YELLOW LEAF SYNDROME AND ALLEGED PATHOGENS: A CASUAL BUT NOT A CAUSAL RELATIONSHIP

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ABSTRACT

Yellow leaf syndrome (YLS) has recently caused considerable concern in Hawaii, Brazil and a number of other countries. Scientists worldwide have devoted considerable efforts to establishing its etiology. The inconsistency of the proposal that YLS is of viral origin and also that a single biological agent is the causal agent is discussed. Based on an analysis of published reports and observations in the field, it is held that the putative pathogens are endophytic and also that the condition is a manifestation of the senescence of certain varieties in specific environments, a problem reported in the past as "autumn decline" or "yellow wilt". In Brazil, what may have led to the confusion between cause and effect was the simultaneous occurrence of symptoms on a variety that was sensitive to environmental stress, mainly low soil fertility and soil compaction, which in turn were intensified by improper management. The complex biotic and abiotic factors that operate over the long cycle of the sugarcane plant affect each variety differently, but are often not properly managed.

Keywords: Sugarcane, yellow leaf syndrome, etiology.

INTRODUCTION

An alleged new disease of sugarcane that is said to cause losses as high as 40-60% in Brazil (Comstock et al, 1994; Lockhart et al, 1996) has aroused worldwide concern among sugarcane technologists and planters. The problem has most commonly been termed yellow leaf syndrome (YLS) (Schenck & Hu, 1991; Ulian & Sanguino, 1994). In Brazil, it is also popularly known as light yellowing (amarelinho) (Vega, 1994).

There has been dispute concerning the biotic or abiotic causal agent(s) of YLS. The arguments and studies claiming that a specific pathogen is involved have prevailed (Irey et al, 1996). The objective of this paper is to present a holistic argument concerning the cause of YLS.

THE BEGINNING OF THE PROBLEM

Following an increase in the planting to variety SP71-6163 in the state of São Paulo, Brazil, from 1988, attention was called to a general yellowing of mature plants of that variety in most fields (Ulian & Sanguino, 1994). Initial observations indicated that reductions in growth were associated with a restriction in root development (Ulian & Sanguino, 1994; Vega, 1994), mainly in compacted soils (Sanguino & Casagrande, 1998). However, most workers later adopted the idea that a pathogen was involved. Reports by Schenck & Hu (1991) that a virus might be the causal agent of a similar anomaly in Hawaii had appeal and research on a viral hypothesis then predominated (Irey et al., 1996; Lockhart et al, 1996; Vega, 1994). Observations on the pattern and mode of occurrence of the anomaly in the field were neglected. As a result, in Brazil and elsewhere, concern about a new disease epidemic of serious proportions grew.

This concern was then echoed in other sugarcane growing countries where a similar condition was recognized,
including Australia (BSES, 1994), mainland USA (Comstock et al, 1994; Irey et al, 1997), other countries of Central and South America (Fors, 1994), Africa (Bailey et al, 1996; Zvoutete, 1997) and Mauritius (Saumtally & Moutia, 1997).

SYMPTOMS

Symptoms of YLS have been described in several recent papers (Comstock et al, 1994). The symptoms conform well with descriptions of an anomaly in Africa called yellow wilt (Ricaud, 1968; Siddiqi, 1969; Rogers, 1970), as recognized by Bailey, R.A. (pers. comm. 1996), Comstock et al (1994), and Zvoutete (1997).

The symptoms appear in maturing plants, generally starting as a yellowing of the leaf midribs and most easily seen on the abaxial surface. Sometimes there is a pink or red color of the midribs on the adaxial surface. Thereafter a symmetrical discoloration of the leaf lamina parallel to the midrib is usually evident and, as the season progresses, the entire lamina and most leaves of the canopy can turn yellow. When most severe, plants show a stunting of the upper internodes, the canopy assumes a fan-like appearance and plants may collapse. These terminal symptoms have never been observed in variety SP71-6163, but have occurred in other varieties in the germplasm collection in dry winters (unpublished data).

Symptoms usually first appear with the onset of autumn and become more conspicuous thereafter (Bailey et al, 1996; 1997). Symptoms may occur in plant or ratoon and usually the more advanced the ratoon, the more severe the symptoms. Initially, symptoms may be more easily noticed at the edges of fields but later, all plants in entire fields may be affected. Varieties that normally do not show symptoms may do so in cane of advanced age, at the end of the harvest season, or when they either flower or are subjected to severe stress.

