Hedging potato production risks in integrated farming with green insurance

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Abstract

In integrated farming of ECO-label potato production, crop protection control requirements are strict, especially for Late Blight. However, weather conditions may force farmers to violate the label conditions in controlling infestation of *Phytophtora infestans*. As a result, the produced ware potatoes have to be sold on the conventional spot market at lower prices, despite the higher production risks of ECO-label production. Under the current condition these production risks cannot be hedged, which is an important reason hampering large-scale participation. In this study the production risks associated with the ECO-label contract and the opportunities for an insurance scheme to cover these risks are analyzed and the consequences for participation rates are discussed.

Keywords: sustainable agriculture, Integrated Pest Management, ECO-label, Late Blight control, risk, green insurance.

Introduction

More efficient and effective nutrient management and integrated pest management can reduce the producer input costs considerably, depending on the amount of inputs previously applied beyond the optimum dosage. At the same time, the environment will benefit by these conservation practices. However, the adoption of these improved managerial practices is lagging behind the expectations. The paradox can be partially explained by the production risks potentially involved, which are in essence the product of the probability of an occurrence and the scope of a loss event (R=P*S). Production risks are managed by applying, for example, amounts of fertilizers and pesticides necessary to realize a certain projected production with high reliability. An important reason why risk averse decision makers may apply more than the recommended amount for a normal year is because of the stochastic nature of the environment. Additional amounts will thus serve as an "insurance" for adverse (weather) events.

Risk transfer tools to absorb part of the production risks involved, thereby stimulating less risk averse decision making or even risk neutral decision making with respect to the appliance of nutrients and pesticides, might enhance the adoption of the conservation practices. An instrument of interest is hedging via an environmental insurance contract, hereinafter referred to as green insurance. There is currently a limited number of green insurance contracts available in the US. Two examples are the Corn Rootworm IPM Policy and the Potato Late Blight Policy. The Corn Rootworm IPM policy facilitates a reduction of soil-applied insecticides in the Midwest. At the end of the tilling season a crop consultant recommends whether to "treat" or "not treat" the following spring by scouting the level of corn rootworm beetle infestation. The policy can be purchased if the producer uses the "not treat" recommendation. Indemnification is triggered if losses do occur (Anonymous, 2000). The Potato Late Blight Policy permits potato producers in the states Maine, Wisconsin and New York to postpone spraying until the recommendation is made by the local extension forecasting system. As a result, fungicide usage is reduced by one to three sprays per season. If Late Blight is detected within ten days of the issue of the recommendation to spray, an indemnity is paid which covers the value of the lost crop, cost of destroying infected plants and recovery treatment (Anonymous, 2000).

In Europe, the Mesurol Insurance Policy in the Netherlands is a successful scheme. Under this policy, corn seed pesticide treatment is forgone, while possible incurred seed damage as a result of damage by soil organisms is indemnified. The adoption rate is considerable since the premium is lower than the actual seed treatment cost (Seegers et. al., 2000). Despite the win-win situation indicated by the previous examples for both the producer and the environment, the development and adoption of green insurance is just beginning to emerge, particularly in Europe.

There are some actuarial reasons why sound green insurance schemes are hard to develop. The requirement that the covered loss is both determinable and measurable is often not met (Rejda, 1998). Agricultural production is rather volatile due to variable and unpredictable weather and other environmental conditions. Losses incurred might be the result of a number of contributing factors whereby the additive effect on the insured peril is difficult or even impossible to ascertain. The total loss could be partially the result of management. However, the factor management should not be compensated for in order to prevent moral hazard (Harington and Niehaus, 1999;

Pritchett et. al.1996; Vaughan and Vaughan, 1996). Another important requirement is that the probability of the loss should be calculable (Rejda, 1998). It is difficult to quantify the probability of the increased production risks because historical observations are obtained under conventional production methods. Thus historical observations of a more sustainable production method are often absent. The difficulties for green insurance schemes in calculating the probability of an occurrence and the scope of a loss event hamper proper premium setting.

In this study the risks of certified integrated production method are quantified with a bio-economic model focussing on Late Blight in potato. Furthermore, the possibilities of hedging the associated risks with a green insurance contract are analyzed and the consequences for participation rates are discussed.

