ECONOMIC COMPARISON OF TRADITIONAL, GUIDED AND BIOLOGICAL PEST CONTROL IN ITALIAN POTATO PRODUCTION

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Abstract

Biological agriculture in Italy shows rapid increases, as farmed hectares, either using fertilizers, or pesticides. In particular, pest control is widely studied, but there are many difficulties to find out natural antagonists to pests.
Potato production has been recently concerned with alternative pest control methods. Beyond the traditional methods, such as timely or guided spraying, the effects of biological pest control have been tested.
A field test has been carried out on the use of *Bacillus thuringiensis subsp. tenebrionis* against *Leptinotarsa decemlineata Say*. Its performances have been compared to those of traditional pesticides, sprayed according to alternative schemes.
This paper analyzes the economic impact of alternative pest control techniques at farm level in relation to prices of pesticides and output quantity.
Different spraying schemes determine various level of costs, depending, namely, on the price of pesticides or natural products employed and, secondly, on the number of sprayings.
As a result of the stationary quantity of product, the analysis is developed following a cost minimization approach and it will draw different scenarious related to alternative variable values.

Résumé

En Italie, l'agriculture biologique connaît une évolution rapide, en termes d'hectares cultivés, en utilisant soit des engrais soit des pesticides. L'étude porte en particulier sur la lutte contre les parasites avec toutes les difficultés qui existent à l'heure actuelle pour trouver des antagonistes naturels.
La production de la pomme de terre a fait récemment l'objet de méthodes de contrôle alternatives. En plus des méthodes traditionnelles, telle que la pulvérisation guidée ou pratiquée à l'équipe appropriée, on a également testé les effets de la lutte biologique contre les parasites.
Un essai au champ a été mené sur l'utilisation du* Bacillus thuringiensis subsp. tenebrionis *contre la* Leptinotarsa decemlineata Say. ***Ses performances ont été comparées avec le pesticides traditionnels, en l'appliquant suivant des schémas alternatifs.
Ce travail analyse l'impact économique des techniques alternatives de la lutte contre les parasites au niveau de l'exploitation agricole vis-à-vis des prix des pesticides et du niveau de production.
Différents niveaux d'application correspondent à différents niveaux de coûts, suivant; premièrement, le prix des pesticides ou des produits naturels utilisés et, deuxièmement, le nombre d'applications.
Compte tenu d'une quantité fixe de produit, on a développé une analyse suivant l'approche du moindre coût et on a successivement exploré différents scénarios liés aux valeurs de variables alternatives.

1. Introduction

The environmental impact of agriculture nowadays is, at least in quantitative terms, reasonably well established and this sector is often identified as responsible of nonpoint source of pollution.
Many farmers have begun to adopt alternative production techniques aiming at reducing input costs, preserving soil fertility and reducing the impact of agriculture on environment and human health.
Wide adoption of alternative farming systems requires that they should be at least as profitable as conventional methods; neverthless, our knowledge of how organic agriculture compares, in economic terms, to conventional practices is still inadequate, despite the increasing adoption this subject has received in the most recent years.
Biological agriculture in Italy shows rapid increases, as farmed hectares, either using fertilizers, or pesticides. In particular, pest control is widely studied, but there are many difficulties to find out natural antagonists to pests.
Potato production has been recently concerned with alternative pest control methods. Beyond the traditional and guided methods, the effects of biological pest control have been tested.
A field test has been carried out on the use of *Bacillus thuringiensis* subsp. *tenebrionis* against *Leptinotarsa decemlineata Say* (Coleoptera, Chrysomelidae). Its performances have been compared to those of traditional pesticides, sprayed according to alternative schemes.
This paper analyzes the economic impact of alternative pest control management at farm level in relation to prices of pesticides and output quantity.
Different spraying schemes determine various level of costs depending, namely, on the price of pesticides or natural products employed and, secondly, on the number of sprayings.
The value of produce depends on its level both as quantity, or as quality. In fact, potato prices change according to the size and pest control performances on quality of product are, therefore, very important but are not concerned with this study.
The analysis is developed following a cost minimization approach and it will draw different scenarious related to alternative variable values.
This study represents a first interdisciplinary attempt aiming to give preliminary economic information about different pest control systems.
When the biological control creates a decrease in farmers' profit a subsidy, or a premium price of product, might be used as budget balancing element. Subsidies to achieve pesticides reduction have been already implemented by EEC Reg. 2078/92 but, in the case of potato production, it was not largely widespread. The existence of a premium price can be explained by market segmentation, in other words by the fact that the organic food market is not the same as the conventional one. This market segmentation is due to the higher quality of organic products and the growing importance that consumers give to environmentally friendly production systems. It is further strengthened by legislation on mark and standards, such as EEC Reg. 2092/91.
On the other hands, if biological systems do not reduce profit levels and are easily implemented by farmers from the technical point of view, this fact is an important result to be widely spread around among farmers and policymakers.

