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THE PHENOMENON OF PHAGE MEDIATED PHAGE INDUCTION IN *ERWINIA "HORTICOLA"* AND THE ORIGIN OF BACTERIOPHAGES 49 AND 59

In this work a new phenomenon named phage mediated phage induction was described for the first time. It implies that exogenous unrelated bacteriophages provoke induction of endogenous phages in pseudolysogenic cells. The release of two temperate phages 49, 59 and one virulent phage E105 occurs as a result of interaction between amylovora-like non-pectolytic bacteria E. "horticola" and phage tail-like macromolecular carotovoricins, Escherichia coli phages T2 and T4. The consequences of phage mediated phage induction are always the same for all three inducing factors. The primary production of induced phages is carried out in a form of abortive infection with an abundance of such viral components as procapsids, separate capsids and tails. Unusual rounded structures with an ability to form conglomerates were observed in the lysates.

The mechanism of phage mediated phage induction is still unknown. However, it can be assumed that the population of E. "horticola" is pseudolysogenic and the induction of productive or lysogenic development of endogenous phages is initiated by some signaling mechanisms after adsorption and the following readsorption of an exogenous inducing phage.

In connection with phage mediated phage induction, the origin of temperate phages 49, 59 and virulent phage E105 was reviewed. They should be considered as phages of E. "horticola", rather than Pectobacterium (Erwinia) carotovorum.

Keywords: Erwinia "horticola", phages 49, 59 and E105, pseudolysogeny, phage mediated phage induction, abortive infection.

Phages 49, 59 and E105 have been previously described as temperate viruses of *Pectobacterium carotovorum* [11, 15]. However, it has not been reliably shown that these viruses are indeed bacteriophages of pectolytic *Erwina* [2]. The results of our studies suggest that phages 49 and 59 are unable to reproduce on any of the 104 *P. carotovorum* strains. In fact, there are two alternative ideas, which may explain the origin of phages 49, 59 and, possibly, the phage E105. Whether these phages are highly specific to sensitive bacterial hosts or they enter one of the pseudolysogenic states and are passed by semi-sensitive cells from generation to generation. In the first case, the functionality of the heterological system that includes phages of *P. carotovorum* and sensitive *Erwinia "horticola"(Eho)* strains appears highly unlikely, because phages rarely violate genus borders of the bacterial world [9]. According to our observations, unlike *P. carotovorum* the representatives of *E. "horticola"* do not produce pectolytic enzymes. On the other hand, *E. "horticola"* species is closely related to *E. amylovora* [1], which is phylogenetically remote from pectolytic erwinia, according to contemporary classification [8]. Thus, phages 49, 59 and E105 are characterized by a different origin than previously thought [15, 14] and, most likely, cannot be considered as bacteriophages of the "*carotovorum*" species. It can be assumed that *E. "horticola"* carries phages 49, 59 and E105

and is initially in the pseudolysogenic state which differs from normal lysogeny [7, 10]. Nevertheless, a more thorough study should be performed in order to get a detailed understanding of phage-phage and phage-bacterial interactions.

In this paper the authors aim to describe the phenomenon of phage mediated phage induction in the pseudolysogenic system of *E. "horticola"* and to review the origin of temperate phages 49 and 59.

Materials and methods. The objectives of this study were related temperate bacteriophages 49 and 59. Bacterial strains used in this research include *P. carotovorum* subsp. *carotovorum* (*Pcc*) (shown in table 1) and two isogenic strains (60 and 450) of non-pectolytic bacteria *E. "horticola"*. All bacterial strains were obtained from the collection of phytopathogenic bacteria of the Institute of Microbiology and Virology NAS of Ukraine.

Phage particles were propagated, purified and concentrated as described previously [16]. Individual phage lysates were concentrated by PEG-precipitation [17]. The DNAs of phages 49 and 59 were extracted according to the procedures described by Maniatis et al. [6]. Restriction analysis of phage DNAs was carried out as provided in Tovkach et al. [13]. Lysogenic induction was performed according to standard procedures [4]. EM images were obtained in accordance with [3]. Dot-hybridization is described in the Results section.

Results. The origin of phages 49, 59 and E105. Two types of sensitive cultures are used for biological detection of temperate bacteriophages, on which they should form turbid negative colonies. Sensitive strains can be obtained by curing a lysogenic strain of its prophage. But actually, this result is not quite that easy to obtain. In fact, the most common way is to use phage sensitive strains closely related to the lysogen.

This approach was applied in our earlier studies on lysogeny in L-asparaginase producing *P. carotovorum* 268R [14]. Phage sensitive strains have not been identified among the related strains of *P. carotovorum* subsp. *carotovorum* and *P. carotovorum* subsp. *astrosepticum*, as well as among other *Erwinia* genus members. They were found only among the strains of amylovora-like bacteria *E. "horticola"*.

