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Blight-MOP: Development of a systems approach for the management of late blight (caused by *Phytophthora infestans)* in EU organic potato production

ANNEXES

***Period*: 01/03/01 – 31/12/05**

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Annex 1: Component strategy evaluation

A: varieties. (see CHAPTER 3)

WP	**2.1: Assessments of variety performance in different EU regions and organic production systems**
method	varieties
WP manager	FiBL
description of method	replace existing variety with a new variety which is more blight tolerant or resistant
effect on foliar blight (Reference: standard variety, no copper)	0-99% reduction, depending on variety
effect on tuber blight (Reference: standard variety, no copper)	0-50% reduction, depending on variety. Not necessarily linked to effect on foliar blight.
effect on yield (Reference: standard variety, no copper)	0-30% increase, depending on variety
estimated material costs/ha	No additional costs
estimated labour costs/ha	No additional costs
estimated machinery costs/ha	No additional costs
efforts needed / bottlenecks for introduction into practice	Introduction requires a lengthy process including (1) variety testing; (2) placement on national/ recommended list; (3) convince market and producers; (4) production of seed takes several years for each individual variety.
domain of application, constraints, technical details	change of variety influences numerous aspects of production, storage and processing. Varieties must be evaluated for each purpose of use separately.
interactions with other component strategies	varieties may differ in their needs with respect to fertilisation, rotational position, N-availability, chitting, etc.
risks	breakthrough of resistance; more aggressive blight strains.
comments	success depends on variety!
availability for field test in WP 7.2	generally yes; depending on country and availability of seed

B: alternating rows. (see CHAPTER 4)

WP	**3.1: Development of within field diversification strategies – Alternating rows of resistant and susceptible varieties**
method	alternating rows
WP manager	INRA
description of method	two or more varieties planted in alternating rows.
effect on foliar blight	0-50 %
effect on tuber blight	No data available at present
effect on yield	0-25 %
estimated material costs/ha	No additional costs
estimated labour costs/ha	Depends whether each row, two rows or four rows are alternated. To be determined in WP 7.2.
estimated machinery costs/ha	0
efforts needed / bottlenecks for introduction into practice	(1) determine degree of mixing; (2) great extension efforts necessary!
domain of application, constraints, technical details	(1) rows must be labelled and harvested carefully, to avoid mixing of varieties; (2) similar harvesting times needed
interactions with other component strategies	varieties should be similar with respect to fertilisation needs, harvesting time etc. This Component Strategy works better when combined with small amounts of fungicides, and when inoculum pressure is low (i.e. in situations with either occasional blight or usually slow epidemics).
risks	Shifts in pathogen population genetics unlikely based on preliminary observations; tends rather to stabilise populations structures
comments	none
availability for field test in WP 7.2	yes

C: intercropping. (see CHAPTER 4)

WP	**3.2: Development of within field diversification strategies – Intercropping**
method	intercropping
WP manager	KU
description of method	small sized potato fields alternate with clover or wheat
effect on foliar blight	5-23% reduction in blight
effect on tuber blight	no tuber blight observed
effect on yield	yield loss relationships on multiple data points linear, but dependent on year and variety bulking characteristics
estimated material costs/ha	No additional costs
estimated labour costs/ha	To be determined in WP 7.2.
estimated machinery costs/ha	No additional costs
efforts needed / bottlenecks for introduction into practice	(1) determine usefulness; (2) great extension efforts needed
domain of application, constraints, technical details	(1) complicates crop rotation; (2) competition reduces yield in border zone; (3) small field size conflicts with effective use of machinery; (4) only applicable in large fields
interactions with other component strategies	
risks	No obvious risks
comments	Combinations with row-crops other than cereals might be interesting (example from China: potato-Maize)
availability for field test in WP 7.2	yes

D: variety mixtures. (see CHAPTER 4)

WP	**3.3: Development of within field diversification strategies – Variety mixtures**
method	variety mixtures
WP manager	EFRC
description of method	two or more varieties planted in an intimate mixture.
effect on foliar blight	18-48% reduction (Santé)
effect on tuber blight	none detected, but levels low
effect on yield	5 % increase
estimated material costs/ha	No additional costs
estimated labour costs/ha	Initial mixing: 0-1 h/ha. Final Separation (if required): 10% increase in sorting time
estimated machinery costs/ha	No additional costs
efforts needed / bottlenecks for introduction into practice	Farmer/Market acceptance
domain of application, constraints, technical details	(1) Mix ecologically and agronomically compatible varieties. (2) Mix highly resistant with more susceptible varieties. (3) Mix different tuber characteristics.
interactions with other component strategies	Likely, as shown by Garrett et al. Expect improved mixture performance as part of an overall system approach to the prevention of late blight.
risks	None evident
comments	none
availability for field test in WP 7.2	Yes, suggested: Cara/Appell under UK conditions

E: planting date. (see CHAPTER 5)

WP	**4.1: Agronomic strategies – Effect of planting date on development of late blight, crop yield and quality in early and maincrop potatoes**
method	planting date
WP manager	UNEW
description of method	Earlier planting gives a prolongation of the growing period before the advent of the blight epidemic, and thus possibly a higher yield.
effect on foliar blight	Effects of planting date on the susceptibility for late blight are dependent of other factors. In some experiments early planted potatoes were more infected by late blight, possibly because senescence had already started when the plants were infected. In other experiments they were less infected, or there was no difference.
effect on tuber blight	no direct effects
effect on yield	Possibly higher yields and larger tubers with a longer growing period (early planting). Effects on tuber quality (dry matter contents)
estimated material costs/ha	No additional costs
estimated labour costs/ha	No additional costs
estimated machinery costs/ha	When storage of seed is a cost factor, early planting saves costs when compared to late planting.
efforts needed / bottlenecks for introduction into practice	extension
domain of application, constraints, technical details	Efficacy depends on weather conditions: soil has to be fit for planting, and weather conditions should allow an undisturbed plant growth. When planted too early, with cold and wet weather, effects will probably be negative. Soil temperatures should be above 10°C. Efficacy will be higher when an early infection by late blight occurs.
interactions with other component strategies	When planted early, effects of chitting are generally lower. When N-availability is limiting for plant growth, early planting can make this problem more severe because mineralisation is still too low. An additional N-fertilisation may be needed.
risks	With an early planting date the risk of a period with cold and/or wet weather is higher. Frost can cause damage as well. N-availability may be too low because of a low mineralisation rate in early spring.
comments	none
availability for field test in WP 7.2	yes

F: chitting. (see CHAPTER 5)

WP	4.1: **Agronomic strategies – Effect of chitting seed tubers on development of late blight, crop yield and quality in early and maincrop potatoes**
method	chitting
WP manager	UNEW
description of method	Chitting in trays, bags or otherwise. Special temperature regime: first (short) warm period, later cooler and light.
effect on foliar blight	No direct effects of chitting on foliar blight, but similar effects as under 1 E. UK: Variable. 50% less blight in early planting in one variety in 2001; 50% less in late planting in one variety in 2002.
effect on tuber blight	No effects. UK: 0
effect on yield	Chitting gives a faster crop development. Tuber formation starts earlier. Tuber yield reaches an acceptable level earlier in the season, and tubers are larger. Effects on tuber quality (dry matter contents). UK: 0-25% increase from early planting; 0-80% increase from full-chitting (biggest response in late planted, susceptible variety).
estimated material costs/ha	chitting equipment: boxes or bags, pallets, lights, …chitting equipment: Chitting trays approx. 3 euro per 50 kg seed; pallets; warm-white fluorescent light tubes if not chitted in glasshouse; possible requirement for heat input. No trays if chitted in bags
estimated labour costs/ha	chitting: Euro 10-15 /ha
estimated machinery costs/ha	eventually special planting machinery. UK: No change in field equipment costs but planter must cause no/minimal damage to sprouts
efforts needed / bottlenecks for introduction into practice	extension. UK extension: chitting plans/requirements for individual varieties: seed needs to be available for early delivery to grower.
domain of application, constraints, technical details	soil temp. min 10°C, otherwise negative impact likely. Success depends on weather and time of blight epidemic. Interactions with plant physiology. Limited by late frosts. Chitting reduces flexibility in planting date. Tuber number may be affected. Need to avoid de-sprouting during mechanical planting; may cause difficulties with fully automatic planters. Adequate light needed to produce strong sprouts. More difficult to manage if several varieties grown on the farm.
interactions with other component strategies	Chitting is more effective when the growing

	season is shorter (early blight-infection or late planting), on heavier soils (where initial plant growth is generally slower), when the planting date is later in time (because the growing period is shorter), for late varieties (because they have a slower start), for susceptible varieties (because they have generally an earlier infection and thus a shorter growing season).
risks	Chitted potatoes are more vulnerable than non-chitted potatoes (risk of breaking off the chits). They have to be handled with more care. Chitting takes 6 - 8 weeks, so an adequate planning is important. The flexibility in choosing the planting moment diminishes. Unexpected bad weather may cause problems. Chitting in trays gives opportunity to identify and remove diseased seed tubers before planting.
comments	Full chitting better than short chitting. Chitting programme will be variety specific.
availability for field test in WP 7.2	yes

G: defoliation strategy. (see CHAPTER 5)

WP	**4.2: Agronomic strategies – Effect of defoliation strategy and timing on crop yield and quality in early and the development of tuber blight**
method	defoliation strategy
WP manager	UNEW
description of method	defoliation by flailing, burning etc.
effect on foliar blight	Burning kills blight and blight-spores (at least partly). Other methods do not. UK: 100% control (foliage destroyed)
effect on tuber blight	No direct effects. UK: 0% (very low levels of tuber blight in both years)
effect on yield	No effects UK: Yield unaffected by method of defoliation. Potential for lower yields with early defoliation but marketable yield may be higher if tuber blight is reduced.
estimated material costs/ha	Gas: Euro 36/ha
estimated labour costs/ha	Defoliation is standard management practice. Total costs: flail: Euro 80/ha; burn: Euro 178/ha; flail+burn: Euro 190/ha
estimated machinery costs/ha	Gas burners specialist equipment on contract
efforts needed / bottlenecks for introduction into practice	depends on costs
domain of application, constraints, technical details	widely applicable. Dependant on availability of equipment. Threshold of foliar blight to trigger defoliation to minimise tuber blight will depend on varietal resistance to foliage and tuber blight. If burner is contracted - availability of equipment at critical time.
interactions with other component strategies	Depends on variety - resistance to foliage/tuber blight. Ease of defoliation will depend on canopy size and could be affected by plant population, fertility input and chitting treatment. Timing may be complicated where mixtures of varieties, or alternating rows are grown.
risks	In crops infected with late blight, mechanical defoliation is risky because of possible infection of tubers through wounds.
comments	In heavy crops only burning is not enough to defoliate. Repeated burning or combination with mechanical methods is necessary. Required interval between defoliation and harvest unaffected by method of defoliation. Efficacy on tuber blight control may be dependent upon weather/rainfall post-defoliation.
availability for field test in WP 7.2	yes

H: fertilization regime. (see CHAPTER 5)

WP	**4.3.1: Agronomic strategies – Effect of fertility management strategies on development of late blight, crop yield and quality - Effect of animal manures and N:K ratio**
method	manure & N/K ratio
WP manager	UNEW
description of method	optimize fertilization regime
effect on foliar blight	crops with a poor nutritional status are more susceptible to late blight. Otherwise no direct effects on foliar blight. In heavy crops, indirect effects via crop structure and microclimate may occur.
effect on tuber blight	no direct effects observed in UK
effect on yield	Higher yields in well fertilised crops. UK: At the same level of N input in field, compost gave 40% higher yield in 2002 than chicken manure pellets.
estimated material costs/ha	Depends on product and on currently used practice
estimated labour costs/ha	fertilizer application- standard costs 46 Euro/ha
estimated machinery costs/ha	fertilizer application - as standard equipment cost
efforts needed / bottlenecks for introduction into practice	Extension
domain of application, constraints, technical details	Improvements of quantitative yield and tuber quality likely even in absence of blight. Restricted by (1) manure available on farm; (2) environmental legislation; (3) organic standards. Composting of manure may require additional expenditure/expertise.
interactions with other component strategies	For early planted and chitted seed, a spring application of easy available N might be needed.
risks	Nitrate leaching unlikely, if applied according to good agricultural practice. Manure may increase pressure by *Rhizoctonia solani*.
comments	Fertility management affects yield but not necessarily blight. Aim should be to fertilise for yield rather than blight control. Relative response to compost and other organic manures is likely to be affected by inherent biological activity of the particular soil. Different potassium levels and N:K ratios have no effect on late blight.
availability for field test in WP 7.2	Yes

I: position in rotation. (see CHAPTER 5)

WP	**4.3.2: Agronomic strategies – Effect of fertility management strategies on development of late blight, crop yield and quality - Effect of position in the rotation (with respect to fertility building grass/clover crops)**
method	position in rotation
WP manager	KU
description of method	change position of potatoes, or of preceding crop in rotation
effect on foliar blight	no direct effects on blight susceptibility. Only indirect effects via crop structure and microclimate. With low status possibly more blight because crop is weak
effect on tuber blight	no direct effects.
effect on yield	Good nutritional status increases yield. Good soil structure increases yield and quality
estimated material costs/ha	No additional costs
estimated labour costs/ha	No additional costs
estimated machinery costs/ha	No additional costs
efforts needed / bottlenecks for introduction into practice	extension; highly farm-specific (depends on rotation)
domain of application, constraints, technical details	Improvements of quantitative yield and tuber quality likely even in absence of blight. May reduce the performance of other crops in the rotation.
interactions with other component strategies	Depending on previous crop and planting time, additional N-fertilisation with easily available N may be needed
risks	tuber pests & diseases, e.g. drycore, wire worms. Soil structure also important. Risks of nitrate leaching with a pre-crop that allows mineralisation late in the season.
comments	Rotational position influences nutritional status of crop, and possibly also soil structure status. Interactions with demands of other crops will influence decisions.
availability for field test in WP 7.2	yes

J: foliar sprays & microbial inocula. (see CHAPTER 5)

WP	**4.3.3: Agronomic strategies – Effect of fertility management strategies on development of late blight, crop yield and quality - Effect of foliar sprays and microbial soil inocula**
method	foliar sprays & microbial inocula
WP manager	UNEW
description of method	compost teas etc. sprayed on foliage
effect on foliar blight	No additional costs
effect on tuber blight	No additional costs
effect on yield	No additional costs
estimated material costs/ha	costs for raw material. Variable/unknown (complimentary samples) See info for WP5.1
estimated labour costs/ha	(1) preparation of extracts; as in WP5.1. Unaffected by size of area to spray (2) spraying - no difference compared with other sprays unless higher frequency required.
estimated machinery costs/ha	machine for preparing compost tea. Home-made extractors built for modest cost.
efforts needed / bottlenecks for introduction into practice	(1) demonstrate effectiveness and consistency of effects; (2) prove harmlessness for farmer and consumer; (3) legal hurdles for application likely; (4) extension
domain of application, constraints, technical details	(1) unknown whether raw material must have specific properties; (2) details for preparation, storage and application of extract. No specific protocol but use de-chlorinated water, aerate during extraction - optimum concentration for application difficult to determine. Short 'shelf-life'. Must be applied within a short time period after preparation. Batch could be lost if spraying delayed by poor weather conditions. Needs to be convincing. May be a nutritional effect.
interactions with other component strategies	Sprayer technology: Formulation. Irrigation regimes.
risks	Check for user safety, ecotoxicity, variability of efficacy, reliability. Risks of crop damage during spraying and thereby increased blight infections.
comments	So far, no evidence that compost extracts are effective in field situation. May be due to limited persistence/lack of rainfastness, sensitivity to light. May be improved by adjuvants.
availability for field test in WP 7.2	yes

K: volunteer removal. (see CHAPTER 5)

WP	**4.4: Agronomic strategies – Effect of volunteer removal strategies on the development of foliar and tuber blight in field grown potato crops**
method	volunteer removal
WP manager	LBI
description of method	volunteers removed by grazing pigs on harvested potato fields
effect on foliar blight	initial inoculum sources removed
effect on tuber blight	None observed
effect on yield	None observed
estimated material costs/ha	fencing, sheds
estimated labour costs/ha	placing of fences and eventually sheds. Leading the pig into the field and back to the stable.
estimated machinery costs/ha	No additional costs
efforts needed / bottlenecks for introduction into practice	(1) demonstrate effectiveness; (2) check effects on soil structure, fertility, weeds; (3) check effects on pig performance and pig health
domain of application, constraints, technical details	only for farms that keep pigs
interactions with other component strategies	No obvious interactions
risks	Negative effects on pig health when they eat too many potatoes
comments	None
availability for field test in WP 7.2	Yes, but difficult to use in replicated trials.

L: planting configuration. (see CHAPTER 5)

WP	4.5: **Agronomic strategies – Effect of planting configuration and spacing on the development of late blight, crop yield and**
method	planting configuration
WP manager	UNEW
description of method	optimize planting configuration
effect on foliar blight	crop structure may influence microclimate and thereby blight. However, only with very low plant densities, blight is reduced.
effect on tuber blight	no effects observed in UK
effect on yield	larger ridge distances with the same plant density per hectare may enhance marketable yield. Very low plant densities reduce marketable yield.
estimated material costs/ha	more or less seed used. Difference up to Euro 536/ha
estimated labour costs/ha	depends on planter - hand assisted or fully automatic.
estimated machinery costs/ha	for adapted ridge distances adapted equipment required for planting, weed control, harvest, …
efforts needed / bottlenecks for introduction into practice	Extension. Seed rate and planting configuration primarily determined through tuber size requirements for specific markets.
domain of application, constraints, technical details	Interactions (positive or negative) with tuber size and yield likely. Seed rate and planting configuration primarily determined through tuber size requirements for specific market. Plant populations and spacings likely to affect blight through microclimate effects are too low/wide for commercial production. Need to be able to achieve good coverage of tubers with soil to avoid tuber blight.
interactions with other component strategies	Method of spray application i.e. coverage influenced by canopy structure/density: Variety choice e.g. crops grown as salad potatoes/bakers. Effectiveness of defoliation.
risks	High seed rates/close spacings may reduce mean tuber size leading to more unharvested tubers and increased volunteer problems. Insufficient soil to cover tubers at high populations increasing greening and tuber blight.
comments	Market demand for specific tuber size grades primary determinant of configuration/ spacing. To be effective on late blight, configurations outside 'normal' commercial practice required. Therefore, not a feasible strategy.
availability for field test in WP 7.2	yes

M: irrigation. (see CHAPTER 5)

WP	4.6: **Agronomic strategies – Effect of irrigation regimes on development of late blight, crop yield and quality**
method	irrigation
WP manager	GRAB
description of method	optimize irrigation regime
effect on foliar blight	None, if correctly managed
effect on tuber blight	none
effect on yield	Optimized regime may increase yield, and especially tuber quality
estimated material costs/ha	water, irrigation material (pump, sprinklers, tubes…)
estimated labour costs/ha	depends on the equipment (which depends of the surface)
estimated machinery costs/ha	No additional costs
efforts needed / bottlenecks for introduction into practice	Extension, availability of water and equipment
domain of application, constraints, technical details	1) in wetter climates, to reduce blight risks 2) in dryer climates, to improve yield.
interactions with other component strategies	Many interactions likely, e.g. with sprays
risks	tuber pests and diseases; if too much irrigation, problems with quality; washing off of foliar treatments
comments	none
availability for field test in WP 7.2	yes

N: compost extracts. (see CHAPTER 6)

WP	**5.1: Alternative treatments – Activity of compost extracts against *P. infestans***
method	compost extracts
WP manager	DIAS
description of method	spray compost extract
effect on foliar blight	UK: 0
effect on tuber blight	UK: 0
effect on yield	UK: 0
estimated material costs/ha	Costs for raw material. No cost if produced on farm and only small quantities of compost required to make extracts.
estimated labour costs/ha	(1) preparation of extracts; largely independent of area to be sprayed (2) spraying 0.15 -0.23 h/ha
estimated machinery costs/ha	machine for preparing compost tea; Home made extractors possible
efforts needed / bottlenecks for introduction into practice	(1) demonstrate effectiveness; (2) prove harmlessness for farmer and consumer; (3) legal hurdles likely; (4) extension, see information for WP4.3.3 above.
domain of application, constraints, technical details	(1) raw material must have specific, consistent properties; (2) details for preparation, storage and application of extract, see information for WP4.3.3 above.
interactions with other component strategies	See information for WP4.3.3 above.
risks	Check for user safety, ecotoxicity, variability of efficacy.
comments	none
availability for field test in WP 7.2	yes

O: microbial antagonists & plant extracts. (see CHAPTER 6)

WP	**5.2: Alternative treatments – Identification of fungal and bacterial antagonists and plant extracts**
method	microbial antagonists & plant extracts
WP manager	BBA
description of method	spray antagonists or plant extracts
effect on foliar blight	0-70 % (glasshouse trials) 0-45 % (semi-field trials) Low in field trials
effect on tuber blight	Not yet investigated
effect on yield	In former studies it was shown that plant extracts enhance yield despite of low efficacy in the field. Yield enhancement might depend on variety used.
estimated material costs/ha	Depends on species; as an estimate: similar as for other biocontrol agents.
estimated labour costs/ha	Similar as for other sprays
estimated machinery costs/ha	Similar as for other sprays
efforts needed / bottlenecks for introduction into practice	(1) find effective strain; (2) develop to practical applicability; (3) antagonists and not yet registered plant extracts: registration efforts & costs; (4) needs efforts by a commercial partner.
domain of application, constraints, technical details	if suitable antagonist found: widely applicable.
interactions with other component strategies	synergistic as well as antagonistic effects possible when using microbiological antagonists and/or plant extracts in combination with other strategies (especially other foliar sprays); use of under-leaf sprayers could enhance activity
risks	user safety: low risk (only microbiological antagonists belonging to risk group ≤ 1); variability of efficacy: high risk -> efficacy strongly depending on i) weather conditions (removing/de-activation by rain, UV, temperature), ii) ratio application date/infection date iii) storage, formulation, application/knowledge of user ecotoxicity: low risk (only use of "native" microbiological antagonists or permitted/authorised plant extracts)
comments	success depends on whether a suitable strain / extract can be found (which is not yet the case).
availability for field test in WP 7.2	Commercially available products: yes; New strains/extracts: only in limited quantities.

P: application equipment. (see CHAPTER 7)

WP	**6.1: Application/formulation technology – Improvement of alternative control treatments for use under field conditions**
method	application equipment
WP manager	UNEW
description of method	apply alternative products optimally
effect on foliar blight	No difference observed in 2002
effect on tuber blight	No difference observed in 2002
effect on yield	No difference observed in 2002
estimated material costs/ha	No additional costs
estimated labour costs/ha	Depends on how many rows can be treated (underleaf sprayers treat fewer rows than standard equipment)
estimated machinery costs/ha	More sophisticated sprayers may be 2 to 4 times more expensive than conventional equivalent
efforts needed / bottlenecks for introduction into practice	Extension. New spray technology needs to be shown to be better than existing.
domain of application, constraints, technical details	Depends on properties of antagonist or extract to be applied. More sophisticated sprayers may be more difficult to use effectively until operators fully trained.
interactions with other component strategies	No major interactions likely
risks	No diffence between methods - expense of new machine - drop leg sprayer use limited to particular crops: conventional sprayer is multi purpose and relatively easy to use. Legs may damage potato foliage.
comments	Dropleg sprayer gave better cover throughout the canopy, but no improvement in blight control over conventional in 2002. Timeliness of the spray and general efficacy is more important than method of application.
availability for field test in WP 7.2	Yes, but may be limited by costs of equipment.