Plants can recover and resume normal growth with the onset of good growing conditions (Bailey et al, 1997). The ratoon re-growth of previously affected plants is normal in the following spring and summer until the cane again approaches maturity. Then, with the onset of autumn, the symptoms reoccur.

AUTUMN DECLINE

Since the start of the debate about the cause of YLS, the author has considered the condition to be the same as that described by Hughes (1964) as "autumn collapse" and also that termed "yellow wilt", which occurred in Africa in the 1960s and 1970s (Ricaud, 1968; Rogers, 1970; Siddiqi, 1969), because the symptoms are so similar. Wismer (unpublished), applied the term "autumn decline" to mild forms of autumn collapse in Brazil in the 1970s. Identical symptoms have been recognized ever since then in sugarcane breeding plots, even at the seedling stage, in germplasm collections and in quarantined plants in Brazil.

CAUSAL OR CASUAL RELATIONSHIP

In the case of autumn decline, stressed plants have a tendency to become yellow earlier than plants with normal growth. Leaf yellowing is not necessarily the expression of a causative agent. Rather, it may be a consequence of senescence. Similar symptoms can be induced either by stalk borers or by simply breaking a leaf (Comstock et al, 1994; Matsuoka, S., unpublished data). Also, in many varieties the symptoms are associated with flower initiation (Comstock et al, 1994), which is a further indication of an association with physiological maturity possibly governed by photoperiodism.

Plants with symptoms of YLS accumulate sugar and starch in the leaves (Sanguino & Casagrande, 1998). This could be an effect of a disorder in the normal source-to-sink system. It could have either a pathological cause, such as infection by a virus or other pathogen (El-Kholi et al, 1997), or be due to abiotic factors, such as

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383
restricted root growth or other injury (Thomas & Strain, 1990). The accumulation of metabolites in the leaves inhibits further photosynthesis, and this could also lead to senescence and reduced growth (Goldschmidt & Huber, 1992).

Leaf senescence is governed by many factors, including day length, temperature, water availability, nutrition and infection by pathogens. Senescence in many plants is a survival strategy to cope with stress. So, the reversibility of senescence becomes an important characteristic (Thomas & Stoddart, 1980). This may be related to what happens in the case of YLS - a number of reports describe recovery from mild YLS symptoms with the onset of good growing conditions (Bailey et al, 1997).

The variable distribution of YLS symptoms in the field and associated poorer growth may simply be due to variation in factors such as soil physical properties, nutrition or herbicide application. The yellowing of these stressed plants might mistakenly be assumed to be the result of infection by a pathogen when the primary cause remains undetermined.

None of the above is to say that autumn decline does not depresses yield in highly sensitive varieties, especially if the plants are left standing in the field.

THE VIRUS ASSOCIATION

Supporters of the virus hypothesis have succeeded in detecting a virus with modern, sensitive techniques. But, a clear, consistent association between the occurrence of virus and YLS symptoms has not yet been reported (Irey et al., 1997). Proof of symptom reproduction by aphid transmission (Scagliusi & Lockhart, 1997) has yet to be critically investigated.

The existence of a virus is not contested. Plants carry many types of microorganisms, either parasitic, symbiotic, or neutral. In sugarcane, endophytic phytoplasmas and bacteria could occur (Döbereiner, 1992; Valdebenito & Tokeshi, 1981) An endophytic virus could therefore exist without causing harm, like other reported latent viruses (Comstock & Lockhart, 1990).

The pattern of YLS plants occurring in the field often does not appear to conform with a circulative aphid-transmitted viral disease. Assuming that the virus is brought into the cane field by infective migrant aphids, primary infected plants should occur in a clustered pattern (Plumb, 1983). Later, other plants should be secondarily infected by colonizing aphids, forming characteristic patches of infected plants. Lines of affected plants should not occur. Also, high populations of aphids would be necessary for the rapid, widespread appearance of yellowed plants to occur. However, intensive colonization of sugarcane by aphids is a rare event, and there is no record of SP71-6163 being heavily colonized in Brazil.

The same pattern of symptomatic plants in subsequent ratoons is another incongruity, likewise the apparent recovery of all plants from a supposed virus infection after harvest of the previous crop.

All the above considerations regarding the hypothesis of a virus as the causal agent of YLS can also be applied to the phytoplasma consistently found in association with YLS in South Africa (Bailey et al., 1996; Cronjé et al., 1997). Phytoplasmas are transmitted only by plant and leafhoppers. The pattern of symptomatic plants in the field does not appear to match that usually associated with those vectors.