2. Environmental policy and economic impact

Water quality, above of all, but also other problems caused by modern farming practices have become a major environmental policy issue in many countries (-OECD 1986, 1989). Conventional agri-

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Paper presented at the *Workshop on pesticides, Policy measures to control environmental impacts from agriculture* (Concerted action AIR3-CT93-1164, European Union), Wageningen, The Netherlands, August 24-27, 1995. Research financed by the Ministry for University and Science (40%).

culture may also be associated with an increase in human health risk, both in terms of farmworkers' safety and food safety. There is growing evidence that pesticide use creates several immediate health problems for farmers and farmworkers (Hoar *et al.*, 1986, 1988; Pearce *et al.*, 1985). Simulation analysis, for example, showed that reducing the use of most toxic materials would have a small effect on productivity because its loss from reduced pest control would be offset by the productivity gain from improved farmer's health (Antle J.M. and Pingali P.L., 1994). These findings imply that if health effects are not considered in the economic assessment of agriculture, the rate of return for agricultural research may be overestimated, and the rate of return for technology that reduces pesticides use, such as pest-resistant crop varietes, may be underestimated.

Such undesired effects of current farming and breeding practices could be reduced through alternative systems.

Reducing pollution from agricultural production could be accomplished easily, from a simplistic technical viewpoint, by banning the use of polluting chemicals and production practices. However, the economic and political costs of that approach would be enormous.

The transition from the *traditional* to the *environmental friendly* agricultural farming might play a useful role in conserving natural resources and providing net environmental benefits. Furthermore, it allows to solve the great European problem of reducing the stockpiling of produce.

The central economic issues in the analysis of pollution control instruments are: the benefits of pollution abatement; the costs of adjustments in production for pollution abatement; the costs of policy administration and enforcement and the incentives created for clean technological innovation.

Policymakers have a variety of instruments available to them. Political, economic, physical and biological conditions will affect the relative effectiveness of each type of instrument. Often several policy instruments are combined together.

Coercion, or the use of the legal system to regulate behavior, is one instrument the government uses to enforce a policy. Governments may demand that people engage in particular activities and refrain from adopting others. The law is also used to regulate relations between citizens.

A second policy instrument is the provision of services. State often provide numerous services to the farmers.

Governments also use money or financial incentives as a tool to achieve policy objectives. Agreements, in fact, might also be reached *voluntarily* between farmers involved in agro-environmental projects and recipients (either suffering pollution or receiving benefits).

Taxes are also used to discourage certain behavior. Cigarette and alcohol sales are taxed to raise revenue and discourage consumption. Developed land is taxed at higher rates than undeveloped land in most States, in hope of preserving rural land.

The ban of pesticides has been applied in Environmentally Sensitive Areas (E.S.A.) where the pollution aspects represent a great problem. Many studies were carried out about economic consequences of the ban of pesticides (Antinelli A. and Venzi L., 1994; Michalek J. and Hanf C.H., 1994) and the problem proved quite difficult to solve. In some cases, such as the one presented in this paper, technology allows to substitude pesticides by natural products, quite efficiently.

Referring to the above mentioned results about the effect of reducing the use of toxic materials on productivity related to human health, it would be more efficient, for example, to confine pesticides restrictions on the most hazardous and least productive materials, rather than restricting all pesticides regardless of their health or productivity attributes.

All these types of policy instruments are guided by different criteria. Policymakers always use criteria of some sort, either esplicitly or implicitly, to make decisions. For purposes of policy analysis, explicit criteria are obviously superior. Policymakers often consider various standards, when selecting appropriate course of action, including ecological, economic, social and political criteria.