Q: alternative sprays. (see CHAPTER 7)

WP	**6.2 a**: **Application/formulation technology – Improved formulation and comparison with existing anti-fungal treatments**
method	alternative sprays
WP manager	FAL
description of method	field screening of commercial and novel alternatives, improvement of formulations
effect on foliar blight	0-40
effect on tuber blight	Not yet investigated
effect on yield	Not yet investigated
estimated material costs/ha	250 Euro/ha (Mycosin, C-2000) or more
estimated labour costs/ha	Only higher, if more sprays needed
estimated machinery costs/ha	As for normal sprays
efforts needed / bottlenecks for introduction into practice	(1) find effective product; (2) find better formulation; (3) collaborate with manufacturer; (4) registration requirements
domain of application, constraints, technical details	Widely applicable, if effective and safe products are found.
interactions with other component strategies	Depends strongly on the type and properties of the product (commercial or novel) resp. the antagonist or extracts used.
risks	None for registered products
comments	No effective products discovered so far
availability for field test in WP 7.2	No effective products discovered so far

R: low dosage of copper. (see CHAPTER 7)

WP	**6.2 b: Application/formulation technology – Development of strategies to use low doses of copper based fungicides**
method	low dosage of copper
WP manager	FAL
description of method	development of strategies to use copper in low dosages
effect on foliar blight	Protection 65-95% of standard treatments
effect on tuber blight	Not yet investigated
effect on yield	Not yet investigated
estimated material costs/ha	Lower than standard treatment
estimated labour costs/ha	As for standard treatment
estimated machinery costs/ha	As for standard treatment
efforts needed / bottlenecks for introduction into practice	(1) compare products (2) compare different concentrations (3) use PhytoPRE-DSS for optimal timing (4) develop and describe best strategy
domain of application, constraints, technical details	Widely applicable, constraints: label (copper: not black and white). Highly dependent on rainfalls.
interactions with other component strategies	unlikely
risks	Reduced protection may cause infections
comments	Does not solve the problem of copper use, but reduces it. Good efficacy achievable with a total amount of about 2 kg/ha/year of metallic copper.
availability for field test in WP 7.2	yes

ANNEX 2: Field tests of optimised late blight management strategies on MODEL and LINK Farms in different European countries

Field evaluation of novel blight control systems in the United Kingdom 2004

UNEW - Nafferton Ecological Farming Group University of Newcastle, UK

Introduction

From 2001 to 2003, the Blight-MOP project evaluated several individual late blight management components with potential to contribute to an overall, integrated blight control strategy. The blight management strategies used in the United Kingdom in both the MODEL and LINK farms incorporated those components that had shown beneficial effects in terms of decreased or delayed late blight infection of the foliage and/or direct effects on yield. These were

- Variety
- Pre-sprouting/chitting of seed tubers
- Fertility management (type of fertility input)
- Alternative to copper fungicide
- Copper fungicide

Preliminary results are presented in this report as further analysis of physical and financial performance continues.

MODEL FARM

Materials and Methods

The model farm was situated in the North of England at Nafferton Farm, which had been in the process of converting to organic production since 2000. Experiments in the Blight- MOP project were carried out in 2002 and 2003. Crops of organic potatoes are grown commercially on contract to packers.
The pre-crop was spring wheat followed by rye and the experiments were planted on 26 April at a fixed spacing of 75cm between rows with 35 cm in-row spacing, using seed graded to 35 to 55mm.
Individual components that had shown potentially beneficial effects were added progressively to provide an increasingly comprehensive integrated late blight management strategy.

The treatments (i.e. component strategies) applied are shown in Table 1 and the progressive combination of the individual components is shown in Table 2.

Table 1. Individual component strategies included in the integrated blight management systems on the MODEL Farm

CULBMS (C0)	**Variety**: Sante (*7,6) **Pre-sprouting**: no managed pre-sprouting prior to planting **Fertility treatment**: composted farm yard manure @ 170kg/ha N prior to planting **Fungicide**: copper oxychloride
C1	**Variety:** Lady Balfour (*8,7) *instead of Sante*
C2	**Pre-sprouting**: 300 ADDs (accumulated day degrees above 4°C) prior to planting in a glass-*house instead of unsprouted seed*
C3	**Fertility Management:** Commercial organic fertilizer at 170 kg/ha N (based on chicken manure) *instead of compost at 170kg/ha N*
C4	**Alternative spray:** Plant extract *instead of copper oxychloride (commercial product COMCAT, an extract of Lychnis viscaria L. (German catchfly)thought to induce resistance)*
C5	**Copper fungicide:** copper oxychloride (at reduced rate)

CULBMS = currently used late blight management strategy
C1 etc., = component strategies included in order of introduction into the integrated blight control strategy

*For the varieties, figures in brackets denote the scores for foliar blight and tuber blight resistance respectively.

Table 2. Progressive adoption of individual component strategies for the construction of an integrated late blight management system.

CULBMS (C0)					
C1	**Variety**				
C1+C2	Variety	**Pre-sprouting**			
C1+C2+C3	Variety	Pre-sprouting	**Fertility management**		
C1+C2+C3+C4	Variety	Pre-sprouting	Fertility management	**Alternative spray**	
C1+C2+C3+C4+C5	Variety	Pre-sprouting	Fertility management	Alternative spray	**Copper fungicide**

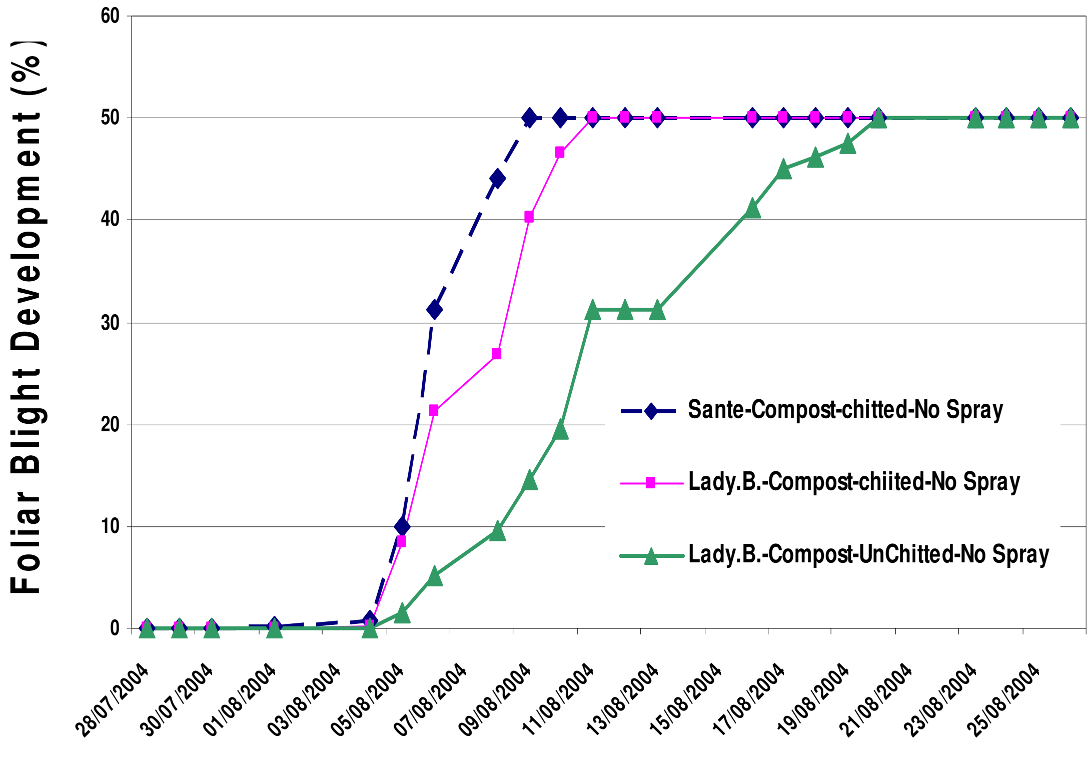
Foliage was destroyed mechanically when late blight infection reached 50% and plots were harvested in mid- September. Total tuber yields, graded yields, diseased tubers and marketable yields were assessed post harvest. In addition to physical performance, financial performance was assessed to provide a cost/benefit analysis of the different late blight management regimes.

Results

Blight Infection

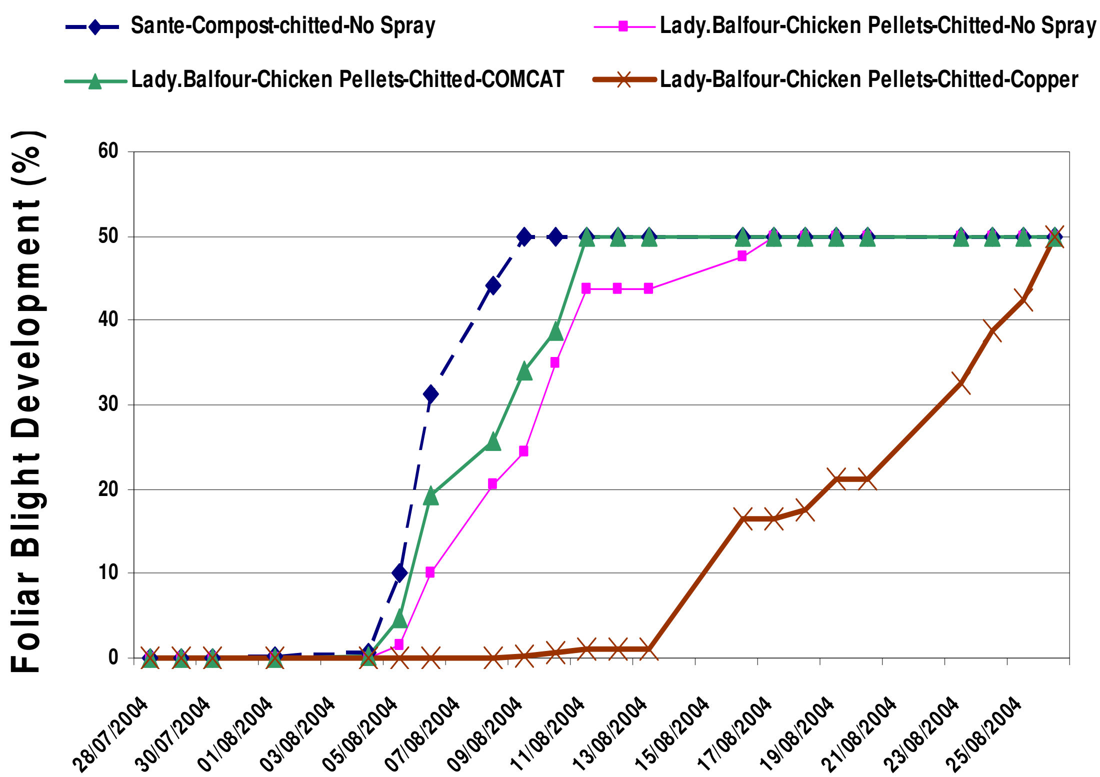
The progress of late blight infection is shown in Figures 1a and 1b. Figure 1a shows that when chitted (300 ADDs), the pattern of foliage blight infection for Lady Balfour was similar to that for Sante. However, for unchitted Lady Balfour, the infection was delayed. This was because of later emergence and delayed growth compared with chitted seed and differences in the physiological age and composition of the canopy may also have been involved.

Figure 1a) The change with time in late blight infection of the foiliage.



Where the fertility input was based on chicken manure pellets rather than composted farm-yard manure, application of the plant extract (COMCAT) had no significant effect on blight infection. Copper fungicide applications effectively delayed the progress of blight infection, by about 14 days.

Figure 1b) The change with time in late blight infection of the foliage.



Tuber yields

Blight infection in terms of AUDPC (Area Under the Disease Progress Curve) and yield data are shown in Table 3.

Table 3. Blight infection expressed as AUDPC (Area under the disease progress curve) and tuber yield data for the MODEL farm

	AUDPC (% days)	**Total yield (t/ha)**	**Marketable Yield (t/ha)**	**Outgrades (t/ha)**	**Blighted tubers (t/ha)**
CULMBS (C0)	998a	23.1a	16.8a	6.2	0.5
C1	729a	31.7b	22.9ab	8.9	0.2
C1+C2	943a	32.1b	28.3bc	4.7	0.8
C1+C2+C3	1237a	40.4c	33.6cd	3.7	0.6
C1+C2+C3+C4	920a	41.1c	36.8cd	2.8	0.4
C1+C2+C3+C4+C5	307b	43.4c	38.5d	3.5	0.8

AUDPC was significantly lower where copper oxychloride had been applied, but there were no significant differences between any of the other treatments. Total and marketable tuber yields increased progressively from CULBMS (C0) to **C1+C2+C3+C4** and **C1+C2+C3+C4+C5.** The substitution of Sante with the variety Lady Balfour resulted in a substantial increase in yield although blight infection was not significantly different between the two varieties either in the foliage or in the tubers. Pre-sprouting seed tubers of Lady Balfour had no effect on total tuber yields but marketable yields were higher following sprouting (although not significantly so). This was because there were fewer outgrades from sprouted seed and mainly accounted for by differences in tuber size grading (Table 4). Unsprouted seed produced a greater proportion of yield in the smallest size grade (<45mm) because of the combined effects of delayed growth and a greater number of tubers.

Levels of tuber blight infection were low in the treatments and the outgrades were mainly undersized tubers and some tubers infected with black scurf and/or common scab, but levels of these blemish diseases were also low.

Table 4. Tuber size grading

	%<45mm	**%45-65mm**	**%>65mm**
CULBMS (C0)	19.3	76.7	4.1
C1	27.3	70.9	1.8
C1+C2	8.8	81.2	10.0
C1+C2+C3	6.0	58.5	35.5
C1+C2+C3+C4	5.2	68.3	27.0
C1+C2+C3+C4+C5	4.2	64.2	31.8

Financial performance

Table 5. Financial performance of the improved late blight management strategies on the MODEL farm

	Costs Euros	**Outputs Euros**	**Benefits Euros**
C0	2654.57	5037.6	2383.03
C1	2589.43	6882.1	4292.67
C1+C2	2752.29	8253.1	5500.81
C1+C2+C3	4112.29	9722.8	5610.51
C1+C2+C3+C4	4192.15	10600.8	6408.65
C1+C2+C3+C4+C5	4442.15	11112.9	6670.75

The financial performance of the different treatments is shown in Table 5. The cost of certified seed of both Sante and Lady Balfour were virtually the same. However, Lady Balfour outyielded Sante, even when it was unsprouted, giving an extra 6t/ha of marketable yield, substantially increasing both output and benefits. Changing variety gave the largest benefit, although blight infection was very similar in the two varieties. Each additional component of the overall, integrated strategy for blight control added to costs. In particular, the commercial fertilizer manufactured from chicken manure (C4) was an expensive input compared with composted farm yard manure but this increased yield and also the proportion of tubers in the larger size grades. (This indicates the importance of fertility management in the production of potatoes in organic management systems, independent of effects on infection with late blight).
Both output and benefits increased as additional components were added into to combined, integrated strategy but at a decreasing rate. The use of copper fungicide gave the smallest additional increase in output and benefits (Table 5) although it had given the most effective control of the disease (Fig. 1b. and Table 3).

LINK FARMS

Materials and Methods

There were 4 LINK FARMS, all located in Northern Britain:

Locations:

- **N** Nafferton, Northumberland, England – planted 26 April
  - Soil Association Certified Organic Farm
- **M** Murtle Farm, Aberdeen, Scotland – planted 17 April
  - Biodynamic Farm
- **G** Gilchesters, Northumberland, England – planted 5 May
  - Soil Association Certified Organic Farm
- **WH** West Hartley, Northumberland, England – planted 24 May
  - Soil Association Certified Organic Farm

- NB: in 2004, intermittent, occasionally heavy rainfall resulted in protracted planting for commercial crops in UK – from early April until late June. This is reflected in planting dates on LINK Farms as shown above

Crop management practices and assessments were essentially the same as those for the MODEL farm. The CULMBS (C0) and the improved strategies (C+) that were compared on the different LINK farm sites were the same.

C0 = Sante , unsprouted + composted farm yard manure with no sprays applied

C+ = Lady Balfour, chitted + chicken manure pellets + alternative spray

Results

In general, results for LINK farms were similar to those for the model farm.
Table 6 shows the effects of the improved, integrated late blight management systems compared with the base-line late blight system for each of the LINK Farms on disease infection and tuber yields. Levels of yield differed considerably between the four sites, from about 15t/ha (G) to over 50t/ha at two others (M and WH), reflecting the differences in growing conditions. Late blight was absent at one site, but developed at the other sites but to a relatively moderate extent.

Table 6. . Blight infection expressed as AUDPC (Area under the disease progress curve) and tuber yield data for the LINK farms.

	AUDPC (% days)	**Total yield (t/ha)**	**Marketable Yield (t/ha)**	**Outgrades (t/ha)**	**Blighted tubers (t/ha)**
C0 N	234	25.5	19.8	5.7	0.5
C+ N	166	38.7	36.4	2.4	0.0
C0 M	0	42.3	31.7	10.4	0.8
C+ M	0	53.5	49.1	4.4	1.0
C0 G	215	14.8	12.2	2.7	0.4
C+ G	245	21.2	17.9	4.1	0.6
C0 WH	393	24.5	18.8	5.7	0.1
C+WH	328	51.2	44.9	6.1	0.5

At all sites, total and marketable yields of tubers were always higher with the ‘improved’ late blight management system. As in the MODEL farm, the substitution of the standard variety Sante with the new variety Lady Balfour was responsible for the major proportion of the yield increases. However, levels of foliage and tuber blight were very similar in the two different systems (original and improved) at all sites.

Table 7 shows the effects of the improved, integrated late blight management systems compared with the base-line late blight system for each of the LINK Farms on financial performance. On every LINK farm, the improved late blight management system was more expensive than the original, but outputs and benefits were always higher. However, differences between the systems were small at one site which gave the lowest yields but very large at another site (WH) – the improved system gave a three-fold increase in benefits. At this latter site (WH), planting was late (end of May) and the seed of Sante, although not deliberately sprouted, had begun to produce weak, etiolated sprouts. On the other hand the sprouts of Lady Balfour which had been produced under controlled conditions in the light were short and sturdy. It is possible that the sprouts of Sante were more susceptible to damaged during mechanical planting than Lady Balfour which would account for delayed growth and tuber bulking.

Table 7. Financial performance of the improved late blight management strategies on the MODEL farm

	Costs Euros	**Outputs Euros**	**Benefits Euros**
C0 N	2654.57	5860.04	3205.47
C+ N	4192.15	10457.48	6265.33
C0 M	2654.57	9452.31	6797.75
C+ M	4192.15	1417.10	9978.95
C0 G	2654.57	3585.24	930.67
C+ G	4192.15	5277.78	1085.63
C0 WH	2654.57	5595.65	2941.10
C+WH	4192.15	13033.69	8841.54

Discussion & Conclusions

Results from both the MODEL and the LINK farms showed that by critically assessing the CULMBS and identifying those components that can be improved and then introducing the better ones, performance of the crop can be improved in both physical and financial terms in a wide range of situations. The beneficial effects may be partly because of enhanced control of blight in terms of the time of onset, the duration or the severity of infection or because of more direct effects on crop yield because of enhanced growth and productivity. In the UK in 2004, the latter seemed to make the greatest contribution to the increases in total and marketable yields.
In practice, the actual management system that is appropriate will be dependent upon the specific situation and tailored to the individual grower. In some cases, scope for improvement could be substantial. In others, growers will have already adopted optimized integrated late blight management strategies and so no further improvement will be possible until another novel variety, technique or alternative treatment becomes available.

Whilst the use of copper fungicides may give enhanced control of the disease, the additional yield and financial benefits may be relatively modest. In some situations, it may give no benefit at all and be removed from the management system with minor consequences.
Taking this approach that has been developed by the Blight-MOP project provides an opportunity improve the production of organic potato production without the use of copper fungicides or with reduced inputs .

Acknowledgements

We gratefully acknowledge the help and collaboration of growers on the LINK farms and technical staff of Nafferton Ecological Farming Group for all their help and collaboration.

Field evaluation of novel blight control systems in Switzerland 2004

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Introduction

In the course of workpackages 2-6 of the EU-funded project 'Blight-MOP' (FAIR project QLK5-CT-2000-01065), a number of component strategies (CS) for the control of potato late blight have been developed. In workpackage 7.1, the potentials and limitations of these CS were determined. In workpackage 7.2, a number of experimental farms were selected and the strengths and weaknesses of their 'currently used late blight management systems' (CULBMS) analyzed. Based on this analysis, a unique combination of CS was developed for each farm: the 'optimized management system' (OMS). In the field season of 2004, we compared the CULBMS with the OMS on all farms. Preliminary results of these tests are reported here.

Materials and methods

<u>*Sites and treatments*</u>

MODEL farm

The trial was situated at Gutsbetrieb Rheinau (canton Zürich, northern Switzerland) on a farm that has been managed bio-dynamically since 1999. The soil is sandy and the local climate allows earlier planting than in most parts of Switzerland. The trial was 1.2 ha large and was embedded in a commercial potato field of ca 7 ha.

The trial design was a completely randomized block design with 6 additive treatments and 4 replicates. Each plot was 15 m (=20 rows) wide and 33.5 m long. The treatments were CULBMS plus a number of added component strategies, as follows:

CULBMS		variety Agria; fertilization with composted cattle manure; no spraying against *Phytophthora infestans*
OMS 1	CULBMS+1	1= variety Naturella
OMS 2	CULBMS+1+2	2= alternating varieties (4 rows Agria / 4 rows Naturella, etc.)
OMS 3	CULBMS+1+2+3	3= commercial N fertilizer
OMS 4	CULBMS+1+2+3+4	4= spraying of Myco-Sin (acidified clay) according to DSS 'PhytoPRE Bio' (with standard sprayer)
OMS 5	CULBMS+1+2+3+4+5	5= underleaf application of Myco-Sin

LINK farm 1

The trial was situated at Werk- und Wohnheim Murimoos (canton Aargau, northwestern Switzerland) on a farm that has been managed organically since 1998. The soil is moory. The trial was embedded in a commercial potato field. The treatments were as follows:

CULBMS	pure stand of Agria, dusting of stonemeal, spraying of copper fungicide.
OMS	alternating stand of Agria and Naturella (4 rows each), seed treated with *Bacillus subtilis*, dusting of stonemeal plus vegetable oil, spraying of acidified clay.

LINK farm 2

The trial was situated at Tann (canton Zürich, northern Switzerland) on a farm that has been managed organically since several decades The trial was embedded in a commercial potato field. The treatments were as follows:

CULBMS	pure stand of Désirée
OMS	alternating stand of Désirée and Appell (2 rows each), seed treated with *Bacillus subtilis*

LINK farm 3

The trial was situated at Hindelbank (canton Bern, central Switzerland) on a farm with a silty loess soil. The trial was embedded in a commercial potato field. The treatments were as follows:

CULBMS	variety Charlotte
OMS 1	variety Naturella
OMS 2	variety Appell

LINK farm 4

The trial was situated at Cossonay (canton Vaud, western Switzerland) on a farm with brown soil. The trial was embedded in a commercial potato field. The treatments were as follows:

CULBMS	pure stand of Charlotte.
OMS	alternating stand of Charlotte and Innovator (2 rows each), seed treated with *Bacillus subtilis*.

At this site, both treatments were tested with and without copper fungicide.

<u>*Assessments*</u>

crop deveopment	Crop development was assessed at intervals of 1-3 weeks, depending on growth stage, using the decimal code given in Radtke & Rieckmann (1990). Results are not reported here.
foliar blight	Foliar blight was assessed at intervals of at least 1x per week. Recording were made of disease severity, using the key provided by Cornell University. Before analysis, the ‘standardized area under the disease progress curve’ was calculated according to Campbell and Madden (1990).
yield & marketable size classes	Plots were harvested manually. After storage, they were graded manually according to the Swiss marketing standards provided by swisspatat. Tuber weight was measured separately for tubers below minimum size, within limits and above maximum size.
tuber quality	50 tubers of marketable size were washed and their quality was assessed. The following tuber defects were recorded: tuber rot; green tubers; common scab; *Rhizoctonia*; tuber deformation; growth cracks; dry core; wireworm damage; slug damage; rodent damage. Tubers which did not show any of the above tuber defects were called ‘marketable quality’, and their weight in t per hectare was calculated.

At all sites, all of the above assessments were made on sub-plots with 20 plants, which were evenly distributed over the plots. On the MODEL farm, there were 4 sub-plots per plot. In the LINK farms, there were 7 sub-plots per plot.

