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FACTORS INFLUENCING THE ROLE OF *BACILLUS THURINGIENSIS* SUBSP. *ISRAELENSIS* IN MOSQUITO CONTROL IN ITALY

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ABSTRACT

Mosquito control in Italy has been misconceived for the last decades as a consequence of the loss in the significance of mosquitoes as vectors of disease. Control programs are generally carried out at a local level by public agencies or private companies, without sufficient professional competence and in the absence of any cost/benefit evaluation. In the majority of cases, the basic organizational preconditions for the efficient use of *Bacillus thuringiensis* subsp. *israelensis (Bti)* do not exist. Data on Italian mosquito control programmes using *Bti* show its effectiveness and economic sustainability, and demonstrate its low environmental impact.

KEYWORDS: Mosquito control, Italy, *Bacillus thuringiensis* subsp. *israelensis*, resistance, *Aedes caspius*, *Culex pipiens*.

INTRODUCTION

The most dangerous human disease vectored by mosquitoes in Italy — malaria, which seriously endangered people's lives for centuries — was eradicated in this country just after World War II (Raffaele, 1964; de Zulueta, 1973). Following this important achievement, mosquitoes lost much of their relevance for public health and are now regarded mainly as a public nuisance problem. In fact, other vector-borne diseases, such as Mediterranean arboviruses (Verani et al., 1979; Vesenjak-Hirjan et al, 1980) or dirofilaria (Genchi et al., 1988; Pampiglione et al., 1991) do not currently represent a serious threat to human health.

As a consequence, attention to mosquito control has become a secondary concern in comparison with the other problems local administrations have to confront. While it is difficult to generalize, as socio-economic conditions vary considerably between Northern and Southern Italy, it is clear that one of the negative effects of this situation is that agencies in charge of mosquito control have progressively lost their professional competence. Public agencies are usually responsible for a range of public services, such as water depuration and urban waste collection. In the absence of a strong motivation to pursue rational mosquito control campaigns and to keep up-to-date with developments of newly available technologies, they have ended up by considering mosquito control as a secondary concern.

Often public administrators do not have the technical competence nor the resources needed to assess the quality of the operations carried out by agencies, and financial resources are more

TABLE 1
Example of a public tender for a mosquito control campaign held by a municipality in Northern Italy in 1996

1. Adulticide control only, by means of chemicals (permethrin, tetramethrin, deltamethrin) directly supplied by the contractor.
2. One treatment only of the catch basins performed in the first half of May.
3. Adulticide treatments over the entire urban area were scheduled as follows:

May 15–31	one spraying per week
June	two sprayings per week
July	three sprayings per week
August	four sprayings per week
September 1–15	two sprayings per week
September 15–30	one spraying per week

Main problems

- high environmental impact
- hazard to human health?
- no link between control activities and seasonal development dynamics
- no field control of the private operators
- no evaluation of the results by regular monitoring activities

commonly allocated on the strength of historical precedents than in relation to real need. This often means that money is wasted without any cost/benefit evaluation.

The situation is even worse when mosquito control operations rely on private companies. The bureaucratic procedures involved in setting up a public tender are complex and time-consuming, prompting public officials to continue using old-fashioned and often obsolete methods. The example summarized in Table 1 refers to a public tender held in 1996 by a Municipality in Northern Italy (a rural town with about 15,000 inhabitants) where, after a one-year experience in integrated control policies, it was decided to turn to adulticide control strategies. The main causes of this shift were difficulties in persuading rice growers to cooperate in the integrated control program, and political reluctance regarding the financial effort needed to support larval control in the surrounding rural areas.

MAIN MOSQUITO CONTROL PROJECTS IN ITALY

This article aims to analyse the current Italian situation from a technical point of view, trying to find answers to a question that is becoming more and more pressing for those who have to deal

with mosquito control. The question can be put simply: why are the best available mosquito larvicides so much less used than expected?

To analyse the importance of the issue on the basis of objective data, I have collected information on the most important mosquito control projects currently under way in Italy. Table 2 roughly summarizes the most significant data recorded over the last three years.