According to the result of traditional spontaneous induction, induction with mitomycin C and the study of artificial lysogens as inducers, a conclusion was made that *Pcc* 268R lysates include three different phages 49, 59 and E105. The first two are homologous and heteroimmune temperate phages. The nature of phage E105 has not been completely defined. In addition, a considerable quantity of phage 69 forming clear plaques was detected. It was suggested that the phage 69 presents a clear-variant of the phage 49 [14].

However, considering the fact, that erwiniophages 49, 59 and E105 were obtained on bacteria *E. "horticola"*, there is no certainty that they are indeed pectobacterium phages.

Few other facts confirm the mentioned question. Firstly, despite the fact that phage E105 is characterized by twice shorter latent periods than phage 59, the induced lysates contained a prevailing quantity of phage 59 in comparison with phage E105 (85% against 4%). Secondly, none of highly concentrated phages (10^{10}-10^{12} PFU/ml) propagated on any of more than 100 *Pectobacterium* strains, which are much more related to *Pcc* 268R than *E. "horticola"*. On the other hand, *P. carotovorum* phage ZF40 is unable to lyse or to lysogenize none of 10 *E. "horticola"* strains.

These circumstances have served as a precondition for establishing the origin and looking for the true host of the phages 49, 59 and E105.

It was determined that 13 of 18 mitC-induced lysates form turbid negative colonies on the lawns of the two major sensitive strains *Eho* 60 and *Eho* 450. Three lysates generated plaques only on *Eho* 450 and two – on the *Eho* 60 strains (table 1).

Table 1

Phage negative colonies formation by the 19 mitC-lysates of 19 strains of *P. carotovorum* subsp. *carotovorum* on the lawns of *E. "horticola"* 60 and 450

Pcc lysates	Sensitive strain	
	Eho 60	*Eho* 450
3A,13A,15A, 18A, 19A, 33A, 42A, 55A, 66A, 70A, 9IIB, j13, 216	+	+
35A, 58A, g157	–	+
62A, 31A	+	–

Most of these phages were recloned on both strains *Eho* 60 and *Eho* 450, as well as on the lysogenic strains *Eho* 450(59) and *Eho* 450(49). These experiments proved the presence of only authentic phages 49 and 59, which was confirmed by restriction analysis.

The results obtained indicate that phages 49, 59 and, probably, E105 are not the viruses of *P. carotovorum* 268R. And the issue of their origin must be radically revised.

In order to finally prove that these phages are not pectobacterium viruses, dot-hybridization was used. Phage 59 DNA labeled by nick translation using [^{32}P] dATP was applied as a probe. Fig. 1 demonstrates that in contrast to the control hybridization experiments with the phage and artificially constructed lysogen *E. "horticola"* 60(59), phage sequences are not detected in the genome of *P. carotovorum* 268R. Since the homology between phages 49 and 59 is around 50% it is clear that prohage 49 would be easily detected in the genome of *P. carotovorum* 268R by means of ^{32}P-labeled DNA 59 probe.

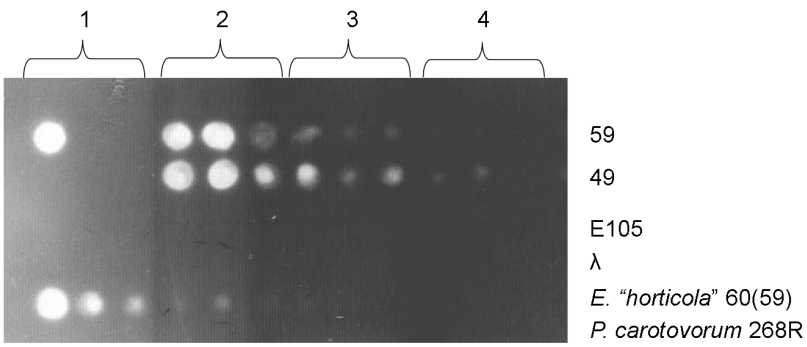

Fig. 1. Dot-hybridization of ^{32}P-labeled DNA of bacteriopage 59 with DNA of *P. carotovorum* and *E. "horticola"* 60 carrying prophage 59. Each row is divided into four sections (from 1 to 4), where the concentration of cold DNA decreases from left to right, in a ratio 6:4:3. The sample concentration reduces 10-fold in each following section. For example, the concentration of cold DNA has values 60, 40 and 30 ng in the row №1 and 600, 400, 300 pg in the row №2. ^{32}P-labeled DNA probe of phage 59 bound to a nitrocellulose membrane has a specific activity of 2×10^6 cpm/μg. Unlabeled DNAs of bacteriophages 49, 59 and lambda were applied as controls (indicated on the right).