<u>*Data analysis*</u>

In-depth analysis is still ongoing; here, we present a preliminary overview over the performance of the various treatments.

Results

MODEL farm
In the variety Agria, treatment CS 2 (alternating varieties) drastically reduced foliar blight (Fig. 1) and increased yield (Fig. 3). CS 3 (improved fertilization) also increased yield, while and CS 4 (application of Myco-Sin) reduced yield (Fig. 3). In the variety Naturella, no foliar blight was observed (Fig. 2). Again, CS 3 (improved fertilization) increased yield, while CS 4 and 5 (overleaf and underleaf application of Myco-Sin) reduced it (Fig. 4).

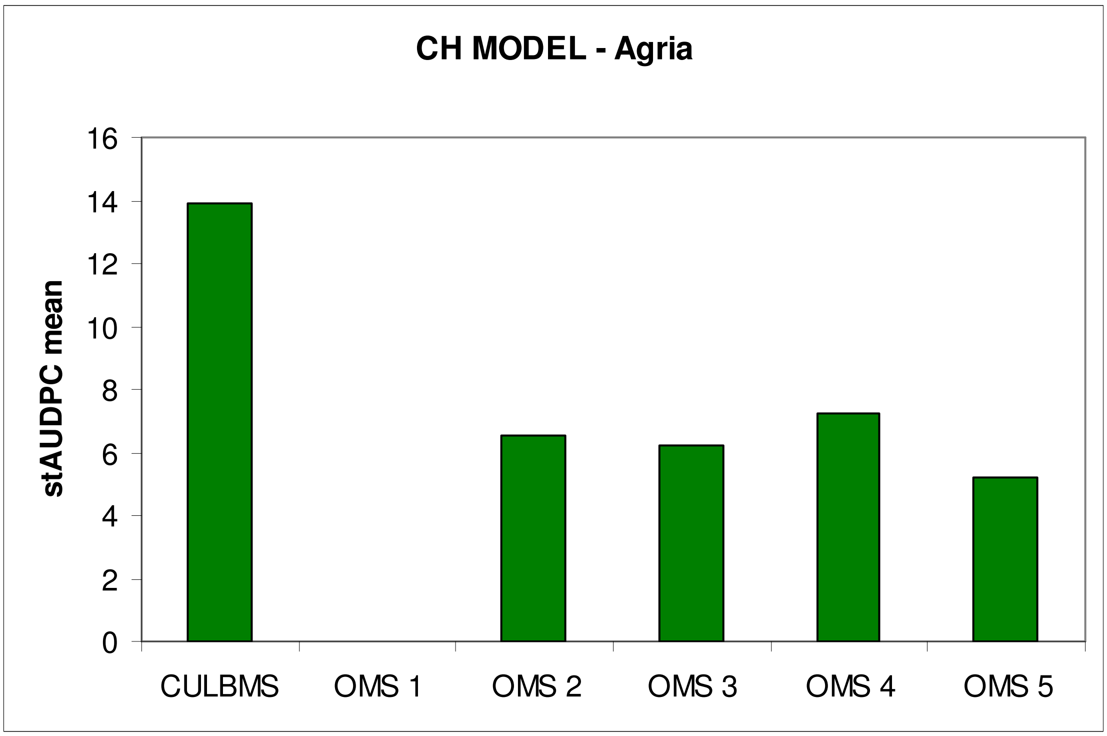


Figure 1: Foliar blight in Agria on the MODEL farm.

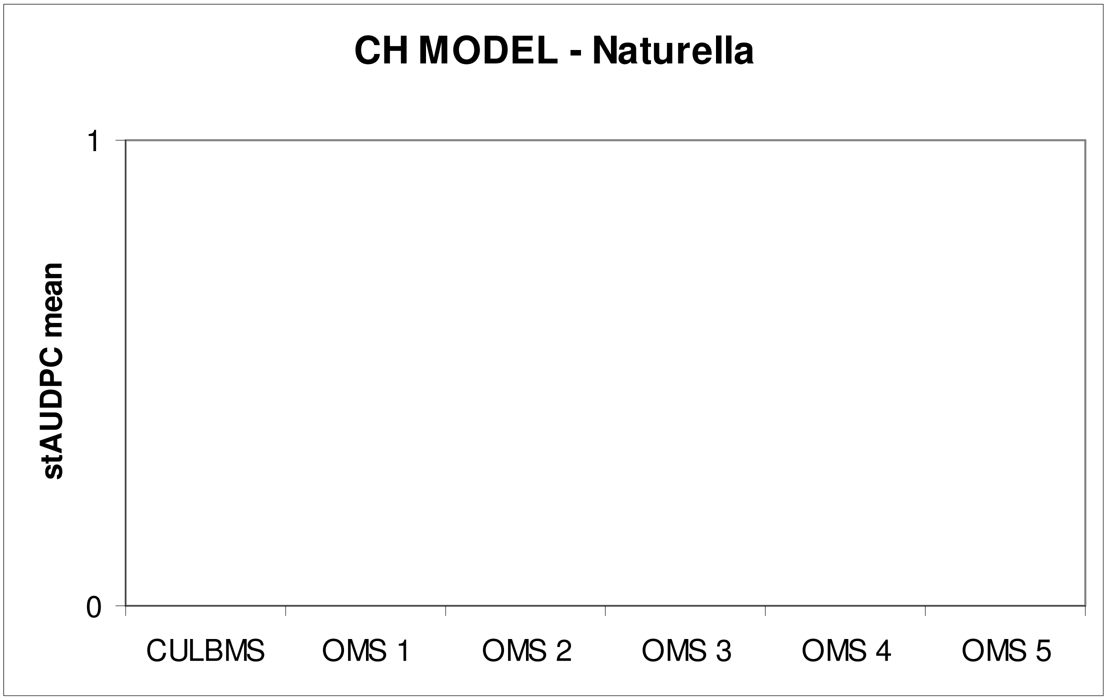


Figure 2: Foliar blight in Naturella on the MODEL farm.

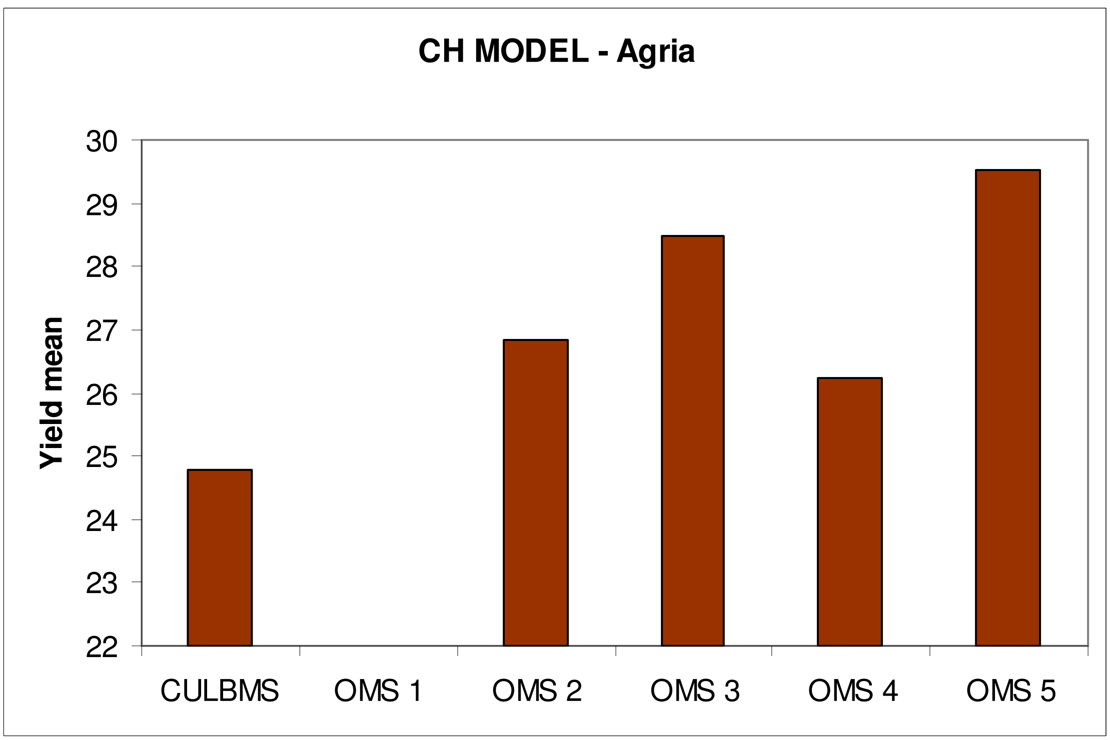


Figure 3: Yield (t/ha) in Agria on the MODEL farm.

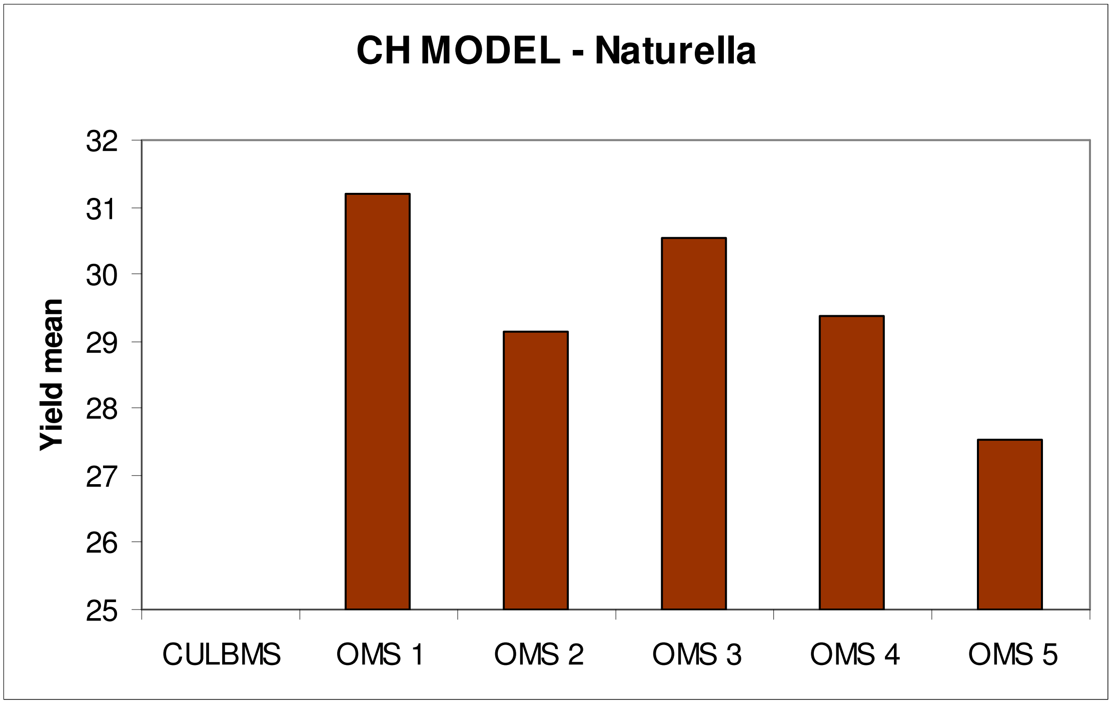


Figure 4: Yield (t/ha) in Naturella on the MODEL farm.

LINK farms

Compared with the CULBMS, the optimized treatments reduced foliar blight on LINK farm 1, 2 and 3, while on LINK farm 4, no blight infection occurred (Fig. 5). The optimized treatments also increased yield on LINK farm 1, and partially also on LINK farm 3, but not on LINK farm 2. On LINK farm 4, the optimized treatment did not increase yield, but the test variety Innovator gave higher yields than the variety Charlotte. Because of the absence of blight, the copper treatment was obviously ineffective.

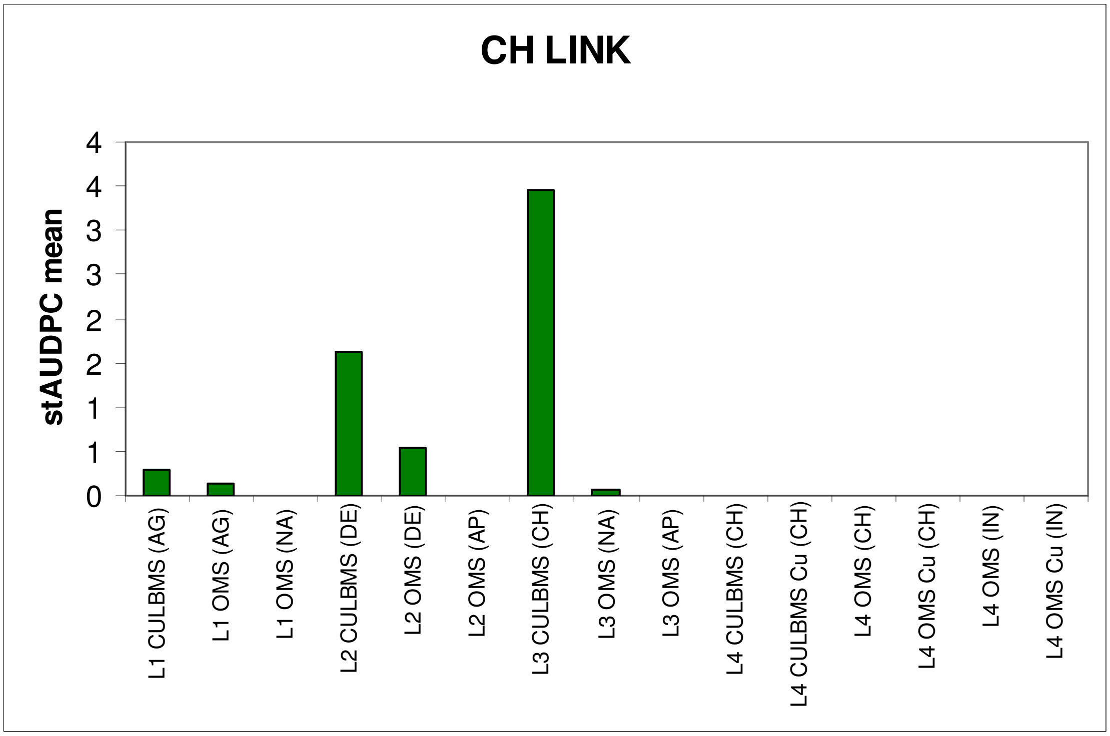


Figure 5: Foliar blight on the LINK farms. AG= measurement on Agria; NA= Naturella; DE= Désirée; AP= Appell; CH= Charlotte; IN= Innovator.

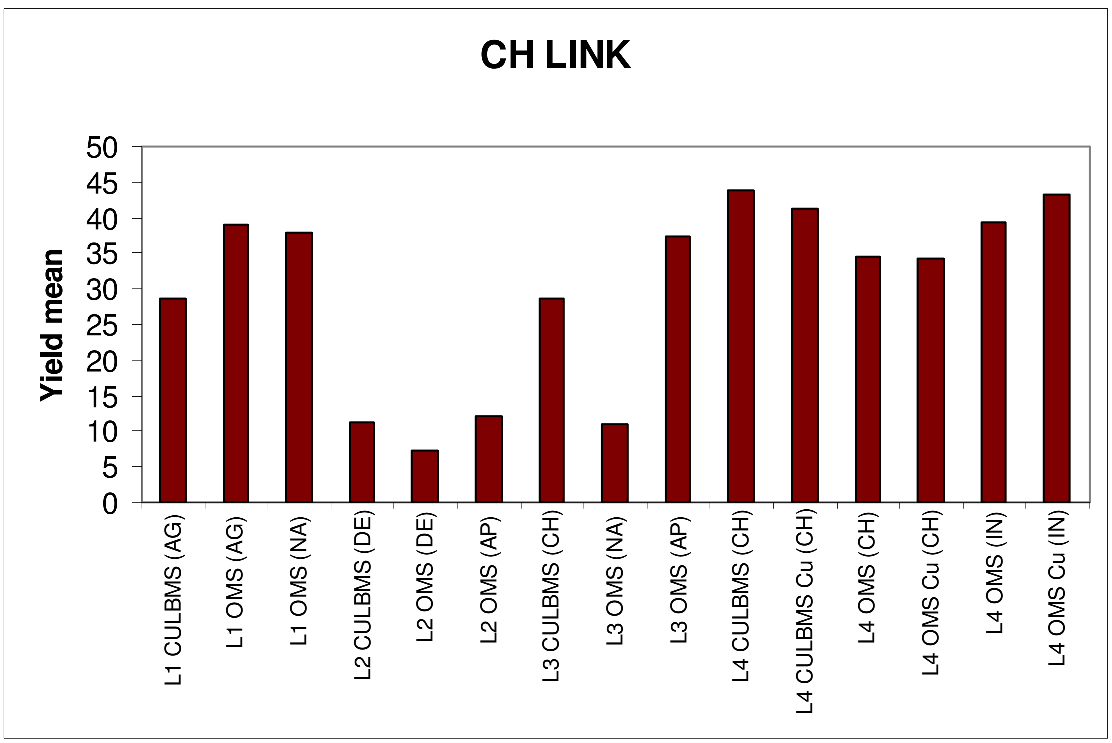


Figure 6: Yield (t/ha) on the LINK farms. For explanations see figure 5.

Discussion and conclusions

In these experiments, a number of OMS resulted in lower levels of foliar blight and/or higher yield, compared with the CULBMS. This shows that there is considerable scope for improvements of the currently used potato management systems. As these vary from one farm to another, the individual combination of component strategies to be recommended to the farmers, the OMS, varies considerably. As a consequence, the scope for improvements is also variable.

In the course of more refined analyses, these findings will be combined with economic data on the costs and potential benefits of each CS. This will allow to base OMS recommendations not only on pathological and agronomic considerations, but also on economic calculation of impact on farm income. Such OMS recommendations are expected to be broadly accepted and rapidly adopted by organic farmers, thus leading to maximum impact of the 'Blight-MOP' project on European organic potato production.

Acknowledgements

We warmly thank the farmers for their collaboration. This study was funded by the European Community (FAIR project QLK5-CT-2000-01065) and by the Swiss Federal Office for Education and Science (99.0878).

Field evaluation of novel blight control systems in Germany 2004

KU - Department of Ecological Plant Protection, University of Kassel, D

Main Message

Overall, strip intercropping reduced epidemic pressure as well in the experiment on the model farm as on three of the four link farms. The use of copper reduced late blight significantly in almost all cases. There were some synergistic effects between strip cropping and copper application. With the reduced disease pressure the effects of copper became more pronounced. Mycosin had no effect on disease in any of the tested treatments (farmers field or strip cropping).

As in the previous years the reductions in disease through copper application did not always result in significant yield increases. On the model farm, copper spraying combined with chitting increased yield significantly by 10 % in both the regular size plots and the in the strip treatments in comparison to the unsprayed and non-chitted control plots (P=0.04 and 0.06, respectively). When comparing to the unsprayed chitted treatments, however the differences became smaller and non-significant in the large plots. In low fertility treatments no yield effect was observed due to copper.

Similarly, on the link farms differences in yield between strips and field could not be explained by differences in disease but were more likely due to differences in fertility levels. This was supported by the fact that, like in previous years, correlations between disease and yield were not consistent. Even where the correlations were significant (in three out of the four link farms with varieties Nicola and Agria), only about 20% of the variation in yield could be explained through disease

Different varieties reacted differently to strip cropping. While the early bulking variety Nicola did not suffer from competition in the edge rows Agria and Marabelle had significatnyl reduced yields in the edge rows. The two latter varieties are later bulking. Thus, they are more sensitive to competition by a neighbour crop later in the season.

This confirms the previous results that copper is only useful when the risk to loose the potential yield is high after late blight infection occurred in fields with higher N-supply.

As in the previous years, the decisive factor influencing yield was nutrient status by far overriding any effects on disease. This could be shown by following the yield development of the different fertility levels on the model farm. At the time the disease strongly progressed the main tuber mass development was already finished and there was no effect of the disease in the lower fertility levels while only small effects could be observed in the higher fertility levels. These results indicate that under the conditions of organic farming in central Germany late blight is not the main yield limiting factor.

Introduction

Late blight, caused by *Phytophthora infestans* (Mont., de Bary) is the most devastating disease in potato production, especially in ecological farming, where growers are not allowed to spray systemic chemicals. These farmers can only use few strategies, such as field hygiene, growing of resistant potato varieties, pre-sprouting and early planting to reduce the risk of yield losses. However, only resistance and possibly hygiene can reduce disease progress or initial infection while pre-sprouting only is a measure to reduce yield losses through a partial escape because bulking of the potatoes starts earlier before onset of late blight epidemics.

Attempts to reduce disease pressure by increasing the plant distance within the limits of practical relevance have failed to contribute to disease control. Only a reduction of the plants as well as the number of shoots per plant to one plant shoot per m^2 had a significant impact on late blight (Rotem, 1983). This is clearly of no practical relevance. Nevertheless, an overall lower density of potato plants should reduce infection pressure by *P. infestans*.

Another way of reducing the density of susceptible plants are various diversification strategies involving different cropping patterns such as cultivar mixtures, alternating rows or strips of different cultivars, and strip intercropping of potatoes with other non-host crops.

The separation of potatoes of the same susceptibility through potatoes of different susceptibility in random mixtures or alternating rows or by suitable barrier crops should restrict the development of blight epidemics by restricting dispersal between plants or beds. The effectiveness of restriction of dispersal is expected to be much larger in crops possessing some resistance than in fully susceptible crops as slower epidemics allow for more pathogen generations on which restrictions to dispersal could act (Garrett and Mundt, 1999; Leonard, 1969).

Cultivar mixtures had moderate effects reducing focal and general epidemics in experiments involving a single pathogen isolate able to infect on emixture component under low inoculum pressure (Garrett and Mundt, 2000). Mixture effects were also generally greater under moderate natural inoculum pressure than under high natural inoculum pressure (Garrett et al., 2001). Similarly, when planting potatoes in alternating rows, the best results were obtained for the slowest epidemics (Andrivon et al., 2003).

When intercropping potatoes with other crops, the microclimatic conditions within the crop will be affected by the type of intercrop and the width of the potato beds, which may also affect late blight severity and its spread. Intercropping potatoes with faba beans (in a mixture of 1:10) under relatively conducive conditions in Ecuador had little effect on late blight (Garrett et al, 2001). However, it is not clear, if potatoes and beans were cropped in a complete mixture or in alternating rows or strips. Also, the plots were extremely small containing only four potato plants per plot making inferences from these data difficult. Strip intercropping of potatoes with faba beans in Denmark did not result in consistent disease reductions (see annual report Feb 2003 and 2004).

Among the discussed diversification strategies growing alternating rows or strips of different varieties or strip intercropping could be implemented by growers without the problem of having to harvest a mixed crop. However, the experiments were conducted at a very small scale and even the large plots of Phillips (2004) were relatively small at a size of $60m^2$ and it is unclear if a grower could benefit from such a strategy and there is a need to scale up the studies of diversification strategies.

One of the benefits a farmer has by not growing all his or her potatoes in one large field but rather in several separated fields is that usually initial disease is not uniformly distributed and the more the potato crop is subdivided the more the disease spread between fields is reduced and single fields have an increased chance of escaping early infections. Plot size has been shown to be negatively correlated to disease pressure (Phillips, 2004) and the chances of being infected by incoming inoculum or of harbouring an infected seed tuber are naturally reduced in small isolated plots in comparison to large fields Waggoner (1962).

Exposure to wind also plays an important role in late blight epidemiology. A common recommendation is to arrange the rows within wind direction to allow for faster drying of the crop and thus rendering the microclimate less conducive for infections. However, this arrangement also favours the spread of inoculum into the field along rows. As the dispersal gradient around an initial inoculum source is rather steep and the prevailing winds are important in spreading the disease within fields (Waggoner, 1952) it might be useful to consider the planting of narrow fields with the rows arranged perpendicular to the wind to allow as much inoculum to be lost outside the field as possible.