ECO-label

The ECO-quality symbol identifies environmentally preferable products based on an environmental impact assessment of a certain product compared to other products in the same category. The environmental impact of crop protection agents by the cultivation of ECO-label crops can be reduced considerably compared to conventional agriculture (Stichting Milieukeur, 2000). The quality label was set up as a form of customer communication emphasizing an added value and quality guarantee via objective inspections and clear standards. ECO-label criteria have been issued for numerous agricultural products and foodstuffs the past decade, varying from arable products and fruits to vegetables and dairy products.

In Dutch potato production, the kind of applied pesticide agents, dosages used and number of applications differs greatly between years, individual growers and regions, and thus the conventional potato sector can be characterized as a rather heterogeneous population. The amount of active ingredients applied serves as an indicator for the environmental impact resulting from crop protection. On average, 13 kg of active ingredients per ha are applied in an average conventional crop protection scheme. The control of *Phytophthora infestans* is the important factor in explaining the diversity that exists (De Vries and Wiskerke, 1998). Janssen (1996) found that, in 1996, an average of 10 kg active ingredient per ha was applied to control *P. infestans*. Furthermore, 60-70% of the variation was caused by the used dosage and 30-40% by the number of applications per season. Decreasing the amount of pesticides to control *P. infestans* has been the central aim of the ECO-label potato production.

Production requirements for ECO-label potato production mainly concern fertilization, crop protection, energy, and waste-disposal. A comprehensive standard of phosphate and nitrogen fertilization is enforced. In addition, only crop protection agents are permitted that are least damaging to the environment. A maximum of 6 kg active ingredient of crop protection agents may be applied, including agents used pre-planting and in storage. However, the kind of applied agents and the active ingredient threshold can be less stringent in adverse production years. For example, in 1998 the ECO-criteria permitted a maximum active ingredient of 8 kg (Stichting Milieukeur, 1998). Contrary to ECO-label production, which permits a limited use of synthetic crop protection agents, organic production only allows natural and biological pesticides. The reduction in pesticide use by means of ECO-label as well as by organic production is depicted in Table 1. It can be concluded that the ECO-label fills the gap between the conventionally produced ware potatoes and the more elaborate and expensive organic production scheme.

The total area cultivated with ECO-potatoes in the Netherlands was approximately 1000 ha in 1998, whereas, in 1999, 747 hectares were planted with organic potatoes, which is approximately 0.4% of the total planted ware potatoes (Platform Biologica, 2000).

Material and Methods

Conceptual model

This section presents the theoretical concept of a Bio-Economic model of Late Blight control Options and Risk (BELABOR). BELABOR was based on the Late Blight warning model of Fry et al. (1983), as updated and expanded by De Buck (2000).

Economic rationality in pest control recommendations starts with the standard economic optimization framework based on marginal conditions. The biological interactions between disease, crop and control measure causes Late Blight control in a potato crop to have features that differ from marginal input use patterns. Instead, a breakeven criterion is used (Carlson and Wetzstein, 1993). The breakeven criterion reduces the decision to a binary one of either no treatment, or, if a certain threshold value is exceed, treatment at a fixed dosage (Headley, 1972; Wossink and Rossing, 1998). The threshold is called the Economic Injury Level (EIL). It represents the point prior to treatment at which yield damage caused by pest incidence equals the total costs of pest control. In the model, control measures were implemented at certain thresholds before the EIL is reached, to take account of time lags in farming practice (as described in Wossink and Rossing, 1998).

Figure 1 illustrates the multi-period concept, with stages *j* (*j* = *1*, .., *J*) and the relations between the processes and data requirements. In one stage, one cycle is completed. For a given stage *j*, the state S_j of the system can be represented as the result of four processes: (1) introduction of first infection; (2) weather-dependent diminishing of fungicidal protection against Late Blight; (3) weather-dependent development of Late Blight and (4) collection of information, followed by decision making according to a strategy. Let S_j be a vector of state variables; representing the disease-free period, the severity of the conditions for Late Blight development (severity value), the remaining fungicidal protection (protection grade) and the delay (in number of days; is not included in Figure 1) since a protective fungicide should have been applied. In BELABOR, a threshold value for the moment of first infection determined the first spraying; thresholds for severity value and protection grade determined the timing of consecutive protective sprayings and the duration of the delay of a protective spraying determined the type of fungicide to spray.