Therefore, prophages of temperate phages 49 and 59 are not integrated in *P. carotovorum* 268R chromosomal DNA.

Macromolecular carotovoricins and phage mediated phage induction. The obtained data indicates that phages 49 and 59 are integral components of the population of amylovora-like phytopathogenic bacteria *E. "horticola"* and are typical for strains 450 and 60 [16]. It may be assumed that these phages are present in a carrier state or in a state of pseudolysogeny. They appear spontaneously after application of *P. carotovorum* lysate to bacterial cells.

It was further established which factors have an impact on bacterial cells and lead *E. "horticola"* pseudolysogenic system to a definite response – phage production.

Five reference strains of *P. carotovorum* (153, J2, 268R, 366, 216) were used for this purpose. Three types of lysates were obtained: spontaneous, mitC-induced and mitC-lysate concentrated according to the Yamamoto method [17]. As indicated in table. 2, the application of spontaneous lysates leads to sporadic and low output of phage plaques. MitC-lysates do not just increase the phage yield but also their diversity. The data obtained correlates with a considerable increase in the number of macromolecular carotovoricin (MCTV[12]) particles detected on sensitive strains of *E.coli* B, C600 and HB 101. This fact implies that MCTV particles act as the inducing factors for phage 49 and 59 release and pseudolysogenic state activation in *E. "horticola"* 60 and 450.

Table 2

Phage yield under the influence of macromolecular carotovoricins on the *E. "horticola"* 60 and 450 cells

Type of lysate	Sensitive culture	*Pcc* strain				
		Ec153	J2	268R	366	216
Spontaneous	*Eho* 450	–	1 pq	–	–	2 pq
mitC-induced	*Eho* 60	–	–	~ 10 pq	–	–
	Eho 450	1 pq	–	~ 10 pq	1 pq	×
	Eco B	–	+	–	+	–
	Eco C600	+	+	–	–	–
	Eco HB101	+	+	–	–	–
mitC-lysate, concentrated by PEG 6000	*Eho* 60	~ 10 pq	–	~ 10 pq	~ 10 pq	×
	Eho 450	–	~ 10 pq	~ 10 pq	~ 10 pq	×
	Eco HB101	+	–	–	–	×

"~", "×" means "approximately" and "unknown", respectively; "pq" – phage plaque; "+" – the presence of a lysis zone on the lawn of sensitive culture resulted by cooperative killing from the outside; "–" – the lack of any response. The abbreviations are explained in the text and in table 1.

The use of the same mitC-lysates concentrated by the Yamomoto procedure finally confirmed the assumption of phage-inducing ability of carotovoricins. Phage yield increases almost 10-fold and is not sporadic (table 2).

Participation of exogenous bacteriophages in phage mediated phage induction. Phage tail-like bacteriocins are quite unstable structures [12]. They can be destroyed by various effects including PEG 6000 concentration with the subsequent chloroform treatment. Table 2 reveals that the concentrated J2 lysate containing MCTV does not lyse the *E.coli* HB101 cells. This significantly hinders the investigation of pseudolysogeny and phage-inducing effect of MCTV.

Considering this, we tried to find other exogenous factors with similar influence on the *E. "horticola"* pseudolysogenic system.

Coliphage T2 was chosen as an exogenous factor of phage mediated phage induction due to the structural similarity between the phage tail and MCTV, and its ability to adsorb to the *Eho* cells.

Phage T2 was used at a concentration of approximately 10^{12} PFU/ml. It was possible to obtain up to 10^5-10^6 particles of the induced endogenous phage under the action of phage T2 by applying 5 μl of lysate on the *Eho* 60 lawn. Significant yield of viable phage particles was obtained by confluent lysis method. Phage 49 and 59 induction has occurred not only under the influence of highly concentrated phage suspensions, but also in the case of the exogenous phage particles purified in a caesium chloride gradient.

A number of conclusions can be drawn from the analysis of phage content in caesium chloride gradient fractions. The isolate of exogenous phages includes at least two types of particles with density 1.44 and 1.48 g/cm^3. It is also possible that the mixture contains phages similar to E105 phages with a higher density than 1.5 g/cm^3, which was not determined in this work. The data presented in Fig. 2 and data obtained in independent control experiments suggest that T2 is not able to propagate in the *Eho* 450 cells but rather launches the process of phage mediated phage induction via reversible adsorption of phage particles on cell surfaces.