Field experiments were conducted within the frame of Blight MOP at KU in 2001 and 2002 to test the following hypotheses:

1. Strip intercropping and reduced plot size should increase the chance of strips to stay healthy longer. i.e. effects on initial infection

2. Arranging the strips perpendicular to prevailing winds should reduce epidemic pressure more than strips grown within wind direction.
3. The strategy will be more effective when disease pressure is overall reduced by growing more resistant crops.

The outcome of these experiments was that at the scale tested (plot sizes of 6*36m) disease was significantly reduced in plots neighboured by grass clover and arranged perpendicular to the wind (Bouws-Beuermann, 2005; Finckh et al, 2004). The effects of the neighbour crop cereal were similar but less strong. Despite the positive effects of strip cropping on late blight, there were no significant yield benefits observed and the varieties used suffered from competition by the neighbout spring wheat in the edge rows (Bouws-Beuermann, 2005. In addition, parallel experiments on the effects of the nutritional status and copper application on disease and yield indicated that plant nutrition appears to be the major factor limiting yields under the conditions in central Germany (Schulte-Geldermann et al, 2005, Annual reports 2003, 2004).

For the year 2004, the objective was to integrate the different findings from the different partners into a practical strategy that might be of use for the farmers.

In the light of the results 2001-2003 the following hypotheses were formulated:

1. Plant nutrition is more important than disease in determining yields
2. Yield potential will be higher when potatoes are chitted
3. Disease pressure in strips is reduced in comparison to normal farmers fields
4. When disease pressure is reduced less effective contact fungicides allowed in organic farming such as copper and Mycosin will be more effective

Following the general plan of Blight MOP the **c**urrently **u**sed **l**ate **b**light **m**anagement **s**trategies (CULBMS) at the model farm and in most of the region which is growing potatoes late in the rotation without spraying was compared to (i) growing chitted potatoes (ii) spraying copper or (iii) Mycosin (iv) at different fertility levels (v) in strips or regular planting patterns.

A slightly simpler design was used on the four link farms where the fertility management of the farmers was amended in one case in the strip and the potatoes were uniformly prepared by exposure to temperature changes and light before planting based on farmers practice.

In the following methods and results of the two experiments will be described separately to avoid confusion.

Experiment 1: Model farm

Materials and Methods

Experimental site: The experiment was conducted on the experimental farm of the University of Kassel in Hebenshausen about 8km NW of Witzenhausen, about 250m asl. Soils are deep loess soils.

Plot arrangement: The rotation trial that had been set up in 1999/2000 for the MOP project (WP4.3. and 3.3, see previous annual reports) was used for the experiment. The trial consists of two four-year rotations in an organic field. Rotation 1 is grass-clover; potato; winter wheat; spring cereal. In rotation 2 the position of potatoes and winter wheat are exchanged to provide for varying levels of nutrition for the potatoes. A total of 32 main plots are arranged as a split plot with rotation as the main factor and subplots

	22m	22m	22m	22m	22m	22m	22m	22m
60m	**4 GC** t5 t6 t7 t8	**8** WW	**12 WW** t5 t8 t7 t6	**16** WW	**20** Oats	**24** Oats	**28 O** t2 t1 t4 t3	**32** Grass clover
60m	**3** Oats	**7** Oats	**11** Grass clover	**15 O** t3 t1 t2 t4	**19 GC** t9 t12 t11 t10	**23** WW	**27** WW	**31 WW** t10 t11 t12 t9
60m	**2** WW	**6 WW** t9 t10 t11 t12	**10** WW	**14 GC** t12 t10 t11 t9	**18 O** t4 t1 t2 t3	**22** Grass clover	**26** Oats	**30** Oats
60m	**1 O** t1 t2 t3 t4	**5** Grass clover	**9** Oats	**13** Oats	**17** WW	**21 WW** t8 t7 t6 t5	**25 GC** t5 t8 t6 t7	**29** WW

no chitting **Total area 1,5 ha**
Strip (6 m with Summerwheat on each side)
Main Plot No and Pre-Crop

Fig. 1. Field set-up at Model Farm KU in 2004. The main plots in which potatoes were planted are subdivided into four subplots each. The pre-crops to potatoes are marked on the top row as O=oats, WW=Winter wheat, and GC= grass clover. For the treatment key see Table 1.

arranged within each main plot (Fig. 1). The size per main plot is 22 x 60m, allowing for the arrangement of four subplots of 15m length each.

In 2004, this trial was used for the model farm trial and included still the main features of the recent experiments in 2001 to 2003. In order to have a distinct fertility impact, potatoes were not only grown after grass clover and winter wheat but also after the pre-crop oats in crop rotation 1. Soil analyses indicated that after winter wheat (pre-pre crop grass clover) and grass clover the fertility levels were very similar and distinctly higher than after oats. Thus, four main plots at low fertility (pre-crop oats) and eight main plots with high fertility (after winter wheat and grass clover, respectively) were available.

The aim of the experiment was to add different management strategies successively to the Current Late Blight Management Strategy (CULBMS). As CULBMS low fertility (50 – 80 kg Nmin at emergence of potatoes), no chitting and no copper spraying was selected. Different treatments – CULBMS, chitting, copper application (Cu-oxychlorid, Spieß Urania, Hamburg) and Mycosin (plant strengthening product, Schaette, Bad Waldsee, Germany BBA-Nr. LS 004997-00-00)- were randomly distributed and arranged within the main plots with pre-crop oats. The same treatments were then arranged in the eight main plots with high fertility levels. Four of these main plots were planted as strips (8 rows of potatoes neighboured by spring wheat), the other four as regular plots (24 rows of potatoes). As there were two pre-crops for the high fertility main plots after discussion with a statistician it was decided to randomly assign the strip cropping to two mainplots with pre-crop crass clover and two to the plots with pre-crop winter wheat (Table 1.).

Table 1. Treatments used in the field trial. All plots were 15m x 18m. In the regular plots there were 24 rows of potatoes, in the strips 8 rows with 6m of spring wheat on either side.

Tmt	Code Fig 5	Chitting	Spray	Fertility/Pre-Crop	Diversification strategy/ plot size
t1[1]	0	-	-	low fertility/oats	Normal field size /24 rows
t2	V	+	-	low fertility/oats	Normal field size /24 rows
t3	VM	+	Mycosin[2]	low fertility/oats	Normal field size /24 rows
t4	VC	+	Copper [3]	low fertility/oats	Normal field size /24 rows
t5	F	-	-	high fertility/ WW or GC	Normal field size /24 rows
t6	FV	+	-	high fertility/ WW or GC	Normal field size /24 rows
t7	FVM	+	Mycosin	high fertility/ WW or GC	Normal field size /24 rows
t8	FVC	+	Copper	high fertility/ WW or GC	Normal field size /24 rows
t9	FS	-	-	high fertility/ WW or GC	Strip /8 rows
t10	FVS	+	-	high fertility/ WW or GC	Strip /8 rows
t11	FVMS	+	Mycosin	high fertility/ WW or GC	Strip /8 rows
t12	FVCS	+	Copper	high fertility/ WW or GC	Strip /8 rows

[1] Treatment 1 represents the currently used latbe blight management strategy CULBMS
[2] 1% concentration applied with 500l/ha at each date
[3] 500g Copper were applied as copper hydroxide (Cuprozin) at each date

The trial design was thus a split plot with pre-crop / fertility as main plots with strips nested within and treatment as sub-plots (see statistical analysis for model).

All field operations are summarised in Table 2.

Table 2: Agronomic measures in 2004

Date	Measure
Feb. 20	Plowing of grass-clover for rotation 1
April 15	planting
May 17 / 18 June 21	Weeding and hoeing
June 26	Mycosin
June 30	sequential harvest
July 6	Mycosin, copper
July 14	Mycosin, copper
July 15	sequential harvest
July 28	Mycosin, copper
Aug. 2	sequential harvest
Sep. 7	harvest

Nitrogen dynamics: Soil analyses were conducted 7 times during the season to asses the N mineralisation in 0-60 cm depth of the soil. Sampling dates were 18.03., 03.05., 18.05., 03.06., 15.06., 28.06., and 16.07.2004

Disease and growth assessments: Plots were checked regularly until the beginning of the late blight epidemic. After this, disease was assessed twice weekly (12 times) in four 7.5m long sections two rows wide covering the four centre rows of each subplot. In addition, in the strip treatments the outer rows in the east and the west were assessed in the same way. Percent diseased leaf area was estimated, following the key of James et al. (1971).

Sequential and final harvests: Three sequential harvests were conducted in treatments 1-8 in the western and eastern row of each treatment (2 times 15m/plot). For the sequential harvests plants in the respective rows were counted and harvested. Four 7.5m long sections which had also been assessed for late light were taken for final harvest. Potatoes were separated into three size classes (Table 3).

Table 3: Size classes (in mm) at sequential and final harvest times.

Harvest	small	middle	large
1	<20	20-35	>35
2 & 3	<30	30-50	>50
final	< 35	35-55	>55

Data analysis: All data were processed using Excel and analysed with SAS.

Cumulative disease severity was calculated as the Area under the disease progress curve (AUDC) using the following equation:

$$AUDC = \sum_{i=1}^{n-1} \left(\frac{x_{i+1} + x_i}{2} \right) \left(t_{i+1} - t_i \right) \qquad (1)$$

where $\mathbf{x_i}$ = % infested foliage at assessment i, $\mathbf{t_i}$ = time (days) of assessment i, **n** = Number of assessments.

All data were tested for normality and homogeneity of variance (Levene-Test) and transformed if necessary before analysis. To determine if the different pre-crops in the high fertility treatments affected the results the data were analysed with PROC Mixed using the following model:

```
proc mixed;
class block mainplot fert precrop tmt;
model ertrag=block fert fert*precrop fert*tmt fert*precrop*tmt/ddfm=SATTERTH;
random block*mainplot;
lsmeans fert*precrop*tmt/pdiff;
lsmeans fert*precrop/pdiff;
lsmeans fert*tmt/pdiff;
MAKE 'Diffs' out=diffs;
run;
```

In this model the effects of pre-crops are tested separately resulting in four replications for treatments 1-4 with pre-crop oats (low fertility) . Pre-crops winter wheat and grass clover with the treatments 5-12 are then present with two replications. As there were no interactions between pre-crop, fertility and treatment, i.e. the results of the strips and large plots with pre-crop winter wheat and grass-clover did not differ significantly, the comparisons based on fertility*treatment are presented in the results. Thus, the model was simplified into an incomplete normal split plot with four replications and three main factor levels: (i) low fertility with large plots (pre-crop oats), (ii) high fertility with large plots (pre crop winter wheat or grass clover), and (iii) high fertility with strips (pre crop winter wheat or grass clover).

Means were separated for all parameters using LSDs, i.e. pdiff in the mixed model (p = 0.05) or linear contrasts.

Results and discussion

Experimental conditions

In 2004, the temperatures were on average while precipitation differed from the average year. (Fig. 2). While in May and June with 31 and 38 mm the rainfall was low, in July, when the main late blight infestation took place, the precipitation was 98 mm, that is 40 mm above the long-time average.

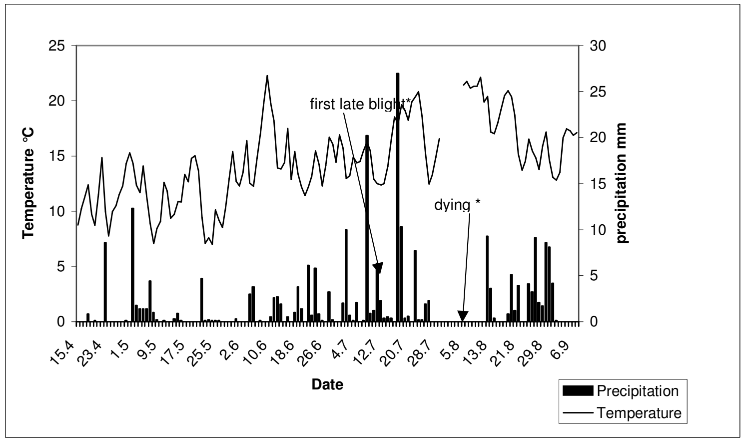


Fig. 2: Temperature and precipitation between April 15 and Sept 9, 2004

Nitrogen Dynamics

Soil nitrogen contents differed depending on the precrop (Fig. 3). From May 18 to June 3 the amounts of NOx-N in a soil depth up to 60 cm increased from 72 kg to 132 kg after grass clover and from 57 kg to 106 kg after winter-wheat. After oats the supply was much lower increasing from 31 kg to 71 kg. After June 3, the differences in N-supply gradually disappeared (Fig. 3). Thus, after the emergence of the crop (May, 17) and during the build up of the foliage until late June, the time when the potential yield of potatoes is determined, the differences between pre crops were highest. The relatively small difference between winter wheat and grass clover might have been caused by a delayed mineralisation of left-over organic nitrogen that had not been mineralised in 2003 as the year had been extremely dry. Therefore, mineralisation of grass clover residues was delayed longer than usual and the difference between the precrops grass clover and winter wheat were lower than in the years before.

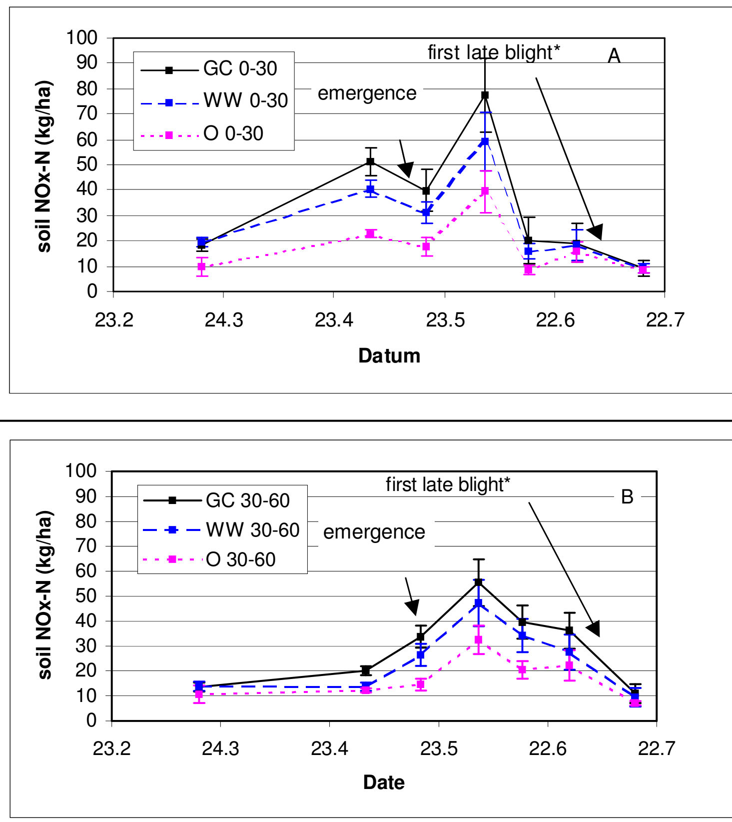


Fig. 3: Soil nitrogen dynamics (NOx-N kg /ha) in potatoes in 0-30 cm (A) and 30-60cm (B) soil depth after Grass clover, (GC), winter wheat (WW) and oats (O)

Disease development

Late blight first was observed in the experimental plots around July 13th. On July 22nd, late blight infections were observed in all plots. Within eleven days the disease increased very fast and destroyed the foliage by 94 % (Fig. 4). The mean infestation was quite similar across main plots. Only between plot 25 (pre-crop grass clover) and 28 (pre-crop oats) in replication 4 which were situated in the western most part of the trial there were rather strong differences in dependence of the pre-crop as after oats the infestation was slow and lower than after grass-clover.

Overall, there was no statistical difference in late blight among pre-crops but the AUDC after precrop

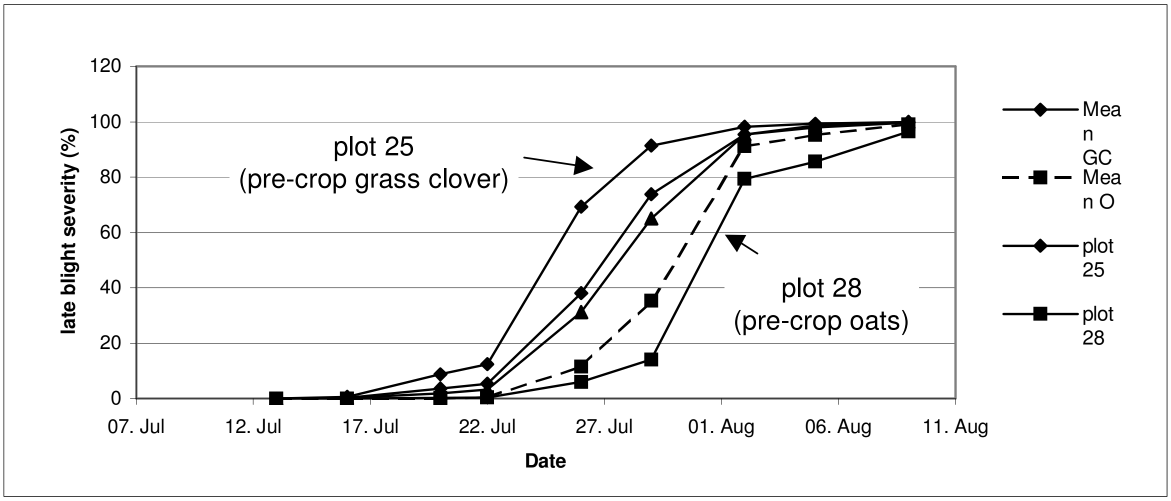


Fig. 4: Mean percent late blight severity in main plots either after pre-crop oats (dashed line, squares) i.e. low fertility, or after grass clover (solid line, diamonds) or winter wheat (solid line, triangles), both representing the higher fertility status. Means over treatments such as chitting and direct control treatments are shown. The two most extreme main plots from replication four are shown in addition (see text).

grass clover was considerably higher than after oats (1298 versus 1016, respectively, P=0.064, Pdiff). Although the difference was nearly statistically significant it should be considered that this might be caused by the strong difference of the plots in block 4 (Fig. 4).

Within the strips late blight severity (AUDPC=1171) was reduced by 15% on average compared to the normal field size growing (AUDPC=1354) but this difference was not significant.

Copper spraying resulted in a statistically significant decrease of late blight severity at all fertility levels when comparing to the chitted unsprayed plots but not when comparing to the non-chitted unsprayed plots (Fig. 5). The slight increase in disease on chitted potatoes is in line with observations from others (Karalus and Rauber, 1996) who reported that because at the onset of late blight chitted potatoes were physiologically older and thus more susceptible. Mycosin had no effect on disease under high fertility conditions and under low fertility conditions it even increased severity in comparison to the untreated unchitted pots (Fig. 5). In the high fertility plots, copper reduced the disease by 24% compared to the average of all other treatments.

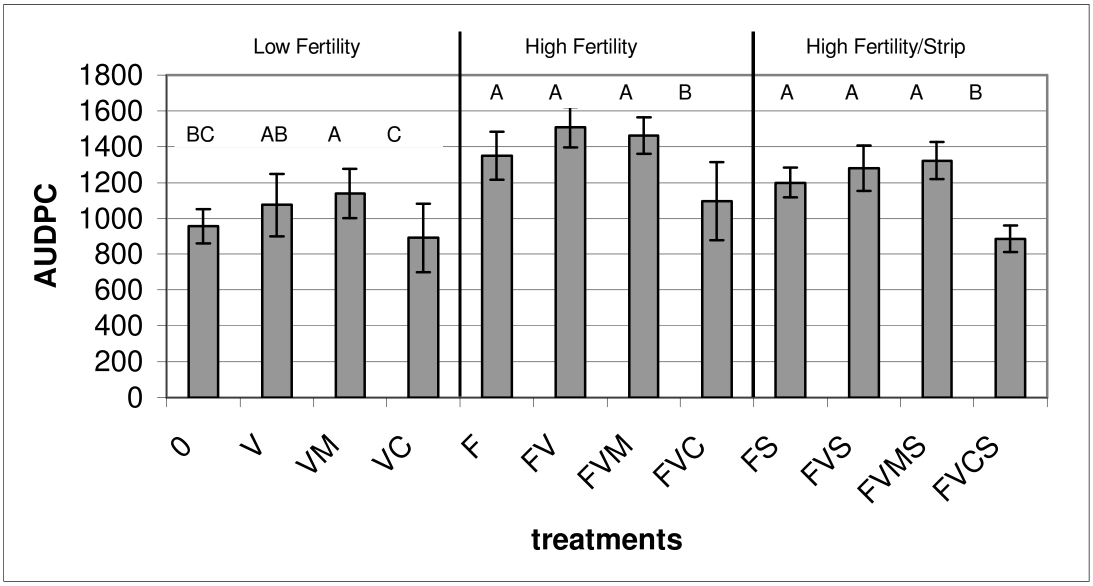


Fig. 5: Means of the area under disease progress curves (AUDPC) and standard deviation in dependence of fertility and treatments [Figures with different letters within a group are significantly different from each other (LSD, p<0,05)]. See Table 1 for treatment code.

Yield

The mean yield in the trial was 24.7 t/ha. Yields in the normal size high fertility plots were 33.6 t/ha and in the high fertility strip plots 32.1 t/ha, significantly higher than after the pre crop oats (23.8 t/ha) at final harvest. Despite the significant disease reductions due to copper, there were no effects of copper on yield in the low fertility treatments. Under high fertility conditions, yields in the copper treated and chitted plots were 9 and 13 % higher than in chitted non-sprayed plots when grown in large plots or in strips, respectively (P=0.09 and 0.02, respectively). Differences to the non-chitted plots were also around 10% (Fig.6).

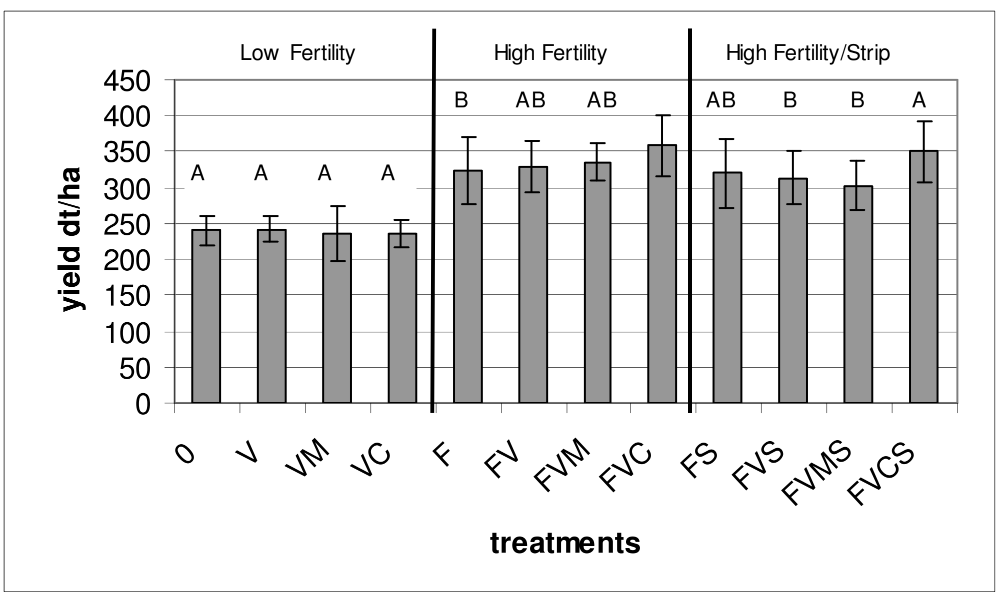


Fig. 6: Means of the raw yield (decatons/ha) at final harvest and standard deviation in dependence of fertility and treatments [Figures with different letters within a group are statistically significant from each other (LSD, p<0,05)]. For treatment code see Table 1.

The lack of beneficial effects of disease reductions on yield after pre-crop oats was most likely due to the effects of limited nutrient supply as the yield development was already slowed down after oats long before late blight started (Fig. 7). Wile yield differences were small at sequential harvest 1 they increased strongly afterwards and yields after grass-clover and winter wheat were significantly higher than after at sequential harvest 2 and 3. As the disease progress was slight during the most important time of tuber mass development it can be assumed that the disease did not influence the yield development negatively. The potatoes in all treatments could build up their potential yield depending on the respective nitrogen supply after emergence (May, 17) until main foliage growth (BBCH 40) stopped around June 24. Throughout most of the time of main tuber bulking and mass development between the end of June and the end of July, disease severity was low on average, not hindering yield development. Only after July 26 late blight progressed very fast and the plants died off by Aug. 5.