STRESS AND THE ROOT SYSTEM

Every plant is subjected to stresses. Although sugarcane varieties are selected for specific environments, adaptation is never complete, and soil and crop management is never optimal. The plant’s environment is complex, in which climatic, edaphic and biological factors interact and are also affected by crop management practices. In sugarcane, a semi-perennial crop, ratooning is another stress factor.
It is well known that sugarcane varieties differ in their capacity to sustain production in successive ratoon crops. An important factor affecting this is soil compaction caused by in-field traffic. In addition to traffic during land preparation, planting and cultural operations, serious damage is often caused by vehicles during harvesting.

Some sugarcane genotypes, including SP71-6163, produce well in plant crops but yields steadily decrease with ratooning. This can be due to the sensitivity of the stubble and roots to damage and soil compaction per se or to the physical, chemical and microbiological changes that can result from compaction. SP71-6163 was widely planted on red latosols, which are very prone to compaction. It also has a less vigorous root system than other current varieties (Silva & Brinholi, 1993) and it suffers more from adverse conditions, especially soil compaction and moisture stress (Silva & Strini Jr., 1994).

Damage by prolonged use of the herbicide tebuthiuron, which has a long residual activity, is another possible factor. It has been reported that the phytotoxicity of trifuralin is greater in compacted soils (Martin et al, 1985). In addition, it is known that SP71-6163 is sensitive to herbicides (Fernandes, 1991).

An excess of water in the soil can elicit the symptoms of autumn decline. This was also reported for yellow wilt in Africa in the 1960s (Ricaud, 1968; Rogers, 1970; Siddiqi, 1969). This happens because, as with soil compaction, an excess of water causes anaerobiosis, which impairs root growth and function (Drew & Lynch, 1980).

**SOIL PATHOGENS**

A number of soil-inhabiting fungi can damage sugarcane roots and cause yield decline, and many await identification (Magarey, 1994). In Brazil, the fungus *Hendersonina sacchari* Butler has consistently been isolated from the roots of sugarcane plants with poor growth, including SP71-6163. This fungus has been described in the past as a sugarcane pathogen in certain countries but of minor importance (Abbott, 1964). We have shown that it can cause severe damage (Meneghin & Matsuoka, 1995). However, it can be hypothesized that *H. sacchari* occurs in soil mainly as a saprobiont, becoming parasitic only in disturbed soils. *H. sacchari* and other soil pathogens can reduce yields but are not considered to be causal agents of YLS but rather an additional stress factor.

**INTERACTIONS BETWEEN SEASON, LATITUDE AND GENOTYPE**

It is clear that YLS is season-dependent. The manifestation of symptoms always begins in the autumn, usually in maturing plants. The more intense are stress factors in autumn and winter, including low temperatures and precipitation, the more intense YLS symptoms (unpublished data). Symptom intensity is also latitude-dependent. It has been observed that varieties selected for higher latitudes show symptoms more frequently and intensively when grown at lower latitudes, and vice versa. For example, CP65-357 and Tuc71-9 consistently show more conspicuous symptoms at latitude 9oS than at 22oS. The latter variety collapses in most years at 9oS (unpublished data). This has similarities to flowering, another manifestation of senescence. It can therefore be concluded that YLS is primarily genotype-dependent but the severity of symptom expression party depends on the displacement of the cultivar with regard to latitude.

**CULTIVAR SP71-6163**

Variety SP71-6163 was released in 1981 after experimental results only from plant cane and first ratoon. At that time it was specifically recommended for planting in fertile soils and not for colder regions, because its performance was better in hotter regions (Nunes Jr., 1992). Compared with other varieties, it has shown lower gains in yield during the autumn-winter period. For the same reason, when its popularity was increasing it
was specifically not recommended for harvesting at the end of the harvest season, since it would then give poor yields in the next ratoon (Sugarcane, 1993). This recommendation was disregarded by many in favor of a mistaken study concluding that better returns would be obtained if it were harvested late. That this was incorrect was confirmed in a survey made in commercial plantations (Fernandes, 1991).

Braga Jr., (1994) and Sordi & Braga Jr. (1994) showed that SP71-6163 is a variety with an inconsistent performance, especially in ratoon crops, due to its lack of adaptability to climatic variations and environmental limitations, especially poor water supply. An acute decrease in yield after second ratoon can also be deduced from results obtained before YLS was noticed.

