reducing the environmental impact of defence practices.

ABRÉGÉ - CERCOSPORIOSE : LUTTE INTEGREE DANS L'ITALIE DU NORD

La Cercosporiose est la principale maladie foliaire de la Betterave sucrière en Italie du Nord, et affecte gravement environ 160 000 hectares cultivés. Les pertes dues au champignon sont généralement très importantes, même si d'autres facteurs interagissent, comme l'année, les conditions de milieu, la date de récolte et les techniques culturales. Au cours de la dernière décade, afin de contrôler la maladie et réduire les pertes au minimum, aussi bien pour les planteurs que pour les sucreries, des stratégies de protection ont été mises au point, basées sur l'utilisation de variétés résistantes et l'emploi de fongicides.

Le but de la protection intégrée est d'augmenter autant les rendements en sucre brut que la qualité des betteraves, de réduire le nombre de traitements, et de faire baisser le risque d'apparition de souches résistantes aux matières actives. Actuellement les variétés les plus performantes en Italie sont celles qui montrent un niveau moyen à faible résistance à la Cercosporiose, ce qui est plus que suffisant pour la première période de récolte. En période tardive d'arrachage, au contraire, les betteraves nécessitent une protection plus attentive en termes de nombre de traitements. D'un point de vue pratique, plusieurs programmes d'intervention ont été établis, basés sur la date du premier traitement, l'alternance des matières actives, et le nombre total de traitements.

Actuellement, les planteurs suivent deux principaux types de stratégies intégrées: a) un programme de protection conseillé par la Commission Technique Nationale, et b) un modèle prévisionnel proposé par les Services de la Région Emilie-Romagne pour les exploitations agricoles qui suivent des normes techniques plus compatibles avec l'environnement.

KURZFASSUNG - CERCOSPORA: INTEGRIERTE KONTROLLE IN NORDITALIEN

Die Cercospora (CLS), ist die häufigste Krankheitsursache von Zuckerrüben in Italien. Sie befällt jährlich rund 160.000 ha. Die Verluste durch diesen Pilzbefall sind meist sehr gravierend, auch wenn sie je nach Jahr, Umweltbedingungen, der Erntezeit und den Anbauverfahren unterschiedlich ausfallen. Zur Kontrolle dieser Krankheit und Reduzierung der Verluste für den Landwirt und die Industrie wurden in den letzten zehn Jahren Anbaustrategien entwickelt, die auf dem integrierten Einsatz von resistenten Zuckerrübensorten und Pilzbekämpfungssprays basieren.

Das Ziel einer integrierten Kontrolle ist die Erhöhung des Zuckeraustrags und der Qualität der Zuckerrüben, um die Zahl der Schädlingsbekämpfungen einzuschränken und das Risiko zu reduzieren, dass die Schädlinge resistent gegen die aktiven Wirkstoffe werden. Die ertragreichen Zuckerrübensorten in Italien haben eine schwache bis mittlere Resistenz gegen den Befall von CLS; dieses Resistenzniveau garantiert eine ausreichende Kontrolle des Befalls für die erste Ernte, sie müssen aber dann mit einer entsprechend zeitlich geplanten Behandlung mit Pilzbekämpfungssprays in der späten Erntephase behandelt werden.