One point that needs to be stressed concerns the difficulties municipalities have experienced in participating in joint programmes with neighbouring communities. This problem is present throughout the country and is rooted in the history of Italian "free cities," when towns used to wage wars one against another. While it is well known that, in order to maximise organizational efficiency, mosquito control programs based on larval control need to be implemented over large areas, involving a number of municipalities, this is often made impossible by local political controversies.

Table 2 also indicates that *Bacillus thuringiensis* subsp. *israelensis* (*Bti*) is used mainly in Northern Italy, (as well as in Sardinia, where an organized mosquito control public service is continuing operations after the institutional re-organization of the Regional Service for the Anti-Anopheles Campaign established in 1946, with the aim of eradicating *Anopheles labranchiae* Falleroni.

This is due to the marked differences in socio-economic conditions between Northern and Southern Italy. In particular, only some Northern local administrations are able to allocate resources to mosquito control rather than to the many other problems they have to deal with. In the South, lower standards of living mean that citizens are more tolerant of mosquito noxiousness, and the low level of environmental consciousness does not give rise to a sufficiently deep concern to promote safe mosquito control methods.

From Table 2 it is also apparent that, where *Bti* is used, its contribution to overall mosquito control projects is important and sometimes unique.

In the case of a mosquito control project implemented in the Bologna province, an irrigated agricultural area of about 700 km^2 in the Po plain, mosquito control activities rely exclusively on larvicide campaigns. *Bti* products have been used since 1986, when the project was started in one municipality, and currently represent about 95% of the total larvicides used (5% is represented by temephos, used in catch basins only). The results obtained through mosquito control are highly satisfactory, according to surveys of citizens' opinions and in the light of the results of the adult monitoring campaigns regularly conducted with CO_2 traps (Fig. 1).

In the case of Comacchio, a tourist resort in the Po delta, the role of *Bti* has increased noticeably since the start of the project in 1991, and a significant reduction in the use of adulticides has been achieved (Table 3). Adult mosquito densities estimated by comparing annual collections obtained by CO_2 traps provided satisfactory results, indicating a reduction of more than 90% in comparison with the first year of activities (Bellini and Veronesi, 1994) (Fig. 2). The experience of the Comacchio project suggests another consideration: larvicide control in general, and with *Bti* in particular, is much more demanding than adulticide treatment in terms of operators' performance and their motivation. Work conditions are often very harsh, especially during the hot Italian summer, and due to the dispersion of breeding sites highly trained staff is required. The reduction of environmental impact in the Comacchio project has been achieved thanks to continuous efforts in motivating operators. However, the same conditions do not apply to many other projects in Italy.

TABLE 2
Main mosquito control projects in Italy (data refer to yearly averages recorded during the last three years)

Area (Region)	Breeding sites (ha)	*Bti* used (lt or kg)	Share of *Bti* (%)	Target species
1. Avigliana (Piemonte)	60	30L + 90P	100	*Ae. sticticus, Ae. vexans, Ae. caspius*
2. Viverone (Piemonte)	30	100L	100	*Ae. sticticus, Ae. vexans, Ae. caspius*
3. Verona (Veneto)	?	350L + 400G	50	?
4. Grado (Friuli)	200–400	200L + 500G	70	*Ae. caspius*
5. Palmanova (Friuli)	22 streams	800L	100	*Wilhelmia paraequina*
6. Comacchio (Emilia-R.)	400 + 460 km of canals	5,100L	70	*Ae. caspius, Ae. detritus, Cx. pipiens*
7. Ravenna (Emilia-R.)	500	1,000L + 300G	20	*Ae. caspius, Ae. detritus, Cx. pipiens*
8. Bologna (Emilia-R.)	?	4,600L	95	*Cx. pipiens, Ae. caspius*
9. Cesena (Emilia-R.)	250 km of canals	700L	80	*Cx. pipiens*
10. Savignano (Emilia-R.)	150 km of canals	300L	95	*Cx. pipiens, Ae. caspius*
11. Nuoro (Sardegna)	?	50G + 40L	2	*Cx. pipiens*
12. Cagliari (Sardegna)	?	1,500G + 300L	15	*Cx. pipiens*

L = Liquid formulation; P = powder formulations; G = granular formulations; ? = data not known.

