Potato Res. 23 (1980) 85-93

The effects of temperature and light on the symptom expression and viroid concentration in tomato of a severe strain of potato spindle tuber viroid

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Accepted for publication: 20 August 1979.

Zusammenfassung, Résumé p. 91

Additional key-words: plant quarantine, cross-protection

Summary

Indexing on tomato of dilution series prepared from young tomato seedlings infected with a severe strain of potato spindle tuber viroid (originally isolated from wild tuber-bearing *Solanum* and later used for cross-protection tests to detect mild strains) indicated that viroid concentration rose more quickly in tomato at 31 °C than at 23 °C at various light intensities. At either temperature, low light intensity for 17–18 hours each day did not critically limit synthesis. At 31 °C, symptoms which were otherwise severe by 2 weeks were delayed and less obvious under low light. At 23 °C, symptoms were delayed at low or higher light intensity and did not appear if the temperature was allowed to fall to 15 °C at night. Leaf vein necrosis which was favoured by moderate rather than by high temperature, possibly was similar to necrosis induced by viruses or other infection.

Introduction

For the task of screening plants of potato and other tuber-bearing species of *Solanum* for potato spindle tuber viroid (PSTV) (not known to occur in commercial stocks of potato in the United Kingdom), the tomato cross-protection test (Fernow, 1967; Fernow *et al.*, 1969) was used in our quarantine unit from 1973 to 1977. The procedure is intended to ensure that any strain that is mild or symptomless in tomato will be detected by the protection offered against a severe strain with distinctive symptoms super-inoculated to the tomato plants after an appropriate interval; but because symptoms are strongly influenced by growth conditions it may not always be possible by this method to distinguish clearly between strains, and even a severe strain sometimes may not produce symptoms. For example, Raymer *et al.* (1964) showed that unless tomato plants are adequately fed, control of temperature and light will not ensure symptom expression.

There are many reports that PSTV symptoms are best developed around or above 30 °C, but in general the appropriate studies did not distinguish between the effects

of temperature and light. We have sought to separate these effects on symptom expression and also to relate them to the rate of increase in the concentration of viroid during the first three weeks after infection.

Methods

Experiments were conducted in growth rooms lit for a 17-18 hour day by fluorescent tubes (Philips 125 W 'reflectalite'). The least density of tubes was 2 per 10 cm of bench width. A 'high' light regime was equivalent to 55 W m^{-2} photosynthetically active radiation (PAR) as measured by a Lambda LI-COR quantum sensor at plant height. (55 W m^{-2} or 550 μE (microeinsteins)$m^{-2}s^{-1}$ was a low intensity compared with summer sunlight). A 'medium' light regime was equivalent to 35 W m^{-2} PAR and a 'low' light regime equivalent to 25 W m^{-2} PAR. Two temperature settings were chosen: 'high', 31 °C; 'medium' 23 °C; and a low night temperature was achieved by allowing the temperature to fall back from 23 °C to a 15 °C minimum. Air temperature was measured in an aspirated screen at plant height and held within 1 °C of the required setting at the medium temperature and within 2 °C at the high setting. There was no control of relative humidity.

A distinctive severe strain of PSTV isolated originally from *Solanum commersonii* Dun, (Cammack & Harris, 1973), was maintained in the diagnostic tomato cv. Sheyenne (Singh et al., 1964). Seedlings at the two-three leaf stage were dusted with carborundum, inoculated by means of a cotton bud and then washed with tap water. Inoculum was prepared by grinding approximately 2 g of tissue from the upper part of tomato plants showing clear symptoms, with 2 ml 0.05 *M* K_2HPO_4 pH7.0 buffer solution in a mortar. All plants were well fed with major nutrients. A 550 ml peat pot containing compost provided adequate feed for 10-14 days after inoculation. Two or three drenches with standard commercial NPK soluble nutrients sufficed for a further 14 days.