In this picture the government role becomes very important: the unregulated market by itself can't provide the necessary instruments to arrive at an efficient situation in which agriculture, forestry and environment might, respectively, operate. Markets, in fact, often fail to meet the requirements, or conditions, for efficient operations that are the basis of the neoclassical statement of market superiority. There are many reasons for market failure such as imperfect knowledge, imperfect competition and so on. The most important in this context, however, is the presence of non-market costs and benefits associated with a good, that are not reflected in market prices. Economists refer to non-market costs and benefits as *externalities*, or secondary effects. These occur when the activities of one person affect the welfare of other persons who have no direct means of control over those activities, whether they are in production, consumption or exchange (Hirshleifer J., 1984). Externalities may occur among individuals and firms at one point in time, or over periods of time.

Most OECD countries have implemented policies of one kind or another, but often with little effect on production (Shortle S. and Abler G., 1991).

Common Agricultural Policy (CAP) has been given added impetus by the Uruguay Round (UR) in the General Agreement on Tariffs and Trade (GATT). The European Union (EU) has a limited history about agro-environmental policies. In 1991, an agro-environmental policy was etablished by EEC Reg. 2092/91: it provides the institution of a label system for biological products. Its adoption in Italy, however, was not very popular among farms.

The first great and widespread policy, however, was implemented in 1992 with Reg. 2078/92. It provides incentives to promote voluntary partecipation to agro-enviromental programs, aiming at the limitation of pesticides use (European Economic Community, 1992). These incentives are granted to compensate for income reduction while maintaining previous profit level.

This policy had a diverse success with respect to different crops. Italian potato production, in particular, was not largely interested in agro-environmental programs, because of farmer's awareness that the incentives were unprofitable respect to income losses.

Efficiency, in fact, seems to play a very important role. Correlation between economic and environmental performances of farming systems, is complex and often poorly documented. In such a context, therefore, it is very difficult to determine, referring to different policy instruments, respectively the incentive to compensate for income loss, the tax for decreasing pesticide use, the premium price for organic products, etc.

In order to help policymakers to adopt different environmental policies, in this study we shall examine, by using experimental field data, the economic impact, at farm level, of different degrees of control on *Leptinotarsa decemlineata* in Lazio Region (Central Italy) in potatoes production. Italian farmers can use, in fact, three types of control: two traditional ones, timely or guided spraying, and the new technique of biological control. Biological pesticides are not still largely widespread and, therefore, the last method is really innovative.

Potato production represents a relevant case study from an agro-environmental viewpoint. In spite of the hectares under cultivation rather limited in number, in

the Lazio Region potato production is widespread as number of farms concerned.
It means that the impact of an agro-environmental policy, aiming at decreasing pesticides inputs in potato production, is very important for the rural sector. If we want such a policy to be successfull, we have to consider farm income and to preserve it covering losses.