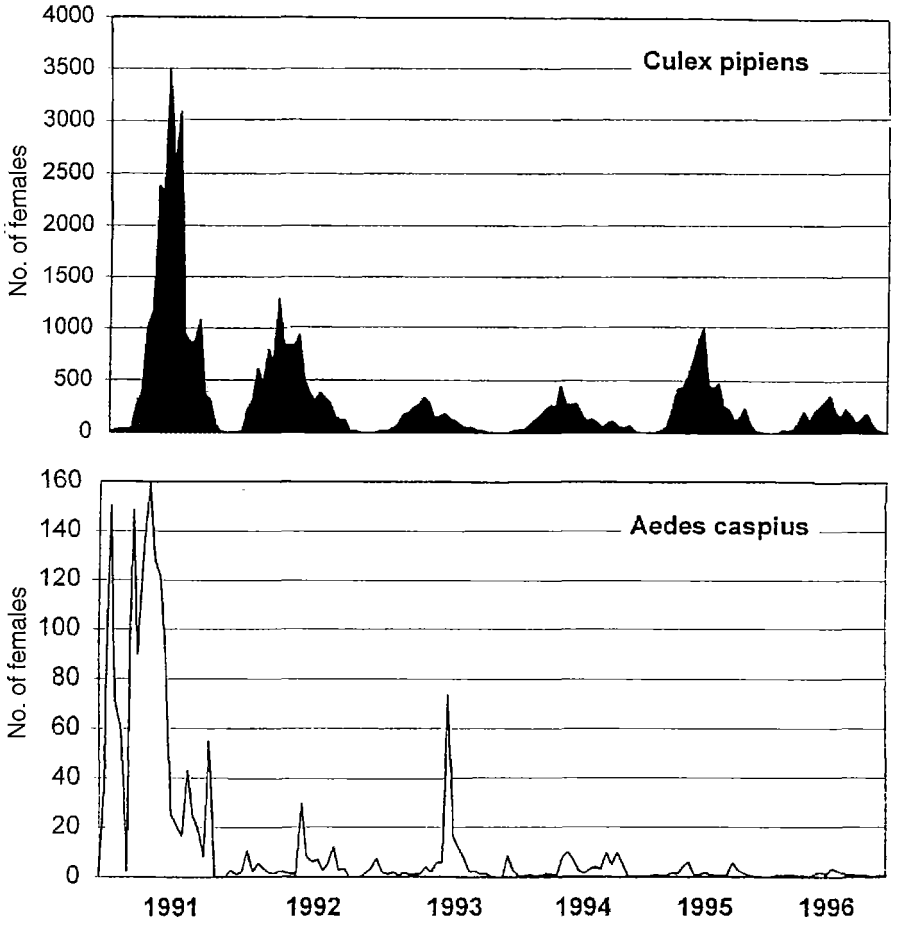

Fig. 1. Pattern of seasonal mosquito dynamics detected by weekly sampling with CO_2 traps in the mosquito control project in the Bologna province (1991: 390 km^2, 7 trap stations; 1992: 533 km^2, 11 stations; 1993: 599 km^2, 18 stations; 1994: 644 km^2, 21 stations; 1995: 693 km^2, 22 stations; 1996: 706 km^2, 22 stations).