Values for relative viroid concentration were obtained by homogenising entire plants (cut at soil level) in phosphate buffer in a liquidiser. Each homogenate was raised to a final volume of 100 ml by the addition of phosphate buffer. Dilution series were immediately prepared and each dilution step inoculated to three seedlings. These were grown for 21 days in a glasshouse at a temperature not falling below 25 °C after which they were scored for the presence or absence of symptoms. In the particular cases where only one plant out of the three inoculated with undiluted homogenate, and one plant out of the three inoculated with homogenate diluted 10-fold became infected, the infectivity of the original homogenate was recorded as 'minimal' (Table 3). Otherwise the infectivity or concentration of each original homegenate was recorded as the maximum dilution infective to at least two out of three plants.

Results and conclusions

Symptoms produced under different temperatures and light conditions (Tables 1 and 3).

In plants grown at 31 °C and at the highest light intensity slight symptoms began

Table 1. Symbols in PSTV-infected tomato plants grown in different temperature and light regimes.

Growing regime[7]		Comment on symptoms[8]	Proportion of plants to which comment applies[9]
light intensity[1]	temperature[4] (°C)		
High[2]	31	Rugosity followed by bunching and stunting at the top of the plant after 12–14 days. Necrosis restricted to necrotic flecks on underside of leaf veins[10]	20/20
Low[3]	31	Poor etiolated growth with late development of slight symptoms, little disease specific necrosis of veins after 21 days[11]	4/4
Low	23	Fair growth only slight stunting but marked epinasty and rugosity after 17–21 days, 9/12 showed necrosis of leaf veins at 21 days[12]	12/12
High	23 day[5] 15 night[6]	Good growth dark and sturdy, nil symptoms[13]	4/4
Low	23 day 15 night	Fair growth[14] dark and sturdy, nil symptoms.	9/9

[1]*Lichtintensität – Intensité lumineuse;* [2]*Hoch – Elevé;* [3]*Tief – Faible;* [4]*Temperatur – Température;* [5]*Tag – Jour;* [6]*Nacht – Nuit;* [7]*Wachtumsbedingungen – Condition de croissance;* [8]*Bemerkungen zu den Symptomen – Description des symptômes;* [9]*Anteil der Pflanzen, auf den sich die Bemerkungen beziehen – Proportion de plantes;* [10]*Rauhblättrigkeit gefolgt von Buschigkeit und Kümmerwuchs des Pflanzenwipfels nach 12–14 Tage. Die Nekrose beschränkt sich auf nekrotische Flecken an der Unterseite der Blattadern – Rugosité suivie d'un groupement des organes végétatifs et d'un rabourgrissement au sommet de la plante après 12–14 jours. Les nécroses sont limitées à des petites taches nécrotiques sur la face inférieure des nervures;* [11]*Geringer, allgemein chlorotischer Wuchs mit später Entwicklung von leichten Symptomen, wenig krankheitsspezifische Adernnekrose nach 21 Tagen – Faible croissance avec étiolement de la plante et développement tardif de faibles symptômes, petites nécroses spécifiques de la maladie sur les nervures après 21 jours;* [12]*Ziemlich gutes Wachstum, nur leichter Kümmerwuchs, aber ausgeprägte Epinastie und Rauhblättrigkeit nach 17–21 Tagen, 9/12 zeigten Nekrosen der Blattadern nach 21 Tagen – Belle croissance avec seulement un faible rabourgrissement, mais épinastie et rugosité marquées après 17–21 jours, 9/12 des plantes ont des nécroses sur les nervures à 21 jours;* [13]*Gutes Wachstum, dunkel und kräftig, keine Symptome – Bonne croissance vigoureuse aucun symptôme;* [14]*Ziemlich gutes Wachstum – Belle croissance.*

Tabelle 1. Symptome an mit PSTV infizierten Tomatenpflanzen, die unter verschiedenen Temperatur- und Lichtverhältnissen herangezogen wurden.
Tableau 1. Symptômes du PSTV sur plants de tomate contaminés et soumis à différentes conditions de température et d'éclairement.

to appear about the ninth day, earlier than under any other regime studied. At first there was rugosity, followed by stunting or bunching and chlorosis at the top of the plant with necrosis restricted to tiny flecks on the underside of leaf veins. At lower light intensities, poorer growth, often etiolated, was associated with late development of less obvious symptoms.

Plants grown continuously at 23 °C and, more particularly, those grown at 23 °C with night temperature falling to 15 °C, were darker green and sturdier than those grown at higher temperatures. Plants grown at 23 °C in low light began to show symptoms, after 17-21 days, as a very slight bunching, eventually showing strong rugosity and veinal necrosis. At 23 °C with night temperature falling to 15 °C no symptoms developed at low or high light intensities.

High temperature, and enough light to ensure good growth, favoured early symptom expression but did not favour necrosis of leaf veins. Conversely, lower temperatures gave later and less obvious symptoms but tended to favour necrosis. A night temperature falling to 15 °C prevented symptom expression entirely for plants otherwise grown at 23 °C.

Effect of transferring plants from one growth regime to another after varying periods of time (Table 2)

Preliminary experiments both in glasshouses and growth rooms showed that when plants with well established severe strain infection were moved from a constant high temperature (around 30 °C) either to a constant 23 °C or to 23 °C by day falling to 15 °C at night under a low light intensity, extensive necrosis occurred within 2–3 days in or alongside the veins in most upper leaves.

Table 2 summarises results obtained in a later experiment in the growth room. All plants kept under the initial 'high light, high temperature' regime showed leaf vein necrosis after transfer to the 'low light, 23 °C day, 15 °C night' regime, including those kept for as little as 8 days after inoculation at the high temperature. Necrosis was also obtained in plants grown initially under low light at 23 °C, but only if they were moved to the low night temperature regime after a minimum of 13–17 days at 23 °C.

Plants kept from the time of inoculation in the low night temperature regime were symptomless (Table 1). It would appear therefore that the degree to which an infection had become established during the initial period was important in determining the degree of necrosis observed when plants were transferred to the cooler regime. Infection seemed to take longer to become established at 23 °C than at the higher temperature.

Plants grown at a high temperature in low light showed poor symptoms and rarely developed necrosis when placed in the cooler environment but when examined for viroid concentration they showed a well established infection (Table 3).

Viroid concentration in infected plants grown under different conditions of temperature and light (Table 3)

Although there was considerable variation in viroid concentration in homogenates of individual plants within each treatment, a trend could be distinguished. The crude extraction procedure and method of measurement of infectivity might explain

Table 2. The appearance of necrosis in or alongside leaf veins of plants grown for different periods in different light and temperature regimes and then transferred to a regime of low light and low temperature (23 °C falling back to 15 °C at night).

Initial regime[7]		Days spent in initial regime[10]	Date of appearance of necrosis in days after inoculation[8]	Proportion of plants showing necrosis[9]
light intensity[1]	temperature[4] (°C)			
High[2]	31	8-9	17-21	5/5
		10-11	15-19	5/5
		12-14	15-19	5/5
Low[3]	23	8-9	24 (nil[11])	0/10
		10-11	24 (nil)	0/5
		13	20-21	1/10
		17	20-21	4/5
Low	31	9-14	20-21	1/12
High	23 day[5] 15 night[6]	9-14	24 (nil)	0/12

[1, 2, 3, 4, 5, 6]*Siehe Tabelle 1 - Voir tableau 1;* [7]*Anfangsverfahren - Régime initial;* [8]*Angabe des Nekrosenauftretens in Tagen nach der Inokulation - Date d'apparition des nécroses en jours, après l'inoculation;* [9]*Anteil Pflanzen mit Nekrosen - Proportion de plantes extériorisant des nécroses;* [10]*Tage unter dem Anfangsverfahren - Nombre de jours consacrés au régime initial;* [11]*Null - Nul.*

Tabelle 2. Das Auftreten von Nekrosen in oder entlang von Blattadern von Pflanzen, die während verschiedener Zeitdauer und unter verschiedenen Licht- und Temperaturbedingungen heranwuchsen und dann einem Verfahren mit wenig Licht und tiefer Temperatur (von 23 °C bei Tag auf 15°C bei Nacht fallend) ausgesetzt wurden.
Tableau 2. Apparition des nécroses sur, ou le long des nervures de plantes cultivées sous différents régimes de luminosité et de température, et ensuite placées en régime de faible luminosité et température (23°C pour retomber la nuit à 15 °C).

variation between individuals within each treatment, but some degree of individual variation in levels of viroid concentration might also be expected. High viroid concentrations appeared to be obtained more rapidly at high temperatures and this could be correlated with rapid expresseion of symptoms whenever light intensity was sufficient. No clear-cut difference in viroid concentration could be detected, using this procedure, for plants kept in different light regimes, although symptoms were less marked under low light at the high temperature.

Discussion

Measurements of the infectivity of tissue homogenates indicate that the viroid concentration rises quickly in tomato plants grown under various light intensities at a temperature around 31 °C. If light is sufficient these plants show severe symptoms

Table 3. Symptoms and viroid concentration of tomato cv. Sheyenne inoculated with severe strain PSTV and grown in different light and temperature regimes

Days after inoculation[2]	Light intensity[3]	The infectivity of individual plants (a, b, c) recorded as the maximum dilution of the tissue homogenate infective to at least 2/3 tomato plants[1]							
		23 °C				31 °C			
		a	b	c	number of plants with symptoms[4]	a	b	c	number of plants with symptoms
9	low[5]	NT	NT	NT	0/3	10^{-2}	10^{-2}	10^{-2}	0/3
	medium[6]	10^{-1}	10^{-2}	+	0/3	10^{-2}	10^{-2}	10^{-2}	0/3
	high[7]	10^{-2}	10^{-2}	0	0/3	10^{-2}	10^{-3}	10^{-3}	3/3
13	low	0	0	NT	0/3	10^{-2}	10^{-3}	NT	0/3
	medium	0	+	NT	0/3	*10^{-2}	*10^{-3}	NT	1/3
	high	10^{-2}	+	NT	0/3	10^{-3}	10^{-3}	NT	3/3
17	low	+	+	NT	0/3	**10^{-2}	10^{-3}	NT	2/3
	medium	10^{-2}	10^{-3}	NT	0/3	10^{-4}	10^{-3}	NT	3/3
	high	10^{-2}	10^{-2}	NT	0/3	10^{-3}	10^{-3}	NT	3/3
21	low	10^{-2}	10^{-3}	NT	3/3	10^{-3}	10^{-3}	NT	2/3
	medium	10^{-2}	10^{-2}	NT	3/3	**10^{-3}	10^{-3}	NT	2/3
	high	10^{-2}	10^{-3}	NT	3/3	10^{-3}	10^{-3}	NT	3/3

NT: 'Not tested' – *'Nicht getestet' – 'Non testée'.*
0: Not infective – *Nicht infektiös – Non infectieuse.*
+: Only minimally infective – *Nur minim infektiös – Faiblement infectieuse.*
* Plants marked thus showed no symptoms – *Auf diese Weise markierte Pflanzen zeigten keine Symptome – Plante marquée donc ne présentant aucun symptôme.*
** Plants marked thus showed no symptoms and were poorly grown – *Auf diese Weise markierte Pflanzen zeigten keine Symptome und waren schlecht gewachsen – Plante marquée donc ne présentant aucun symptôme et de faible végétation.*

[1] *Die Infektiosität der einzelnen Pflanzen (a, b, c), dargestellt als maximale Verdünnung des Gewebehomogenates, die für mindestens 2/3 der Tomatenpflanzen ansteckend ist – Le pouvoir infectieux de plantes individuelles (a, b, c) est considéré comme étant la dilution maximale d'un homogenat de tissu infectant au moins 2/3 des plantes de tomate;* [2] *Tage nach der Inokulation – Jours après inoculation;* [3] *Lichtintensität – Intensité lumineuse;* [4] *Anzahl Pflanzen mit Symptomen – Nombre de plantes avec des symptômes;* [5] *Niedrig – Faible;* [6] *Mittel – Moyenne;* [7] *Hoch – Elevée.*

Tabelle 3. Symptome und Viroid-Konzentration bei der Tomatensorte Sheyenne, die mit einem stark pathogenen PSTV-Stamm inokuliert und unter verschiedenen Licht- und Temperaturverhältnissen herangezogen wurde.
Tableau 3. Symptômes et concentration en viroïde pour la variété de tomate Sheyenne, après inoculation avec une souche de PSTV et soumis à différents régimes de température et d'éclairement.

after two weeks. The concentration of the viroid continues to increase over a period of two to three weeks in plants grown at 23 °C or 31 °C, even when light intensity is low and only just able to sustain growth. Yang & Hooker (1977) showed that when light intensity was approximately 1000 foot-candles, highest concentration of infection could be obtained by growing plants under continuous light Whereas higher light intensity and longer light periods may result in greater viroid synthesis, a low level of light for 17-18 hours each day does not critically limit synthesis.

The appearance of necrotic lesions in or alongside leaf veins appears to be favoured by high viroid concentration in plants exposed to moderate temperatures. Most necrosis is seen after plants grown for 2-3 weeks at about 30 °C, in good light, experience a drop in temperature to 23 °C or below and a change to poor light conditions. The appearance of necrosis at moderate rather than high temperatures is a well-known phenomenon with many virus infections. Observations (Harris; unpublished) of fluorescence in UV light around necrotic local and systemic PSTV lesions in *Scopolia sinensis* Hemsl. (a local lesion host, Singh, 1971) may indicate that necrosis associated with severe strain PSTV infection is similar to a very general, widely observed, plant reaction to infection.

It has been widely observed that higher viroid concentrations are obtained at temperatures greater than 25 °C and are highest at temperatures around or above 30 °C. We suggest that our results are in agreement with these observations although we note that at temperatures below 25 °C viroid concentration can, with time, rise to levels sufficient to induce symptoms and to make the tomato plant highly infectious.

As part of a procedure for detecting PSTV suggested by Morris & Smith (1977), tomato cvs. Sheyenne and Ailsa Craig have been used recently in our quarantine unit to build-up concentrations of viroid.

Acknowledgements

We thank Christina M. James for excellent technical assistance, Mr J. M. Todd for helpful criticism of the manuscript and Dr R. P. Singh (Canada Agriculture) for gifts of seeds.

Zusammenfassung

Einflüsse von Temperatur und Licht auf die Symptomausbildung und die Viroidkonzentration in Tomaten mit Befall durch einen stark pathogenen Viroidstamm der Spindelknollenkrankheit des Kartoffels.

Für die Aufgabe, Kartoffelpflanzen und andere knollentragende Arten von *Solanum* auf Befall mit Kartoffel-Spindelknollenviroid (PSTV) zu testen (Vorkommen in handelsüblichen Kartoffelposten in Grossbritannien nicht bekannt), wurde ein auffallender, ursprünglich aus *Solanum commersonii* Dun. isolierter PSTV-Stamm für einen Prämunitätstest an Tomatenpflanzen verwendet in der Absicht, einen durch milde Stämme angebotenen Schutz zu entdecken.

Die Symptome variieren je nach den Wachstumsbedingungen. Die Tomatenpflanzen mussten gut ernährt werden. Bei der Sorte Sheyenne, inokuliert im 2-3-Blattstadium und in einer Wachstumskammer bei 31 °C gehalten, zeigen sich nach 2 Wochen schwere Symptome, wenn genügend Licht vorhanden ist. (Volles Licht: 55 W m^{-2} oder 550 $\mu E\ m^{-2}s^{-1}$ photosynthetisch aktive Strahlung (PAR)

während 17–18 Stunden täglich: Tabelle 1.) Die Symptome sind: Rauhblättrigkeit, Epinastie und Chlorose am Wipfel der Pflanze und, charakteristischerweise, Kümmerwuchs. Bei einer niedrigen Lichtintensität von 25 W m^{-2} PAR wird die Symptomausbildung bei 31 °C verzögert, und anstelle des Kümmerwuchses wird allgemeine Chlorose sichtbar. Die hohe Temperatur begünstigt die Nekrose an Blattadern nicht. Ein mässige Temperatur von 23 °C bei niedriger oder höherer Lichtgabe bringt spätere und weniger augenfällige Symptome (Tabellen 1 und 3), neigt aber zur Förderung von Nekrosen. Eine Nachtabsenkung von 23 °C auf 15 °C während 24 Tagen verhütet die Ausbildung von Symptomen an Pflanzen sowohl bei hoher wie bei niedriger Lichtintensität (Tabelle 1).

Bringt man Pflanzen, die anfänglich bei mittlerer oder hoher Temperatur und gutem Licht gewachsen waren, in ein Verfahren mit wenig Licht und mittlerer Temperatur und – wie in Tabelle 2 zusammengefasst – zu 23 °C Tag- und 15 °C Nachttemperatur, so erhält man bei gut infizierten Pflanzen starke Nekrosen. Eine erfolgreiche Infektion scheint bei 23 °C mehr Zeit zu beanspruchen als bei höherer Temperatur (Tabelle 2).

Messungen der Infektiosität von Homogenaten der ganzen Pflanzen, dargestellt als die maximale Verdünnung jedes Homogenats, die mindestens bei 2 von 3 Tomatenpflanzen (Tabelle 3) Symptome hervorruft, zeigen, dass die Viroid-Konzentration bei 31°C rasch ansteigt. Dies kann mit dem frühen Erscheinen von Symptomen, sobald genügend Licht vorhanden ist, in Zusammenhang gebracht werden. Eine niedrige und eine mittlere Lichtintensität (35 W m^{-2}) bewirken keine signifikante Reduktion viroider Konzentrationen bei 31 °C, obwohl sie die Symptomausbildung verzögern. Die Konzentration steigt bei 23 °C oder 31 °C über einen Zeitraum von 2–3 Wochen weiter an, auch wenn die Lichtintensität während 17 – 18 Stunden täglich nur gerade genügt, das Wachstum zu erhalten (Tabelle 3).

In der Diskussion wird darauf hingewiesen, dass ein niedrigerer Lichtstand während 17–18 Stunden täglich die Synthese nicht entscheidend begrenzt, während längere Lichtperioden und höhere Lichtintensität eine erhöhte Viroidsynthese ergeben könnten. Es wird auch vermutet, dass die temperaturabhängige Nekrose, die durch dieses Viroid induziert wird, ähnlich sein dürfte wie die Nekrose, die durch Viren oder eine andere Infektion ausgelöst wird. Nicht veröffentlichte Beobachtungen von Fluoreszenz in UV-Licht rund um die Läsionen in *Scopolia sinensis* Hemsl., die mit PSTV befallen sind, werden zur Stützung dieser Ansicht angeführt.

Als Teil eines neuen Verfahrens zum Nachweis von PSTV wurden die Tomatensorten Sheyenne und Ailsa Craig verwendet, um Viroid-Konzentrationen aufzubauen.

Résumé

Les effets de la température et de la lumière sur l'expression des symptômes et sur la concentration en viroïde, pour la tomate, d'une souche virulente de spindle tuber de la pomme de terre

Afin de sélectionner des pommes de terre et d'autres espèces de *Solanum* 'tubérifères' résistantes au viroïde du 'Spindle tuber' (PSTV) (inconnu au Royaume Uni), on a utilisé une souche différente de PSTV isolée à partir de *Solanum commersonii* Dun. pour surinfecter des plantes de tomate, dans un test de protection croisée de manière à détecter l'effet de protection apporté par des souches peu virulentes.

Les symptômes varient avec les conditions de culture, et les plantes de tomate doivent recevoir une alimentation correcte. Pour la variété Sheyenne, inoculée au stade 2—3 feuilles et maintenue à 31 °C, des symptômes sévères apparaissent en 2 semaines si la lumière est suffisante (une forte luminosité correspond à une radiation photosynthétiquement active (PAR), de 55 W m^{-2} ou à 550 μE $m^{-2}s^{-1}$, pendant 17 à 18 h par jour: tab. 1.)

Les symptômes correspondent à une rugosité, une épinastie et une chlorose au sommet de la plante, on a également un rabougrisse-

ment caractéristique. Une faible intensité lumineuse de 25 W m^{-2} PAR, retarde l'expression des symptômes à 31 °C, et le rabougrissement est contrecarré par un étiolement. La haute température ne favorise pas la nécrose des nervures. Une température modérée de 23 °C, à éclairement faible ou plus élevé donne des symptômes plus tardifs et moins évidents (tab. 1 et 3), mais ces facteurs tendent à favoriser la nécrose. Une chute de température à 15 °C, chaque nuit, empêche l'expression des symptômes pour des plantes placées à 23 °C pendant 24 jours, et soumises à une intensité lumineuse élevée ou faible (tab. 1).

Des plantes initialement cultivées à des températures modérées ou élevées, en luminosité correcte, et soumises ensuite à un régime de faible luminosité et de température modérée, respectivement 23 °C le jour et 15 °C la nuit, extériorisent des nécroses sévères si la contamination a été réussie (expérimentations qui ont été résumées dans le tableau 2).

L'infection semble prendre plus de temps pour s'installer à 23 °C, qu'à température plus élevée (tableau 2).

Des mesures du pouvoir infectieux d'homogenats de plantes entières, considérées comme étant la dilution maximale de chaque homogenat infectieux sur au moins 2/3 des plantes de tomate (tab. 3), indiquent que la concentration en viroïde augmente rapidement à 31 °C. Cela peut être corrélé avec l'apparition précoce des symptômes chaque fois que la lumière est suffisante. Une faible intensité lumineuse et une intensité lumineuse moyenne (35 W m^{-2}) bien que cela retarde l'expression du symptôme, ne semble pas réduire significativement les concentrations en viroïde à 31 °C.

La concentration continue à augmenter durant une période de 2 à 3 semaines à 23 °C ou 31 °C, même quand l'intensité lumineuse de 17 à 18 h chaque jour est juste capable de maintenir la croissance (tableau 3).

Dans la discussion, les auteurs émettent l'hypothèse que les périodes d'éclairement plus longueus et l'intensité lumineuse plus élevée peuvent se traduire par une augmentation de la synthèse viroïde; un éclairement faible pendant 17 à 18 h chaque jour ne limitera pas de manière critique la synthèse.

On suppose que les nécroses dépendant de la température et induites par le viroïde, peuvent être identiques aux nécroses induites par les virus ou par d'autre infection.

Des observations non publiées sur la fluorescence en lumière UV, autour des lésions sur *Scopolia sinensis* Hemsl. contaminé par PSTV, sont citées pour défendre ce point de vue.

Dans le cadre d'un nouveau procédé de détection du PSTV, les variétés de tomate Sheyenne et Ailsa Craig ont été utilisées afin d'augmenter la concentration en viroïde.

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