BELABOR simulated the decision process separately for each strategy. Based on the state S_j, at each stage *j* a decision *x* is made: see box 4 in Figure 1. Prices *p* and requirements for inputs *a* are attributes of the control decision *x*. The optimal multi-period solution is the sequence of *J* decisions *x* with minimal costs *c* of execution, that is the economic objective function (De Buck et al., 1999).

$$c = \min \sum_{i=1}^{I} \sum_{j=1}^{J} \left(p_{i,j} \cdot a_{i,j} \right) \quad \text{with} \quad a_{i,j}\left(x, S_j\right), \tag{1}$$

where $p_{i,j}$ denotes the price times the number of units $a_{i,j}$ needed of input i at stage j. Breakeven criteria determine the input of $a_{i,j}$ and, hence, minimal costs of execution. If environmental concern is the objective, Equation 1 must be replaced by minimization of the total use of fungicides (in kg, $\Sigma_i \Sigma_j a_{i,j}$.). The state S_j is subject to uncertainty caused by stochastic weather conditions. Risk is introduced via stochastic weather conditions ξ (Equation 2). In Equation 2, the transition function τ – or equation of motion– updates state S_j given ξ and the Late Blight control decision x to the next period (S_{j+1}).

Equation 2 describes the cumulating severity value and protection grade that are restored by a fungicide application. This control efficacy was assumed to be deterministic. The Cumulative Distribution Function (CDF) of A is represented by Equation 3.

$$S_{j+1} = \tau\left(S_j, x, \xi\right). \tag{2}$$

$$\mathrm{F}(A_i) = \mathrm{P}(a_i \leq A_i) \quad \text{with} \quad a_i = \sum_{j=1}^{J} a_{i,j}. \tag{3}$$

From Equations 1 and 2 it follows that $a_{i,j}$ depends on the stochastic parameter ξ. Realisations ξ_t of parameter ξ, based on existing weather scenarios T ($t = 1,\ldots,T$) can now be used to determine values of: $\sum_{j=1}^{J} a_{i,j,t}$. Hence, the CDF is approximated by Equation 4.

$$\mathrm{F}(A_i) = \mathrm{freq}\left(\sum_{j=1}^{J} a_{i,j,t} \leq A_i\right) \cdot T^{-1} \qquad (4)$$

BELABOR allows the outcomes of the strategies under different weather scenarios to be compared. The outcomes of a strategy were the distributions of costs, use of *a.i.*, number of fungicide sprayings and labor required..

Meteorological scenarios

BELABOR was used to simulate the strategies one by one for 17 seasons representing a range of conditions, which were assumed to represent all possible meteorological scenarios for the Flevopolder area of The Netherlands. The meteorological data used in this research was acquired from the Dutch Royal Meteorological Institute, De Bilt, The Netherlands; supplemented with data from the Department of Meteorology of WAU and from PAV, Lelystad, The Netherlands. The data consist of the parameters of minimum and maximum temperature and precipitation on a daily basis and temperature and relative humidity on an hourly basis; recorded at various locations in Flevopolder for the years 1981-1997.

Simulation of first infection

The moment of first fungicide application, which coincides with the end of the disease-free period, was identified by the moment of canopy closing (Asselbergs et al., 1996). BELABOR calculated canopy covering with the potato growth model developed by Spitters (1987), that is based on the temperature-sum.

Simulation of protection grade

BELABOR measured the decline in Late Blight protection (protection grade) since the most recent fungicide application in fungicide units (according to Fry et al. 1983). The protective value of a fungicide spraying decreases over time: Fungicide units at stage j are updated to stage j+1, according to Equation 2 (in the case of fungicide units, ξ was represented by daily rainfall). More fungicide units are allowed to accumulate if the potato cultivar has a higher resistance index. The threshold levels of fungicide units for these three cultivars were initially taken from Fry et al. (1983) for susceptible, moderately susceptible and moderately resistant cultivars respectively and were modified during model calibration by De Buck (2000).

Simulation of Late Blight development

Fry et al. (1983) introduce blight units as a measure of favourability of weather circumstances for the development of *P. infestans*. Blight units account for temperature (optimum is between 12°C and 23°C) and the duration of leaf wetness required for *P. infestans* to develop (the minimum is 6 hours). Following Fry et al. (1983), in BELABOR, leaf wetness was estimated as the number of hours with relative humidity $\geq 90\%$ (measured at 1.5 m height). The number of blight units per day for a moderately resistant, a moderately susceptible and a susceptible cultivar, respectively ranged from zero to a maximum of 5, 6 and 7. As with fungicide units, blight units were updated according to Equation 2 (ξ was represented by temperature and number of hours with relative humidity $\geq 90\%$). Hence, blight units and fungicide units both trigger fungicide application independently: with a variable interval scheme, a next protective fungicide application is advised when a cultivar-specific threshold for blight units (blimax) or fungicide units (funmax) is reached. Late Blight resistance of a cultivar is accounted for by a slower daily accumulation of blight units and higher blimax and funmax levels than susceptible cultivars.

