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Co-existence of GM and non-GM potato varieties on Finnish potato farms – potential costs and remedies

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Abstract: The aim of this study is to estimate by the seed potato inspecting data and farm model calculation that what the costs are caused by the segregation by potato varieties at farms. Furthermore this study assesses that, how contract production will be build up because of segregation. Co-existence is expensive to implement if the inspections are systematic. When a farmer starts cultivating a GM variety, it is no longer profitable for the farmer to return to cultivating non-GM potatoes. The deployments of gene technology and isolation requirements contribute to the networking of the supply chain

Key Words: Gene technology, potato, co-existence, supply chain, contracts, vertical coordination, profitability, profitability ratio.

Introduction

On 24 February 2005 the Finnish Ministry of Agriculture and Forestry released its interim report on the enabling of co-existence between genetically modified crops and conventional (non-GM) and natural agricultural production in Finland. The purpose of this study was to determine the financial impact of the various measures involved in co-existence on the farm level in Finnish food potato production.

The interim report by the Ministry of Agriculture and Forestry was based on the recommendation by the Commission of the European Union on the drafting of national strategies and best practices for the co-existence of different production forms when cultivating genetically modified crops and conventional (non-GM) or naturally produced varieties. According to the principles of the recommendation, farmers should be able to employ the cultivation method they desire: genetically modified varieties, varieties produced in the conventional (non-GM) way or varieties produced naturally. Furthermore, according to the Commission, the question involves the consumer's freedom of choice. In order for European consumers to have a realistic possibility to choose between foodstuffs produced by the different methods, the new statutory traceability and labelling requirements alone will not suffice but the agricultural industry must also produce different goods and in a variety of ways.

Co-existence is involved in whether framers can practically choose between producing Conventional (non-GM), natural or genetically modified crops by conforming to the labelling and/or purity provisions. The aim is that the threshold values would not be exceeded for farmers whose product otherwise would not require the genetic manipulation label (MMM 2005).

Parallel use of different production methods is not a new issue in farming. For example, there is plenty of experience in the field of in cultivation seed production and potato production with respect to cultivation policies aimed at ensuring purity and genuineness requirements (Virolainen 2001, Niemi et al. 2003).

On principle of co-existence is, according to the Commission's recommendation, that the party that introduces a new production method in a specific area must see to the cultivation measures required in the area to restrict the genetic flow. The success of co-existence requires, however, that farmers implement broad collaboration with their close neighbours regardless of who has introduced the most recent production method on the area (MMM 2005).

One of the central questions is the crossbreeding of varieties or species. The genetic flow thus incurred can be reduced with a number of measures, but particular attention must in that case be paid to the crossbreeding features and biological compatibility of each species, their mutual competition on pollination and seed production. Also natural obstacles, such as forests and bodies of water between fields, are significant in reducing the genetic flow of plants for which the intervening terrain does not have natural occurrences or easily crossbreeding natural relatives (MMM 2005 Angevin et al. 2002).

Another central factor is the reduced variety purity in cultivation caused by mixing of seeds or residual plants. Unintentional mixing can be reduced for example by using high-quality, certified seeding seed. If a farm is using its own seeding seed, it should be harvested from the parts of the cultivation where mixing with the material of the neighbouring field is minimal. Cleaning up of seeding and harvesting equipment and field machinery can reduce the transportation of seeds between fields, while careful and planned harvesting reduces the quantity of seeds that drop on the ground. Correctly planned post-treatment of fields and anti-weed measures reduce residual vegetation and unnecessary genetic flow on a farm (MMM 2005, Virolainen 2001, Niemi ym 2003).

With the exception of the potato, Central-European genetically modified cultivation crops are most usually not suitable for cultivation in Finland without further refining (MMM 2004). It is likely that the potato will be the first genetically modified crop that will be introduced in Finnish farming. Therefore this study has been restricted to discuss the costs incurred by the co-existence of genetically modified and conventional (non-GM) potato. This report does not discuss the environmental impact of genetically modified plants but attempts to solve the financial aspects arising in the parallel application of different production forms.

Agricultural production in Finland

The surface area of Finland is 33.8 million hectares, of which agricultural land in use amounts to 2.2 million hectares (6.5 percent). The cultivated surface (including fallow) total 2,212,000 hectares. The cultivated area has increased steadily by a total of 89,800 hectares since 1996. (MTTL 2004).

According to the statistics of the Ministry of Agriculture and Forestry's information service centre (TIKE), the use of agricultural land in 2004 was primarily as follows: cereal crops approximately 54 percent, grassland approximately 30 percent, fallow approximately 9 percent and other crops (such as potato, sugar beet, turnip rape and oilseed rape) approximately 8 percent. (MTTL 2004).

The cultivation area of the turnip rape and oilseed rape was approximately 82,000 hectares (3.7 percent of the agricultural land in use) while approximately 29,000 hectares were used for the potato (1.3 percent of the agricultural land in use) (TIKE 2004). During the past five years, the cereal crop area has increased by 5 percent while the grassland area has decreased by 6 percent. (MTTL 2004).