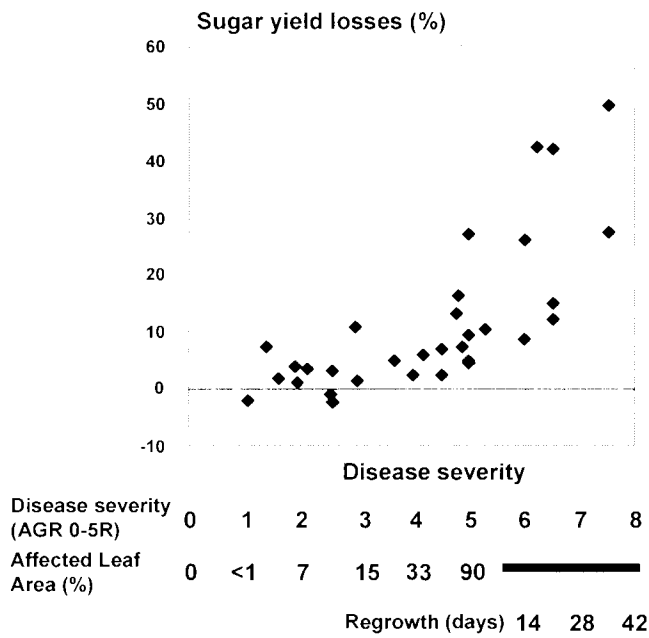
Basierend auf dem Beginn der Behandlung, der Anzahl der Sprays und dem abwechselnden Einsatz von aktiven Wirkstoffen wurden zahlreiche Schutzrichtlinien entwickelt. Zur Zeit sind zwei Arten von integrierten Strategien im Einsatz: a) ein CLS Management, das vom Nationalen Technischen Komitee entwickelt wurde und b) eine Strategie zum Management der Krankheit, die auf CLS Prognosen basieren, vorgeschlagen von der Region Emilia Romagna für landwirtschaftliche Betriebe mit einem Anwendungsprotokoll für integrierte Produktionen, die auf die Reduzierung der Umweltbelastung durch Schädlingsbekämpfungsmaßnahmen zielt.

RELEVANCE OF CERCOSPORA LEAF SPOT IN ITALY

Cercospora leaf spot (CLS) in sugar beet (*Beta vulgaris* L.), caused by *Cercospora beticola* Sacc., has a wide geographical distribution and may causes crop losses changing from very severe to absent (Bleiholder and Weltzien, 1972).

Losses in sugar yield have been reported as very severe in many beet-growing areas of Europe (Byford, 1996). In northern Italy, the influence of CLS epidemics on plant growth and yield is manifold (Rossi et al. 2000). In a first phase, the pathogen develops on the primary leaf apparatus causing the progressive increase of the necrotic leaf spots and the drying of the leaf blades; in a latter phase, when beets are severely damaged, plants react to the leaf loss by producing new leaves. In this phase, the flux of dry matter from leaves to roots reverses, and the sugar content of roots decreases. As consequence, when CLS affects the primary leaf apparatus only, yield losses are usually lower than those occurring when the plants are regrowing (fig.1).

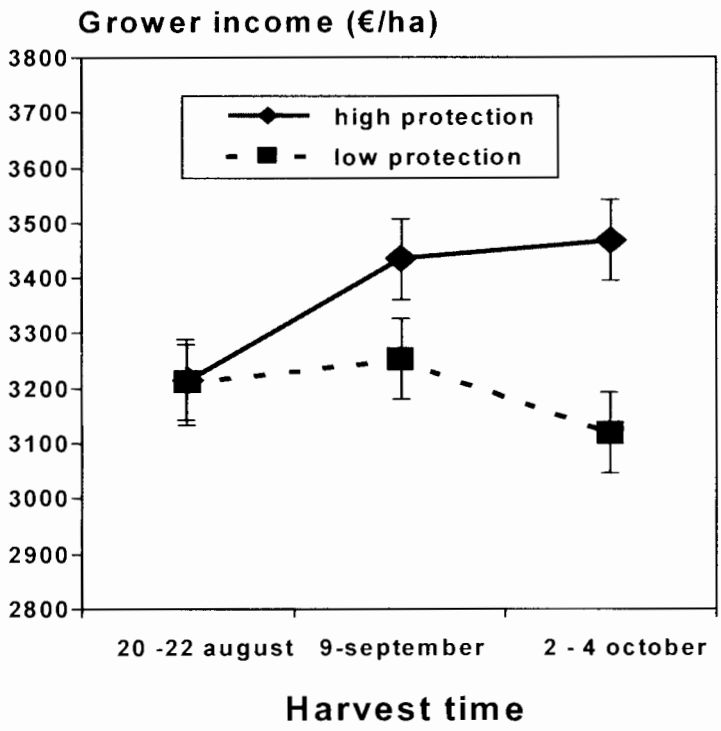
Fig. 1 – Relationship between losses in gross sugar yield (expressed as the % difference between plots treated with fungicides and untreated) and Cercospora leaf spot severity at harvest on utreated plots (disease rating according to Agronomica Scale – AGR, Affected Leaf Area % - ALA and time of leaf regrowth) (from Rossi et al., 2000).