3. Biological and integrated pest control in Italy

As a consequence of the recent growing of the problems connected to the use of chemical products in agriculture and with respect to the economic, ecological and toxicological requirements, from many sides there is a growing interest on methodological control of pests at low environmental impact.
Whilst as far as the biological production is concerned, Reg. CEE 2092/91 has organised the confusion in brands, labels and various production methodologies, as far as the integrated pest management at European Union level ius concerned, only general indications have been given in the Green Book in 1985.
At national level, this guideline has been implemented in the Plan of integrated plant enemies control (1987), even if the various regions have operated with different times and methods.
Due to the deficiencies shown by public administration, considering now the market of products, many big food processors have moved to satisfy the growing demand of quality (*sensu lato*) on the part of the consumer. Some of them work directly in specific areas where they buy raw materials, others draw up particular contracts with farmers, providing know how and often various inputs, others set specific standards to their suppliers.
The last feature of this behaviour is the growing number of brands put on food products, which often remind the consumer of an ambiguous concept of guided, integrated, biological and biodynamic pest control.
As for production techniques geared mainly towards environmental safeguard, we must underline that in Italy they became widely spread only after the European Union issued specific norms in their favour.
Under this situation the provision of EU incentives doesn't allow serious doubts on a theoretical level, because somehow they repay the farmer of the higher cost of production whilst preserving public health.
On a pragmatic level, instead, the supply of European funds sets many problems which are not easy to solve, and calls for some considerations:
– a low environmental impact production very often has to be adopted in the overall management of the farm, and at the same time on various crops;
– there is no certainty that these political guidelines will be supported again for a long period at the same level.
The first consideration involves the evaluation of the integrated pest control for a larger range of crops than usually considered; the second imposes eventually a forced comparison with traditional techniques following new production functions with low input of chemical products.
Those going towards biological production today have two precise reasons (1) for doing so:
– aim at an increase in value of products obtained through the application of new techniques;
– favour European Union contributions, without following market and consumers' preferences.
The first profile is typical of farmers cooperating in organisations along with horizontal and vertical integration in the food sector. They support increases in production costs, within acceptable limits, keeping, however, the certification or commercialisation of their products at competitive prices as a priority.
The second profile, very popular in marginal areas, often looks at the European funding as the principal source of income. In this case the «environmental role» of farmers is very strong and production is no longer seen as the main source of income.
In this situation, obviously, the farmer stretches production costs to the limit, if possible sometimes getting close to quitting.
Both these behaviours are based on rational choices: the first follows consumers' preferences in order to increase income; the second follows the same aim but without passing through the market.
Support for the first choice seems to come from the results obtained from recent research to determine a likely Willingness To Pay (WTP) for an increase of prices on some particular products. The results are shown in **table 1** and **2**.
Even tough the increases of prices are referred to the entire food chain, it seems that the market still seems able to offer consistent opportunities to products covered by guaranty labels.
The second typology, instead, determines a variation in the economic scale only by the cost function. It stretches the costs to the limit because production increase is not convenient, or suitable, by biological or low impact methods. Obviously, the previous choices are often a function of the cropping technique developed in the farm. Indeed, fruit and vegetables are products mostly oriented to the market, while crops like hard wheat, sunflower and colza have low profits if compared to the subsidies per hectare that cushion them. So it is necessary to investigate a series of products, among them the potato. On one side the increases of prices that can make more profitable the use of new production techniques and on the other side the variation in production costs and therefore in farmer income.
So to verify the opportunities that most cultivation, obtained with biological or integrated pest control, have to insert themselves in the privileged sectors from the GDO.

4. Materials and methods

Our analysis was carried out in a farm out of one of the best production areas for potatoes, in central Italy.
Once homogeneous fields for exposure, chemical and physical characteristics had been found, the selected seeds of *Solanum tuberosum* have been put into place keeping a distance of 70 cm between rows and 30 cm between plants.
The test was conceived following the experimental methodology of Latin square by four thesis and four repetitions. Each thesis was subsequently submitted to different treatments against *L. decemlineata*; i.e. control plot, traditional, guided and biological techniques. The repetitions combining the four different thesis have been put at a distance of 5 m. For the thesis, extent 48 squared meters, inside each repetition was defined a distance of 3 m. In each thesis was found an inner area with 100 plants. Of these 40 have been selected and numbered.
Usually the traditional method of cropping is based on a great number of sprayings, each carried out approximately every ten days, ignoring from the real presence of the pest. It is clear that in this case we have a double impact: an economic one by carrying out unnecessary treatments, and an environmental and toxicological one by introducing chemical factors without determining their real need.

(1) Sometimes a combinations of them is also possible, where European fundings are pursued jointly with market policy by the producers organizations.

In the thesis destined for this kind of control, following the criteria adopted by the farmers in the specific area, 6 distributions of Phosalone have been used in the dose recommended by the chemical firm.
The guided pest control, instead, tends to follow the population dynamic of insects. In this way it is possible to carry out treatments only when the presence of pest is so high that it is likely to be dangerous on economic scale.
It is very important to determin the economic threshold beyond which the pest can cause relevant losses of production. In this way it is also possible to hit the insects at the best time, when the efficiency of the spraying is higher, using also low concentration of pesticide.
In the thesis undergone of guided control 2 sprayings of with Phosalone have been carried out, exceeding the economic threshold, previously calculated at ([2]) 0.5 egg masses per plant.
The biological control follows the same criteria as the guided one, but using only biological products. In this particular case, we have applied the results of previous researches which demonstrated that the delta-endotoxin produced by *Bacillus thuringiensis* is responsible for a high mortality of *L. Decemlianeata* larvae, as it damages their epitelial cells of the mesenteron. Other effects were found also on adults, as inhibition of feeding, prevention of egg-laying, ect. were induced.
For the biological control a product based on *Bacillus thuringiensis* subsp. *tenebrionis* was used kindly supplied by the company SANDOZ and labeled SAN 418 SC 62 serotype 8a 8b. It contained 3200 u.t./mg of compound, which also was used at the exceeding the economic threshold of 0.5 egg masses per plant.