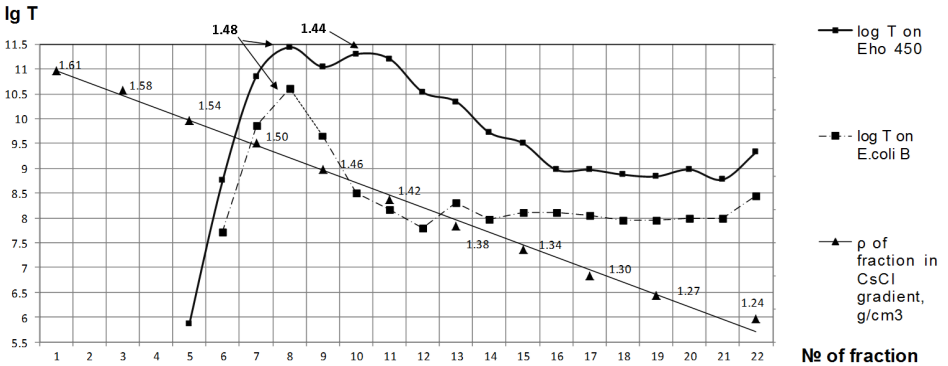

Fig. 2. Analysis of CsCl gradient fractions phage content.

It was also noted that the induced mixture contains plenty of clear-mutants of 49 and 59 phages in the quantity up to several percentages. So many clear-mutants cannot be explained according to classical genetics which sees mutation as a quite rare phenomenon.

The contents of the lysate and its separate fractions are illustrated by the micrographs in Fig. 3 and 4. They revealed that the phenomenon of phage mediated phage induction is an active morphogenetic process.

Two types of procapsids (Fig. 3, PcI, PcII) forming prior to DNA-packaging initiation are indicative of particle assembly. DNA-filled mature capsids (Mc) look like regular icosahedral structures similar in size and shape to the capsids of complete virions. Phages devoid of DNA (so-called "ghost") are quite

common as demonstrated by micrographs. Possibly, these structures represent secondary transformed virions, which have lost their DNA due to a violation in tail assembly, perhaps in the basal plate.

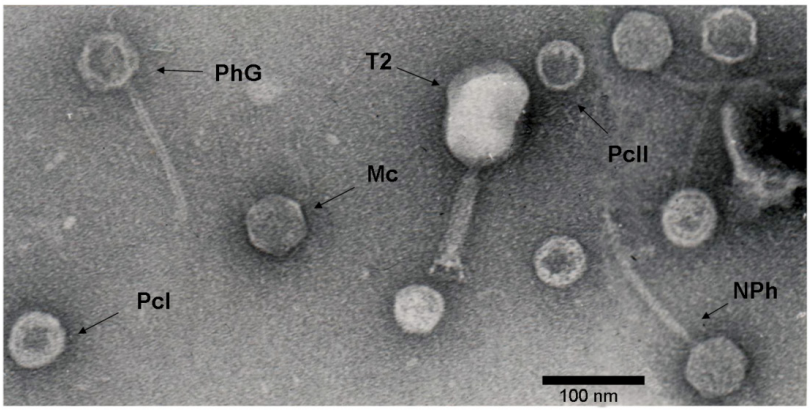

Fig. 3. EM micrographs showing the T2-affected *E. "horticola"* lysate. NPh – native phage particle, T2 – T2 phage particles; PcI, PcII – procapsids I and II; PhG – phage "ghost"; Mc – mature capsid.

The virion morphogenesis and morphopoiesis are known to be effective and complete stages of assembly in the case of normal infections. We were able to show that normal virions of the phage 59 "pure line" significantly dominate over the intermediate assembly products. Therefore, the EM data imply that the formation of viable phage particles during phage mediated phage induction can take place in form of abortive infection.

As a result of interaction between T2-particles and cells of *E. "horticola"* 450, different macromolecular structures are found in addition to normal phage virions and their structural components (Fig. 4). They appear as round-shaped particles of 17-19 nm, which form conglomerates. Some of these conglomerates remind "a bunch of grapes". Rounded particles have a tendency to be grouped together near the "phage ghosts" (Fig. 4A, B). It is likely that this grouping near the hollow capsids is preceded by conglomerate formation (Fig. 4 C, D). These observations have allowed to suggest a connection between the round-structured particles and the phage mediated phage induction. They are not produced under normal productive infection with the participation of phage 59 and *E. "horticola"* 450.

The *Eho* 450 lysates containing phage tail-like particles are illustrated by the micrographs in Fig. 4A and B. There are two types of such structures: flexible (Fig. 4A and B) and rigid. In some cases, the length of these structures greatly exceeds the one of phages 49 and 59 native tails (168 nm). Unlike the hollow capsids, tail-like structures are not surrounded by round-shaped formations (Fig. 4).