TABLE 3
Products used in the Comacchio mosquito control project

	1991	1992	1993	1994	1995	1996
Bti liquid (lt)	719	724	1,734	2,259	4,661	4,722
Bti granular (kg)	0	0	90	160	307	160
Chemical larvicides (kg)	108	271	473	97	96	82
Adulticides (kg)	5,092	2,478	1,468	2,461	2,276	1,638

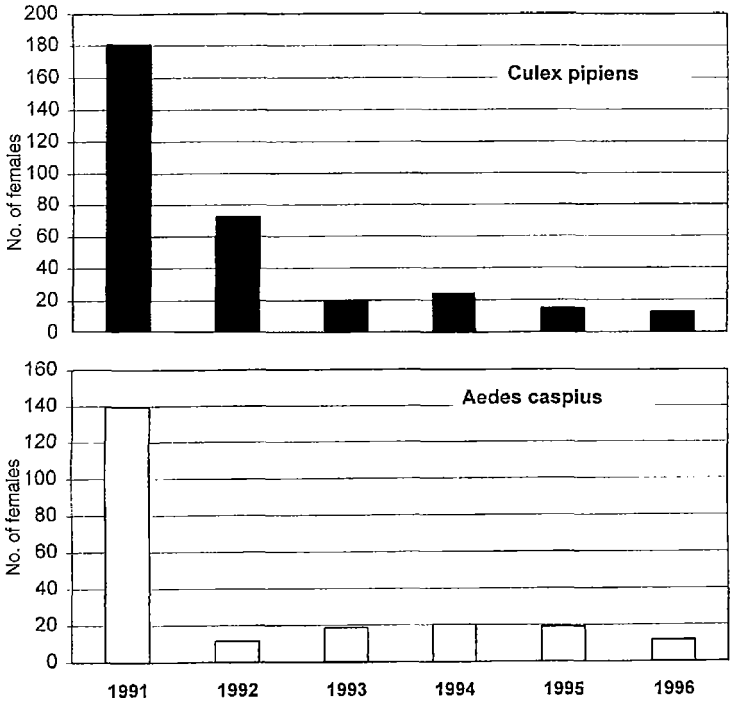

Fig. 2. Seasonal mosquito density averages detected by sampling with CO_2 traps in the Comacchio mosquito control project (1991: 250 km^2, 10 stations, one weekly sampling; 1992-93-94-95-96: 250 km^2, 16 stations, three weekly samplings).

CONCLUSIONS

An argument often raised against the utilization of *Bti* is its cost/benefit ratio, not always considered satisfactory. This is a very complex issue to analyse in depth, especially because it is very difficult, if not impossible, to quantify the advantages of minimising environmental impact. Moreover, every area has specific mosquito problems and different strategies have to be implemented to ensure cost-effective control. In countries such as Italy, where mosquitoes are not a serious public health hazard, it should be possible to work towards the goal of mosquito control by reducing environmental as well as human health risks that may derive from it. Those in charge of mosquito control programmes should make every effort to improve life quality and, no doubt, the reduction of environmental pressure is an important objective in this work. I am convinced that environmental precautions should be part of the policies adopted, rather than an obligation imposed by law or by public opinion pressure. This is especially true where mosquitoes do not represent a sanitary hazard.

To return to the issue of finances, we can consider as an example the situation of the low-lying lands around Bologna, where the main problem is represented by *Culex pipiens* L. and *Aedes caspius* (Pallas) breeding in ditches and irrigation canals. A total of about 440 km of canals are regularly treated with *Bti* only, at 5 to 7 day intervals (depending on water

temperature). The global cost of the project in 1995 was approximately 0.5 mill. US$. The cost of the project when switching to a chemical larvicide like temephos, can be estimated at 0.4 mill. US$, viz., a reduction of about 20%, deriving mainly from the greater residual activity of temephos in comparison with *Bti* and the consequent reduction in the number of treatments needed.

Distribution costs are certainly the main factor affecting *Bti* use. To reduce the incidence of labour, we developed an overland vehicle specifically designed to spray canals and ditches. The results obtained with the hydraulic telescopic arm mounted on it are very satisfactory. A single operator, rather than the two normally required, can simultaneously drive the vehicle and operate the spraying equipment. A camera located on top of the arm shows the exact position of the sprayers. Moreover, the sprayers working vertically on the water to be treated achieve better penetration in breeding sites thickly covered by vegetation, thus reducing waste and increasing the efficacy of the products.

In areas where 20–24 treatments/year were performed against *Cx. pipiens*, we can estimate that about 220 treatments were performed with *Bti* since its introduction. Periodical checks on the sensitivity level of the target population provided satisfactory evidence of complete sensibility (Fig. 3) thus confirming that the target species finds it difficult to develop resistance to *Bti* toxins.