Observation and decision making

The first step in the decision was to determine the number of days since the last application. A new application was only considered if that interval exceeded 5 days. EIL was reached when blight units equalled blimax or when fungicide units equalled funmax. In order to simulate the farmers' anticipation of unfavourable spraying conditions[1], the application of a protective fungicide was triggered at 0.8·EIL provided that conditions for application were good. In Fry et al. (1983) an application is triggered at 1·EIL, regardless of the conditions for spraying. A delay of one or two days, due to bad weather conditions, led to the application of a curative fungicide. A maximum permitted delay of two days was assumed; followed by a curative application, regardless of the weather conditions assumed in BELABOR. Protective and

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[1] In BELABOR, *pF* values are used to determine the trafficability of the soil for tractor operations. Daily precipitation and soil physical parameters representative of the situation in the Dutch Flevopolders were used. *pF* values, are calculated with the water movement module of the model for Water and Agrochemicals in the soil, crop and Vadose Environment (Vanclooster et al., 1994). Spraying is considered to be impossible when $pF < 1.8$.

curative fungicides were assumed to have the same protective characteristics. In the previous version of BELABOR a maximum delay of three days was allowed followed by the application of an eradicant agent (De Buck, 2000). New legislation however prohibits the application of these types of agents.

Results

Three cultivars were considered in our research, namely Bintje (resistance index = 3 on a scale of 1-10 (Ebskamp and Bonthuis, 1997), Agria (index = 5.5) and Texla (index = 8.5). The characteristics of the distribution of the annual active ingredient use were obtained by aggregating the independent simulations for the 17 seasons representing the range of all possible meteorological conditions and are presented in Table 2. As already pointed out by De Buck et al. (2000), growing a more resistant cultivar not only offered opportunities for cutting down on the average load of fungicide input for Late Blight control; also peak levels in fungicide input in unfavorable years (denoting a high environmental risk) were reduced. A more resistant cultivar was a safer option to reduce fungicide loads, as epidemiological risks were lower.

For the most resistant cultivar evaluated, that is Texla, the average annual active ingredient use was 3.71 kg with a standard deviation of 1.52 kg (Table 2). Other characteristics of the active ingredient use distribution showed that the distribution tails off more to the right (skewness = 1.36) with a relatively peaked distribution (kurtosis = 2.09). Given an annual threshold of 4, 5 and 6 kg, the probability of violating the label conditions in controlling infestation with *P. infestans* was 52.90%, 11.80% and 11.80% respectively.

From incidence-rate of non-compliance and associated lower financial returns the loss cost of the investigated insurance product can be calculated. For a particular insurance, the loss cost reflects the expected frequency and amount of indemnity payments. The loss cost assumes zero profit and administrative costs for the insurer and excludes a deductible for the producer. Table 3 presents a sensitivity analyses with respect to the effect of the thresholds of ECO-label crop protection conditions as well as the assumed price difference between ECO-label and conventional production on the loss costs of the green insurance.

A threshold of 6 kg in combination with an assumed price difference of 0.50 Euro per 100 kg resulted in a loss cost of 30 Euro per hectare for the resistant cultivar Texla. With a more stringent threshold of 4 kg or a doubled price difference the loss cost amounted 136 Euro per hectare and 61 Euro per hectare respectively. The production of less resistant cultivars Bintje and Agria resulted in a substantial increment of the loss cost.

Conclusion and discussion

In this study the production risks associated with the potato ECO-label contract in the Netherlands are analyzed in order to calculate the so-called loss cost of a green insurance scheme to cover these risks. In the default situation with the resistant cultivar Texla, non-compliance for ECO-label production was 11.80%. Given an assumed average loss of 0.50 Euro per 100 kg, the loss cost of the green insurance contract would be 30 Euro per hectare.