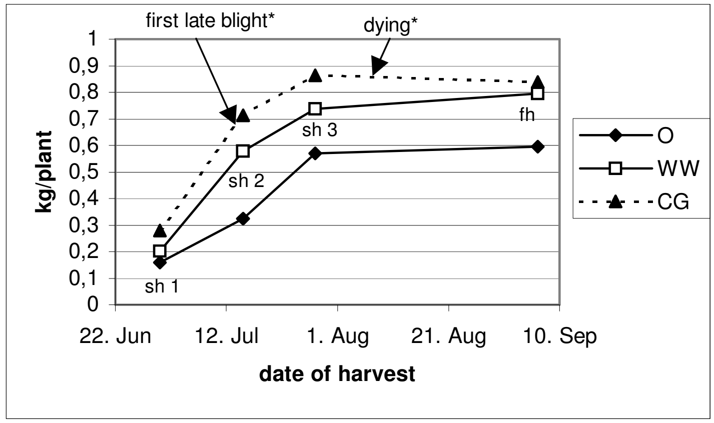


Fig. 7: Tuber mass development of potatoes (kg/plant) at three sequential harvests (sh1 = June, 30; sh2 = July, 15; sh3 = July, 28) and at final harvest in dependence of fertility level. O=pre-crop oats, low fertility, WW and GC = precrop winter wheat and grass clover, respectively, high fertility.

Thus, the impact of the disease on yield was only slight while fertility improved the potential of the plants to build up a high tuber mass before the disease destroyed them. Therefore, early bulking, nutrient efficient varieties benefit from a good N-supply. Delaying crop death in those cases through copper spraying or advancing plant development through chitting will then result in yield benefits. Most likely, however, only the early copper applications on July 6 and 14 were successful in delaying the epidemic. Between July 14 and 28 no further spraying was possible due to the rainy weather and the last spray on July 28 was not any more useful and could have been omitted. Clearly, an environmentally sound late blight control system will have to be based on exact knowledge of the site where the potatoes are to be grown, a variety adapted to the site, a sufficient nutrient supply at the site and if finally still necessary some relatively early control measures e.g. based on copper which will have to be based on predictive systems for contact fungicides such as Bio-Phytopre as developed within Blilght MOP in Switzerland.

Experiment 2. Whole field comparisons on four LINK Farms

The effects of strip cropping interacting with copper and Mycosin treatments were tested on-farm in four unreplicated large-scale trials.

Experimental conditions and set-up

The four on-farm experiments were conducted on the commercial farms attached to the two experimental farms (Frankenhausen = farm 1, Neu-Eichenberg = Farm 2) and on two private farms near Göttingen about 60km NE of Kassel (farm 3 and 4). All sites were certified organic farms and characterised by predominantly loamy silt soils of moderate to high natural fertility.

Fields were chosen to be as flat as possible with the soil conditions as homogeneous as possible based on the experience of the farmers on the commercial farms. Precrops and field operations on the farms varied depending on site and year (Table 4)

Table 4. Field operations and beginning and end of epidemics 2004 in four link farms[1].

Operation	Farm 1	Farm 2	Farm 3	Farm 4
Pre-Pre-crop[2] Pre-crop	GC / SW SW / SB	GC cabbage + manure	GC WW	GC WW
Variety	Agria	Nicola	Nicola	Marabelle
Neighbour crop	spring wheat	spring wheat	carrots	spring wheat
Planting	20.4.04	3.4.04	19.4.04	20.4.04
Harvest	20.8.	8.9.	3.9.	24.8.-3.9.
Beginning infection[3]	14.7.	14.7.	14.7.	14.7.
Death of crop	3.8.	8.8.	13.8.	31.7.
Copper applications[4]	6., 14. 28.07	5., 14., 28.07	15., 23., 26.06, 16.07	23., 26.06, 09.07
Mycosin applications[5]	26.6, 6., 14., 28.7	26.6, 6., 14., 28.7	26.06, 3., 14., 21.7	28.06, 3., 14., 21.7
Number of assessments	7	8	9	6
Harvest date	24.8. and 3.9.	8.9.	3.9.	20.8.

[1] Farm 1 = Frankenhausen, about 10km north of Kassel, farm 2 = Neu-Eichenberg, about 30km east of Kassel, farm 3 = Etzenborn near Göttingen, farm 4 = Ebergötzen near Göttingen.
[2] GC = Grass clover, WW=winter wheat, SW= Spring Wheat, SB=Spring barley. If two crops are listed the first is for the regular potato field, the second for the field where the strip was planted.
[3] First time disease was found.
[4] 500g Copper were applied as copper hydroxide (Cuprozin) at each date.
[5] 1% concentration applied with 500l/ha at each date.

Each farm was visited in September 2003 to determine appropriate fields for the experiments based on the conditions of the fields. Strip cropping was compared to normal farming practice in a regular field. In addition, the effects of copper or Mycosin application were tested.

On each farm, three plots of $30*30m^2$ were set up within an existing commercial potato field. One plot was treated exactly as the farmers treated their potatoes, i.e. planting of slightly pre-sprouted potatoes either without any spray application (farm 1) or with copper applications (farm2-4). The second plot was either treated with copper (farm 1) or untreated (farm 2-4) while the third plot was treated with Mycosin. In a field near the regular potato field each farmer then set up a strip of potatoes of the same variety the width of the commercial spraying equipment (12 m). Neighbour cultures were spring wheat in farms 1, 2 and 4 and carrots in farm 3. The same three treatments as in the regular field were applied (Fig. 8).

Cultivars chosen by the farmers were: Agria in farm 1, Nicola on farm 2 and 3, and Marabelle in farm 4. All potatoes were grown according to standard practise with a row distance of 75cm and within-row distance of 33cm, i.e. 40,000 plants per ha.

All experiments relied on natural inoculum.

Copper applications were carried out by the farmers on their own schedule based on the regional warning system and local weather conditions. Mycosin applications were carried out by the field technicians if possible in weekly intervals. However, frequent rains often prevented such regular applications. In addition, probably some of the sprays were washed off rather quickly due to rain.

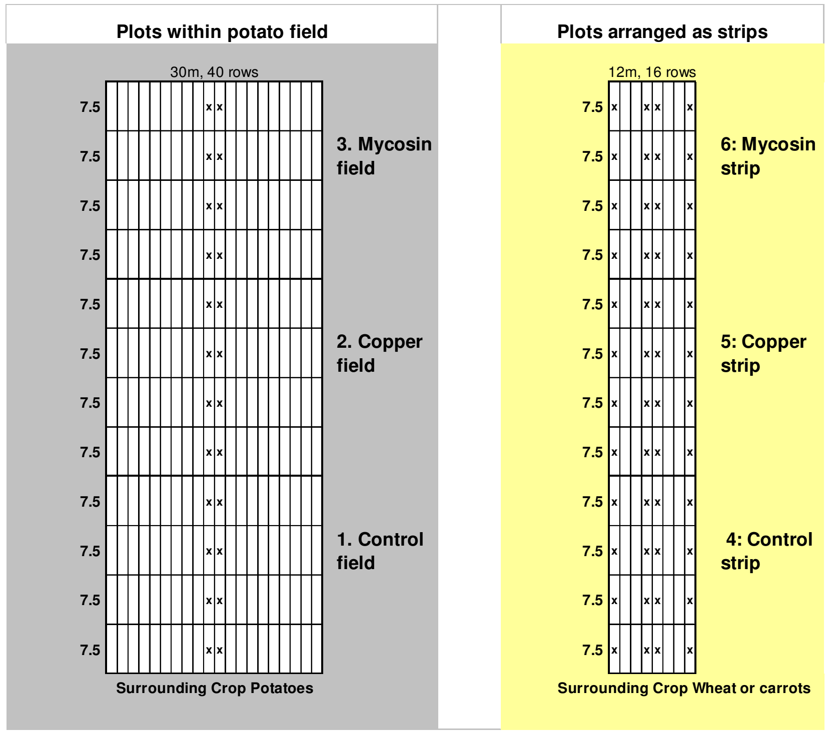


Fig. 8. Schematic arrangement of plots with six treatments on link farms. Assessment sections are marked with x and were 7.5m long each spanning two rows in the center of the plots. In the strips the edge rows were assessed separately in addition.

Disease and growth assessments: Plots were checked regularly until the beginning of the late blight epidemic. Assessments were carried out twice weekly in 7.5m sections in two inner transects in the plots plus the edge rows of the strips (Fig. 8). Depending on the epidemic progress six to nine assessments were carried out (Table 4). Percent diseased leaf area was estimated, following the key of James et al. (1971).

Harvest assessments

Harvest was carried out in the same sections that had been assessed. Potatoes were sorted according to standard size classes (small<35mm, marketable yield 35-55mm, oversize>55mm). After two weeks storage samples of 200 tubers were assessed for tuber diseases as prescribed by the common protocols of Blight MOP. These data were all transferred to FIBL for further analysis.

Climate measurements

On Farm 1 and 2 climate stations were on-site and hourly data on temperature, humidity and rainfall were collected and converted into daily rates. The nearest official weather station for farm 3 and 4 was located in Göttingen and the data were purchased from the *Deutsche Wetterdienst*.

Data analysis

All data were processed using Excel and analysed with SAS (1986).

Disease data were analysed as well on a per farm basis as across farms while yield data were only analysed per farm.

For each assessment section the Area under the disease progress curve (AUDC) was calculated using equation (1)

For the presentation of the data across farms the standardised AUDC was calculated. For this, the maximum AUDC per site is calculated as the number of days the epidemic lasted times 100. The obtained AUDC at a site is then divided by this maximum. In this way, differences in the length of the epidemics are taken out and the maximum AUDC in each site is 1.

While there were no real replications within the farms the sectioning of the large plots into four sections of equal length resulted in four pseudo replications per plot and this allowed for the estimation of experimental errors within farm. For a rough analysis a split plot model with growing pattern (large plots within the farmers field versus plots in strips) as main plot and treatment (unsprayed, copper or Mycosin application) was used. When necessary, data were transformed before analysis to reach normal distribution and homogeneity of variance. As this was not always successful, the Tukey test was applied for all multiple comparisons. Fields and strips were compared with linear contrasts.

Across farms, farms were treated as replications and the means per treatment were used. Again, a split plot model was used.

Results and discussion

The climatic conditions in 2004 were relatively warm but there were many rainy events throughout June and July (Fig. 9). The data from the station in Göttingen can only be used to estimate general conditions for farm 3 and 4 as local weather conditions can vary within a few km.

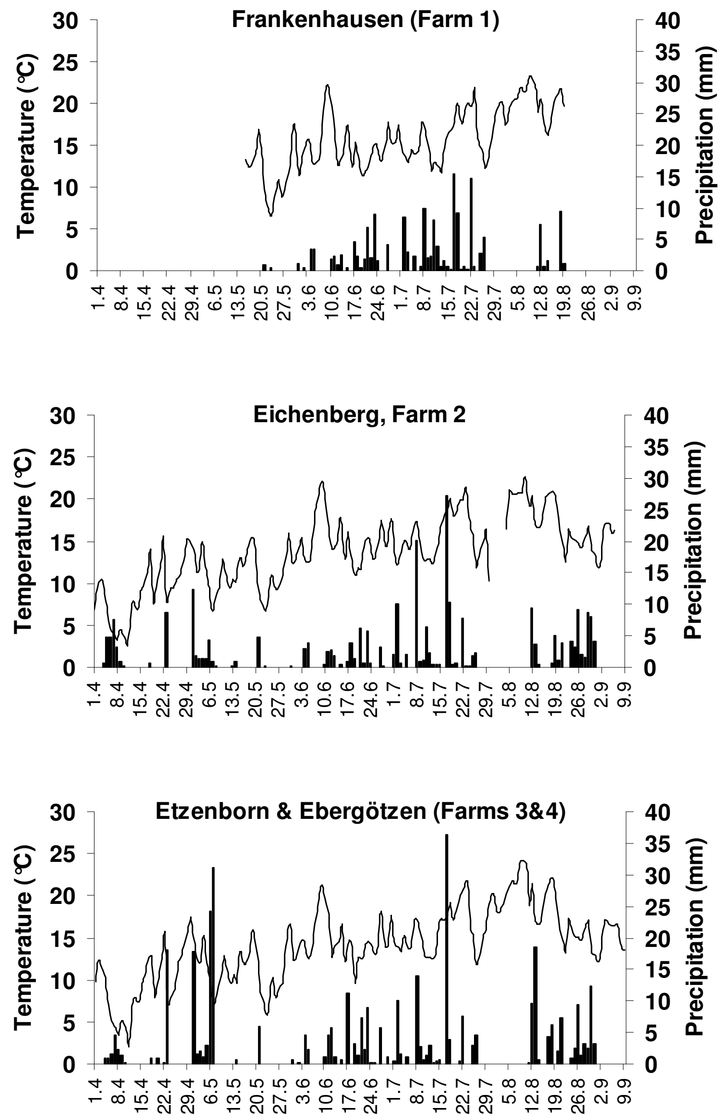


Fig. 9. Temperature and precipitation between April 1 and Sept 9 2004 on or near the four link farms. Own data for Frankenhausen and Eichenberg, data from the nearest official weather station Etzenborn and Ebergötzen (Göttingen) from the German weather service. The station in Frankenhausen malfunctioned in April.

Disease development

Disease development was variable at the four sites (Fig. 10). While late blight was first observed on July 14 at all sites (Table 4) disease did not increase immediately except on farm 2. Also, the duration of the epidemics was very variable among sites with the longest time until crop death at farm 3. There were no obvious differences due to variety as overall disease progress was quite fast at all sites.

At farms 2-4, the highest disease was observed in the control and Mycosin treated plots in farmers fields and the lowest in the copper treated plots (Fig. 11). In contrast, at farm 1, the highest disease pressure was observed in the control and Mycosin plots in the strips.

The ANOVA per site based on the split plot design with the pseudo replications revealed no significant replication effect (see Table A1 in the Appendix), indicating that there were no specific edge effects at the borders between the large plots. Therefore, the results of the analysis can be taken as indicative of treatment effects within each site.

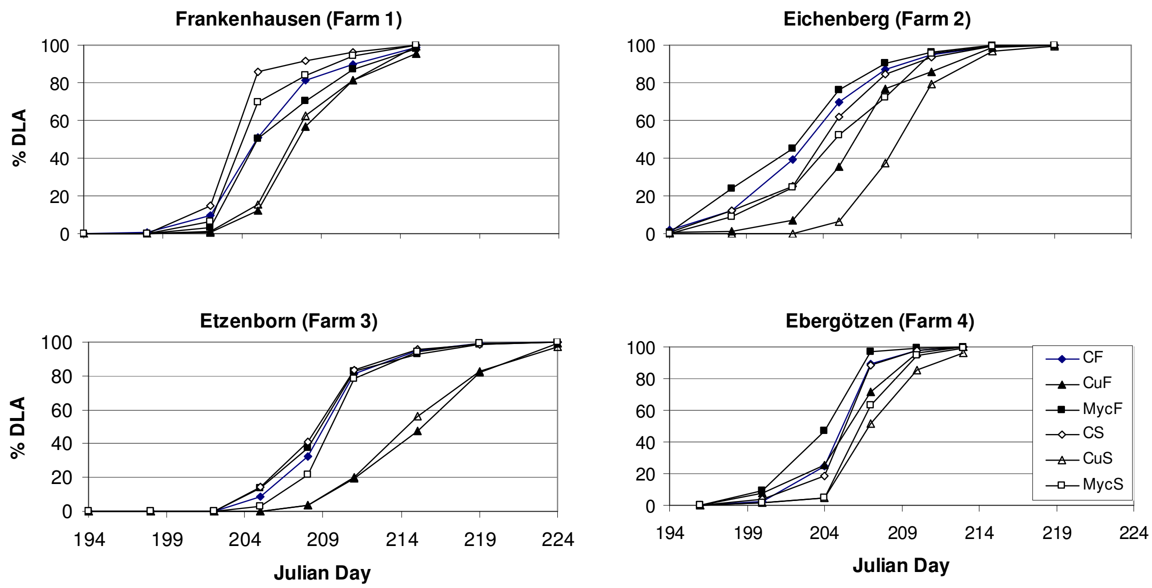


Fig. 10. Disease development of *Phytopththora infestans* on four link farms in 2004 in 30x30m plots laid out within farmers fields (solid symbols, F) or arranged as 12 or 15m wide strips neighboured by wheat or carrots (hollow symbols, S). Treatments were unsprayed control (Diamonds, C), Copper applications (Triangles, Cu) or Mycosin applications (Squares, Myc) (see Table x for details).

Table 5. Standard AUDC in 30*30m plots situated within large potato fields and in 12-16m wide strips bordered by wheat or carrots on four link farms in 2004

Frankenhausen (1)	AUDC[1]
Field	0.397**
Strip	0.450
Eichenberg (2)	
Field	0.606**
Strip	0.491
Etzenborn (3)	
Field	0.431
Strip	0.425
Ebergötzen (4)	
Field	0.487*
Strip	0.399

*, ** Pairs of values differ significantly at $P<0.1$ or 0.01 (ANOVA F-Test)

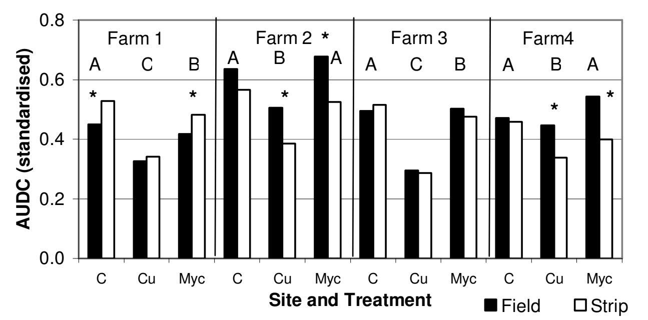


Fig. 11. Standardised AUDC for *P. infestans* at four farms in 2004. Plots were either arranged within farmers fields (filled bars) or as strips neighboured by wheat or carrots (open bars). Significant differences in AUDC between field and strips are indicated by * (Linear contrasts, $P<0.05$). Treatmets were either unsprayed control (C), Copper (Cu), or Mycosin (Myc). Different letters within farm indicate that differences between treatment means were significant at $P<0.05$ (Tukey).

AUDC in the large plots within farmers fields was significantly greater than the AUDC in the strips in Farm 2 and 4 while it was significantly greater in the strips in Farm 1 (Table 5). Thus, in farm 2 and 4, the hypothesis of reduced disease pressure through strip cropping appeared to be true, while in farm 1 the opposite appeared to be the case and in farm 3 no effects were seen.

While in farm 2 and 4 the disease pressure was significantly reduced in the copper and the Mycosin treated strips in comparison to the large plots there was no difference in the disease pressure between the unsprayed treatments in these sites and also in Farm 3 (Fig. 11). In contrast, in farm 1, even in the control treatments AUDC was higher in the strips than in the field. This suggests that the overall pressure on farm 1 was considerably higher in the strip. However, the difference between the copper treatments and the respective controls in farm 1 was larger in the strip than in the field just as in farm 2 and 4 indicating that the efficacy of the copper treatment was increased in the strips. This supports the hypothesis of synergistic effects between strip intercropping and fungicide applications. While there were no differences between the strip and the field on farm 3 the same tendency as on the farms 2 and 4 could be observed

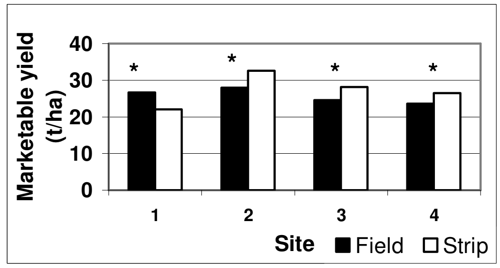


Fig. 12. Mean marketable yields of potatotes in four link farms when planted in farmers field or in strips. Significant differences between strips and fields are marked with * (F-test, $P < 0.05$)

Yield

Yield levels varied depending on farm and variety. The highest yields were obtained with the variety Nicola on farm 2 and 3 with a mean total yield of 31.5 and 27.4 t/ha, respectively. Agria on farm 1 yielded 24.7 t/ha and Marabelle on farm 4 26.0 t/ha. The highest total yields were obtained with the cultivar Nicola when treated with copper in the strip on farm 2 with 41.3 t/ha while the lowest yields were obtained with Agria on Farm 1 also in the strips either when not treated or when treated with Mycosin with 21.6 t/ha.

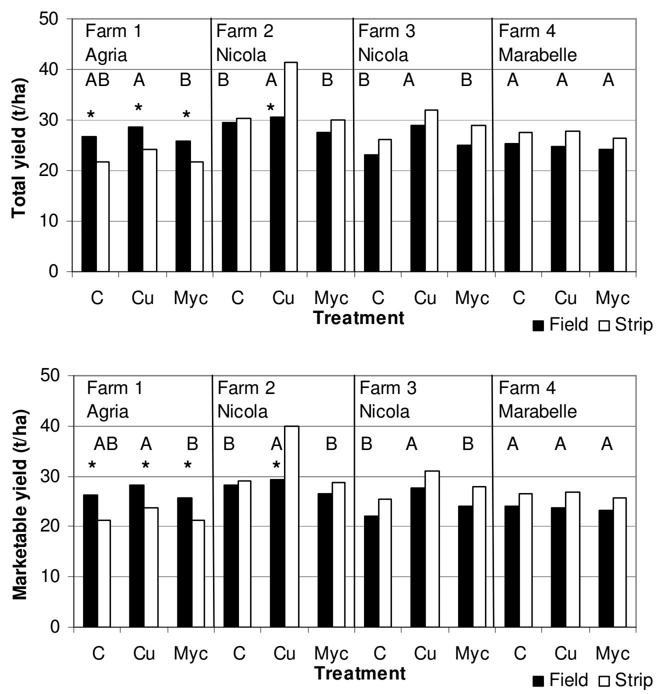


Fig. 13. Total and marketable (>35mm) potato yields at four farms in 2004 for the cultivars Agria, Nicola and Marabelle, respectively. Plots were either arranged within farmers fields (filled bars) or as strips neighboured by wheat or carrots (open bars). Significant differences in yield between field and strips are indicated by * (Linear contrasts, $P<0.05$). Treatments were either unsprayed control (C), Copper (Cu), or Mycosin (Myc). Different letters within farm indicate that differences between treatment means were significant at $P<0.05$ (Tukey).

There were very few undersize tubers ranging between 0.3 and 1.4 t/ha depending on treatment, resulting in very similar results for total and marketable yields. However, when comparing results for total and marketable yields the effects of strips were more pronounced for marketable yields indicating that the differences were more consistent when removing the undersize tuber class (Table A2, Appendix).

On farms 2, 3, and 4, marketable yields in the strips were significantly higher than in farmers fields. However, on farm 1 yields in the strip were significantly lower (Fig. 12). This was due to differences in N-levels on farm 1 which could not be equilibrated through additional fertilisation.

The differences in yield between strips and fields in farms 2-4 cannot be easily explained through disease reductions. E.g. on farm 2 significant disease reductions in the copper treated strip in comparison to the copper treated field plot corresponded with yield increases in the strip while no such effects were observed for Mycosin (Fig. 11 and 13). On farms 3 and 4 yields in the strips were consistently higher in the strips independent of treatment and only overall differences were significant (Fig. 12 and 13).

As disease was also higher in the strips on farm 1 it could be that the differences in yield were due to disease. However, the disease levels in the field and strip treated with copper were equal (Fig. 11) but yields were not (Fig. 13). This indicates that disease was not the main factor influencing yields (but see below).