Regrowth is then the main cause of yield losses in sugar beets affected by CLS; other factors, like climatic stresses (drougth stress especially when followed by heavy rainfall, hail, etc.), nutritional disorders (excess of nitrogen supply), genetic characters (beet genotypes react differently) and other foliar disease, can act together with CLS in inciting beet regrowth in late season. In fact, in northern Italy, heavy losses usually occur in the late harvest periods, after the

middle of September, when a change in climatic conditions (from dry and hot to rainy and temperate climate) touches beet plants with a severe leaf destruction caused by CLS. In these conditions, an efficient protection of the sugar beet canopy by fungicides is economically important, as shown in fig. 2 where the Grower's income obtained by a complete spray program, based on 3 or 4 tratements, is compared to a protection program based on 1 or 2 sprays.

Fig. 2 – Interaction between harvest time and fungicide spray programs against Cercospora leaf spot on the net Grower's income. Average of 3 experiments carried out at 3 locations of northern Italy in 2002. High protection was based on 3 or 4 sprays, while low protection on 1 or 2 sprays. Vertical bars show the 95% confidence interval for means.



RESEARCHES DEVELOPED IN THE LAST YEARS

Unfortunately, the control of CLS in Italy does not achieve optimal results and severe yield losses frequently occur in practice, especially in the late harvests (after the middle of september). For this reason, many research activities were carried out in the last years to obtain knowledge aimed at improving the control strategies.

The main research topics are:

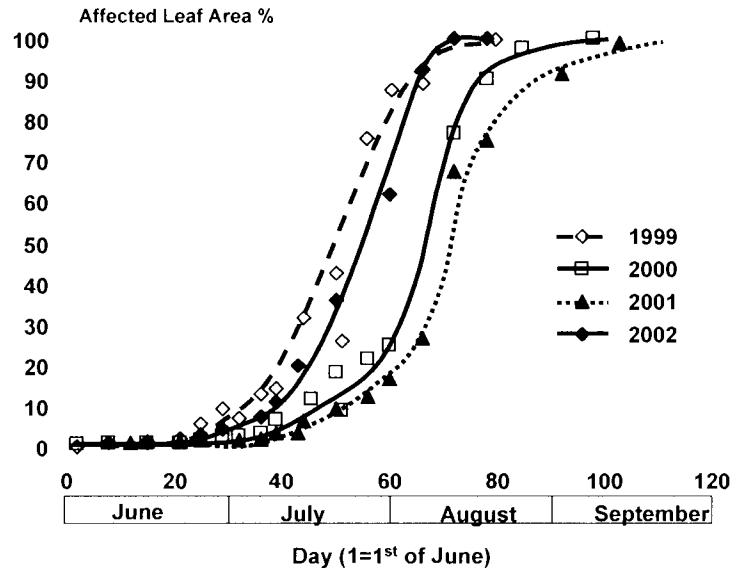
1. epidemiology, forecasting models and risk maps,
2. genetic resistance of sugar beet varieties,

3. efficay of fungicides,
4. scheduling and control strategies.

1. - EPIDEMIOLOGY, FORECASTING MODELS AND RISK MAPS

Biology and epidemiology of CLS were studied at different levels, both in environment-controlled experiments and in the field conditions, to understand the effect of meteorological conditions, host susceptibility and cultural practices on disease onset and development. Many experiments were carried out to determine the dynamics of disease appearance and progress under different epidemiological conditions (fig. 3); for this purpose specific protocols for disease assessment were elaborated and applied.