5. Data treatment

The information obtained from the cultivation of *S. tuberosum* involved 40 plants for each thesis for a total amount of 640 plants. The weight and the diameter of tubers were taken into consideration.
The production was divided according to different diameter classes. This parameter is in fact the discriminating factor for the quality of potatoes with or without industrial transformation. It is necessary to remember that only the production with a diameter greater than 40 mm, is bought from the farmers.
Under this consideration, we can divide production in three classes:
– Diameter < 40 mm
– 40 < Diameter < 70 mm
– Diameter > 70 mm.
The dynamic of the data is graphically presented in **graph 1-3**; the analysis of weights for tuber production gave the mean values shown in **table 3**.
To find out the impact of different methodologies of pest control on tuber production quantity, we have submitted the experimental data obtained to the Fischer test of the analysis of variance in such a way as to verify the significance of differences between the means of weight in the four repetition of diameter classes.
The results are reported in **table 4**.
As we can see, it's impossible to attribute any production difference to the treatment done. Indeed for the first two diameter classes the critical values of the Ficher distribution are largely higher than the calculated values for = 0.05 or = 0.01.

6. Economic analysis and comment on results

Potato production in Lazio Region, represents the 0.4 % (3432 hectares) of the total as surface and the 8 % (n. 19103) of the total farm number (ISTAT, 1991). In terms of value of production, the 156,600 tons of potato (23.2 million of ECU) represent the 3.9 % of grass production and the 1,7 % of total production (INEA, 1994).
It means, therefore, that many farmers are involved and, in addition to the environmental pollution, it is relevant the impact of production costs and health risk of the crop.
This study may be carried out by the profit maximixation function. Different spraying systems aiming to pest control, in fact, generally create profit changes because of the variability in production quantity and in price of product:

$$P_r(Y,P) = P f(X) - C(X)$$

where:
P_r = Profit;
Y = Production;
P = Price;
X = production factor;
C = Cost function.
In the classical formulation, profit function allows to determine optimal quantity in the use of production factor (X) so to have the maximum profit (P_r). This result is possible to be reached by having a great quantity of data coming from field test of several years.
Considering the limited number of data we had at our disposal, it is clear that this study represents a first interdisciplinary attempt aiming to give preliminary economic information about different pest control systems.
Statistical data analysis developed by ANOVA has demontrated that the adoption of different technologies not creates significative differences in the production quantity (Y). Furthermore, the price of product (P) has been assumed to be constant because this study does not aim to determine differences in price due to the quality of product: the price of potato, because of the difficulty in establishing different price levels related to different quality levels of production, is constant.
Wide differences between organic and conventional farming methods can be found, instead, in cost structures: as a general rule, conventional systems have higher expenses in capital inputs, while organic ones are more labour intensive.

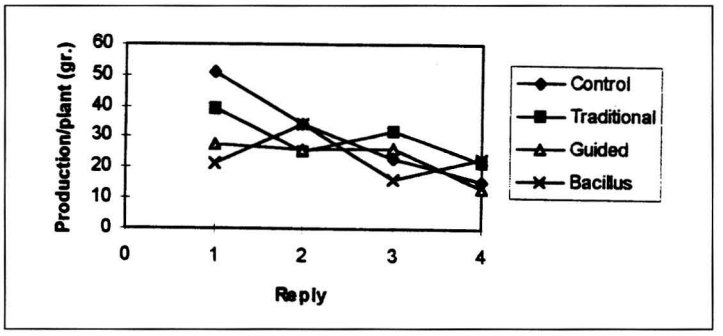
Table 1 ***WTP a premium price for products under guaranty labels (By Centro Operativo Ortofrutticolo - Ferrara).***

	YES	NO	Total
Tomatoes	77	3	80
Salad	76	4	80
Apples	77	3	80
Strawberries	77	3	80
Table grapes	77	3	80
Peaches	78	2	80

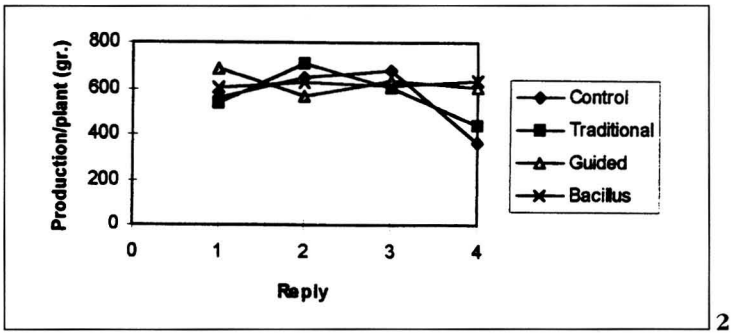
([2]) Cfr. Pucci C., Dominici M., Forcina A., «Population dynamic and economic threshold of *Leptinotarsa decemlineata* Say (Coleoptera, Chrysomelidae) in Central Italy», J. Appl. Ent. 111 (1991) 311-317.