In 2003, Finland had a total of 72,000 farms with an area in excess of one hectare that had applied for subsidies. During 1995–2003, the number of farms has decreased by 25 percent: of 95,562 farms, 23,562 have discontinued business (MTTL 2004)..

The agricultural production structure, measured by the number of farms, has considerably changed during the EU membership. The portion of farms with domesticated animals has decreased while the number of farms with plant cultivation has clearly increased. In 2003, 39 percent of farms that had sought subsidies were domesticated animal farms and approximately 57 percent were plant production farms (MTTL 2004)..

As the number of farms has decreased, the average size has increased. The average size of farms that received subsidies in 1995–2003 has increased by 36 percent from 22.8 field hectares to 31.0 hectares. The cultivated field area has increased more by means of field rental than through additional field sales. Of the 2.23 million cultivated hectares of the farms that received subsidies in 2003, 39 percent were rented (MTTL 2004)..

Agricultural production in Finland is almost completely based on family-run farms. 88.6 percent of farms that received subsidies were owned by private individuals and 10.5 percent by estates and family companies and corporations. Co-operatives, limited liability companies and production rings owned 0.8 percent of the farms, while the state, municipalities, schools and parishes owned 0.1 percent. The average age of farmers on farms that received subsidies is 49 years.

In 2004, fields used in natural cultivation or in a transition phase amounted to 7.6 percent of the entire farming area, or 169,000 hectares. The number of naturally cultivated farms was approximately 4,900 in 2004 (MTTL 2004)..

Potato production in Finland

The most important forms of production of the potato are production for food, industrial food potato, starch potato and seed potato (Table 1). The proportion of natural farming of the entire potato production is approximately two percent (KTTK 2004).

Table 1. Potato production forms, their cultivation areas and share of natural production in 2002 (sources: TIKE 2004, KTTK 2003, KTTK 2004).

	Traditional production		Natural production	
	[t]	[ha]	[t]	[ha]
Food potato	289,000	11,300		362
Food industry potato	126,300	4,200		
Starch potato	264,000	8,800		28
Seed potato etc.	100,800	5,400		13
Other potato				214
Total	780,100	29,800	7,950	616

Professional potato production is focused on a narrow strip on the coastal areas of Finland where the arable soil types are commonplace. Potatoes for the food industry and starch production are primarily produced in the vicinity of the factories that utilise the raw material. The increase and cultivation of the highest seed potato grades is then focused on the Northern Ostrobothnia region's high-grade seed potato production area, where viral diseases spread particularly by insects are rare. (Tuomisto 2003, Tuomisto 2004) The origin of seed potato used in garden plot for household use is often unknown.

The potato differs from other crops in that potato is largely cultivated in gardens in addition to the professional production. When cultivating potatoes in garden plots for household use, excess food potato is often used as the seed potato, and the origin in unknown. A special feature of professional potato production is, on the other hand, contract production (Tuomisto 2003).

In particular the food potato and starch potato industries acquire the raw material from contract producers, whereby the high quality requirements of the produced potatoes can be best implemented. Contract framing often involves stringent variety requirements and detailed farming instructions provided with a variety, as well as advising and monitoring of farming measures during the growth season (Tuomisto 2003). However, food potatoes produced for grocery stores is not as commonly contract production or the contract is based on a more loose connection between the farmer and the store. Many store chains have, however, attempted to assure the quality of food potato by means of contract farming and packing functions.

Certification no longer requires approval on the national variety list but the potato varieties approved in Europe are also approved for cultivation in Finland. Yet the importers of new varieties want to test the variety properties in Finnish conditions before broader dispersion of the variety (Tuomisto 2003). The potato differs from other crops in that varieties refined in Central Europe can also be utilised in Finland. The germination of seed potatoes reduces the growth season of the potato and allows with certain restrictions the cultivation of potatoes with different growth season requirements or potatoes refined for Central European conditions also in Finland.

Potato refining largely takes place elsewhere in Europe, primarily in the Netherlands (Tuomisto 2003). New potato varieties on the variety lists are of foreign origin with a few exceptions. Finnish seed potato companies and the industry acquire representation rights for other European varieties in Finland. In practice, this should mean that the genetically modified potato varieties that become commonplace in other parts of Europe are introduced in Finnish farming primarily through their variety representatives (Tuomisto 2003). Figure 2 shows the breeders and agents of potato varieties cultivated in Finland, as well as seed potato supplies to the market, through different chains. The left-hand side of the figure shows the primary breeders of seed potato varieties available