Yield loss relationships

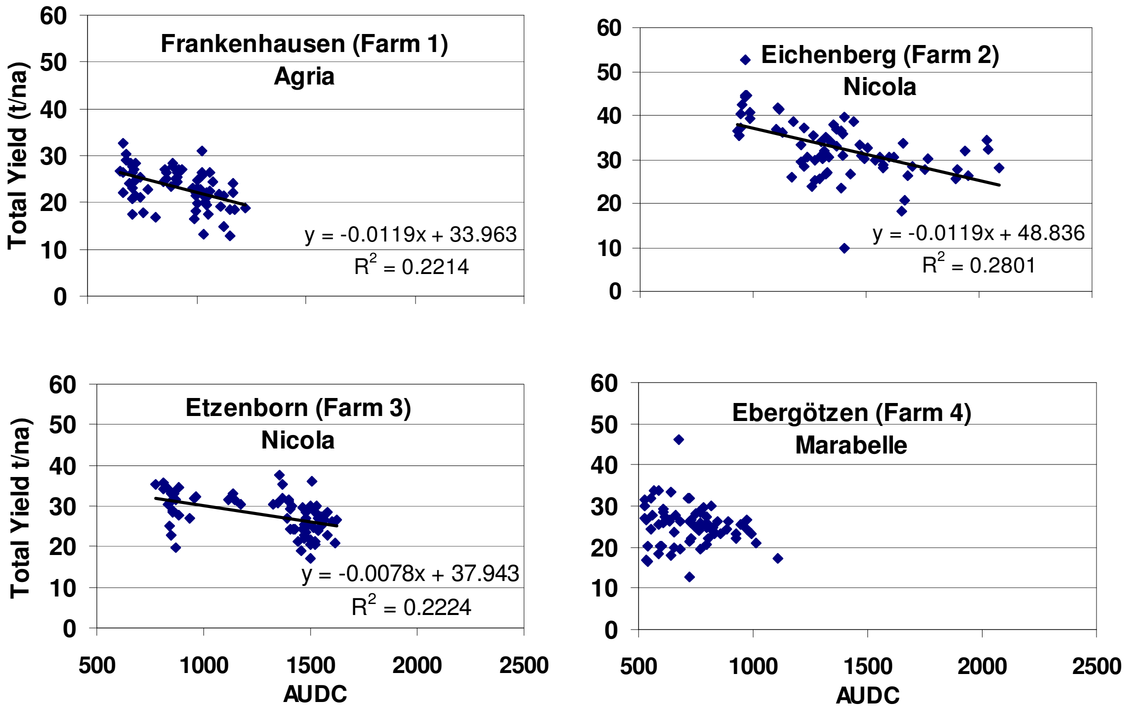


Fig. 14 Yield levels as affected by AUDC at four link farms in 2004. The varieties used at the farms are noted within each graph. Significant correlations are shown.

The 8 or 16 different sections that had been assessed for disease in the fields and strips, respectively, were also harvested separately. This allowed for the determination of the effects of disease in these sections on yields. For each site, a total of 72 data points was thus available.

On farms 1-3, where the cultivars Agria and Nicola had been grown, the correlations between total yield and AUDC were significant and between 22 and 28% of the variation in yield could be explained through AUDC (Fig. 14.). In contrast, on farm 4, where cultivar Marabelle had been used differences in disease levels had been relatively small and no correlation was found. It is likely that Marabelle had already reached its potential yield in farm 4 by the end of July when about 60% of the crop was killed by late blight. At that damage level it is assumed that no more tuber mass can be accumulated

These results are in line with previous results. In the experiments conducted in 2001 and 2002 with cultivars Agria and Linda planted in strips also about 20% of the variation in yield could be explained with AUDC in 2001. However, no such relationship was observed in 2002. This was probably due to the cold temperatures during the critical first six weeks of potato development in 2002. This prevented proper nitrogen mineralization and yield was limited due to a lack of nutrients already in May and June long before late blight had started (Bouws-Beuermann, 2005).

Competition effects of the neighbour crops on potato yields

On farm 1 and 4, yields of Agria and Marabelle, respectively, were significantly lower in the border rows than in the centre rows (T-test, $P<0.01$) probably due to competitive interactions with spring wheat neighbour. In contrast, no such differences could be found for Nicola on farm 2 and 3 (Fig. 15.).

In the previous years´ strip cropping experiments yields of cultivars Agria and Linda were consistently depressed in the edge rows of strips when neighboured by spring wheat (Bouws-Beuermann, 2005). On the model farm in 2004, where Nicola had also been used, there were also no border effects on yield (Simon, 2004). These results suggest that there are considerable differences between cultivars in their reaction to different crops as neighbours. As Nicola is a fairly early bulking variety in comparison to Agria and Marabelle it is likely that Nicola could make use of available nutrients at a time when the spring wheat is not at the peak of nutrient use.

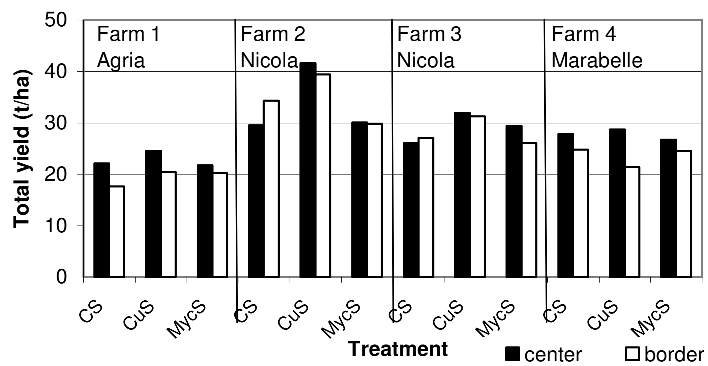


Fig. 15. Yields in the center (closed bars) and border rows (open bars) of cultivars Agria, Nicola and Marabelle on four link farms when planted in strips neighboured by spring wheat (farm 1-3) or carrots (farm 4). Treatments in the strips were: untreated (CS), copper sprays (CuS) or Mcosin sprays (MycS).

References

Andrivon , D., J. M. A. Lucas, and D. Ellisseche. 2003. Development of natural late blight epidemics in pure and mixed plots of potato cultivars with different levels of partial resistance. Plant Pathol. **52**:586-594.

Bouws-Beuermann, H. 2005. Effects of strip intercropping on late blight severity, yields of potatoes (*Solanum tuberosum* Lindl.) and on population structure of *Phytopathologyhthora infestans*. Dissertation, University of Kassel, Faculty of Organic Agricultural Sciences.

Finckh, M. R., H. Bouws-Beuermann, H. P. Piepho, and A. Büchse. 2004. Auswirkungen von Streifenanbau und Ausrichtung zum Wind auf die räumliche Verteilung und epidemiologische Parameter der Kraut-und Knollenfäule. Mitt.Biol.Bundesanst.Land-Forstwirtsch.Heft515-516.

Garrett, K. A. and C. C. Mundt. 1999. Epidemiology in mixed host populations. Phytopathology **89**:984-990.

Garrett, K. A. and C. C. Mundt. 2000. Host diversity can reduce potato late blight severity for focal and general patterns of primary inoculum. Phytopathology **90**:1307-1312.

Garrett, K. A., R. J. Nelson, C. C. Mundt, G. Chacon, R. E. Jaramillo, and G. A. Forbes. 2001. The effects of host diversity and other management components on epidemics of potato late blight in the humid highland tropics. Phytopathology **91**:993-1000.

James, C. 1971. A manual for assessment keys for plant diseases. APS, St Paul, MN.

Karalus, W. and R. Rauber. 1996. Effects of presprouting on potato diseases in organic farming. J.Plant Diseases & Protection **103**:420-431.

Leonard, K. J. 1969. Factors affecting rates of stem rust increase in mixed plantings of susceptible and resistant oat varieties. Phytopathology **59**:1845-1850.

Phillips, S. 2004. The ecology and epidemiology of potato variety mixtures in organic production. Dissertation, University of Reading.

Rotem, J. and Y. Cohen. 1974. Epidemiological patterns of Phytopathologyhthora infestans under semi-arid conditions. Phytopathology **64**:711-714.

Simon, S. 2004. Auswirkungen von Bodenfruchtbarkeit sowie unterschiedlichen Anbaumaßnahmen und Behandlung auf Befall mit *Phythophthora infestans* und Ertrag bei Kartoffeln (*Solanum tuberosum* L.) im ökologischen Landbau. Diploma Thesis University of Kassel.

Schulte Geldermann, E., Dlugowski, S., Finckh, M. R., and Bruns, C. 2005. Einfluß von sortenspezifischen Merkmalen, unterschiedlichem Stickstoffangebot und Kupfer auf die Ertragswirksamkeit von *Phytopathologyhthora infestans* in Kartoffeln [The impact of varietal features, different nitrogen supply and copper treatment on the yield affecting influence of *Phytopathologyhthora infestans* in potatoes]. In: Heß, J. and Rahmann, G., eds. *Ende der Nische, Beiträge zur 8. Wissenschaftstagung Ökologischer Landbau.* 1.3-4.3.2005.

Waggoner, P. E. 1952. Distribution of potato Late blight around inoculum sources. Phytopathology **42**:323-328.

Waggoner, P. E. 1962. Weather, space, time, and change of infection. Phytopathology **52**:1100-1108.

Appendix

Table A 1

Results of ANOVA based on Split Plot design for Area under the Curve (AUDC) at the four link farms

Frankenhausen (1)	Source	DF	Mean Square	F Value	Pr > F
	rep	3	440.25	0.49	0.698
	field/strip	1	73836.89	292.72	**0.0004**
	field/strip*rep	3	252.24	0.28	0.8397
	tmt	2	230857.48	255.14	**0.0001**
	field/strip*tmt	2	10077.62	11.14	**0.0018**
Ebergötzen (4)	source	DF	Mean Square	F Value	Pr > F
	rep	3	6388.67	1.12	0.3797
	field/strip	1	134132.89	19.62	**0.0214**
	field/strip*rep	3	6838.25	1.2	0.3521
	tmt	2	43671.47	7.65	**0.0072**
	field/strip*tmt	2	26438.16	4.63	**0.0323**
Eichenberg (2)	source	DF	Mean Square	F Value	Pr > F
	rep	3	1420.40	0.19	0.9012
	field/strip	1	489979.24	34.22	**0.01**
	field/strip*rep	3	14320.34	1.91	0.1811
	tmt	2	402536.32	53.82	**0.0001**
	field/strip*tmt	2	20715.25	2.77	0.1026
Etzenborn (3)	source	DF	Mean Square	F Value	Pr > F
	rep	3	1434.08	2.29	0.1303
	field/strip	1	1449.85	0.23	0.6621
	field/strip*rep	3	6214.51	9.93	0.0014
	tmt	2	1022091.53	1632.38	**0.0001**
	field/strip*tmt	2	10795.23	17.24	**0.0003**

Table A2

Results of ANOVA based on Split Plot design for total yield and marketable yield (>35mmtubers) for the four link farms.

Frankenhausen (1)		**Total yield**			**Marketable Yield**		
Source	DF	MS	F Value	Pr > F	MS	F Value	Pr > F
rep	3	0.481	0.53	0.6671	0.40	0.44	0.7266
field/strip	1	32.455	24.47	**0.0159**	32.69	28.15	**0.0131**
field/strip*rep	3	1.327	1.47	0.2712	1.16	1.30	0.3203
tmt	2	3.894	4.33	**0.0385**	4.11	4.59	**0.0330**
field/strip*tmt	2	0.061	0.07	0.9352	0.06	0.07	0.9312
Eichenberg (2)							
rep	3	0.005	2.02	0.1645	0.006	2.30	0.1294
field/strip	1	0.009	8.37	***0.0629***	0.013	11.12	**0.0446**
field/strip*rep	3	0.001	0.41	0.7510	0.001	0.43	0.7359
tmt	2	0.001	0.47	0.6332	0.001	0.35	0.7137
field/strip*tmt	2	0.000	0.07	0.9333	0.000	0.06	0.9458
Etzenborn (3)							
rep	3	0.195	0.18	0.9052	0.140	0.14	0.9355
field/strip	1	17.012	37.83	**0.0086**	17.918	46.91	**0.0064**
field/strip*rep	3	0.450	0.42	0.7395	0.382	0.38	0.7720
tmt	2	16.492	15.54	**0.0005**	15.865	15.62	**0.0005**
field/strip*tmt	2	0.126	0.12	0.8888	0.035	0.03	0.9658
Ebergötzen (4)							
rep	3	4.871	2.14	0.1485	5.137	2.43	0.1155
field/strip	1	9.568	7.54	***0.0710***	11.992	9.29	***0.0555***
field/strip*rep	3	1.269	0.56	0.6531	1.291	0.61	0.6205
tmt	2	0.694	0.30	0.7429	0.445	0.21	0.8130
field/strip*tmt	2	0.082	0.04	0.9649	0.059	0.03	0.9727

Field evaluation of novel blight control systems in Denmark 2004

DIAS - Danish Institute of Agricultural Sciences, DK

Main Message

Early crop establishment achieved by early planting of pre-heated seed tubers significantly improves the yield of potatoes, since larger tuber yield is obtained before appearance of *Phtytophthora* epidemics. In growth seasons of very late *Phtytophthora* epidemics, additional effects of seed tuber chitting on total tuber yield cannot be achieved. However, in case of high risks of *Rhizoctonia* attacks, seed tuber chitting may improve marketable yield, because the faster plant emergence reduces attack of the sprouts by *Rhizoctonia solani*. The advantage of early crop establishment achieved by seed tuber chitting is **not** lost due to increase in susceptibility of physiologically older crops to *Phtytophthora* attacks. No effect of the Duxon insect soap can be expected if the physiological age of the crop has entered natural plant senescence.

Introduction

Based on results from previous years of the BlightMOP project, two subjects were identified as the most promising in Denmark: 1) early crop establishment in order to escape from late blight epidemics as long as possible during growth cycle, 2) treatments of the crop with solutions of alternative control ingredients in order to suppress late blight development when applied to potato leaves.

Materials and methods

MODEL farm.

In Denmark, the currently used late blight management system (CULBMS) was defined as; seed tubers of the cultivar Sava, preheated at 14°C for 14 days and planted May 1. Treatments at the MODEL farm located in Jyndevad, southern Denmark were:

C0. Sava. (CULBMS)

C1. Ditta. The cultivar Sava was replaced with Ditta in order to accelerate crop establishment.

C2. Ditta, early planted. Seed tubers were planted when the soil temperature reached 8°C in 10 cm depth, equivalent to April 12.

C3. Ditta, early planted, chitted. Seed tubers were chitted in trays from February 15 under illuminated conditions at 18°C until 2-3 mm sprouts, and thereafter at 8°C until planting April 12.

C4. Ditta, early planted, chitted, soap. The crop was sprayed with 10 L/ha of a natural soap (BioDux 40, potassiumoleate) on June 10 and repeated with 3-4 days intervals.

C5. Marabel, early planted, chitted, soap. The cultivar was changed from Ditta to Marabel in order to accelerate crop establishment.

LINK farms.

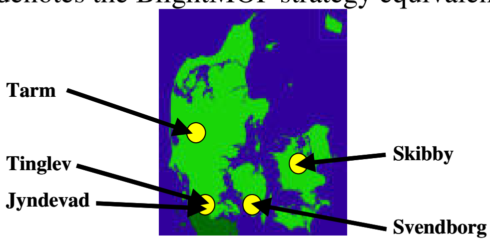
In addition the "additive trial"-designed experiment at the MODEL farm, two different systems were compared in non-replicated whole field experiment at four LINK farms located at four different geographical sites in Denmark.

A. *Local farm strategy.* The locally used management strategy.

B. *BlightMOP strategy.* The *C4* treatment from the experiment at the MODEL farm was used as the BlightMOP strategy at all four LINK farms.

Table 1 shows agronomical data for the two different management systems employed at the LINK farms (Tarm, Tinglev, Skibby, Svendborg).

Table 1. Geographical locations of the MODEL and LINK farms in Denmark and agronomical data for the two management systems employed at the LINK farms. **A.** denotes the practice of the local farmer, **B.** denotes the BlightMOP strategy equivalent to C4 at the MODEL farm (see text).



Location	Cultivar	Chitted	Planting date	Plant emergence	
	A	A	A og B	A	B
Tarm	Ditta	No	22-Apr	31-May	16-May
Tinglev	Sava	No	16-Apr	31-May	11-May
Skibby	Ditta	No	22-Apr	04-Jun	21-May
Svendborg	Ditta	Yes	14-Apr	05-May	05-May

The growth stages of the crop and percentage attack of the leaves by *Phytophthora infestans* and *Alternaria solani* were monitored during growth. Attack of the sprouts by *Rhizoctonia solani* at the time of plant emergence was registered. After harvest the tubers were graded into size fractions of <35 mm, 35-60 mm and >60 mm. Thereafter, the marketable size fractions (35-60 mm) were examined for late blight symptoms, black scurf (*Rhizoctonia solani*), common and netted scab (*Streptomyces spp*), mechanical damage and rot. The harvested tubers were classified as inferior quality if the surface of tubers were covered with more than 5 % black scurf or scab. The official threshold of surface coverage by black scurf and common scab in Denmark is 20 % for premium grade, so the threshold of surface blemishes used for the present experiments were relatively strict.

Results and discussion

In Denmark late blight epidemics generally started very late (July 20) in the growth season of 2004 compared to a normal year. Therefore the plants had already reached the beginning of natural leaf senescence at the date of *phytophthora* appearance.

MODEL farm

Huge differences in terms of plant emergence were seen between treatments. Plant derived from early planted (April 12) and chitted seed tubers (C3, C4, C5) emerged 27 days earlier than plants derived from late planted (May 1) and pre-heated seed tubers (C0, C1). These differences between treatments declined to 8 days at the time of row closure defined by character 40 on the BBCH scale. No significant differences between the treatments in dates of late blight attack were seen.

Total tuber yield increased by 4.2 t/ha when the cultivar Sava was replaced with the cultivar Ditta planted on May 1 (Fig. 1a, C1). The yield was further increased by 6.1 t/ha when the planting date was advanced to April 12 (C2). No further increases in total tuber yields were seen due to the additional treatments (C3, C4 and C5), probably because of the very late *phytophthora* attack. Early crop establishment obtained by seed tuber chitting did not increase total tuber yields compared to total tuber yields produced by non-chitted seed tubers (C3). Moreover, no effect of soap treatments was seen on total tuber yields (C4). Finally, the use of the very early cultivar Marabel could not benefit from the prolonged growing season in 2004. Therefore, slightly reduced total tuber yield of Marabel was seen (C5) compared to total tuber yield of Ditta (C4). Similar effects of seed tuber chitting and soap treatments on the yield of the marketable tuber size fractions (35-60 mm) were seen (Fig. 1b).

Although no effect of seed tuber chitting was registered in tuber yields, the treatments of C3 and C4 significantly increased the quality of the harvested tubers because of less black scurf on the tuber skin (Fig. 2a). This may be explained by faster plant emergence and thereby reduced attack of the sprouts by *Rhizoctonia solani* when seed tubers have been chitted. Mainly because of the effect of seed tuber chitting on black scurf incidence, marketable yield of C3 was significant higher than marketable yield of C2 (Fig. 2b). No other significant differences between treatments in terms of the registered quality aspects were found. However, it also seemed that the soap treatment improved marketable tuber yield (C4) but this effect was not significant. It is likely, that significant effects of the soap treatments would have been detectable if late blight epidemics had appeared earlier in the growth season as in a normal year.

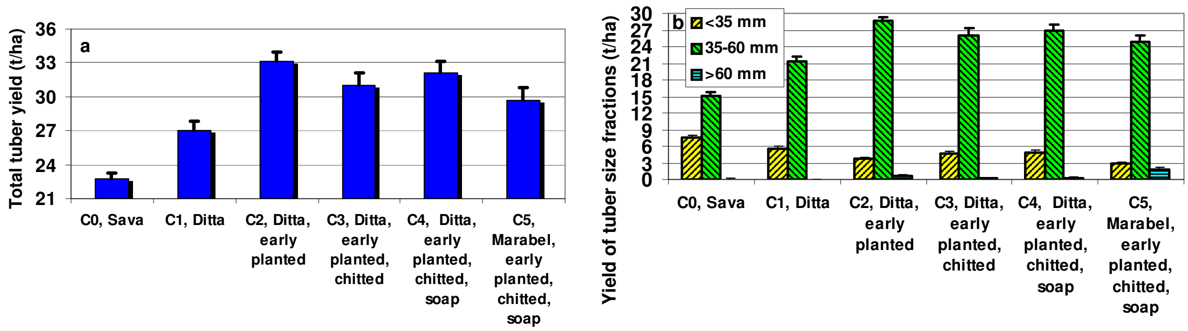


Figure 1. The effect of the six treatments at the MODEL farm on, a) total tuber yields and, b) yields of various size fractions. Error bars are std. error of means.

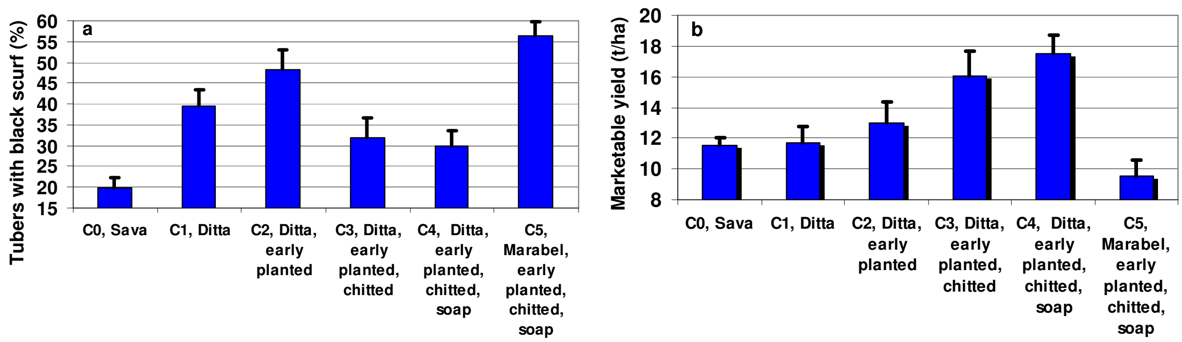


Figure 2. The effect of the six treatments at the MODEL farm on, a) the percentage of tubers with more than 5% of the surface covered with black scurf (*Rhizoctonia solani*), b) marketable yield defined as the 35-60 mm size fraction without quality defects. Error bars are std. error of means.

LINK farms

The demonstration experiments indicated that the BlightMOP strategy was able to improve the local practice at two of the LINK farms. Although the planting dates at each LINK farm were the same for both the BlightMOP strategy and the strategy of the local farmer, seed tuber chitting improved plant emergence from 14-20 days (Table 1). Fig 3a illustrates the growth stages of the crop beyond July 1 and Fig 3b illustrates the percentage of foliar blight at the LINK farm located in Tarm. According to the BBCH characters the huge difference between the two strategies at plant ermengence (15 days) was slowly diminished towards crop maturity but it was noticeable that the oldest crop, produced by the BlightMOP strategy, was the most susceptible to *Phytophthora* attack at the end of July. At the date of 50 % foliar blight, the development of the BlightMOP crop advanced crop development as a result of the strategy of the local farmer by 7-8 days, whereas foliar blight symptoms on the BlightMOP crop were only advanced by 2-3 days compared to foliar symptoms on the crop of the farmer.

In general huge differences between the four LINK farms in averaged tuber yields were registered (Fig 4). These differences probably could be explained by differences in soils fertilities since late blight attacks more or less appeared at the same dates at the four locations. The BlightMOP strategy improved total tuber yields by 10.4 and 9.8 t/ha and the marketable tuber yield by 8.4 and 4.8 t/ha at the LINK farms located in Tarm and Skibby, respectively (Fig. 4). No difference was seen between the effects of the BlightMOP strategy and the strategy used by the LINK farm in Tinglev on total and marketable yields. At the LINK farm located in Svendborg, tuber yields were already very high, and the BlightMOP strategy did not result in additional improvements. In contrast, the results indicated that the BlightMOP strategy reduced the marketable yield at this LINK farm. This farm was the only one of the LINK farms where chitted seed tubers were used.