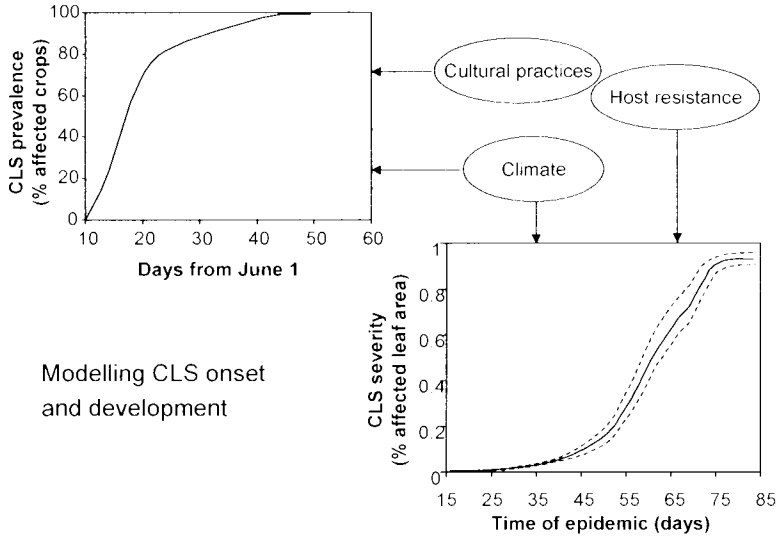
Fig. 3 – CLS epidemics on untreated susceptible variety (Gabriela) in four years (1999 to 2002) in northern Italy, as an average of three locations (same locations each year).



Some of these studies were aimed at developing simulation and forecasting models to be used in CLS warming (fig. 4). A first model, named CERCOPRI (acronym of Cercospora primary infections) determines the prevalence of affected sugar beet crops as influenced by air temperature and relative humidity (Rossi et al., 1991). Based on these meteorological data, the model provides a daily proportion of affected crops, which can be corrected on the basis of an estimate of the overwintering inoculum, that depends on crop rotation, on sugar beet prevalence in the cropping area and on the severity of CLS in the previous year. This model is actually in use in different sugar beet growing areas in Italy and in Germany (Bugiani et al., 2002; Racca et al., 2000), to advise growers or technicians about the need of disease scouting in the field. A second model, CERCODEP (acronym of Cercospora development of epidemics), simulates daily the disease progress in field as % of affected leaf area, based on

meteorological conditions and host susceptibility (Rossi et al., 1994). This models produces accurate and robust simulations, that can be used to advise growers about the need of fungicide applications (Bugiani et al., 2002). For this purpose, the model uses two levels of disease severity as thresholds. A first threshold is based on the weekly progress of disease severity: when the affected leaf area increases by 2% in a week, it can be assumed that the epidemic goes to the exponential phase of increase. A second threshold is an economic threshold: it was demonstrated that there is no economic fungicide application when disease severity is lower than 10% of affected leaf area. The model uses a threshold equal to 4% of disease severity, because at this moment about 6% of leaf area is affected by latent infections that will be visible within 10-12 days. CERCODEP is able to determine these thresholds 10-15 days in advance: warnings are produced when there is a prognosis for either thresholds.

Fig. 4 – Two models were developed in Italy to simulate time of disease appearance and disease progress over time, which use meteorological data , information on cropping practices and on host resistance to simulate daily disease prevalence over time and dynamic of disease severity, respectively.



In the last 8 years, Agronomica and the main Industries of the Po valley developed a survey network to observe the first disease stage on an untreated susceptible variety. The aim of this network was to produce advises for growers of each sugar beet growing area about the time for beginning fungicide applications. In this activity,

the susceptible variety 'Gabriela' was sown at many locations in northern Italy (36 to 75 location per year), with a homogeneous geographic distribution, to scout the disease two times per week, from early June to mid July by using the Agronomica scale.