T4D phage and its amber mutant in gene 23 unable to form capsids on permissive strain *E. coli* B^E were used in the following series of experiments. This mutant yields normal progeny on the suppressor host *E. coli* CR63.

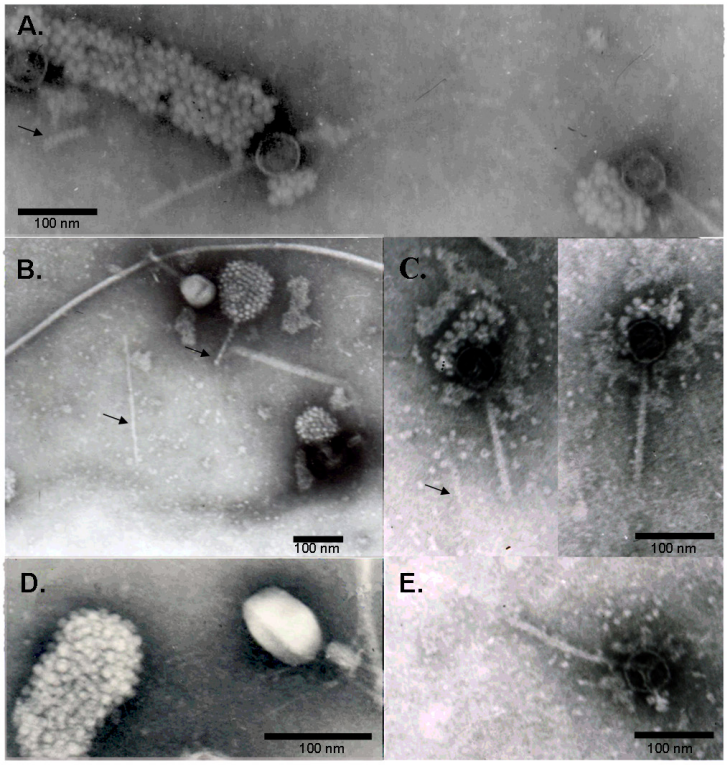

Fig. 4. Unusual particles found in T2-lysate of *E. "horticola"*. Arrows indicate phage tail-like structures.

To exclude the effect of other possible factors that could influence phage mediated phage induction, both phages were purified in caesium chloride gradients.

Then their tenfold dilutions were spotted on the lawns of *Eho* 60 and 450. The titers were determined simultaneously on the relevant strains of *E. coli*. Clear plaques (clear-phenotype) were easily identified in comparison with the plaque of turbid-phenotype. Table 3 presents the results of concentration calculations and induction frequency of two endogenous phages.

Table 3

The titer and frequency of induced endogenous phages with turbid (tu) and clear (cl) plaque phenotype formed on pseudolysogenic strains of *E. "horticola"* 60 and 450

Exogenous phage-inducer	The sensitive strain of *E. coli*		Pseudolysogen: endogenous phage *			
	B^E	CR63	*Eho* 60		*Eho* 450	
			cl	tu	cl	tu
T4D	5×10^{10}	–	1×10^{6} / 2×10^{-5}	6×10^{6} / 1.2×10^{-4}	–	2×10^{7} / 4×10^{-4}
T4D23^{-}	–	4×10^{11}	1×10^{7} / 2.5×10^{-5}	–	2.7×10^{7} / 6.8×10^{-5}	–

* – virus titers are expressed in plaque forming units (PFU/ml); the induction frequency of endogenous phages is shown through "/"; "–" means "no data obtained", "cl" and "tu" – clear- and turbid-phenotype, respectively.

It was determined that the clear-variants yield is always less than the yield of phage with turbid negative colonies. However, the amount of the first phage reached significant quantities and constituted about 20% of the total phage pool obtained using phage T4D. The same rate is typical for the phage yield of clear-variants in case of phage T4D23$^-$ influence on the pseudolysogenic cells. We found no significant difference in endogenous phage production between strains *E. "horticola"* 60 and 450.

Hence, the provided results clearly confirm that phage mediated phage induction is provoked only by exogenous T4-particles.

Next, eight pure lines of turbid- and clear-plaque phages were isolated. Their virion DNAs were digested by restriction endonucleases *Eco*RI, *Pvu*II and *Hpa*I. The studied phages were characterized by restriction patterns identical to authentic phages 49 and 59 induced by macromolecular carotovoricin of *P. carotovorum* 268R. No derivatives of phage 49 (analogue of phage 69 [14]) were found among randomly selected clear-variants.

Both the *Eho* 60 (one variant) and the *Eho* 450 (two variants) strains produced mainly the 59-like plaques. The ratio between turbid plaque phages 49 and 59 is 1 (3:3) and they are produced by both *Eho* starins in equal proportion.

Summarizing the key results of the comparative study of exogenous phage-inducers (MCTV and coliphages T2 and T4), the following conclusions can be drawn. Firstly, all these factors force pseudolysogenic strains *E. "horticola"* 60 and 450 to produce endogenous phages. At the same time, only two phages are induced and accompanied by considerable yield of clear-plaque variants unable to lysogenize pseudolysogenic cells. The state of clear-plaque phages still remains unclear. Whether they are carried by the cells or are formed as extremely often mutants in the process of phage mediated phage induction. Secondly, the induction frequency is low and sporadic in the case of MCTV, while phages T2 and T4 are capable of carrying out this process with a much higher probability. Thirdly, the ratio between phages 49 and 59 can vary in the case of MCTV-inducers, T4 and T2. In the last two cases the ratio is close to 1.

We did not focus on the phage E105 yield during phage mediated phage induction. However, such viruses were detected by electron microscopy in some primary fractions of T2-induced lysates (Fig. 2). Their separate study is an important step in the subsequent description of phage mediated phage induction.

To describe the mechanism of this phenomenon, dynamics of the endogenous phage release provoked by the interaction between T4D and *E. "horticola"* 60 was studied. As shown in Fig. 5, the interaction process starts with T4 particles adsorption. This process lasts approximately 50 minutes. Phage particles remain attached to cells for about 30 min. T4-particles readsorb within the next 40 min and the maximum level of readsorbtion is approximately equal to the primary level of unadsorbed phage. Interaction of exogenous phage and *E. "horticola"* 60 cells takes approximately two hours under infection multiplicity of 100 PFU/ml. Induced endogenous bacteriophages with turbid-phenotype appear after complete adsorption of phage T4. The existence of phage mediated phage induction signaling mechanisms in pseudolysogenic system of *E. "horticola"* is confirmed by coinciding titer increase and readsorption dynamics.

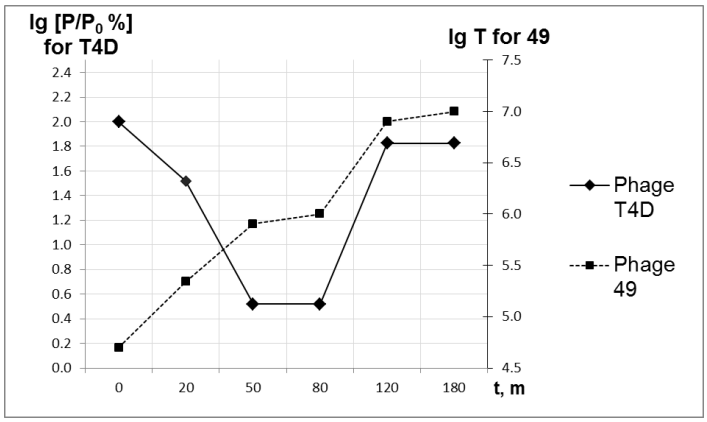

Fig. 5. Adsorption of T4D on bacteria *E. "horticola"* 60 and the endogenous bacteriophage yield. lg[P/P$_0$%] – logarithm of unadsorbed phage percentage, T – phage titer in PFU/ml.

Summary. In this work the phenomenological evidence of a fundamentally new phenomenon of phage mediated phage induction is presented. This phenomenon implies that, exogenous unrelated phage may activate bacterial cells through the receptor system and initiate endogenous phage progeny production. This endogenous phage is not related to the inducing phage and presents an integral part of the phage-bacteria system. The induced endogenous phage may be temperate (phages 49 and 59) or virulent (phage E105).

Three types of inducing exogenous phages were used for studying the phenomenon of phage mediated phage induction. The first type is the defective temperate phages of pectolytic phytopathogen *P. carotovorum* subsp. *carotovorum* (former *E. carotovora* subsp. *carotovora*). These phage particles are produced by erwinia treated with mitomycin C or nalidixic acid and represent phage tail-like structures with an ability to kill related strains of *Pcc* [4]. They were previously named as macromolecular carotovoricins (MCTV).

MCTV-particles interact with the cells of amylovora-like non-pectolytic bacteria *E. "horticola"* and force them to produce viable phages of B1 and C1 morphotypes. MCTV produced by 23 strains of *P. carotovorum* subsp. *carotovorum* stimulate induction of temperate phages 49 and 59 when interacting with two strains *E. "horticola"* 60 and 450.

Some aspects of phage mediated phage induction were studied using the well-known coliphages T2 and T4 which tails are very similar in structure to defective phages of *P. carotovorum*.

It has been shown that phage mediated phage induction undergoes similarly to the abortive infection. The interaction of phage T2 and bacterium *E. "horticola"* 450 resulted in normal viable phage production along with generation of separate virion components - procapsids capsids, tails and rounded particles which tend to gather into conglomerates. Their origin and nature remain unknown.

As shown for T4, the phage interaction with the cells of *E. "horticola"* 60 includes two stages. Initially, phages adsorb on bacterial cell surface and later readsorb. The induction of the main endogenous phage with B1 morphotype occurs during readsorbtion.

The diagram from Fig. 6 is intended to explain the phenomenon of phage mediated phage induction.

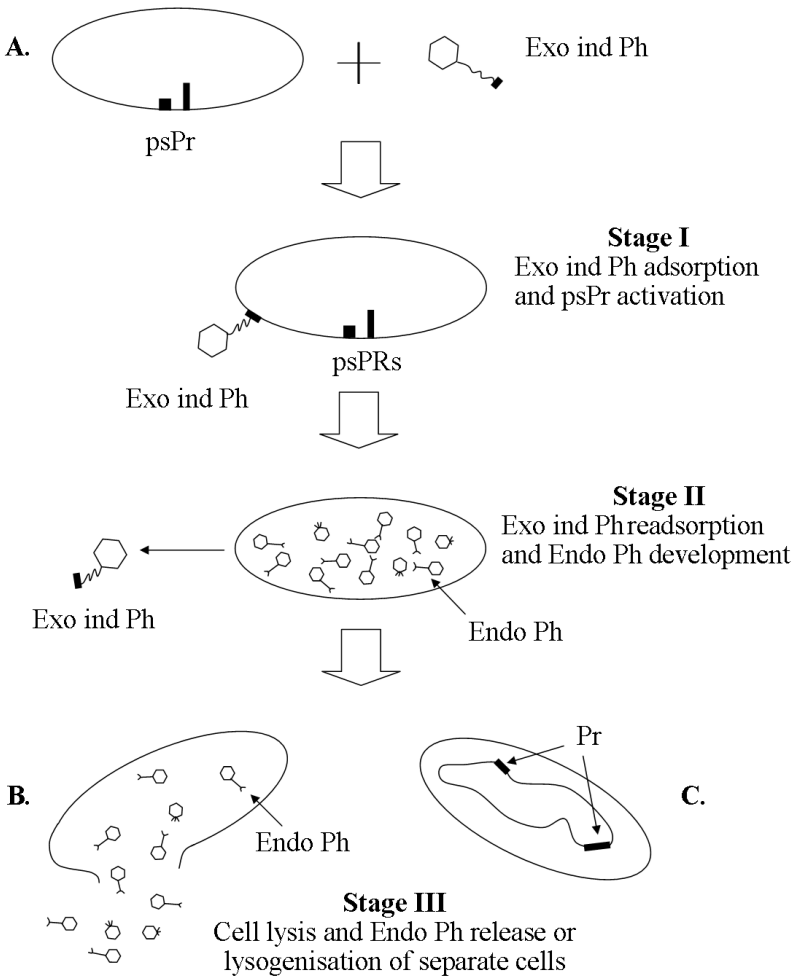

Fig. 6. The scheme of phage mediated phage induction. Exo ind Ph – exogenous phage-inducer; psPr – pseudophage; Endo Ph – endogenous phage; Pr – prophage.

Presumably, phages 49, 59 and E105 are in the carrier state and in a certain way associated with the host cell (Fig. 6, A). This state fundamentally differs from the true lysogeny as, in this case, the cell is not immune to homological bacteriophages and able to maintain its productive development (B), or becomes a true lysogen (C) if the phage is temperate. On our opinion, research of the cell lysogenisation stage can provide the key evidence in support of the presented visualization.

Therefore, the studied bacteriophages could be named pseudoprophages based on the fact that they are unable to be induced without the action of such endogenous factor as a phage contractile tails. Repeated attempts to induce pseudoprophage by substances affecting cell membrane and shell (SDS, deoxycholate, Triton x100) have failed.

The obtained data suggests that exogenous phage-inducers engage their tail

fibers when initiating phage mediated phage induction. The fact of reversible adsorption confirms this assumption.

In addition, there are single particles of T2 with contracted tails on the microphotographs. It still does not prove that phages of B-morphotype are able to induce pseudoprophages in *E. "horticola"*.

The study of pseudoprophage state is interesting, and specification whether it is an extracellular or intracellular condition and whether phages 49 and 59 are able to establish this state in model studies could shed light on this phenomenon.