Only actually incurred losses are indemnified because the scope of the loss event is the difference between the pursued ECO-label price and the obtained conventional price at delivery. The associated transaction costs would be relatively low since the loss calculation is transparent without appraisal on site. A deductible should be included to limit moral hazard; a deductible encourages loss prevention since the insured must pay part of any loss (Pritchett, 1996). Another potential problem is that producers with a higher than average probability of loss will buy insurance to a greater extend than producers with an average or low probability of loss (i.e. adverse selection) (Vaughan and Vaughan, 1996). Premium differentiation overcomes this problem; however, information asymmetry limits the scope to distinguish completely among insureds. The differentiation could be based on, for example, region, soil type and potato cultivar, but also on historical observations about pesticide usage when ECO-label potatoes have been produced for several years (e.g. bonus / malus discount system). Additional empirical research is recommened to refine the probability distribution functions of pesticide usage for a sounder premium calculation and premium differentiation.

The requirement that ideally the loss should not be catastrophic (Rejda, 1998) cannot be entirely met since phytophtora losses are, partially, induced by adverse weather conditions. This means that a larger proportion of exposure units than on basis of randomness incur losses in the same year. The principle of pooling is therefore violated but can be overcome by dispersing the insurance company coverage over a large geographic area or by using the reinsurance market or both (Rejda, 1998). The extent to which dispersing reduces the catastrophic loss is not yet quantified. Weather derivatives might be an option if a strong relationship is present between the applied active ingredient of phytophtora protection and a particular weather index. By means of weather derivatives indemnity payments can be objectively triggered between reinsurers (or other financial organizations) and the insurance company or even between the insurance company and the insureds (Skees, 1999).

There are considerable additional requirements of ECO-label production comprising administration, soil sampling, balanced fertilization causing yield reductions in some years, use of more expensive crop protection agents for weed control and Late Blight control. Despite the higher production costs, the additional returns depends on whether or not the requirements are met at the end of the season. Late Blight control is the most important risk factor causing violation of the ECO-label conditions. So these extra costs in combination with the uncertainty about the addition returns may be a barrier to participation. Green insurance might increase the participation rates but to what extend is hard to estimate. Decisive factors include the perceived risk and the premium charged.

Up to now, ECO-label crop protection conditions have depended on the average active ingredient of crop protection used by the producers. The flexible threshold ensures the processing industry a more constant supply of ECO-label potatoes. In addition, the producers can comply with the released conditions in years with a high phytophtora infestation due to adverse weather conditions. Participation is therefore stimulated since it reduces the risk of lower prices despite the higher production costs.

The premium of the insurance contract must account for the dynamic probability of indemnity payments if the current practice is continued. However, ad hoc production conditions are hard to understand by consumers and might hamper sales. Green insurance facilitates more rigid production conditions while at the same time larger participation can be expected. Moreover, the combination of higher participation rates and rigid conditions may result in a more constant supply of potatoes of a label with a higher credibility and standing. This may well result into a larger price difference for ECO-label potatoes as compared to conventional, increasing the profitability of ECO-label production.

In general, green insurance will stimulate the adoption of conservation practices but till now there is a limited number of commercial green insurance contracts. The current example for the cultivation of ECO-label potatoes showed that common pitfalls associated with (green) insurance can be overcome partially with a well designed insurance scheme. Particularly the transparent calculation of the scope of the loss event, that is the difference between the ECO-label price and the obtained conventional price, opens a window of opportunity. Although the research focussed on ECO-label potatoes, the design can be applied to other ECO-label products as well.

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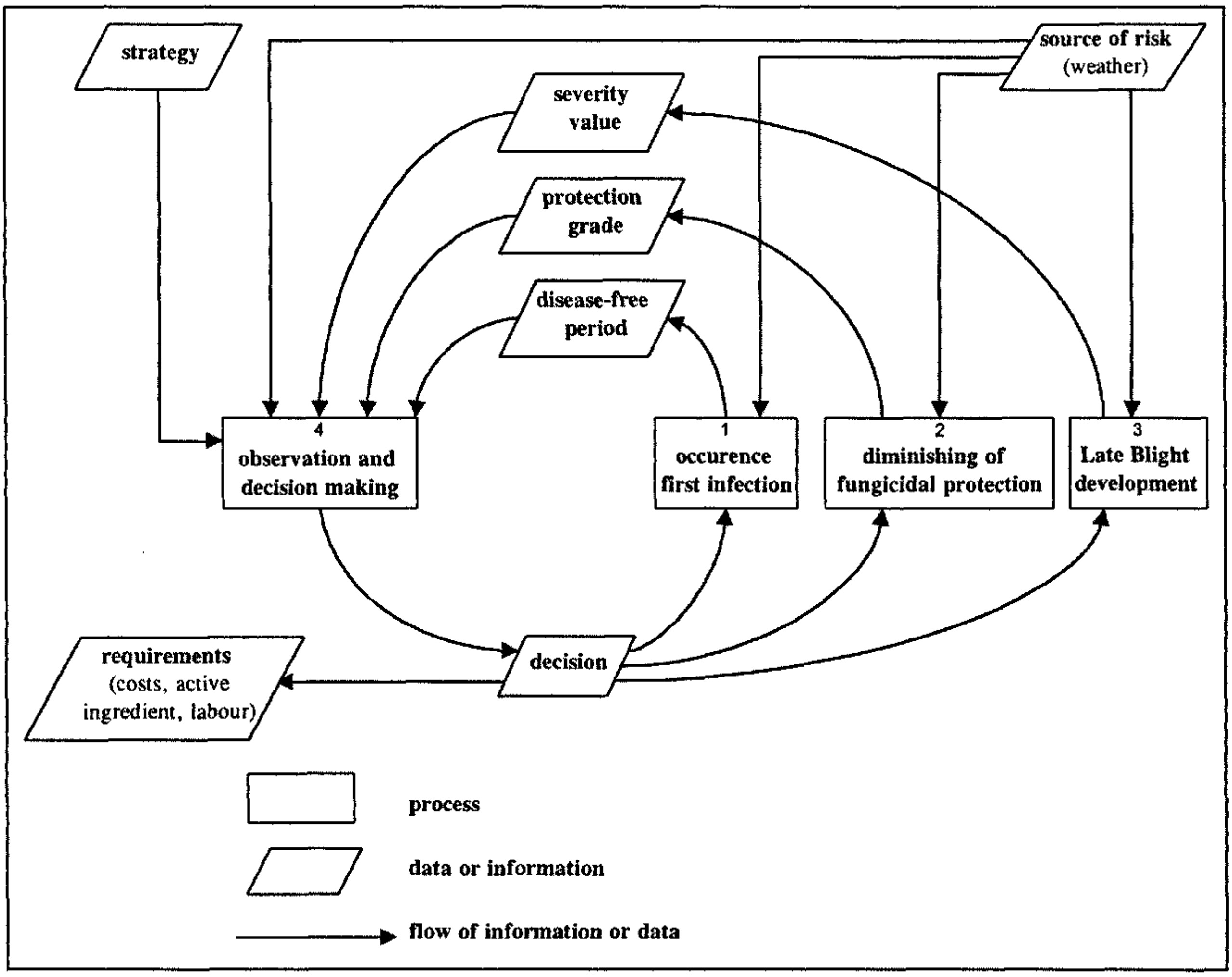

Figure 1 Conceptual model of Late Blight control in potatoes.

Table 1: Results on pesticide reduction in Dutch potatoes by ECO-label and organic production compared to conventional production.

	Pesticides use (%)	Pesticide emission to open water (%)	EIP (%)[1]
ECO-label	57	80	98
Organic	99	100	98

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[1] Environmental Impact Points of pesticides, based on their effects on water organisms and soil organisms (De Vries and Wiskerke, 1998).

Table 2: Distribution of simulated annual active ingredient use (kg/ha) for three cultivars.

Cultivar	X	SD	P(a.i.>threshold)		
			4	5	6
Bintje	5.58	2.80	70.60	64.70	47.10
Agria	5.12	2.49	67.70	41.20	41.20
Texla	3.71	1.52	52.90	11.80	11.80

Table 3: Loss cost of a green insurance for three cultivars, price differences and thresholds.

Cultivar	price[1]	Loss cost per hectare[2] given three thresholds		
		4	5	6
Bintje	0.25	91	83	61
	0.50	182	167	121
	1.00	364	333	243
Agria	0.25	87	53	53
	0.50	174	106	106
	1.00	349	212	212
Texla	0.25	68	15	15
	0.50	136	30	30
	1.00	272	61	61

[1] Assumed price difference in Euro per 100 kg between ECO-label and conventional production.

[2] Average production of ware potatoes in the central clay area is 51,500 kg per hectare.