The first CLS symptoms usually appeared between the end of the first decade of June and the first days of July, with low differences between years (fig. 5); on

the contrary, the distribution of data (showed as boxes, whiskers and outliers) demonstrated that there was a wide variability within each year, due to the different meteorological conditions of each area. The outliers in 1999, 2000 and 2002 represented the average of the locations in the district of Alessandria (AL), where there was a delay in the CLS onset. The effect of the sugar beet area was shown in fig. 6, where the distribution of disease appearance in 8 representative districts during a 8-year period was compared. Differences between areas were high, but variations within areas were high too, like in the districts of Ravenna, Bologna and Piacenza. This survey demonstrated that variability in disease appearance is higher between locations each year than between years, but the district is to wide for defining homogeneous areas. For this reason, to produce a more precise information, a map of disease onset was drawn by splitting some districts into smaller homogeneous areas (fig. 7).

Fig. 5 - Distribution of appearance of the first CLS symptoms between 1999 and 2002; box plots represent variability between locations within each year.

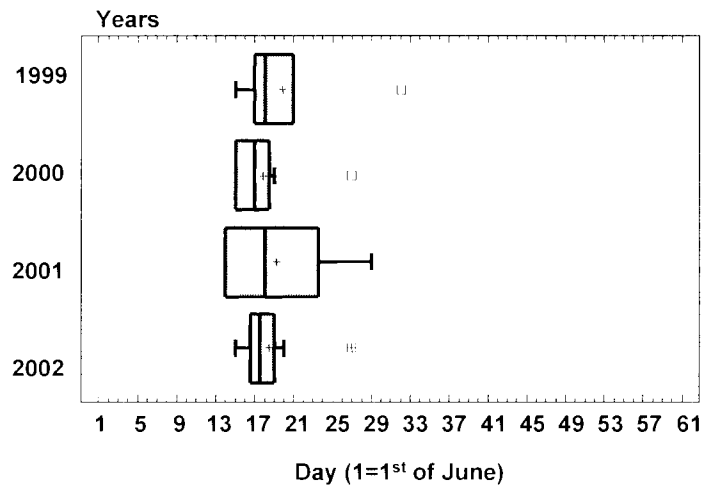
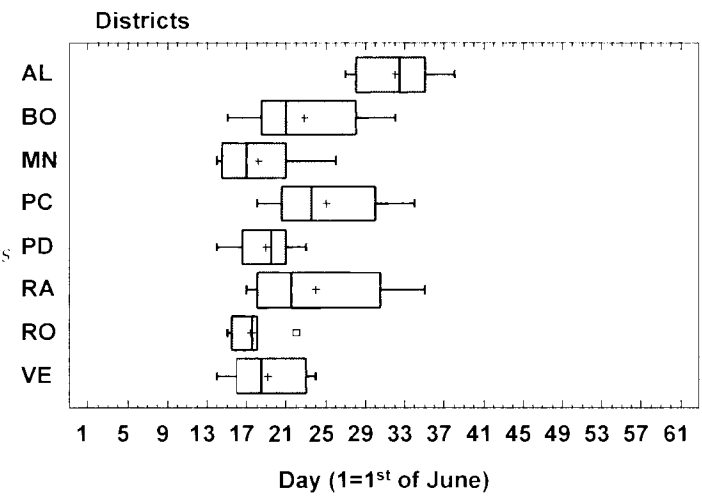
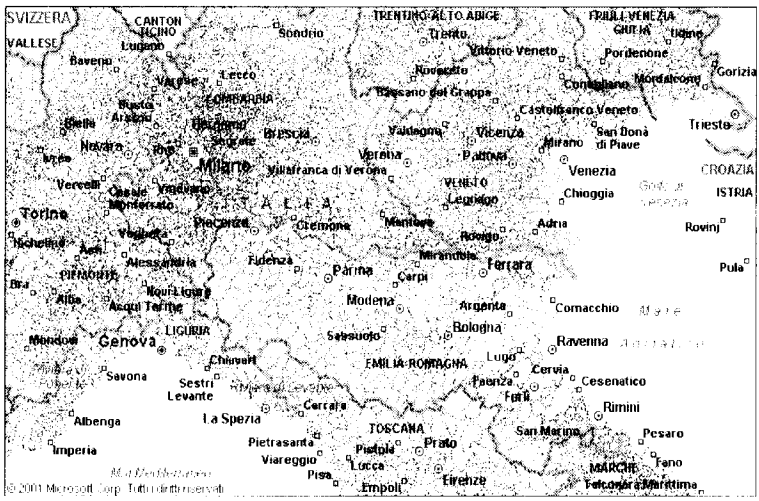


Fig. 6 - Distribution of appearance of the first CLS symptoms in 8 different districts of North Italy (Alessandria=AL, Piacenza=PC, Bologna=BO, Mantova=MN, Rovigo=RO, Venezia=VE, Padova=PD and Ravenna=RA); box plots represent variability between years (8 years) within each districts.