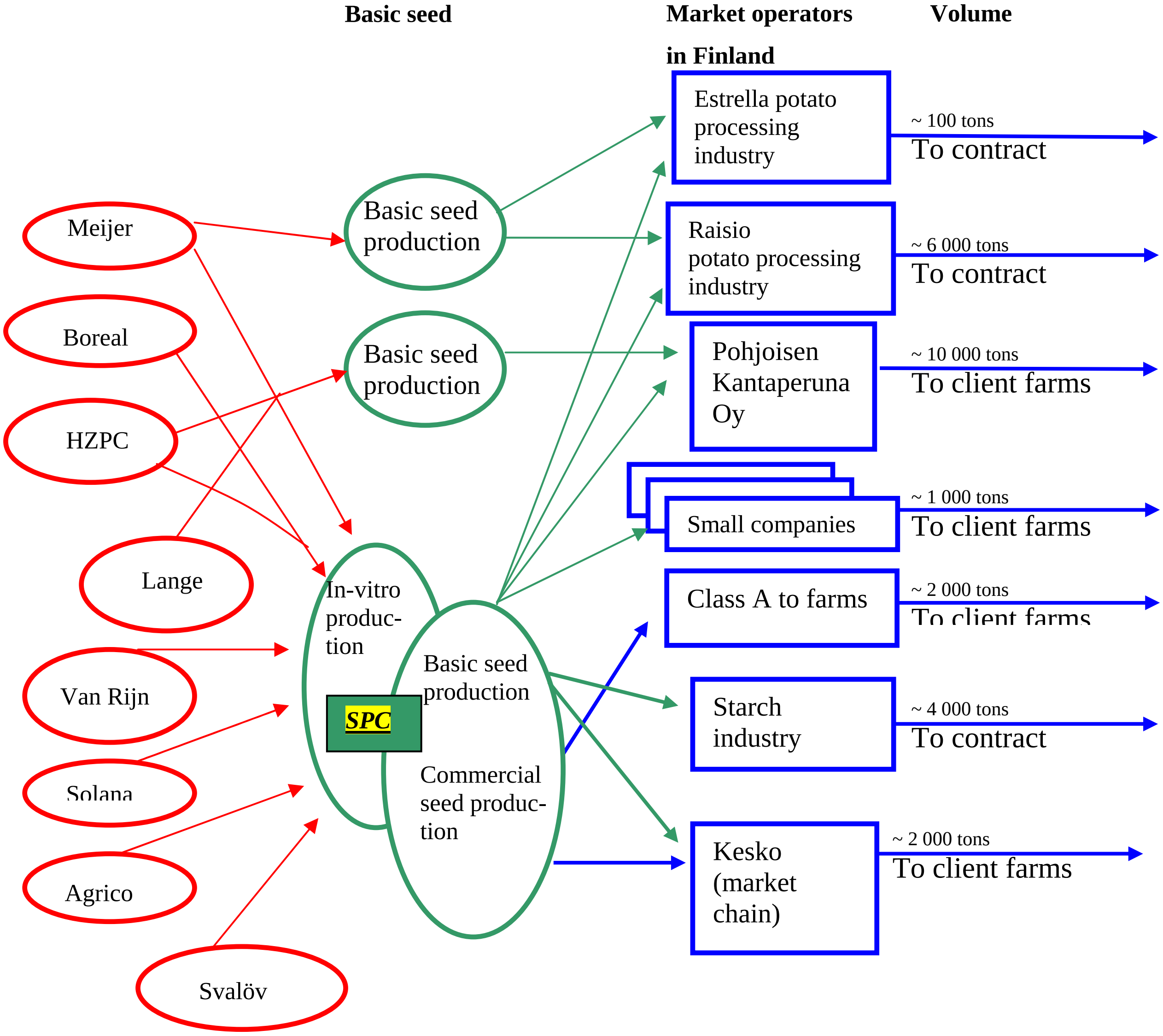

Figure 1. The potato supply chain in Finland (Tuomisto 2003)

in Finland, and the right-hand side displays the companies offering seed potato with their supply amounts. The middle of the figure shows the *Seed Potato Centre* (SPC), which is responsible for micro-propagation (in vitro) of seed potato and basic seed production. Companies that operate as agents on the market or under license from agents can also import seed potato or engage in higher-class basic seed production. (Tuomisto 2003).

Cultivation cycle

Monoculture is a problem of Finnish potato farming (Tuomisto 2004). Farms that specialise in the potato often cultivate excessively large potato areas considering the field area. The farm may have mechanised equipment solely for cultivating potatoes. In the unbalanced cultivation of the potato, the risk for pests is rapidly increased and the soil composition deteriorates. Financial aspects have, however, driven the potato farms to their monoculture operation.

Seed cultivation

In professional potato farming, the utilisation ratio of certified seed potato averages 35–45 percent. The remainder of the utilised seed in-farm seed produced of seed certified on the farm.