CONCLUSIONS

The interaction between plant and environment is complex and the performance of each variety, and even each plant, presents a specific response to the dynamically changing agricultural ecosystem. The same management practices should not be applied to different varieties with the expectation that they will all respond similarly in different situations.

In the case of sugarcane, several varieties are concurrently cultivated in order to meet production requirements. A continuum of adaptability to specific environments occurs among varieties. Any disturbance caused by mismanagement or variation in weather affects each variety cultivar differently. This seems elementary but it is not always remembered.

Variety SP71-6163 has been shown to be extremely sensitive to environmental stresses, so that it requires more careful management than other varieties. It is held that it was the mismanagement that led to the purported yield losses of 40 to 60% in this variety rather than a disease caused by an alleged new pathogen. It was also the concurrent occurrence of autumn decline in the same cultivar has led to the YLS disease hypothesis. Autumn decline is a manifestation of plant senescence related to decreasing day length in autumn and winter, rather than a response to a specific pathological agent.

Sugarcane pathologists are urged not to simply follow the bandwagon. They must practice caution, careful diagnostics and attempt on understanding of the complex multi-disciplinary nature of the interaction between plants and environment that might result in quasi-disease symptoms before reaching conclusions. The concerns of Skelly and Innes (1994) in relation to forest pathology apply to the situation reported in this paper. Paraphrasing these authors, it would be a pity if the reputation of sugarcane pathology were to suffer.

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EL SÍNDROME DE LA HOJA AMARILLA Y LOS PATÓGENOS ASOCIADOS: UNA RELACIÓN CASUAL PERO NO CAUSAL

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RESUMEN

El síndrome de la hoja amarilla (YLS) es un problema que recientemente causó considerable preocupación en Hawai, Brasil y otros países y resultó la dedicación de distintos científicos alrededor del mundo por establecer su etiología. La inconsistencia de la propuesta sobre el origen viral del YLS o de que un agente biológico en particular es el directo responsable del problema se discute en el presente trabajo. Con base en un análisis de los informes publicados y de las observaciones de campo, se sostiene que los supuestos patógenos son endófitos y que la condición es una manifestación de la senescencia de ciertos cultivares bajo ambientes específicos, un problema conocido en el pasado como "disminución otoñal" o "marchitamiento amarillo". En Brasil, donde principalmente se originó la confusión entre causa y efecto, debido a la aparición de los síntomas en un cultivar muy susceptible al estrés ambiental, y a su vez, cultivado en suelos de baja fertilidad y compactación del suelo, los síntomas fueron intensificados por un manejo inadecuado del cultivo. El complejo de factores bióticos y abióticos que actúan sobre una planta de ciclo vegetativo largo como la caña de azúcar hace que el efecto sobre cada cultivar en particular sea diferente y más aún cuando los manejos agronómicos no son los apropiados.

Palabras claves: caña de azúcar, síndrome de la hoja amarilla

LE SYNDROME DE JAUNISSEMENT DES FEUILLES ET LES PATHOGENES PRESUMÉS: RELATIONS DE CAUSES A EFFETS

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RÉSUMÉ

Le syndrome de jaunissement des feuilles (YLS) est un problème qui a suscité beaucoup d’inquiétude à Hawaii, au Brésil et dans beaucoup d’autres pays. Un peu partout les scientifiques ont consacré beaucoup d’efforts pour établir son étiologie. La présente communication discute de l’incohérence des présomptions sur l’origine virale du problème et met en question l’hypothèse qu’un seul agent biologique en soit responsable. À la lueur d’une analyse des rapports publiés et des observations faites au champ, l’auteur soutient que les pathogènes présumés ne sont que des endophytes et que le syndrome est le résultat d’une sénescence de certaines variétés dans des environnements spécifiques, un problème déjà rapporté dans le passé comme “autumn decline” ou “yellow wilt”. Au Brésil, ce qui a le plus souvent provoqué des confusions entre causes et effets, c’est la présence simultanée des symptômes dans une variété sensible aux effets de stress, principalement mauvaise fertilité et compaction de certains sols, aggravés à leur tour par une mauvaise gestion. L’ensemble des facteurs biotiques et abiotiques qui opèrent au cours du long cycle de croissance de la canne à sucre ont des effets variables sur les différentes variétés, et ces effets sont souvent mal gérés par beaucoup d’agriculteurs.

Mots clés: Syndrome de jaunissement des feuilles, YLS, canne à sucre