Between 1995 and 2001, the growers of a homogeneous area received advises about the first fungicide spray from the factories, based on the survey data. In 2002, recommendations were produced by the National Technical Committee (CTN) based on the map of fig. 7, for both susceptible and resistant varieties. Warnings for the resistant varieties are delayed of about one week compared to the susceptible ones (Meriggi et al., 2002).

Fig. 7 – Map of CLS in northern Italy, drawn according the surveys carried out between 1995 and 2000.

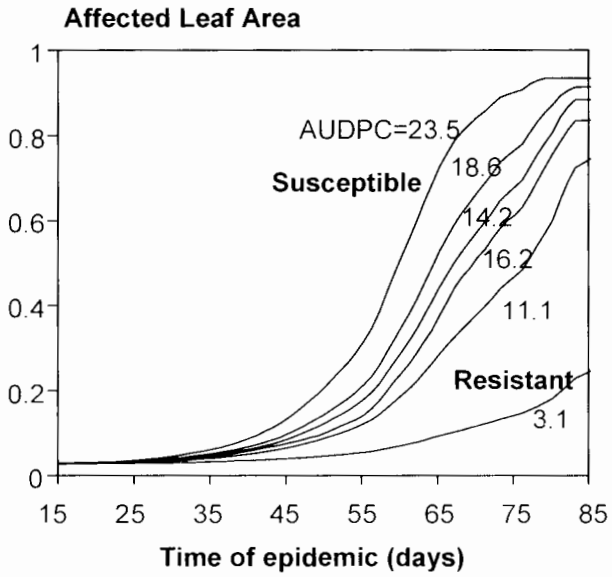


2. - GENETIC RESISTANCE

Resistance to *C. beticola* in sugar beet is a rate-reducing resistance: under natural conditions, disease progresses slower on resistant varieties compared to the susceptible ones, so that at any time disease severity is lower (fig. 8) (Rossi et al., 1990). This kind of resistance is due to the combination of different resistance components which act together in lengthening and reducing the infection process (Rossi, 2000).

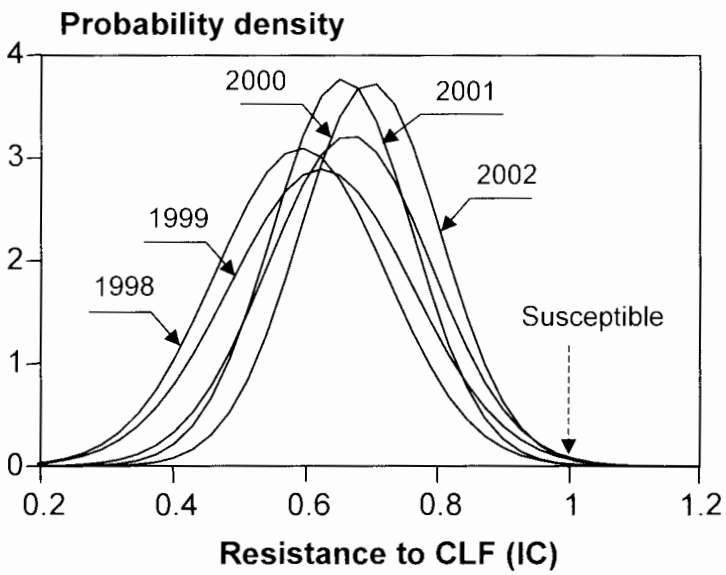
Sugar beet varieties resistant to CLS are a very important component in the integrated control measures. For this reason, field experiments aimed at determining the resistance level of commercial sugar beet varieties are carried out each year in different epidemiological conditions, with no fungicide sprays. Assessments of CLS severity are carried out on different times during the growing season on each variety at each location. Assessments are used to draw the disease progress over time by a logistic regression analysis; afterwards, the average rate of disease increase of each variety is calculated as a proportion of the rate of a susceptible variety. This resistance index (named IC, index of CLS resistance) is then a number equal to 1 for the susceptible varieties, while it assumes values lower than 1 for the resistant ones: an IC equal to 0.5 means that the daily increase of disease severity over the time during the growing season is one half of that of the susceptible variety.