In Finland, seed potato certification takes place so that the *Plant Production Inspection Centre's* (KTTK) seed testing department's authorised inspectors inspect all seed plantation. The inspector reviews whether the seed culture (seed population) meets the quality requirements set in the provisions of the Ministry of Agriculture and Forestry (for example preceding crops, isolation distances, quality of basic seed, absence of wild oat). The culture inspector recommends the approval or rejection of the seed culture. A decision on the approval or rejection is made by KTTK. If the requirements are not met, the culture or part of it is rejected. The variety pureness of higher-grade seeds is inspected at the cultivation inspection centre and on KTTK's own test field. The farmer submits the harvest collected from the seed culture to packing. The seed material can be packed by a packing service with KTTK's valid permit for conducting packing business. The packing service processes the harvest and forms a trade batch from which an official sampler takes an official sample. Purity, sizes of tubers, diseases and variety genuineness are determined from the sample by variety and seed class. The results are compared to the requirements provided for by the Ministry of Agriculture and Forestry. If the batch meets the requirements, it can be certified and certificates are printed for the batch. After this the batch can be marketed. The seed potato inspection differs from the inspection of other types in that in addition to the culture inspection, also potato root eelworm is inspected from the soil samples taken from the culture patches. The tuber harvest is inspected for bacterial ring rot and viruses. If the harvest meets these requirements, visual warehouse inspection can be carried out for the batch. After the warehouse inspection the batch can be certified. Seed potato is marketed in packages with certificates attached. (MMM 2005, Tuomisto 2003)

Figure 2 illustrates briefly the structure of the Finnish food potato supply chain. Breeders use techniques based on the alteration of genetic traits to develop new potato varieties with agronomic characters and crop use values that meet the requirements of both the farmer and the crop user. The breeder co-operates with an agent. The breeder supplies the agent with genetic material either in test tubes or in the form of tubers, which are used by the *Seed Potato Centre* (SPC) to produce basic seed, pre-basic seed or new micro-propagation (in vitro) material. (Tuomisto 2003)

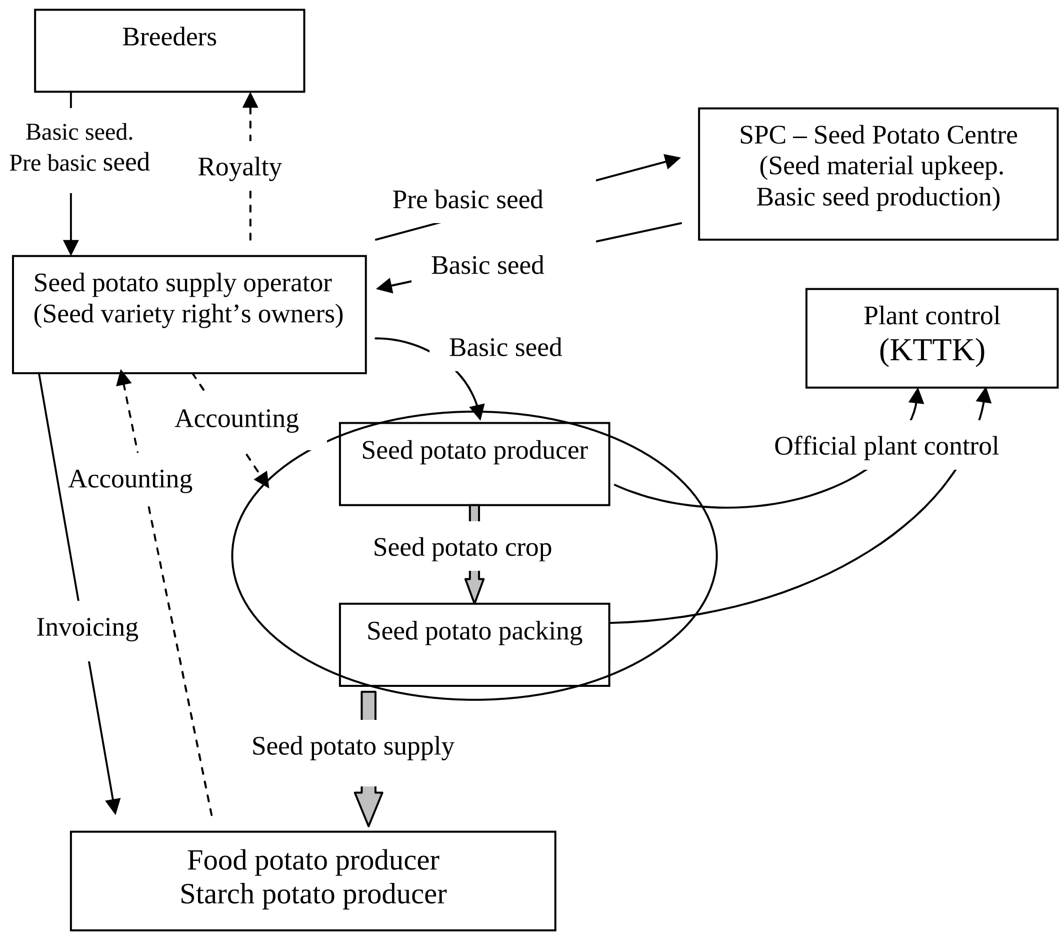

Figure 2. The vertical supply chain of the seed potato market (Tuomisto 2003).

The breeder can also directly supply the agent with basic seed, which the agent can forward to contract producers for the production of certified food potato seed. Seed potato producers and packing plants will most often work in close co-operation with agents and seed potato marketing companies to supply food potato producers with seed which has been prepared, packed and inspected by the Plant Production Inspection Centre, although invoicing will be handled through a marketing company. The marketing company pays the seed potato fees either to the packing plant or directly to the seed potato producer. Starch potato production and food industrial potato production operate in contract production but table potato production operates in the full competition market in Finland. (Tuomisto 2003)

Requirements set for seed potato production (certified seed potato, threshold assumption 0.3 percent). (MMM 2005)

- The field that produces certified-class seed potato may produce other potato in parallel only provided that the other potato fields have been established at least with certified seed potato and that their populations are inspected. The other potato produced must not be of the same variety as the seed potato being produced.
- Preceding crop restrictions: After two consecutive seed potato cultivation years the patch must not be used for potato cultivation for two growth seasons with certified seed and for three growth seasons with basic seed. Seed potato may be cultivated on one patch for two growth seasons with the following restrictions: *a*) the variety being cultivated is the same during both years and *b*) the grade of the potato cultivated during the second year cannot exceed the indication of the determined fungus and bacterial disease quantity during the first-year culture inspection.
- Isolation distances: To prevent the spreading of plant diseases, a seed potato patch may not be closer than 10 m to another potato patch of a lower quality grade or a food or industrial potato warehouse or a greenhouse.
- Requirements on plant enemies and ground-spread viral, mechanical or physiological damages, soil and quantity of debris.
- Pureness at least 99.5 percent.

The genetic flow from the potato to its relatives in Finland is highly unlikely. Close relatives that occur in Finland are the black nightshade (*solanum nigrum*) and bitter nightshade (*solanum dulcamara*). The possibility of crossbreeding the potato and either of the nightshades has been studied by manually pollinating between the species. Despite attempts, crossbreeding has not succeeded and seeds have not been formed (Eijlander & Stiekema 1994). Therefore the spreading of genetic modifications of the potato by weeds in Finland appears almost impossible based on the studies.

Pollination

The potato is a crop that reproduces asexually by means of tubers (Angevin et al. 2002). The spreading of pollination in the case of the potato is limited, as no nectar is formed in the flowers that would attract pollinating insects to do the pollination. Studies have determined that cultures of genetically modified potato varieties do not spread pollen to other potatoes that have grown at a distance of 20 m (Tynan et. al. 1990, McPartlan & Dale 1994, Connor & Dale 1996).

The spreading of the pollen to non-modified potato varieties can therefore be prevented with sufficient isolation buffers. This saves the producer from the pondering whether the berry and seeds formed from the potato inflorescence will remain germinable to the following year and whether the seedlings growing from the seeds will succeed in the following year.

Residual plants

The potato harvest studies carried out by the Finnish Work Efficiency Institute (TTS) and VAKOLA (MTT Agricultural Technology Research Institute) at the end of the 1980s measured more than one tonne of residual potato per hectare after the harvest. If the average size of the tubers were 30 grams, the remaining potato would total almost 35,000 units per hectare. The studies of the potato research institute have determined that the growth formed by the residual potatoes can occur up to four years after the discontinuation of potato cultivation (Kuisma 2005).

With potato growth, the problem in co-existence becomes the mixing of varieties caused by the residual potatoes, if different varieties are cultivated in one field during consecutive years. The variety restrictions of consecutive potato years reduce the risk of mixed varieties. If the potato variety is changed from a genetically modified one to a conventional (non-GM) one, at least one year must be set aside and the cultivation area must be used for cereal crops or oil plants or fibre plants or the area must be grassed over. Also cultivation rotation requirements should be considered to avoid variety mixing (MMM 2005).

In fighting residual potatoes, the objective should be to prevent residual potatoes from remaining germinable in the ground over winter. The cultivation system study of the potato research institute in 2001 found four residual potato units per 10 square metres in the early autumn. No residual potato was detected in soil that was ploughed in the spring and only cultivated in the autumn (Kuisma 2005).

The best way to avoid the residual vegetation problem would be to transfer the ploughing to the spring. When a potato field is not ploughed in the autumn, the potatoes remaining in the top parts of the soil after the harvest are not buried at the bottom of the ploughing depth but remain close to the surface of the field throughout the winter, thus exposing them to alternating freezing and melting. Tubers that remain underground after the harvest can be better exposed for destruction by night-time frost in the autumn by harrowing the surface after harvest at a depth of 5–7 cm. Repeated harrowing after a few frosty nights assures that the residual potatoes are destroyed by frost. Preceding crop restrictions can also avoid residual vegetation problems (Kuisma 2005).

The mixing of potato batches during transportation and warehousing as well as the lack of traceability of seed potatoes used by household use in garden plot are likely to be the most significant way in which genetically modified and non-modified potatoes can be mixed. Genetically modified varieties can be cultivated without a significant mixing problem in contract production as well as for the needs of the food potato and starch potato industries. However, the patches used by household use in garden plot have an apparent risk of mixing between genetically modified and other potato varieties (MMM 2005).

The Finnish Ministry of Agriculture and Forestry's recommended measures to prevent the spreading of genetically modified material in non-seed-potato production (threshold value 0.9 percent, 0.1 percent for natural production as a working figure) (MMM 2005)

- The assumption is that the share of genetically modified production does not exceed 50 percent of the total potato cultivation area

- the tubers must be analysed and inspected (use of certified seed potato)
- natural production must use naturally produced seed potato
- the equipment must be cleaned very carefully if they are used by several parties and in areas where genetically modified potato is cultivated
- isolation distances 20 m
- residual vegetation must be collected and destroyed
- plant rotation must be arranged: the potato may only be cultivated for two consecutive years in one patch
- the soil must be worked after harvesting so as to lift the residual plants to the surface
- pesticide treatment must be correctly timed and applied whenever needed
- the monitoring measures must be sufficient and properly targeted

Research material

In Finland, an independent state-run agency, the Seed Testing Department of the Finnish Plant Production Inspection Centre (KTTK) inspects all seed potato patch of Finland. Food potato and starch potato patches are not inspected with the exclusion of random tests for dangerous plant diseases.

The inspections for seed potato production provide, however, indications of how many foreign varieties have been found on potato patches in the vegetation inspections. In this case, isolation distances to patches where another variety is cultivated and the impact of cultivation rotation on the germinability of residual tubers are considered.

In 1998–2003, the Plant Production Inspection Centre inspected 2,524 seed potato farms, totalling 9,203 hectares. A total of 315,500 tubers to be inspected were collected from that area. Foreign varieties were detected in 256 tubers, or 0.08% of the inspected volume. In only one seed potato farm were there more than 0.1% foreign varieties in the field. The number of fields that contained foreign varieties was 50[1], which means 1.98% of the inspected volume. Of these, ten had had potato in the same patch the year before, while 35 had had potato in the same patch 3 years earlier, which meant that some other plant had been cultivated for two years. Potato cultivation dating back three years no longer posed the wintered potato problem. The average cultivation distance in potato fields was 57.6 metres. In patches where varieties had been mixed, the average distance was 8.9 metres. Of these, the distance to another potato field was less than 3 metres in 74% of the cases. The tendency of the tubers to physically shift from one patch to another increased rapidly with patch distances of less than 3 metres. Also the patch size appeared to affect the variety mixing. The average size of all seed potato patches where culture inspections have been carried out in 1998–2003 was 3.65 hectares. On the cultures where incorrect varieties were found, the average size was 1.81 hectares. The wintering of the potato, patch sizes and distances of the patches contributed the most strongly to variety mixing.

Costs incurred by the co-existence of genetically modified and non-modified food potato on Finnish farms

With the current regulations in Finland, it is possible to isolate GM seed potato from non-GM potato. In seed potato production, the requirement is that two potato cultivation years must be followed by a rotation of (at least) two years of some other plant. Cultivation of two different varieties on one patch in two consecutive years is also forbidden. In food potato production problems differ one of the most difficult being monoculture.

The economic impact of segregation of gene technology was studied with farm model calculations. Previous research was used as the basis data for the farm models (e.g., Tuomisto 2004, Tuomisto 2003, Tuomisto and Antila 2001, Turunen 2001). Farm models for three farm sized, 14.29, 37.50 and 90.00 food potato hectares, were devised to suit the business budgets, and it was determined how segregation requirements would affect the income, profitability and liquidity of the farms. The profitability of potato production in the various farm models was inspected with net profit calculations and profitability coefficients:

[1] Of these 50 fields that contained foreign varieties, 37 had been used for cultivating a higher seed grade, the basic seed. The variety pureness of the basic seed is tested on KTTK's test fields while the variety pureness of a lower seed grade, certified seed, is only determined by culture inspections. Of the patches that were inspected on KTTK's test fields, 0.15 percent of the inspected contained incorrect varieties. This indicates that even professional inspectors cannot completely distinguish foreign varieties from the population with visual inspection.

$$\pi_{AVERAGE} = \frac{\sum_{t=1}^{T}\left(\sum_{i=1}^{n} p_i y_i - \sum_{j=1}^{m} w_j x_j + \sum_{k=1}^{z} s_k\right)}{T} \qquad R_{AVERAGE} = \frac{\sum_{t=1}^{T}\left(\frac{a}{l+r}\right)}{T} = \frac{\sum_{t=1}^{T}\left(\frac{\pi + l + r}{l+r}\right)}{T} \tag{1}$$

The average net profits π in the various segregation requirements are an average subtraction between sum of total returns and sum of total costs plus sum of total support in the contracts. When we ignore share of value of farmers own workload ***l*** and capital interests ***r*** from the net profit, we can achieve share of the agricultural income ***a*** by sum of value of farmers own workload ***l*** and capital interests ***r***, we can achieve profitability ratio ***R*** of potato producer in the various segregation requirements. When we sum all profitability ratios and divide the sum by years our study, we can achieve an average profitability ratio.