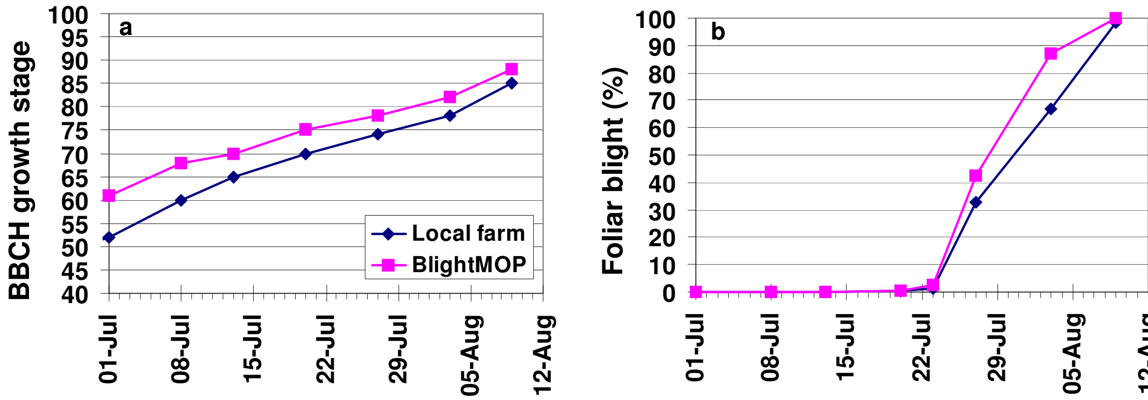


Figure 3. The effect of the normal practice at the LINK farm located in Tarm and the effect of the BlightMOP strategy, equivalent to treatment C4 at the MODEL farm, on crop development (a) and the susceptibility of crop to develop late blight symptoms on the leaves (b).

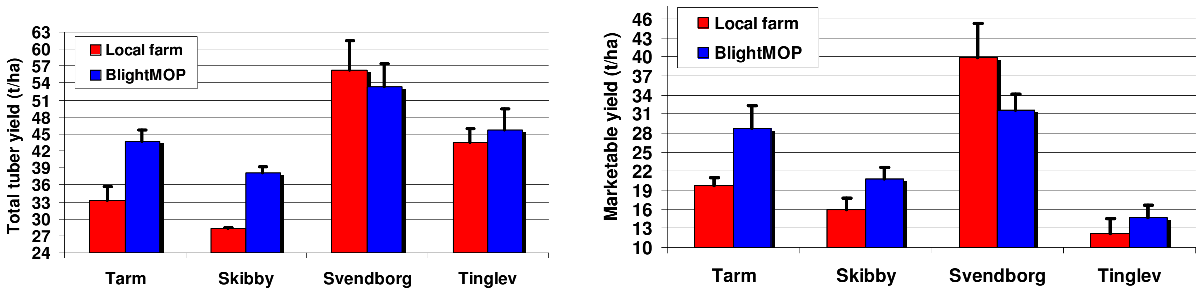


Figure 4. The effect of the practice of the local farm and the effect of the BlightMOP strategy, (equivalent to treatment C4 at the MODEL farm, on total and marketable tuber yields. Error bars are std. error of means of the four subplots at each LINK farm.

Conclusions

- Due to the very late appearance of *Phytophthora* epidemics in Denmark 2004, the effects of the various treatments were expected to be smaller as they would have been in a normal year.
- No differences in susceptibility of the crop to *Phytophthora* attack in the end of July due to the various treatments were registered at the MODEL farm.
- Total tuber yield of Ditta was found 4.3 t/ha larger than that of Sava when pre-heated seed tubers were planted late (May 1), however, more black scurf appeared on the tubers of Ditta than on the tubers of Sava.
- Total tuber yield of Ditta, produced from pre-heated seed tubers planted early, increased by 6.0 t/ha compared to the yields of Ditta produced from pre-heated seed tubers planted late.
- Total tuber yield of Ditta, produced from chitted seed tubers, did not surmount the yields of Ditta produced from pre-heated seed tubers when they were planted early, however, significantly less black scurf appeared on the tubers produced from chitted seed tubers. Therefore, marketable yield of Ditta, produced from chitted seed tubers surmounted the yields of Ditta produced from pre-heated seed tubers.

- No effect of the Duxon insect soap BD 40 on late blight epidemics and tuber yields were registered at the MODEL farm 2004. This is in contrast to results found in 2003, and the lack of significant effects is probably due to the very late *Phytophthora* outbreak at the stage where the plants were very susceptible to *Phytophthora* attacks due to the advanced physiological age of the crop.
- At two of the LINK farms, the BlightMOP strategy improved total tuber yields by 10.4 and 9.8 t/ha. Early crop establishment due to seed tuber chitting probably achieved this effect, since no effect was seen at the LINK farm where seed tuber chitting already was the current practice.
- The results at the LINK farms indicated that the advantage of early crop establishment achieved by seed tuber chitting is **not** lost due to chronologically earlier *Phtytophthora* attacks as a result of increased susceptibility of the physiologically older crop.

Field evaluation of novel blight control systems in Norway 2004

NCEA – Norwegian Centre for Ecological Agriculture, N

A) MODEL FARM

1. Main Message

The potato variety Peik showed a better performance than the standard variety Troll regarding foliar blight and yield. Alternating rows of the two varieties, chitting, sprays with the plant strengthener OASE and total mixture of Troll and Peik did not reduce the blight infections related to non-chitted pure stands of Troll. However, OASE caused some more tuber blight than untreated. Chitting caused some more foliage blight than non-chitted but increased the marketable yield. Chitting had the most significant positive impact on the net economic results of the tested strategies.

2. Materials and Methods

Troll, which is the most commonly grown potato variety in Norwegian organic potato production, was used as "the currently used late blight management system" (CULBMS) = C0.

The other treatments were: C2: variety Peik, C3: variety mixture (alternating rows of Troll and Peik), C4: variety mixture plus chitting, C5: C4 plus sprays with OASE, C6: Total mixture of Troll and Peik (every other plant with Troll and Peik in the same row), chitting plus sprays with OASE.

The product OASE is primarily used as a plant strengthener. It contains plant extracts and some nutritional micro-elements. Copper is amongst them to a level of 27 mg Cu per litre undiluted product. Spraying with OASE took place July 12, July 20, July 27, and August 3 using 5 litres in 200 l water per ha (OASE All Round - 8N 6P 6K).

The field trial was located at Særheim research station in Southwest Norway with a relatively cool and moist northern Atlantic coast climate. The field was managed organically and consisted of a moraine soil. The eight single grown varieties and the complete mixture in the six treatments were tested in a randomised block design with four replicates. Each plot was 26 rows wide (0.75 m each) and 25 m long, representing an area of 487.5 m^2. There was a 30 cm distance between the plants within the row.

The plots were planted on May 24. Fifty percent emergence was reached on June 7 for the treatments with chitted potato seed. The late planting date was due to heavy rainfall in the beginning of May.

The first symptoms of leaf infection were found August 2. From this moment on, the plots were assessed for late blight twice a week until the end of the epidemic.

Tubers from each sub-sub plot were harvested from one row of 3.1 m (2.325 m^2) in October 11.
The yield was recorded as total yield and as marketable yield comprising tubers over 42-millimetre diameter. To allow development of tuber blight the tubers were stored for about 4 weeks at about 15ºC before assessment.

Data analysis: From the late blight severity data, the standardised "area under the disease progress curve" was calculated. StAUDPC values for foliage blight and data about the yield were analysed with Minitab using GLM (Analysis of Variance). LSD tests were made for pair-wise comparisons.

The economic impact of the various strategies was analysed based on the standardised costs for the different items (labour, machinery, agronomic inputs): These data were derived from the Norwegian Agricultural Economics Research Institute, Handbook 2004/2005.

3. Results

1) Foliar blight

The first infections were found August 2 in different treatments (C3, C4, C5, C6).
The disease developed relatively fast and reached 50 % infected foliage about 10 days later. On August 30 about 90 % of the foliage was blighted.

Variety Peik (stAUDPC= 43.5) had statistically (P<0.0005) less foliar blight than Troll (stAUDPC=47.3) in the experiment. Chitting (stAUDPC=46.5) caused statistically (P<0.0005) more blight in comparison to non-chitted seed (stAUDPC=44.3). There were no significant effects on foliar blight when other strategies were added. Details about foliar blight in each treatment are given in Figure 1.

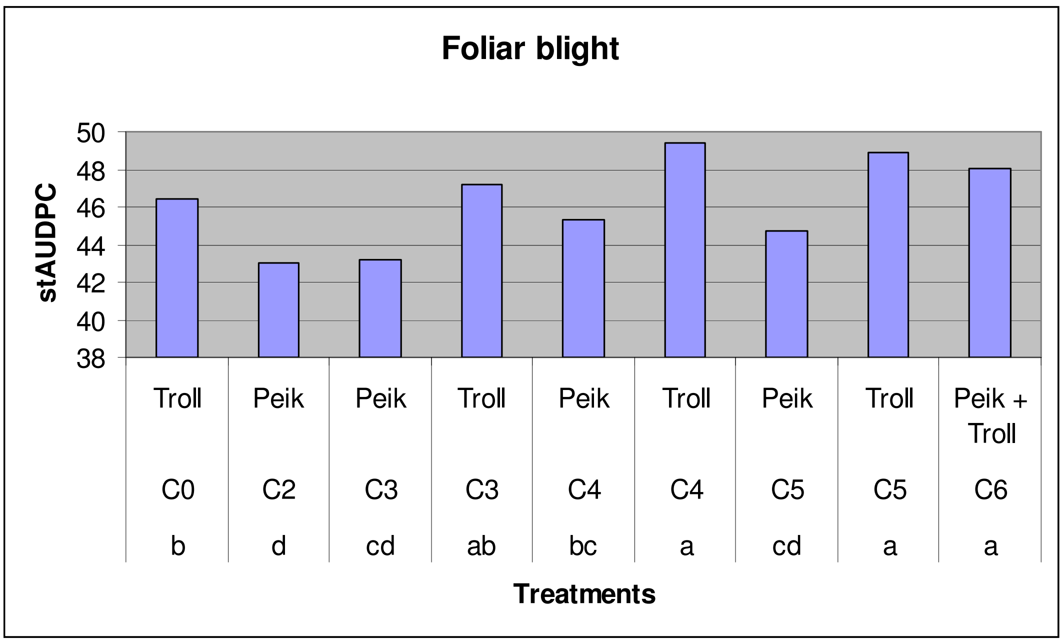


Figure 1. Foliar blight (stAUDPC) in different treatments (C0-C6), varieties and mixtures. Treatments with the same letter are not significantly different (LSD 5%).

2) Yield

Peik had 3.6 t/ha higher total yield and 2.4 t/ha higher marketable yield than Troll ($P<0.0005$). Chitting increased the total yield by 3.14 t/ha ($P=0.003$) and marketable yield by 4.3 t/ha ($P<0.0005$).

Details about yields in each treatment are shown in Figure 2.

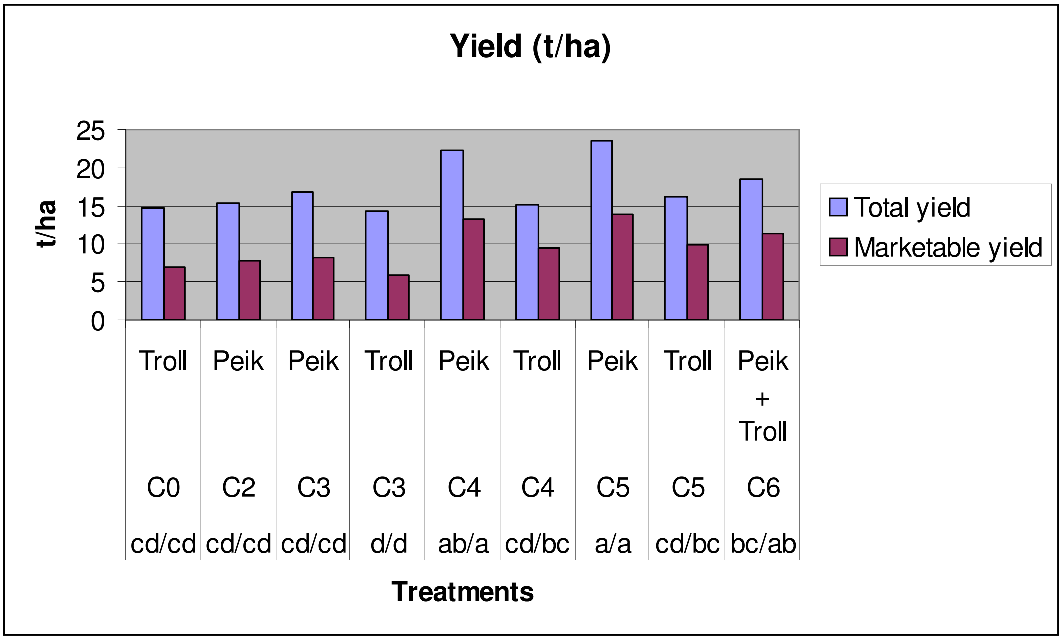


Figure 2: Yield (total and marketable) in different treatments (C0-C6) varieties and mixtures. Treatments with the same letter are not significant different (LSD 5%).

3) Tuber blight

The blighted yield was low, as shown in Fig 3. In the analyses of the differences between varieties, Peik had higher blighted yield (0.37 t/ha) than Troll (P<0.0005). Treatment with OASE caused 0.23 t/ha more blighted tubers than unsprayed (P=0.049). The tuber blight yield in all different treatments is shown in Figure 3.

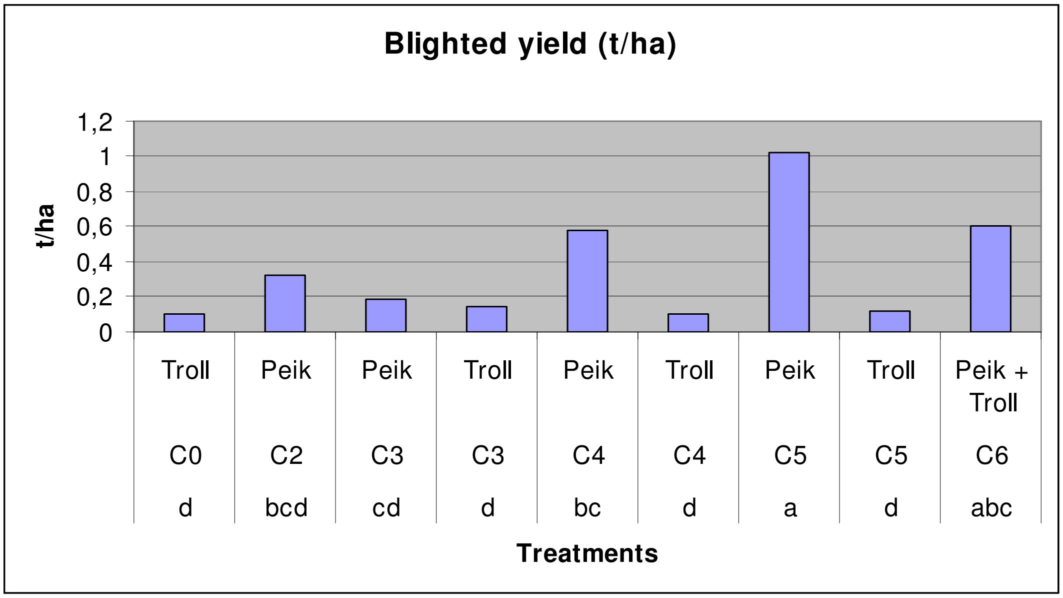


Figure 3: Tuber blight in different treatments (C0-C6) and varieties. Treatments with the same letter are not significantly different (LSD 5%).

4) Economic impact of the strategies

The analysis of the economic impact of the various compound strategies as carried out under the MODEL farm regime showed that chitting (treatment C4-C6) had a marked influence. A summary is given in table 1. It also illustrates that the impact of unfavourable climate conditions, in this case resulting in delayed planting, had marked consequences, since the growing season is too short to being able to compensate for this delay. In this study only the treatment with chatted seed potatoes give a positive economic result.

Strategy	Standard C0	C2	C3	C4	C5	C6
Costs (euro/ha)	6002	5758	5894	5964	6370	6370
Total yield t/ ha	14,7	15,3	15,8	18,7	19,8	18,5
marketable yield t/ha	7,0	7,8	7,1	11,3	11,8	11,4
price per kg	0,61	0,61	0,61	0,61	0,61	0,61
Yield (euro/ha)	4255	4766	4301	6916	7219	6936
Yield - costs (euro/ha)	-1748	-992	-1593	953	848	566
Extra costs in comparison to standard						
Costs (euro/ha)	0	-244	-108	-39	368	368
Extra yield (euro/ha)	0	512	47	2662	2964	2681
Extra yield -extra costs	0	755	155	2700	2596	2313

Table 1: Economic results in different treatments (C0-C6).

4. Discussion and Conclusions

Because of late planting, caused by rainy weather in May the yield in the experiment at Særheim was low. The chitted seeds reached about the same level of yield as the non-chitted seeds of the same varieties in the Blight MOP experiment at the same location in 2001 and 2002.

Peik had significantly higher yield (total and marketable) than Troll in 2004. The same ranking between the varieties was seen at Særheim in 2002, but not in 2001. However there were no significant differences between the varieties in this respect in those two years.

Both Troll and Peik are intermediate susceptible varieties to foliage blight. Peik was somewhat more resistant than Troll, which is in accordance with the data from 2001 and 2002.

No other treatments than varieties Peik caused less foliar blight than CULBMS (Troll). Use of alternating rows of the two cultivars, chitting, sprays with OASE and total mixture of the varieties did not improve the late blight control. Chitting caused some increase in the foliage blight. Reduced resistance in more mature chitted plants might explain this. However, the positive effect of chitting was more important causing significantly increase in the marketable yield.

The percentage of diseased tubers was low in both varieties (3.5 % in Peik and 2 % in Troll), however the proportion diseased yield of Peik was statistically higher than Troll. There were no significant differences in percentage of tuber blight between the two varieties in 2001 and 2002 at Særheim (WP 2.1). Treatments with OASE caused some increase of the yield of diseased tubers. This might be explained by changes both in the tuber development and other indirect effect on the tuber blight infections.

In conclusion, the experiment at Særheim did not show positive effects of adding “new methods” for late blight control in addition to the classical use of resistant varieties and chitting to obtaining higher marketable yield in organic potato production. The economic analysis supports this conclusion.

Field evaluation of novel blight control systems in Norway 2004

B) LINK FARMS

1. Main message

The concept of site specific strategies for late blight management based on a combination of various components have resulted in a better yield and economic performance of the organic potato crop on the four Norwegian LINK farms. Since this result is the outcome of a systems approach, it is not possible to attribute this general positive result to one specific single factor valid for all farms. However, chitting appeared to be a crucial factor in Norwegian organic potato production.

2. Material and Methods

The LINK farms
The LINK farms are located in three different regions in Norway, all are mixed farms (arable and animal husbandry) but they differ in management structure. The farms in Stange (60"40'N 11"10'E) and Ottestad (60"45'N 10"15'E) are located in Hedmark county in central Norway: This area can be characterized as an area with a moderate risk for late blight. The Sande farm (59"40'N 10"20'E) is located at the western side in the Oslo estuary; an area with a moderate to high risk for late blight. The Vanse farm (58"10'N 6"30'E) is in the very south of the country (Vest-Agder county); an area with a relatively high risk for late blight and with a substantial production of early potato under plastic cover.

The choice of a new late blight strategy
On each of the farms the standard potato and late blight management strategy was discussed with the farmer, and possible changes with an expected reducing impact on late blight development were considered. From this discussion a new farm-specific late blight management strategy emerged.
The following new strategies were chosen:

- Ottestad farm: chitted seed in stead of non-chitted potato seed; use of seed produced in an almost late blight free region (viz. Finnmark in the very north of the country). Because of the high fertility of the soil, the farmer planned to reduce the fertilization slightly.
- Stange farm; The choice of a more resistant and somewhat earlier variety (”Beate” in stead of ”Pimpernel”); spraying of EM (effective microbes) (trade mark Terra Biosa) beside the usual silicate preparations.
- Sande farm: This farm had already chitting as a standard procedure in combination with an early bulking variety (“Sava”). In the new strategy a treatment with the plant strengthener OASE. This product contains plant extracts and some nutritional micro-elements. Copper is amongst them to a level of 27 mg Cu per litre undiluted product. Spraying with OASE took place July 30, and August 6 using 5 litres in 200 l water per ha (OASE All Round - 8N 6P 6K).
- Vanse farm: On this farm a “row-mix” of the varieties “Grom” and “Oleva” were chosen as the new strategy. Chitting was already a standard procedure.

Observations and assessments
In the fields with both the standard and new strategy the following assessments were made: growth stage, percentage area of the soil covered by leaves, development of late blight. The observations and assessments were made at seven locations, spread in a W-shaped pattern in the field. Tubers were harvested from a 6 m long row (4.5-4.8 m^2), incubated for about two weeks at about 12^oC for assessment of tuber blight. Total yield and marketable yield are calculated, as well as the tuber blight incidence. The assessments were made according the Blight-MOP handbook for WP7.2.

Economic impact of the new strategies

The economic impact of the new strategies was estimated through a calculation of the costs of labour, machinery and materials used in the potato production, and income from product sales. The costs of the different items are based on the generalized cost statements made by the Norwegian Agricultural Economics Research Institute, Handbook 2004/2005.

3. Results and discussion

Performance of the farm specific new strategies

In all cases the new strategy gave a higher marketable yield (Table 1). This better performance cannot simply be attributed to a better control of late blight because of the interactions with other factors. The remarkable difference between the LINK farms with regard to late blight development is primarily based on differences in variety choice and the risk for late blight in the region the farms are located. The slowest development was at the Stange farm in the region with a moderate risk for late blight in general. The most rapid development was observed in Sande and Vanse, farms in areas with a high risk for late blight. Nevertheless, the Vanse farm revealed a relatively high yield (large yield variation within the field). At this farm the early variety “Sava” was grown that probably escaped largely the yield reducing effect of late blight.

LINK farm	Stange		Ottestad		Sande		Vanse			
							Var. Grom		Var. Oleva	
Strategy	standard	new	standard	new	standard	new	Pure stand	Mixed stand	Pure stand	Mixed stand
stAUDPC[2)]	72	133 [1)]	374	371	1026	1011	491	402	209	314
Yield-total (tonnes/ha)	17,6	20,0	21,3	23,8	35,0	36,5	23,8	23,5	22,9	28,0
Yield - marketable (tonnes/ha)	12,7	16,4	17,9	21,4	29,8	35,1	17,3	17,4	17,6	24,2

Table 1. Potato Late Blight (stAUDPC) and yield performance on four Norwegian LINK farms comparing standard and new management strategies.

[1)] Late blight severity probably overestimated since symptoms were difficult to separate from cicads attack.

[2)] stAUDPC is only comparable within the same LINK farm because of different time series of observation on each LINK farm.

At the farm in Vanse row mixtures were included in the new strategy. It was found that variety Grom accelerated the epidemic in the more resistant variety Oleva, but this had no negative consequences for the yield of variety Oleva in the mixed stand. Oleva yielded even more, probably due to changed competition in the mixed stand. This indicates that the choice of the varieties in the mix may be crucial for the impact of this strategy. On the Ottestad farm the better performance was probably based on the earlier start of the vegetation period through the use of chitted seed. This was reflected by the soil cover measurements (data not presented in this report).

Economic impact of the new strategies

The economic results from potato production show large differences among the four LINK farms. These are in agreement to the general differences in performance of the different agricultural regions in Norway.