Table 2 ***Accepted increases of price for some fruit and vegetables under guaranty labels (By Centro Operativo Ortofrutticolo - Ferrara).***

	0-5%	5-10%	10-15%	15-20%	more than 20%	Total
Tomatoes	8	28	28	9	4	77
Salad	8	24	27	14	3	76
Apples	5	26	29	11	6	77
Strawberries	6	15	27	18	11	77
Table grapes	7	21	29	13	7	77
Peaches	7	18	33	12	8	78



1



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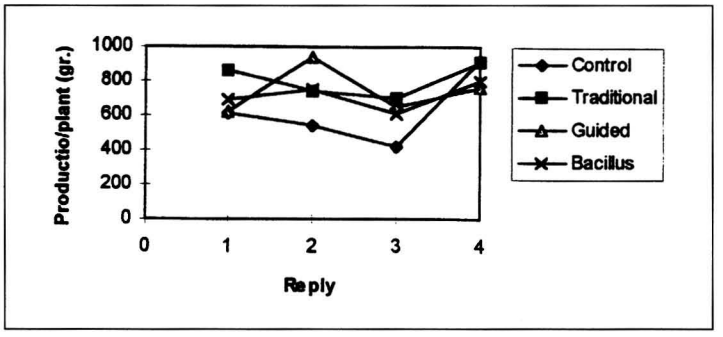

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Graph 1 - Diameter < 40 mm.

Graph 2 - 70 > Diameter > 40 mm.

Graph 3 - Diameter > 70 mm.

These cost differences could be reduced if more efforts are placed into research and development of technical solutions specifically oriented towards organic farming methods, expecially in terms of natural weed and pest control.

As consequence of this scenary, we will limit our study to a cost analysis by using the cost minimization approach respect of the alternative techniques: Guided (G), Bacillus (B) and Traditional (T).

We have three cost series for the three different techniques:

$$C(X) = \sum_{i=1}^{n} X_i,\ P_i = \begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_{g,b,t} \\ \vdots \\ P_n \end{bmatrix}$$

$$= C^{G,B,T}[X_1, X_2, \ldots, X_{g,b,t}, \ldots, X_n]$$

where total costs of each techniques are:

$C(X_G) = [x_1, x_2, \ldots, x_g, \ldots, x_n]$
$[p_1, p_2, \ldots, p_g, \ldots, p_n]$;

$C(X_B) = [x_1, x_2, \ldots, x_b, \ldots, x_n]$
$[p_1, p_2, \ldots, p_b, \ldots, p_n]$;

$C(X_T) = [x_1, x_2, \ldots, x_t, \ldots, x_n]$
$[p_1, p_2, \ldots, p_t, \ldots, p_n]$;

and $[(x_g, x_b, x_t)(p_g, p_b, p_t)]$ are those for *Leptinotarsa* control.

In this case study, in particular, there is no great difference among alternative different pest control schemes. Different spraying schemes determine, in fact, different levels of costs depending, namely, on the price of pesticides, or natural products employed and, secondly, on the number of sprayings, but labour input is not relevant.

The quantity of other production factors $(x_1, x_2, \ldots, x_{n-1})$, that are not affected by the pesticides input, as quantity or type, and the price of other production factors $(p_1, p_2, \ldots, p_{n-1})$, that are exogenous and not related to the pest control scheme, are constant. Costs for *Leptinotarsa* control $[(x_g, x_b, x_t)(p_g, p_b, p_t)]$, instead, change.

The value of production depends on the quantity of potato (Y). The statistical data analysis above developed showed, in fact, not significant differences in terms of quantity of production.

Table 5 describes the levels of gross product value per hectare: 19,387,000 Lit for the three spraying schemes.

Differences in costs are related to the spraying system.