Appendix 1 presents the production cost calculation on an average Finish food potato farm and the impact of product-isolation assurance measures on the production costs of the farms. According to the farm model calculation, the premise is that long-term potato production on the average-size Finnish farm of 14.29 hectares is not profitable. The farm produces net loss and the profitability factor is 0.75[2]. Potato production is not profitable until with a medium-sized farm of 37.50 hectares that primarily produces potatoes (Appendix 1).

Whether certified seed or self-added seed is used on the potato farm does not appear to have an economical impact with any farm size[3]. On a 37.50-hectare farm, monoculture is profitable regardless of whether the farm employs its own seed regeneration or acquires the seed from a seed potato producer.

If the isolation requirements call for cultivation rotation, the farm’s business becomes non-profitable. Farms generate, however, agricultural income but the farmers do not receive sufficient interest on the capital invested in the farm. If the cultivation rotation required for ensuring isolation between genetically modified and traditional potato is such that potato and cereal crops should alternate each year, this requirement would reduce the profitability factor on a 37.50-hectare farm from 1.36 to 0.53. This would impose an annual cost of € 31,000 on the farm (5.4 ¢/potato kg). The requirement of two years between varieties in the cultivation rotation would cost almost € 42,000 annually (11 ¢/potato kg) if the intervening plant were cereal crop. The requirement of one fallow year would impose an annual cost of almost € 35,000 on the farm (6.2 ¢/potato kg).

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[2] The average profitability factor of Finnish farms was 0.72 in 2000, which means that the farms generate loss in average. This means that farmers do not receive sufficient cover for their work and sufficient return on their invested capital.
[3] The use of seed other than certified seed or once regenerated certified seed has not been considered in the calculations as the use of other seeds should not be possible in Finland within the framework of potato production subsidising rules. On potato overproduction years it is, however, apparent that residual (remains) potato is used as the seed.

Harrowing the potato field after harvest can reduce the germinability of residual tubers. This would cause an additional cost of € 190 on a 37.50-hectare farm. This is the cheapest and one of the confident segregation methods (Kuisma 2005).

Various test methods can be used to ensure that variety mixing will not happen in the actual cultivation. Population inspection will increase potato production costs by 2.2 ¢ per potato kg, and laboratory inspection (PCR testing) by 3.6 ¢. Building a dedicated warehouse will increase the costs by 1.4 ¢, and additional cleaning of machines and devices by 1.3 ¢ per potato kg. Product labelling and certification will increase the production cost by 4.5 ¢/potato kg.

It is possible to isolate genetically modified potato with the current regulations in Finland without additional costs. In seed potato production, the requirement is that two potato cultivation years must be followed by at least two cultivation rotation years, during which time potato may not be cultivated in that section. Neither is it allowed to cultivate two different varieties in one section during two consecutive years.

Summary

Co-existence is expensive to implement if the inspections are systematic. When a farmer starts cultivating a GM variety, it is no longer profitable for the farmer to return to cultivating non-GM potatoes in those patches if excessively high variety purity criteria are set for non-GM products: the farmer can always state that the products produced may contain genetically modified material and therefore avoid stringent isolation requirements. However, if the farmer wishes to produce non-GM potato and market it as a non-GM product, the costs may rise too high. This would cause a competitive advantage to farmers that use genetically modified potatoes.

The most problematic issue is potato cultivation on small patches for household use and the implementation of internal seed regeneration on the farm. Moral hazard problems may arise in connection with the implementation of measures needed for the co-existence of genetically modified and traditional potato. A food potato producer may sell genetically modified potato directly from the farm for food potato use or as seed for domestic-use patches as conventional (non-GM) seeds. Unintentional transportation of seed material may then take place from the household-use patches.

The deployments of gene technology and isolation requirements contribute to the networking of the supply chain. Even today, Finland exhibits signs of networking in the potato supply chain: in seed potato production, each variety representative represents their own seed potato variety, which can only be cultivated and marketed in with marketing companies or seed potato producers that have an agreement with the variety representative on the cultivation and marketing of the said varieties. Of these varieties, the seed potato producer pays a royalty to the potato processor or the variety representative that collaborates with the processor. The two largest variety representatives cover 67% of the Finnish seed potato market. This share has increased twofold since 1994 despite the fact that the seed potatoes they represent were 1 – 6 cents more expensive per kg than the seeds of the royalty-free varieties (Tuomisto 2003). This also indicates that once the genetically engineered potato varieties enter the market, farmers with a production agreement can only cultivate them with the variety representative.

If genetically engineered potato can be produced at lower production costs, their producers will gain competitive advantage compared to farmers that cultivate traditional varieties. This means the long-term disappearance from production of the traditional varieties. The consumers' opposition to genetically engineered food may slow down this development.