The best results were obtained on the Sande farm in the Vestfold county. The central region with usually a late start of the growing season had the most modest economic performance. However on all the farms the new strategy showed a better economic result (Table 2)

LINK farm	Stange		Ottestad		Sande		Vanse	
Strategy	standard	new	standard	new	standard	new	standard	new
Yield –costs (euro/ha)	3086	4880	6232	8135	12579	15718	5088	6910
Extra costs (euro/ha)	0	372	0	402	0	93	0	7
Yield (euro/ha)	0	2166	0	2305	0	3232	0	1829
Extra yield – extra costs (euro/ha)	0	1794	0	1903	0	3139	0	1822

Table 2. The economic performance of organic potato on the LINK farms

4. Conclusions

The major conclusion that can be drawn this on-farm investigation, is that there is a considerable potential for improving the performance organic potato production under Norwegian conditions. The experience from this Blight-MOP workpackage is that it is not only late blight that is a main determinant for a successful organic potato production, but the importance of factors like variety choice, the various agronomic measures should be considered as well. The study also underlines that good and successful farm- and crop- management has important site-specific elements which may be crucial for the overall results.

Field evaluation of novel blight control systems in the Netherlands 2004

LBI - Louis Bolk Institue NL

Introduction

In work packages 2.1 – 6.2 of the Blight-MOP-project all possible aspects of organic potato production were assessed with respect to their possibilities to contribute to a better control of late blight and to obtain better (economic) results of the potato crop for organic farmers . Individual measurements often have only a limited effect. The combination of individual measurements, however, into combined, site specific, strategies might have larger effects, because of the additive value of the different components of that strategy to each other.

Materials and methods

On five organic farms, in a discussion with the farmer, an optimized potato production strategy was designed. The strategy was site- and farm-specific, and the farmer was the person to decide whether a given component was suitable for his farm, or not. Details of the standard and optimized strategies are summarized in table 1.
On the MODEL farm, the optimized strategy was tested step-wise: to the standard strategy (C0) the first component was added (C1), and then the second (C2), and so on until C5. C5 consisted of C0 plus all new components (see table 2). Each strategy was tested in 4 replications.
On the 4 LINK farms the standard and optimized strategy were compared on a whole field basis, without replications.

Table 1. Standard and optimized potato growing strategies on 1 MODEL farm and on 4 LINK farms in the Netherlands in 2004.

	Standard	Optimized
MODEL-farm	Variety Remarka, no chitting, plant distance 22 cm, fertilization with 2,5 t/ha Vinasse before planting	extra fertilization with feather meal before ridging, application of compost before planting, chitting, plant distance 28 cm, application of plant strengthener
LINK-farm 1	Variety Agria, pre-crop grass-clover, fertilization 15 t/ha cattle slurry	Pre-crop maize (better soil structure), fertilization 25 t/ha cattle slurry
LINK-farm 2	Variety Nicola, pre-crop maize with rye green manure, fertilization 30 t/ha solid goat manure	Pre-crop barley with rye green manure (better soil structure), fertilization 60 t/ha compost (instead of manure)
LINK-farm 3	Variety Agria, pre-crop wheat with clover green manure, fertilization 25 t/ha cattle slurry plus Vinasse	Two strips with red clover, Phacelia and mustard as intercrop
LINK-farm 4	Variety Ditta, pre-crop cabbage, fertilization 20 t/ha deep litter manure	Variety Santé, pre-crop shallots, fertilization 20 t/ha deep litter manure plus 1500 kg/ha Vinasse

Table 2. Step-wise testing of an optimized strategy on the MODEL farm.

C0	C2	C2	C3	C4	C5
Variety Remarka, no chitting, plant distance 22 cm, fertilization with 2,5 t/ha Vinasse before planting	C0 plus feather meal	C0 plus feather meal plus compost	C0 plus feather meal plus compost plus chitting	C0 plus feather meal plus compost plus chitting plus larger plant distance	C0 plus feather meal plus compost plus chitting plus larger plant distance plus plant strengthener

Results

On the MODEL-farm the chitted potatoes were slightly ahead of the non-chitted potatoes with respect to early development and soil cover. Later in the growing season these differences disappeared. The first infection by late blight was detected on 13 July. The epidemic developed very fast, and on 23 July the potatoes were defoliated at an average infection level of 20 – 25 %. The different strategies did not result in differences in late-blight-infection.
Yield differences, however, did show up (see table 3). All potatoes treated with compost gave a higher brut yield, but only for C3, C4 and C5 yields were statistically different to C0. There were no differences in tuber quality (scab, Rhizoctonia, dry matter contents) between treatments.

Table 3. Yields for the different strategies on the MODEL farm.

	C0	C1	C2	C3	C4	C5	Different to C0 (p=5%)
Brut yield(t/ha)	33.00	30.67	35.01	36.86	38.58	36.63	C3, C4, C5
Yield 40-65 mm (t/ha)	26.59	25.47	29.86	29.31	30.45	31.19	***C4, C5***
Yield >65 mm (t/ha)	4.00	2.43	2.19	4.80	5.57	2.96	**--**

The different strategies were also evaluated economically. The extra cost (work, equipment, material costs) of the new components were determined, and compared to the extra yield (see table 4). For C1 and C2, the extra costs for the new strategy are higher than the extra yields. For C3 the extra costs match the extra yield, and only for C4 and C5 the total strategy gives an economically positive effect.

Table 4. Economic evaluation of the tested strategies on the MODEL farm.

Strategy		**C0**	**C1**	**C2**	**C3**	**C4**	**C5**
costs (euro/ha)		**3999**	**4127**	**4267**	**4337**	**4034**	**4119**
Yield40-65 mm (ton/ha)		**22,94**	**23,50**	**24,72**	**24,05**	**25,46**	**24,27**
Yield >65 mm (ton/ha)		**3,59**	**2,23**	**1,96**	**5,00**	**5,17**	**3,46**
Yield (euro/ha)	**40-65: 0,20 euro/kg**	**4589**	**4699**	**4945**	**4810**	**5092**	**4853**
	>65: 0,10 euro/kg	**359**	**223**	**196**	**500**	**517**	**346**
YIELD (euro/ha)		**4948**	**4922**	**5141**	**5310**	**5608**	**5199**
yield - costs		**949**	**796**	**874**	**973**	**1574**	**1080**
Extra t.o.v. standard							
Costs (euro/ha)		**0**	**128**	**268**	**338**	**35**	**120**
Yield 40-65 mm (ton/ha)		**0**	**0,6**	**1,8**	**1,1**	**2,5**	**1,3**
YIELD (euro/ha)		**0**	**-26**	**193**	**362**	**660**	**251**
Extra yield - extra costs (euro/ha)		**0**	**-153**	**-75**	**24**	**625**	**131**

On LINK-farm 1 the optimized strategy gave plants that were slightly ahead in development when compared to the standard strategy. The first late blight infection was detected on 16 july. The epidemic developed very fast, and both crops were defoliated on 23 july, at an average infection level of 55%. The different strategies did not result in differences in late-blight-infection.

Yield differences were small , but the optimized strategy gave a slightly higher yield than the standard strategy (see table 5). There were no differences in tuber quality (scab, Rhizoctonia, dry matter contents) between the standard and the optimized strategy.
Both strategies were evaluated economically. The extra costs (work, equipment, material costs) of the optimized strategy were determined, and compared to the extra yield (see table 5). The optimized
strategy gave an extra yield of €1131,=/ha when compared to the standard strategy.

On LINK-farm 2 the optimized strategy gave plants that were behind in development when compared to the standard strategy. In the optimized strategy the compost was given instead of the basic fertilization, whereas it was intended to give the compost in addition. As a result the potatoes on the optimized plot suffered from a lack of nutrients. The first late blight infection was detected on 23 July. The epidemic developed fast, and both crops were defoliated on 29 July. At this moment the standard crop had an infection level of 25%, whereas the optimized crop was hardly infected. But this crop was not growing any more.
Yields are shown in table 5. The optimized crop gave a very low yield, only 8,5 t/ha. The optimized crop showed more Rhizoctonia and scab when compared to the standard crop.
Both strategies were evaluated economically. The extra costs (work, equipment, material costs) of the optimized strategy were determined, and compared to the yield (see table 5). Because of the lower yield, the optimized strategy had a negative economic result of minus €2873/ha.

Table 5. Yields and costs for standard and optimized potato growing strategies on 4 LINK farms in 2004.

		Strategy	
LINK-farm 1		**standard**	**optimal**
Costs (euro/ha)		**3782**	**3794**
Yield 0-40 mm (t/ha)		**2,09**	**1,52**
Yield 40-65 mm (t/ha)		**20,54**	**24,91**
Yield 0-40 (euro/ha)	Price 0,12 euro/kg	626,79	456,56
Yield40-65 (euro/ha)	Price: 0,30 euro/kg	6160,52	7473,47
Yield (euro/ha)		6787,31	7930,03
Yield – costs (euro/ha)		**3005**	**4136**
	Extra, compared to standard		
Costs (euro/ha)		0	12
Yield 0-40 mm (t/ha)		0	-1
Yield 40-65 mm (t/ha)		0	4
Yield 0-40 (euro/ha)		0	-170
Yield40-65 (euro/ha)		0	1313
Yield (euro/ha)		0	1143
Extra yield -extra costs		0	1131
LINK-farm 2		standard	optimal
Costs (euro/ha)		**3762**	**3858**
Harvest 40-65 up (ton/ha)		**17,89**	**8,63**
Yield (euro/ha)	Price: 0,30 euro/kg	5366,26	2589,41
Yield – costs (euro/ha)		**1605**	**-1268**
	Extra, compared to standard		
Costs (euro/ha)		0	96
Yield40-65 mm (ton/ha)		0	-9,25
Yield (euro/ha)		0	-2777

Extra yield - extra costs (euro/ha)		0	-2873

LINK-farm 3		standard	optimal
Costs (euro/ha)		4145	3527
Harvest 40-65 up (ton/ha)		**24,75**	**17,94**
Yield (euro/ha)	Price: 0,30 euro/kg	7425	5382
Yield – costs (euro/ha)		**3280**	**1855**
	Extra, compared to standard		
Costs (euro/ha)		0	-618
Yield40-65 mm (ton/ha)		0	-6,81
Yield (euro/ha)		0	-2043
Extra yield - extra costs (euro/ha)		0	-1425

LINK-farm 4		standard	optimal
Costs (euro/ha)		**4162**	**4288**
Harvest 40-65 up (ton/ha)		**19,49**	**32,67**
Yield (euro/ha)	Price: 0,30 euro/kg	5846,13	9800,16
Yield – costs (euro/ha)		**1684**	**5512**
	Extra, compared to standard		
Costs (euro/ha)		0	126
Yield40-65 mm (ton/ha)		0	13,18
Yield (euro/ha)		0	3954
Extra yield - extra costs (euro/ha)		0	3828

On LINK-farm 3 the development of the standard crop was the same as for the optimized crop. The first late blight infection was detected on 15 July. The potatoes were defoliated on 22 July, at an average infection level of 2%. The strips effectively isolated the infection from other parts of the field: an infection spot outside the strips did only after a couple of days spread to the potatoes between the strips, and an infection spot between the strips did not directly spread to the rest of the field.
Yields were comparable for the standard and the optimized strategy when calculated per hectare potatoes: 25 t/ha. But because the strips held 25 % of the surface of the field, the yield in the optimized part was 25 % lower. There were no differences in tuber quality (scab, Rhizoctonia, dry matter contents) between the standard and the optimized strategy.
Both strategies were evaluated economically. The extra costs (work, equipment, material costs) of the optimized strategy were determined, and compared to the yield (see table 5). Because of the 25% lower potato yield, the optimized strategy had a negative economic result of minus €1425/ha.

On LINK-farm 4 the first late blight infection was detected on 15 july. The epidemic developed fast, and both crops were defoliated on 22 july, at an average infection level of 4 – 5 %. The different strategies did not result in differences in late-blight-infection.
Yield differences, however, did show up (see table 5). The optimized crop yielded 32 t/ha in the marketable size, compared to 19 t/ha for the standard crop. The standard crop had a higher infection by Rhizoctonia.
Both strategies were evaluated economically. The extra costs (work, equipment, material costs) of the optimized strategy were determined, and compared to the extra yield (see table 5). The optimized crop resulted in an extra yield of €3823/ha.

Discussion

On three organic potato growing farms in the Netherlands the results of a farm- and site specific optimized potato growing system were better than those of the standard system on the same farm, both in terms of tonnes/hectare and in terms of euros/hectare.
On one farm with strips of an intercrop (LINK farm 3), the late-blight-infection could be effectively isolated between strips. The whole field was defoliated at the same moment, resulting in a lower yield per hectare for the optimized system because the strips held 25% of the surface. When the crop would be defoliated strip-wise, the full potential of the system, resulting in longer a growing period for parts of the field, could show up.
Only on one farm (LINK farm 2) the result was negative, but in this case the 'optimized' strategy suffered from a lack of nitrogen because of a wrong fertilization.

The results demonstrate that it is possible to identify agronomic measurements that can contribute to a better result of the potato crop, even for the very skilled Dutch organic potato growers who have already developed already very optimal potato growing systems.
The results on the MODEL farm demonstrate that where individual measurements have only a small effect, the combination may give a much better result.

Information

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Summary data descriptions and detailed results of statistical analyses can be obtained with m. Hospers

Field evaluation of novel blight control systems in France 2004

GRAB - Group de Recherche en Agriculture Biologique, F

A table containing the results of the statistical analysis for the different observations is given at the end of this document.

1- Model Farm :

Location : Western France (Suscinio – Brittany)
Climate : oceanic
Plantation : 8th April & 12th May
Harvest : 15th September

11- protocole :

split-plots design with 4 repetitions

main plots :

C0	CULBMS
C1	CULBMS+cs1
C2	CULBMS+cs1+cs2
C3	CULMBS+cs1+cs2+cs3
C4	CULMBS+cs1+cs2+cs3+cs4
C5	CULMBS+cs1+cs2+cs3+cs4+cs5

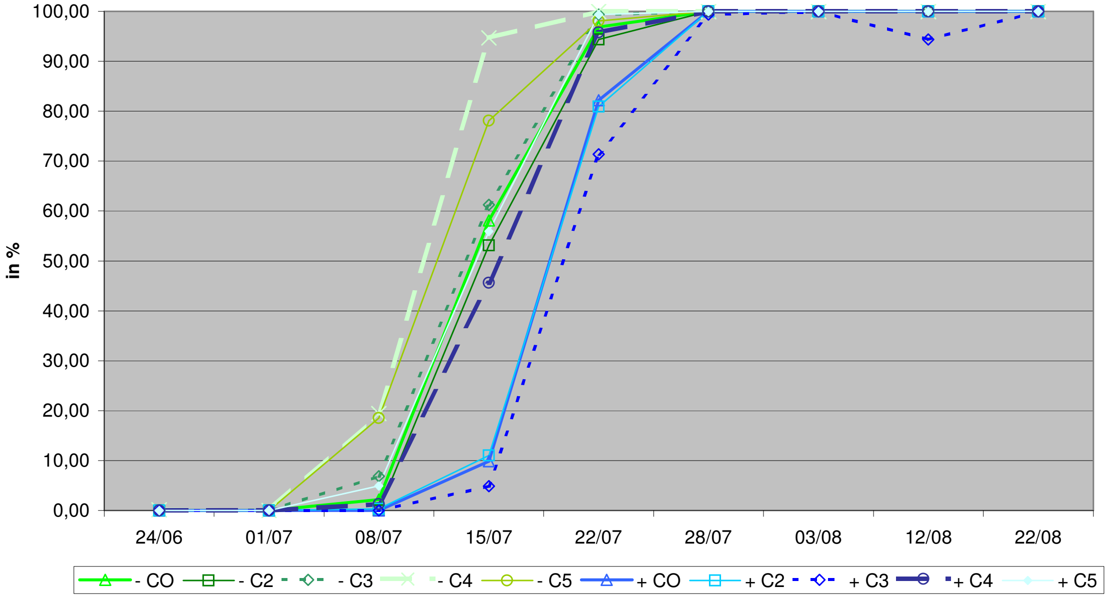
CULBMS : pure stand : Charlotte
cs1 : resistant variety : Eden
cs2 : alternating rows (2x2)
cs3 : presprouting
cs4 : early plantation
cs5 : alternative treatment (Mycosin 0,9 kg/ha)

sub-plots :
with or without copper treatments (total copper dose : 1,2 kg/ha in 6 treatments)

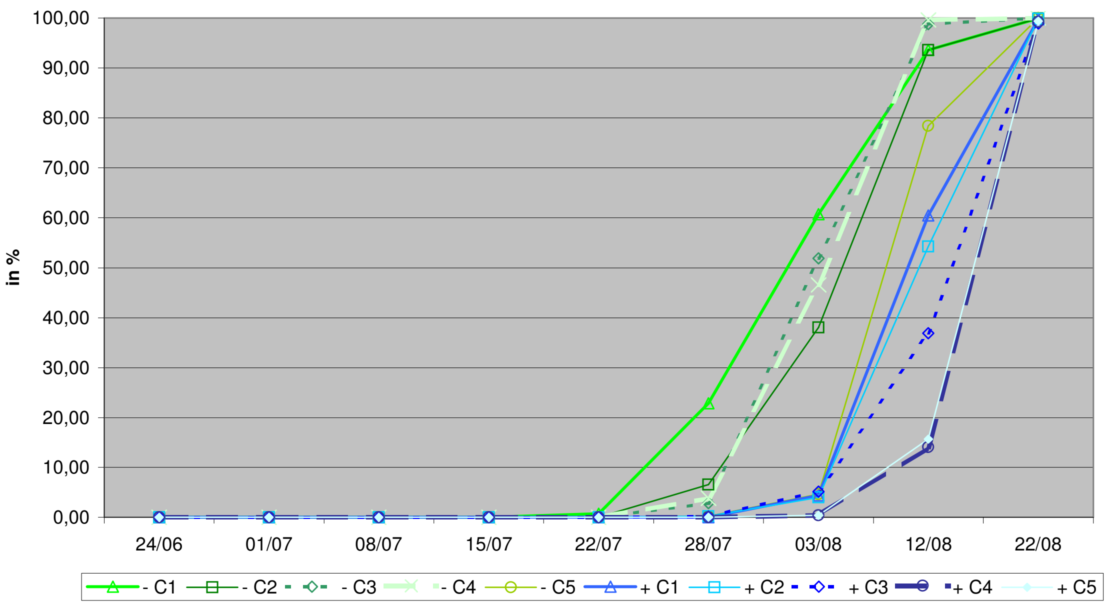
12- Results :

121- Foliar late blight

Model farm (Brittany - Suscinio) : evolution of average severity in % of foliar surface diseased by late blight - variety Charlotte



Model farm (Brittany - Suscinio) : evolution of average severity in % of foliar surface diseased by late blight - variety Eden

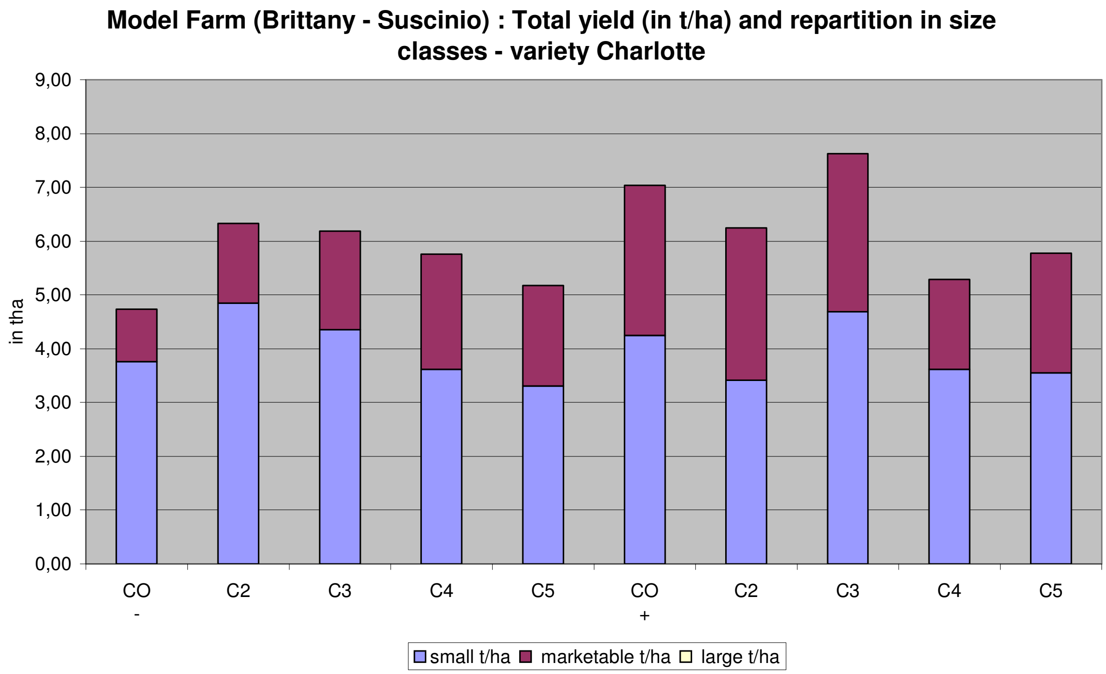


Calculation of St AUDPC

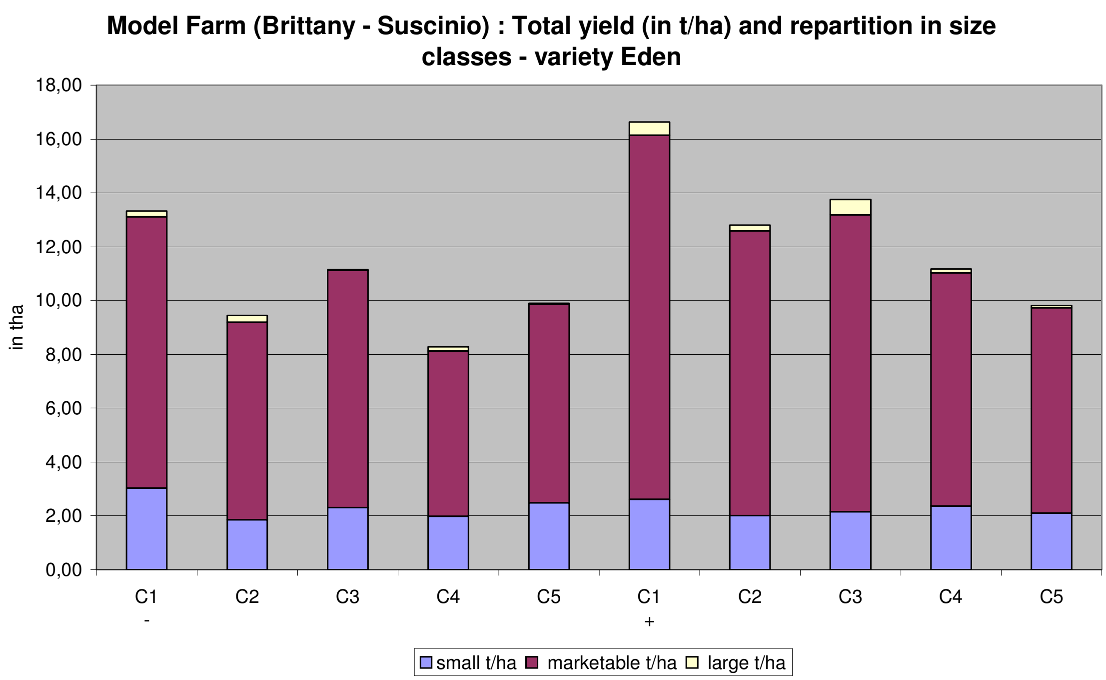
variety	copper	C0	C1	C2	C3	C4	C5
Charlotte	-	65,29		64,16	66,49	72,03	69,74
	+	57,69		57,72	54,93	63,58	65,63
Eden	-		33,66	29,04	31,27	30,83	21,70
	+		18,75	17,73	15,01	10,73	11,01

As expected, Charlotte is more susceptible to foliar blight than Eden.
Copper treatments reduce AUDPC for both Charlotte and Eden, more for Eden than for Charlotte. Late blight outbreak was huge this year : foliage for Eden was completely destroyed despite its supposed resistance to late blight.
For Charlotte and Eden, added CS to CULBMS have no major effects on AUDPC. C2 (alternating rows) has no effect on AUDPC). C5 (treatment with Mycosin) have led to a light reduction of AUDPC.

122- