Final Report for

HDC Project FV 128

AN INVESTIGATION OF THE CAUSES OF OEDEMA IN WHITE CABBAGE

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CONTENTS

A. OBJECTIVES

This preliminary project had two primary objectives:

a) To review the literature on oedema and related problems.

b) To investigate in a field experiment the role of onion thrips, *Thrips tabaci*, in oedema damage on varieties of Dutch white cabbage differing in their reported susceptibility to *T. tabaci*.

B. LITERATURE REVIEW

OEDEMA LOSSES IN DUTCH WHITE CABBAGE

The cabbage crop in the UK occupies 25,000 ha and, in 1991, was worth in the region of £148 million, of which £28 million was Dutch white cabbage.

Oedema on Dutch white cabbage is becoming an important problem in the UK and in 1991 the yield losses attributable to this disorder were estimated by growers to be as high as 20% in some crops. Severe losses were also reported from the Netherlands in the same year. In Germany the problem varies from year to year but still the cost to the industry is great. In the USA the problem appears to have became serious in the last decade. For example, North (1986) reported that this disorder was the most serious problem for New York's 5,000 ha of cabbage.

THE NATURE OF DAMAGE ON CABBAGE

The disorder (Fig. 1), which appears late on in the growing season and then in winter storage on cabbage, has been described as cork or callus by Kretchemer (1984) and Giessmann (1988). Von Zohren (1984) has given a detailed description of this cork development; under the epidermis on both sides of the leaf non-coloured cells (without chlorophyll) develop from the phellogen (cork cambium). These cells expand to became slightly larger than the normal parenchyma cells. The number of these cells is also greater than is normal in this area of the leaf. The outer cells store suberin, a complex mixture of oxidation and condensation products of fatty acids, present in the walls of cork cells rendering them impervious of water. Suberin causes the different colours that occur (yellow, brown, black), the more suberin the darker the colour.

Shelton *et al.* (1982), Shelton, Becker & Andaloro (1983) and North & Shelton (1986) describe the disorder as having a rough texture with bronze colour. The term 'rough bronze oedema' has been adopted by Hoy & Kretchman (1991) while Shelton recently used the term 'edema' (the USA spelling of oedema) or 'bumps' (unpublished data). Ramsey & Smith (1961) also named this symptom as oedema, but the term was rejected by Fox & Delbridge (1977) because this implies the invasion of tissue by a fluid and evidence of this was not seen, so they used the alternative terms 'rasping' and 'galling'.

Van Nostrand defines the term 'edema' in animals as the accumulation of excess fluids in the tissues of the body. The condition may arise from several causes. Physiologically the balance of the body fluids between the cells (intracellular fluid), the fluid bathing the cells (extracellural fluid), and the blood plasma are upset. Fluid

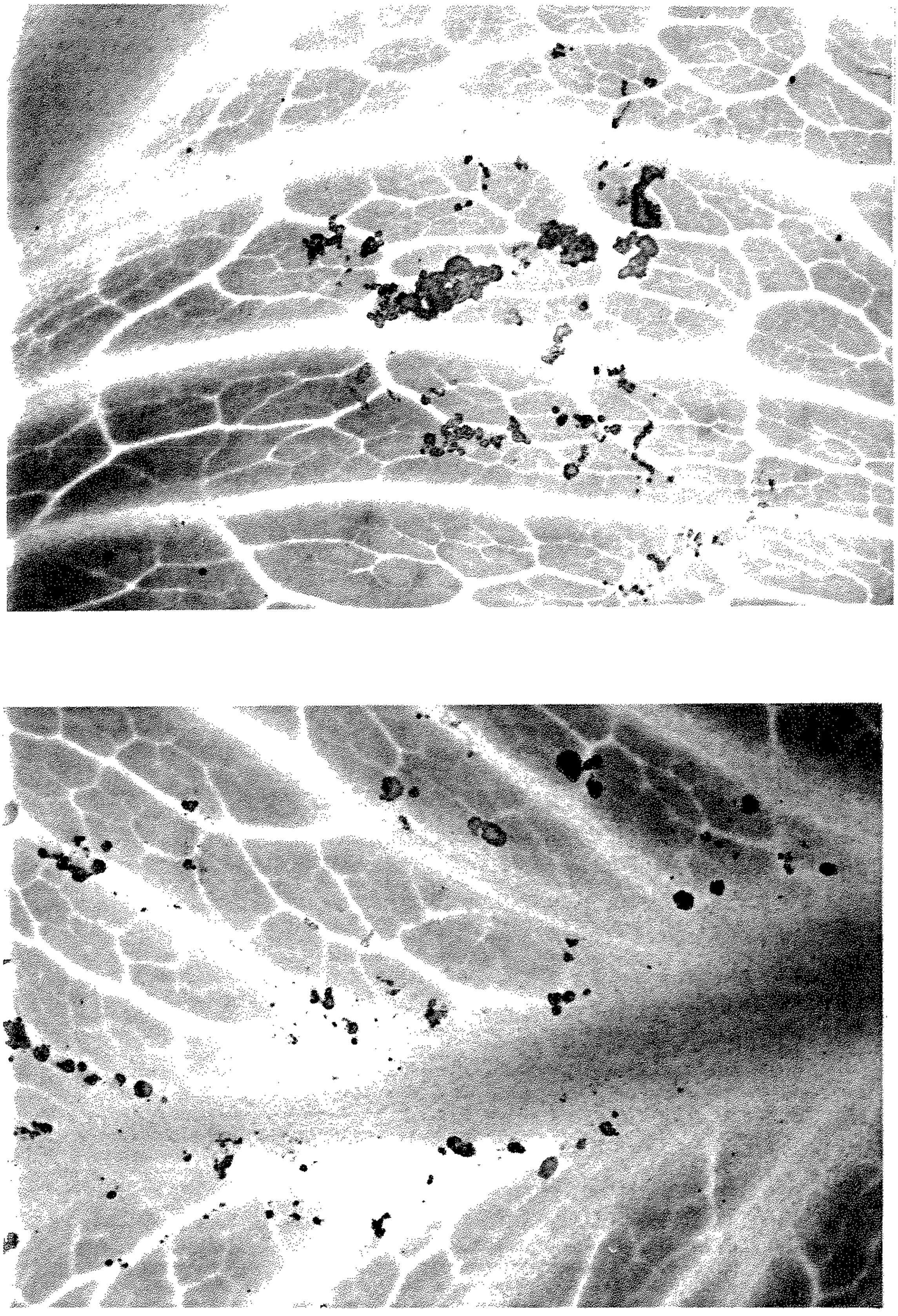

Fig. 1: *T. tabaci* damage on Dutch white cabbage (x5) (HRI Wellesbourne, 1993)

is drawn from the blood into the tissues because there is a higher osmotic pressure in the tissue than in the blood. Capillary damage due to infection, bacterial toxins, or to trauma will allow the passage of the fluid from the blood into the tissue spaces and produce edema. It is worth bearing in mind these points concerning edema in animals when considering the disorder in Dutch white cabbage.

POSSIBLE CAUSES

There are several theories about how this disorder develops in cabbages. Kretschmer (1984) said that large amounts of water taken up through the root system are concentrated in the cells. Excess water causes an expansion of the cell when atmospheric humidity is high and when the transpiration rate is low. This theory is identical to that proposed for oedema or dropsy in tomatoes (Grimbly, 1986). Kretschmer suggested that this disorder was caused by physiological changes as a result of high environmental humidity or low transpiration level or by small animals. However, he concluded that feeding by thrips caused this damage. It is not known if this disorder is produced as a defence mechanism of the plant or if it is caused by the thrips causing mechanical injury during feeding. It is possible that the environmental conditions encourage cork development but they are definitely not the cause of cork formation.

North & Shelton (1986) reported that several thrips species fed on cabbage plants but only *T. tabaci* was found in the heads of cabbages. Live adults and larvae of *T. tabaci* could still be found inside the heads after several months of storage under natural air or common storage systems (Stoner & Shelton, 1988d). In support of this, Glessmann (1988) reported that at 1°C he found live *T. tabaci* as well as *T.*

anguisticeps under the same cooling conditions. Stoner & Shelton (1988a) reported that these bronzed and blistered areas can be caused either by thrips feeding or egg-laying. A similar symptom appears on citrus leaves when *Heliothrips haemorrhoidalis*, which has the same oviposition habits as *T. tabaci*, embedded eggs in leaf tissue. The citrus leaves reacted to the presence of the eggs by developing cork cells in the surrounding tissue. This protected the egg from excessive water in the leaf, but in warm moist weather or in young leaves, the proliferation of these cells may be so great that the egg was encrusted inside the cavity or was even pushed out of the leaf. This may be why this thrips prefer to lay in old leaves (Lewis, 1973). Mollema (personal communication, 1992) reported that the same disorder appears on sweet pepper plants when *Frankliniella occidentalis* are released on them. Our own observations in the laboratory showed that virtually any damage to cabbage tissues can cause oedema development. Damage caused by fine needles or by feeding of small caterpillars on young expanding leaves resulted in the development of oedema at the site of the damage, although on some occasions this disorder appeared on the plants without any visual signs of mechanical damage.

FACTORS AFFECTING THE EXPRESSION OF THE DISORDER

Varietal effects on the expression of the disorder

Although onion thrips has been reported as a pest of cabbage since the late 1800s, plant resistance has been studied only recently. In a survey of varietal resistance to thrips in processing cabbage, Shelton *et al.* (1983) found that no commercial varieties were immune from damage but that substantial differences were found in the severity of damage and in the number of leaf layers injured. Stoner &

Shelton (1988a) concluded that resistance was caused largely by differences arising from the distribution of thrips on a plant. Thus, both susceptible and resistant varieties supported the same number of thrips, but the ratio of thrips on the head to frame leaves were lowest in resistant varieties before harvest. These differences remained when thrips numbers were adjusted using the head and frame dry weight as covariates to remove any effect of differences in head or frame size among varieties. These studies suggested that the observed reduction in thrips damage to cabbage is, at least, in part, the result of reduced thrips numbers in the head rather than a difference in the response (production of bronze and blistered areas) to thrips feeding or egg laying. They concluded that although there are differences among varieties in rates of growth and senescence, and thus the size of the head and frame leaves, the differences in resistance between the varieties is caused by other morphological or biochemical factors. A further study by Stoner & Shelton (1988c) was made to determine whether resistance was caused by non-preference, antibiosis, tolerance or a combination of these or whether it was a form of pseudoresistance. Stoner & Shelton (1988b) concluded that differences in preference were not observed in the laboratory but in field trials adult *T. tabaci* accumulated on heads of susceptible varieties in greater numbers than on heads of resistant varieties. Shelton *et al.* (1983) did the first study on varietal resistance to onion thrips in processing cabbage and discovered 'Hinova' was the most susceptible while 'Titanic 90' was resistant. In a later study in 1988 they concluded that commercial green varieties did differ in susceptibility to damage by *T. tabaci*. 'Supergreen' and 'Market Prize' were the most susceptible ones while 'Titanic 90' and 'Falcon' were the most resistant. Experimental varieties and one commercial red variety used for comparison varied in susceptibility to damage caused by *T. tabaci*. Observations by growers, and in seed company trials in Europe, indicated that there are differences in the response of cabbage varieties to *T. tabaci* attack. For example, the Dutch white cabbage varieties 'Slawdena', 'Polinius' and 'Bartolo' have been scored the most susceptible, while 'Rivera', 'Felix' and 'Zerlina' were found to be resistant.

Storage conditions

To maintain continuous supplies of cabbage during the winter the crop is stored. Most cabbages can be kept in natural air or 'common' storage (an insulated structure which is cooled with ventilation equipment) but refrigerated storage or controlled atmosphere storage (5% CO_2, 3% O_2) is preferred. The optimum storage environment for cabbage is about 1°C (-0.5 is the freezing point) and relative humidity above 95%; at temperatures above 1.7°C the crop may be damaged by fungal diseases. The quality of post-cropping treatments appears to be important in determining levels of oedema. Studies, on the effects of winter storage on thrips damage to cabbage by Stoner & Shelton (1988d) included the monitoring of changes in thrips damage in commercial storage over four months. These studies showed that the depth of very light damage increased for the variety 'Bartolo' but there was no significant increase in severity of damage per leaf or in overall level of damage. In further experiments thrips damage was compared in peeled samples of freshly harvested and stored cabbages in refrigerated storage at 2.2°C, slightly above the optimum, comparing two susceptible and two resistant varieties. The susceptible variety 'Supergreen' had significantly more leaves severely damaged and an increased depth of noticeable damage in storage, while 'Superdane' which is also susceptible, did not display these differences. Several factors during the study could have caused these differences. The resistant 'Titanic 90' also differed significantly in the level of damage during storage when compared with the other resistant variety 'Falcon'. The quality of the post-cropping storage environment seems to be important in determining damage. If the temperature is kept higher than the optimum, respiration increases during the senescence of leaves and the cabbage leaves pass through a phase of rapid chlorophyll and protein loss in the dark during which energy is released in the form of heat (Zhang, 1988). These factors may assist thrips survival in cabbage heads during storage and thus influence leaf damage during this period.

PREVENTION AND CONTROL

Growers are concerned about the presence of *T. tabaci*, or other thrips species, on plants because of the potential damage to the crop, the difficulty in controlling them once they move into the head and the difficulty in identifying them from other species in the field. This concern has led to prophylactic insecticide treatments for much of the cabbage crop (North & Shelton, 1986). Delaying planting from 6 June until 2 July significantly reduced damage on susceptible varieties. This evidence suggests that farmers can reduce thrips damage to cabbage by planting susceptible varieties late in the season as well as by making most use of resistant varieties.

In the evaluation of fungicides for control of ringspot and light leaf spot in Brussels sprouts, oedema was detected on leaves and its incidence was significantly reduced from 15% damaged leaf area in untreated plots to 0.7-0.5% by treatment with chlorothalonil (Gladders, Jones & Slawson, in press).

C. FIELD EXPERIMENT

Materials and Methods

Four varieties of Dutch white cabbage were chosen for a field experiment; 'Zerlina', 'Rivera', 'Polinius' and 'Slawdena' (Elsoms seeds). The first two varieties had been reported to possess high levels of resistance to oedema while the other two were reported to be highly susceptible (unpublished report).

Seed of the four cabbage varieties was sown on 27 May 1992 in 2 x 2 cm peat blocks in 308 Hassay trays and raised in the glasshouse. They were hardened off in a cool glasshouse. The cabbage plants were transplanted on 30 June 1992 in Pump Ground West at Horticulture Research International, Wellesbourne, and arranged in a randomised block design experiment, using 4 blocks with 4 plots per block. Each plot consisted of 8 x 5 rows, that is 40 plants of each variety spaced 50 x 50 cm apart within a plot.

On 14 July 1992 a light frame of pipework measuring 12 x 18 x 1 m was constructed around each of the four blocks and covered with Agralan Envirofleece (Agralan Ltd.), a non-woven synthetic material. This semi-permeable cover was used to exclude all large cabbage pests but to allow thrips to enter the enclosure.

With the use of a hand-sprayer, plants were treated with a 1% solution of Savona on 17 June 1992 to control the cabbage aphid and other pests that established on the plants in the first two weeks after transplanting. One of the four cages or blocks was selected as the control block and sprayed with 5 g deltamethrin/ha (2.5% a.i. EC; Decis, Hoechst) on the 14 August 1992 to eliminate all pests. No other insecticides or fungicides were used during the cultivation period. However, frequent visits were made to each cage to remove by hand all pests found on the plants and any weeds growing in the crop.

A culture of onion thrips, *T. tabaci*, was established in April 1992 in a polythene tunnel on Dutch white cabbage, chinese cabbage and onion. During the week 10 - 18 August 1992 about 7,000 *T. tabaci* were collected from this culture for release in the field cages. Fifteen *T. tabaci* at a time were collected with a pooter and transferred to polypropylene microcentrifuge tubes. These tubes were taken to the field and the content of each released on the test plants. The control block received no thrips inoculum.

On 17 November 1992 the cabbage heads were harvested. Four crates (A, B, C and D) 50 x 30 x 30 cm, were filled with similar-sized cabbage heads from each plot and labelled appropriately. Each of the boxes was enclosed in a polythene bag. These crates were packed in large wooden containers (A, B, C and D) and transported to a cold store maintained at 1°C. With this arrangement all four varieties and both treatments were represented in each wooden box to facilitate scoring during the storage period.

The damage was assessed over a period of four months (December 1992 - March 1993). Each month the content of one of the wooden containers was transferred from the cold store to the laboratory. Each cabbage head was weighed and the number of infested leaves per head counted. Also the presence of live and dead thrips in the cabbage heads was determined.

Results and Discussion

The results of this one-year study confirm that thrips cause the disorder known as oedema which occurs within the interior of Dutch white cabbage heads.

Live thrips and their damage were found on practically all cabbage heads with a significantly higher level in the cages which were inoculated with the insect. The presence of thrips and their damage on cabbage heads harvested from the control cage indicates how difficult it is to eliminate the insect from crops in the field.

There were significant differences between the cabbage varieties in the number of infested leaves per plant (Fig. 2) thus confirming the findings of growers. 'Zerlina' was the least damaged in this experiment.

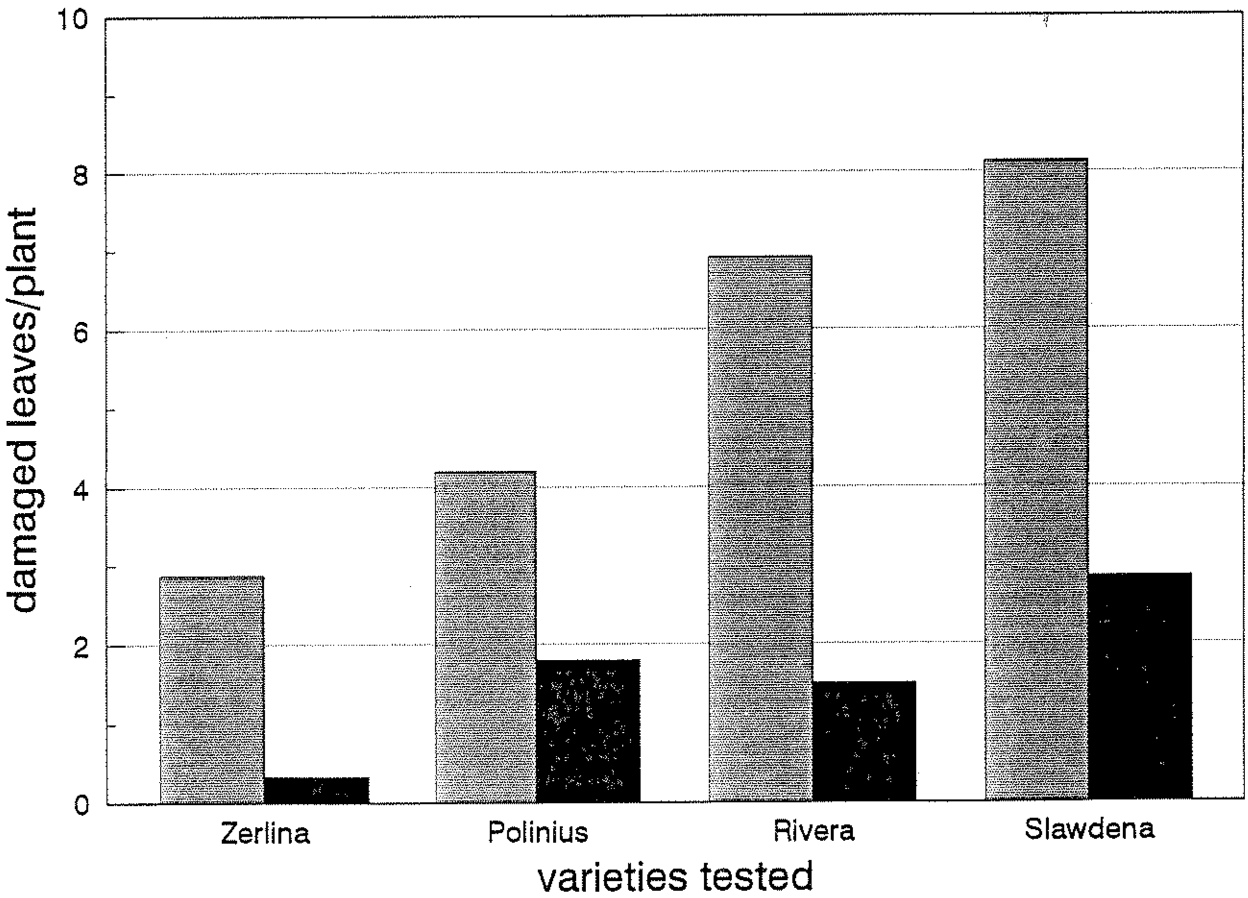

Fig. 2: **Number of leaves per plant damaged by oedema on treated (light grey) and not treated (dark grey) with thrips on the four Dutch white cabbage varieties used. Means of 12 replications (treated) and 4 replications (not treated) with S.E.M. 1.45 and 2.50 respectively.**

The reasons for the different level of resistance are not obvious. The density of cabbage head does not offer an explanation as 'Slawdena' (density class 8) (classes are 1, loose up to 9, most dense), which was the most severely damaged variety, has a denser head than 'Zerlina' (7) or 'Polinius' (7) (NIAB, 1992).

There was a significant difference between the assessments. This may have been partly due to the scoring method as in later assessments the outer leaves could not be scored as they had rotted and were discarded.

There were no interactions between the various treatments thus confirming the variety differences.

This 12-month preliminary study of oedema has reviewed the literature on the subject and has confirmed that the disorder can be caused by thrips. Quantitative evidence has been collected of significant differences between Dutch white cabbage varieties in their resistance to thrips. The experiment also showed that it is possible to inoculate plants in the field and induce oedema.

D. FUTURE STUDIES

It will be valuable to investigate, in a series of glasshouse, field and laboratory experiments, the following topics:

1. The effects of morphological characters, such as leaf thickness, prominence of leaf veins, thickness of wax layers, and how tightly the leaves are packed, on thrips colonisation.
2. The effects of physiological aspects of water content, speed of growth and gaseous exchange within the cabbage head on thrips development.
3. Biochemical differences in the leaves which might influence thrips

colonisation and development of oedema in the tissues.

Field studies on the relationship between thrips attack and cabbage varieties possessing different levels of resistance would be continued. Particular emphasis would be placed on water relationships in the plant and whether there is any scope for influencing oedema by manipulating water supplies to the plant during head formation and close to crop harvest. Future work would involve close collaboration between entomologists, plant physiologists and biochemists.

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