Abortive character of the primary infection after induction is particularly revealing. And this fact complements the data of ecological studies reporting about the predominance of virus-like particles (VLP) over normal viral particles. It is possible that this type of infection, including pseudoprophage induction, is widespread in many ecological systems of land and oceans [5].

In this paper we have shown that the adequate sensitive cultures related to the lysogen are needed for searching and studying temperate phages. However, obviously, it is also impossible to get reliable results, since bacteriophage populations present a labile system adapting to the new conditions and new host [9]. Curing of a lysogenic strain is, therefore, a necessary condition for studying lysogeny in such bacterial cultures.

In relation to this, we revised the origin of temperate phages 49, 59 and virulent phage E105 which actually are the viruses of *E. "horticola"* instead of *P. carotovorum.*

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ЯВИЩЕ ФАГ-ФАГОВОЇ ІНДУКЦІЇ У *ERWINIA "HORTICOLA"* І ПОХОДЖЕННЯ ФАГІВ 49 І 59

Резюме

В роботі вперше описано явище, яке автори означили як фаг-фагову індукцію. Його суть полягає в провокуванні виходу ендогенних фагів з бактеріальної псевдолізогенної клітини під дією екзогенних неспоріднених бактеріофагів. Продукція двох помірних фагів 49 і 59, а також вірулентного фага Е105 відбувається в результаті взаємодії фітопатогенної, аміловороподібної бактерії *Erwinia "horticola"* з каротоворицинами типу фагових хвостових відростків, а також фагами Т2 і Т4 *Escherichia coli*. Наслідки фаг-фагової індукції за участю всіх трьох ендогенних факторів являються однаковими. Первинне утворення фагів внаслідок індукції відбувається по типу абортивної інфекції з утворенням надлишку таких компонентів віріона, як прокапсиди, окремі капсиди і хвостові відростки. В лізатах спостерігаються незвичайні

сферичні утвори, ймовірно, фагової природи, котрі збираються в конгломерати різноманітної форми та розмірів.

Механізм фаг-фагової індукції поки залишається невідомим. Однак можна припустити, що популяція *E."horticola"* являється псевдолізогенною, а індукція продуктивного чи лізогенного розвитку ендогенних фагів запускається за сигналінговим механізмом після завершення адсорбції екзогенного індукуючого бактеріофага та його подальшої реадсорбції.

З огляду на явище фаг-фагової індукції здійснено перегляд походження фагів 49, 59 і E105, які мають розглядатися як фаги *E."horticola"*, а не *Pectobacterium (Erwinia) carotovorum*.

Ключові слова: E."horticola", фаги 49, 59 і E105, псевдолізогенія, фаг-фагова індукція, абортивна інфекція.

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ЯВЛЕНИЕ ФАГ-ФАГОВОЙ ИНДУКЦИИ У *ERWINIA "HORTICOLA"* И ПРОИСХОЖДЕНИЕ ФАГОВ 49 И 59

Резюме

В работе впервые описано явление, которое авторы обозначили как фаг-фаговая индукция. Его суть состоит в провоцировании выхода эндогенных фагов бактериальной псевдолизогенной клетки при воздействии на нее экзогенных неродственных бактериофагов. Выход двух умеренных фагов 49 и 59, а также вирулентного фага E105 происходит в результате взаимдействия фагопатогенной, амиловороподобной бактерии *Erwinia "horticola"* с каротоворицинами типа фаговых хвостовых отростков, а также фагами T2 и T4 *Escherichia coli*. Последствия фаг-фаговой индукции с участием всех трёх эндогенных фагов являются одинаковыми. Первичное образование фагов вследствие индукции идет по типу абортивной инфекции с образованием избытка таких компонентов вириона, как прокапсиды, отдельные капсиды и хвостовые отростки. В лизатах наблюдаются необычные округлые образования, вероятно, фаговой природы, которые собираются в конгломераты различных форм и размеров.

Механизм фаг-фаговой индукции пока неизвестен. Однако можно предположить, что популяция *E. "horticola"* является псевдолизогенной и индукция продуктивного или лизогенного развития эндогенных фагов запускается по сигналинговому пути после завершения адсорбции экзогенного индуцирующего бактериофага и его последующей реадсорбции.

В связи с фаг-фаговой индукцией сделана ревизия происхождения фагов 49, 59 и E105, которые должны рассматриваться как фаги *E. "horticola",* а не *Pectobacterium (Erwinia) caratovorum*.

Ключевые слова: Erwinia "horticola", фаги 49, 59 и E105, псевдолизогения, фаг-фаговая индукция, абортивная инфекция.

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