Fig. 8 – Dynamic of CLS progress on susceptible and resistant varieties. AUDPC is the area under disease progress curve, that summarises differences between varieties.



The above mentioned activity produces, each year, a list of resistant varieties. A comparison between the resistance level of the commercial varieties in the years between 1998 and 2002 shows that there is a shift towards a lower level of resistance. This shift should be reversed, because the use of genetic resistance is a key factor for integrated disease management.

Fig. 9 – Shift in the resistance level of the commercial sugar beet varieties between 1998 and 2002. Curves represent distribution of the varieties according to their resistance level (1 represents susceptibility; resistance increases with the lowering of the number on the x-axis).



3. - FUNGICIDE EFFICACY

The fungicides registered in Italy during the last 43 years are reported in tab. 1. The availability of site specific inhibitors of fungal metabolism is actually very wide, and the DMIs i family has the larger number of active ingredients. On the other side, the number of fungicides belonging to the multi-site inhibitors should be reduced in the next future, because tin compounds will be impeded and the copper compounds have a poor efficacy.

Researches carried out in northern Italy in the last years demonstrated the presence of *C. beticola* strains with a reduced susceptibility to triazoles; as a consequence, defence strategies based on the alternance of fungicides showing different fungi-toxic mechanisms were proposed to the growers. The official recommendations of the CTN about the fungicides divide the fungicides into categories characterized by a different mechanism of action.

The results of some experiments carried out in 2002 show that this is a very efficient strategy, because the protection level of leaves and the grower's income are higher using the anti-resistance strategies than the traditional ones (fig. 10). This effect is more evident in the location with a severe pressure of CLS.

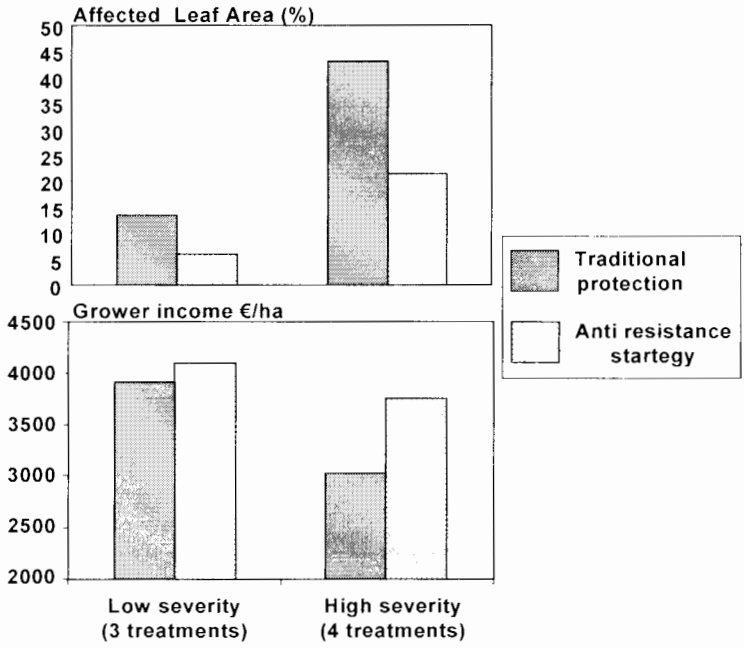
Tab. 1 – Fungicides available in Italy for the control of CLS during the last 43 years.