The cost of spraying depends on the price and quantity of insecticides used in each pest control system (Deltamethrin for the traditional system, Phosalone for the guided scheme and *Bacillus thuringiensis* subsp. *tenebrionis* for the biological spraying). Spraying costs per each hectare are 22,400 Lit., 55,900 Lit. and 42,000 Lit. respectively for traditional, guided, or biological system.

The number of sprayings (N_s) is 6, 2 and 3 respectively for traditional, guided or biological pest control scheme. Each spraying needs of 30,000 Lit. to cover labour and machinery costs.

Table 6 shows the costs per hectare of potato pest control according to the type of *Leptinotarsa decemlineata* control. As result of different prices and number of sprayings the costs are 314,000 Lit., 172,000 Lit. and 216,000 Lit. respectively for traditional, guided or biological spraying system. Considering the other costs for pesticides input (herbicides, fertilizers and other insecticides) as costant, i.e. 1,730,000 Lit., the cost for *Leptinotarsa decemlineata* control is, as percentage on the total, 15%, 9% and 11% respectively for traditional, guided or biological pest control scheme.

As result we have the stationarity of fixed costs (FC) and the changing of variable costs (VC) related to different techniques. In particular:

$VC_g < VC_b < VC_t$

and, as consequence, total costs (TC) are:

$TC_g < TC_b < TC_t$.

Graph 4 shows that is possible to reach the same level of production ($Y_{G,B,T}$) at different level of costs:

The result of the variability in potato pest control costs is that profit is 2,043,000 Lit for the traditional system, 2,185,000 Lit. for the guided scheme and 2,141,000 Lit. for the biological spraying.

Profit decreasing, due to the biological *L. decemlineata* control is 44,000 Lit. with respect to the guided system; profit difference with respect to the traditional control, instead, is negative (–98,000 Lit.). In terms of percentage the decrease is of 5% and the increase is of 2%.

It means, therefore, that biological control is cheaper than the traditional one. It is an important result to be spread around farmers and policymakers: the control of *Leptinotarsa decemlineata* according to the biological scheme allows farmers to increase their profits.

The decrease in farmer' profit, in the case of guided spraying, allows us to suggest the level of incentives to be granted to the farmer who decides to carry out biological pest control instead of the guided one.

If policymakers decide to keep unchanged farmer's profit by increasing potato price, they should increase it only of 0,25%: are consumers available to

Table 3 ***Mean production of tubers (gr) each plant.***

	Diameter <40				*70> Diameter >40*				*Diameter >70*			
	Control	Traditional	Guided	Bacillus	Control	Traditional	Guided	Bacillus	Control	Traditional	Guided	Bacillus
Reply A	50,87	39,50	27,28	21,17	560,21	539,37	688,74	606,17	608,22	863,42	622,00	686,58
Reply B	34,31	24,97	26,00	34,25	651,78	707,65	567,83	626,63	537,72	739,53	936,45	750,83
Reply C	23,14	31,83	26,56	16,33	679,60	601,47	631,23	609,07	421,15	703,90	654,11	605,92
Reply D	15,69	22,10	13,32	22,92	364,86	436,26	603,11	636,07	915,47	911,20	755,82	801,35
Mean	31,00	29,60	23,29	23,67	564,11	571,19	622,73	619,48	620,64	804,51	742,09	711,17
Global mean		25,52				604,47				752,59		

Table 4 ***Output for one way ANOVA.***

	Diameter <40	*70> Diameter >40*	*Diameter >70*
F value	0.9458	0.5212	1.8267
P value	0.4585	0.6783	0.2125

pay such a price for a healthier product ? Referring to the data above quoted (**table 2**) on the WTP for quality products, it seems to be acceptable by consumers to sustain higher prices.

The existence of a premium price can be explained by market segmentation, in other words by the fact that the organic food market is not the same as the conventional one. This market segmentation is due to the higher quality of organic products and the growing importance that consumers give to environmentally friendly production systems. This is further strengthened by legislation on marks and standards, such as EEC Reg. 2092/91.

Otherwise, if it has been chosen to stimulate farmers' restrain by a subsidy, the level of the subsidy should be of 44,000 Lit. per hectare. As above mentioned, the potato production in the Lazio region involves 3,432 hectares. If we suppose to give a subsidy to all regional farmers, we shall have an expenditure of 151 millions of Lire. Is there the political will to sustain such limited expenditure ?

EEC Regulation 2078/92 provides 462,000 Lit. per hectare (i.e., 1,58 billion Lire for regional total farmed hectarage) for potatoes produced according to the rules established by the agro-environmental program of the Lazio region. We have to specify, however, that it compels farmers to use limited amount of fertilizers and to spray only mildly dangerous pesticides. In our study, instead, we are referring only to the *L. decemlineata* control in a totally biological way. This case study shows that biological farming systems are not necessarily associated with heavy shortfalls in supply. When this does not happen it may be due to a lack of technical solutions tailored for organic systems, more than to tecnology itself.

Table 5 ***Potato balance-sheet per hectare (.000 lit).***

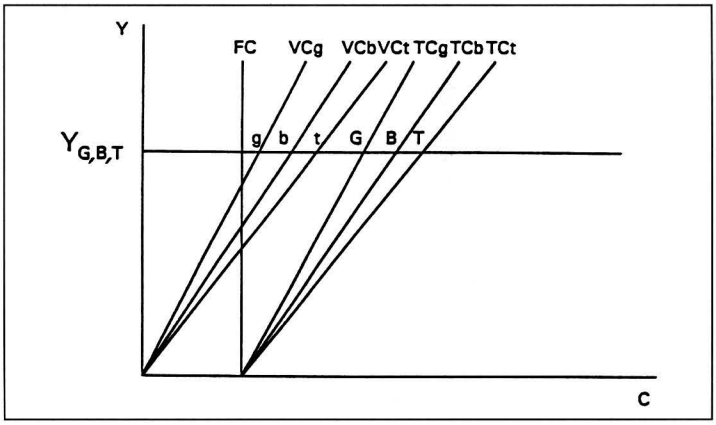
	Traditional	%	Guided	%	Biological	%
Gross product	19387	100	19387	100	19387	100
Costs						
Leptinotarsa control	2044	10	1902	10	1946	10
Other costs	15300	79	15300	79	15300	79
Total	17344	89	17202	89	17246	89
Profit	2043	11	2185	11	2141	11
Profit difference	–98	–5	44	2	0	0

Source: our own survey.

Table 6 ***Potato pest control costs per hectare according to the type of Leptinotarsa control (.000 lit).***

	Traditional	%	Guided	%	Biological	%
Common costs	1730	85	1730	91	1730	89
Leptin. dec. control	314	15	172	9	216	11
Total	2044	100	1902	100	1946	100

Source: our own survey.



Graph 4 - Representation of the variability of costs.

7. Concluding remarks

The paper aimed at determining the economic impact of the biological pest control in Lazio region, Italy. In particular, we analyzed the use of *Bacillus thuringiensis* subsp. *tenebrionis* against *Leptinotarsa decemlineata Say* in potato production.

Potato production, in fact, has been recently concerned with alternative pest control methods. Beyond the traditional and guided methods, the effects of biological pest control have been tested through a field test.

The analysis has been developed by means of a cost minimization approach.

Three different spraying schemes determine three levels of farmers' profits depending on the price of pesticides, or natural products employed, and the number of sprayings. No differences in quantity of production, in fact, arose as the ANOVA analysis demonstrated.

The value of production depends on its level either as quantity, or as quality. In this study we did not consider the quality aspect.

Because of the limited number of data referred to only one year, this study represents the first interdisciplinary attempt aiming to give economic information to farmers. Next field tests will provide more data series so to estimate parameter of production function and cost function.

The economic results in terms of cost minimization give evidence to some differences in value according to the variability of production costs, confronted by almost equivalent revenue results. Differences in profits are not striking and one could reasonably infer that a biological control method (*Bacillus thuringiensis)* is safer than the other more profitable procedures. In particular, profit decreasing, due to biological control, appeared with respect to the guided system; profit difference with respect to the traditional control, instead, was negative and the biological scheme allows farmers to increase their revenue.

Should the difference in incomes be «refunded» two ways are open and previous calculations show that this opportunity is not too devastating.

In fact, the total amount of compensatory subsidy and/or the necessary price increase seem to be not much expensive, respectively, for regional budgets or consumers. ●

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This paper, with section 1 and 7, is a result of the common effort of the three authors. Neverthebless sections 2 and 6 are the exclusive work of A. Antinelli, section 3 and 5 are due to A. Coletta and section 4 is exclusive work of C. Pucci.

The authors thank Prof. Lorenzo Venzi for his comments and suggestions that allowed us to develop this paper. The responsability of any inaccuracy, however, belongs to the authors.