What hope is there for the future? Formulations must be improved to increase residual activity against multivoltine species such as *Cx. pipiens*. Even a small increase in residual activity may result in a greatly improved performance under the operational point of view, allowing the adoption of *Bti* in more mosquito control programmes.

Moreover, in situations such as rice fields (covering about 240,000 ha in Italy), which are only now starting to be targets of mosquito control activities, the distribution of *Bti* by airplane

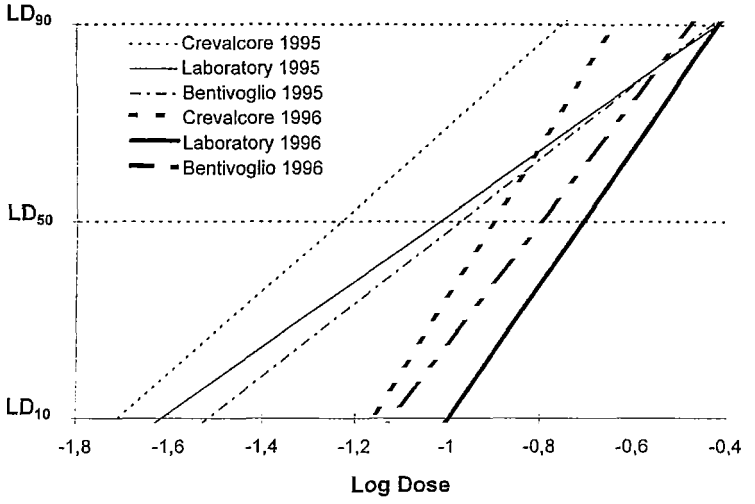

Fig. 3. Sensitivity levels to *Bti* in *Culex pipiens* field populations after approximately 200 treatments in (1995) and 220 in (1996), compared with a sensitive lab colony.

is not economically feasible. A possible solution to the problems caused by rice field mosquitoes may rely on formulations carried by the water continuously fed into the rice paddies.

A general effort must be made by those involved in mosquito control activities to understand the term "quality of life" in its fullest sense and to regard public awareness of environmental problems not as an irrational obstacle to the achievement of the best results in mosquito control, but as a stimulus to develop new approaches to the problem.

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REFERENCES

Bellini, R. and Veronesi, R. 1994. Il programma di lotta ai Culicidi nelle località costiere della regione Emilia-Romagna inserite nel Parco del Delta del Po. In: *Atti del XVII Congresso Nazionale Italiano di Entomologia, Udine, 13–18 June, 1994.* pp. 795–798.

Genchi, C., Traldi, G., Di Sacco, B. and Benedetti, M.C. 1988. Epidemiologia della filariosi cardio-polmonare del cane in Italia. In: *Atti IV Seminario SCIVAC, Cremona.* pp. 53–64.

Pampiglione, S., Canestri Trotti, G. and Rivasi, F. 1991. La dirofilariose humaine en Italie. *Annales de Parasitologie Humaine et Comparée* 66:195–203.

Raffaele, G. 1964. Note sull'eradicazione della malaria in Italia. *Rivista di Malariologia* 43:1–27.

Verani, P., Balducci, M. and Lopes, M.C. 1979. Arboviruses in Italy. In: *Arctic and Tropical Arbovirus. Proceedings of the Second International Symposium on Arctic Arboviruses, Mount Gabriel, 26–28 May, 1977.* Edit. E. Kurstak. Academic Press, New York, NY. pp. 101–121.

Vesenjak-Hirjan, J., Porterfield, J.S. and Arslanagic, E. (Edits) 1980. Arboviruses in the Mediterranean Countries. *Zentralblatt für Bakteriologie, Mikrobiologie und Hygiene Series A*, Suppl. 9, Gustav Fischer Verlag, Stuttgart. 322 pp.

Zulueta, J. de 1973. Malaria and mediterranean history. *Parassitologia* XV:1–15.