			Periods								
	Fungicides Group	Active ingredients	1960/65	1966/70	1971/75	1976/80	1981/85	1986/90	1991/95	1996/00	2001/03
Multi-site inhibitors	Copper and tin compounds. Nitriles	TPTA (1)									
		copper hydroxide									
		TPTH (1)									
		copper oxychloride									
		clorotalonil									
Site specific inhibitors	Benzimidazoles. DMIs Morpholines. Strobilurines	benomyl									
		thiophanate methyl									
		bitertanol. propiconazole									
		prochloraz. nuarimol									
		flutriafol. cyproconazole. flusilazole									
		tetraconazole. difenoconazole. bromuconazole. fenpropidin									
		azoxystrobin. trifloxystrobin									

(1) TPTA and TPTH will be forbidden in the next years

= on the market

Fig. 10 – Effect of different spray programs (traditional protection vs anti-resistance based on alternating mode of action of fungicides) on CLS severity and on grower's income. Data from 2 experiments carried out in northern Italy at 2 locations with different disease pressure.



4. - DISEASE MANAGEMENT STRATEGIES FOR CONVENTIONAL, LOW INPUT AND ORGANIC BEET CROPS

Italian sugar beet crops are divided into three types of technical husbandry: conventional, low input and organic. The conventional farms cover about the 85 % of the Italian production, and the low input farms the remaining 15 %. Organic production involves a very few surface.

The guidelines adopted to control CLS in these three kinds of sugar beet cropping are listed in tab.1.

Guidelines for conventional and low input farms are quite similar. In both cases the use of resistant varieties is very important: these varieties are recommended for conventional farms, but the susceptible ones are admitted; on the contrary, only resistant varieties must be sown in the low input guidelines. As previously mentioned, a list of resistant varieties is published by the CTN each year, together with information about their agronomic value.

Tab. 1 – Guidelines adopted in Italy for controlling CLS in conventional, low input and organic farms.

Control measures	Conventional	Low input	Organic
Resistant varieties	Resistant varieties recommended.	Restriction to resistant varieties.	No restriction.
Crop rotation	Restriction minimum 4 years.	Restriction minimum 4 years.	
Beginning of fungicide sprays	According to risk maps and level of resistance of variety.	According to disease thresholds and forecasting models.	
Number of sprays	1 to 4 according to the harvest time.	0 to 3 according to the harvest time.	
Fungicides	List of recommended fungicides. Anti-resistance strategies recommended.	Restrictions for toxicity of fungicides. Anti-resistance strategies recommended.	Only copper compounds allowed.

Another difference between the two guidelines concerns the beginning of fungicide sprays. For the conventional farms, the first spray is regulated by the calendar, based on the map of fig 7. In practice, there is an association between the risk area and the date of fungicide applications. For instance, in area n. 1 the start of protection program is from 18th to 25th of June; in this interval susceptible or less resistant varieties should be treated. This approach is based on a consolidated rule, that the first treatment must be carried out rapidly, as soon as the first CLS symptoms appears, because any delay has repercussions on sugar yield, especially for the crops harvested after the middle of September. For the low input farms, the first fungicide spray is applied based on the epidemiological conditions of each sugar beet area and year, which influence the epidemic development of the disease. Fungicides are applied when the disease reaches a threshold level, that can be assessed in field or estimated by the previously described simulation models. Warning systems operate at a regional level, producing advises to growers concerning the need of first fungicide spray.

In both guidelines, the fungicides scheduling after the first spray continues at regular intervals of about 18-21 days, but there are differences in the maximum number of applications. The active ingredients are quite similar: in the guidelines for low input farms, the most toxic active ingredients have restrictions or are forbidden. In the organic farms the only admitted fungicides are the copper compounds.

FUTURES PERSPECTIVES

- Research has developed effective guidelines based on the principles of Integrated Pest Management. This approach features most efficient use of chemicals associated with lower costs, better control of the disease and, in perspective, better environmental respect.
- Actually, only a part of the sugar beet crops are properly protected by the growers, especially in the late growing season. For this reason, it will be necessary to obtain a better spread of information by promoting technical assistance.

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