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APPENDIX 1

	Monoculture		Compulsory cultivation rotation				Separate warehouse for GM products (50/50)	Extra cleaning	Extra harrowing in the autumn	Extra inspections (KTTK)			With certified seed cultivation provisions
	No cereal	No cereal, 100% certified seed	50% cereal	2/3 cereal	50% fallow	1/3 fallow, 1/3 cereal and 1/3 potato				Laboratory inspection	Vegetation inspection	Marketability inspection	
Total surface 14.29 hectares													
- input cost	36,943	43,646	20,051	14,445	18,663	13,520	25,912	25,832	36,960	25,832	25,832	25,832	23,458
- work cost	25,341	25,606	14,390	10,739	13,871	10,394	18,092	19,241	25,381	18,092	18,092	18,092	14,535
- general cost	4,155	4,308	3,474	3,249	3,436	3,223	3,619	3,622	4,156	4,148	3,812	5,200	5,228
- capital cost	37,500	37,808	32,838	31,294	32,838	31,294	35,032	33,695	37,500	33,695	33,695	33,695	33,007
PRODUCTION COST	103,939	111,368	70,753	59,727	68,809	58,431	82,656	82,390	103,998	81,768	81,432	82,820	76,228
+ sales income	87,827	96,617	44,286	30,063	43,478	29,524	60,850	60,850	87,827	60,850	60,850	60,850	49,117
+ production subsidies	10,386	10,539	9,051	8,555	6,546	8,047	7,375	7,375	10,386	7,375	7,375	7,375	9,051
TURNOVER	98,213	107,156	53,337	38,618	50,023	37,571	68,225	68,225	98,213	68,225	68,225	68,225	58,168
COVERAGE 1 (without the farmer’s salary)	35,660	37,739	14,808	8,065	12,877	7,939	21,111	21,552	35,643	21,038	21,366	20,012	14,507
COVERAGE 2 (farmer’s salary included)	23,795	25,774	7,951	2,882	6,531	3,098	12,564	11,871	23,737	12,491	12,819	11,465	7,594
EARNINGS	6,140	7,753	-10,558	-15,926	-12,440	-16,018	-5,883	-4,483	6,122	-4,995	-4,659	-6,047	-11,147
AGRICULTURAL INCOME	16,786	18,466	-1,124	-6,893	-3,005	-6,985	3,633	4,635	16,768	4,123	4,459	3,071	-1,676
NET PROFIT	-5,725	-4,212	-17,416	-21,109	-18,785	-20,860	-14,430	-14,164	-5,784	-13,542	-13,206	-14,594	-18,060
PROFITABILITY RATIO	0.75	0.81	-0.07	-0.48	-0.19	-0.50	0.20	0.25	0.74	0.23	0.25	0.17	-0.10
Total surface 37.50 hectares													
- input cost	101,289	114,724	54,880	39,341	51,227	36,906	81,361	81,123	101,338	81,123	81,123	81,123	61,599
- work cost	54,629	55,403	29,863	21,696	28,862	18,421	43,641	45,249	54,767	43,641	43,641	43,641	30,195
- general cost	7,626	7,951	5,885	5,305	5,791	5,189	6,755	6,725	7,630	7,707	7,095	11,132	9,945
- capital cost	76,678	77,566	64,523	60,472	64,523	60,472	74,090	70,078	76,678	70,078	70,078	70,078	64,967
PRODUCTION COST	240,222	255,644	155,151	126,814	150,403	120,988	205,847	203,175	240,412	202,550	201,938	205,974	166,707
+ sales income	228,189	253,543	116,216	78,891	114,094	77,477	182,551	182,551	228,189	182,551	182,551	182,551	128,893
+ production subsidies	27,656	27,656	23,752	22,451	17,177	21,116	22,125	22,125	27,656	22,125	22,125	22,125	23,752
TURNOVER	255,845	281,200	139,968	101,342	131,272	98,593	204,676	204,676	255,845	204,676	204,676	204,676	152,645
COVERAGE 1 (without the farmer’s salary)	97,397	108,465	48,166	31,005	43,101	33,485	74,993	76,353	97,211	75,395	75,992	72,053	50,049
COVERAGE 2 (farmer’s salary included)	77,477	88,545	35,811	21,902	31,735	24,860	57,522	57,294	77,290	57,924	58,521	54,583	37,595
EARNINGS	35,543	45,476	-2,828	-16,368	-7,766	-13,770	16,300	20,560	35,354	19,597	20,209	16,173	-1,607
AGRICULTURAL INCOME	58,717	68,843	17,184	2,591	12,246	5,188	38,008	41,075	58,527	40,112	40,724	36,687	18,501
NET PROFIT	15,623	25,556	-15,183	-25,471	-19,131	-22,394	-1,171	1,501	15,433	2,127	2,739	-1,298	-14,061
PROFITABILITY RATIO	1.36	1.59	0.53	0.09	0.39	0.19	0.97	1.04	1.36	1.06	1.07	0.97	0.57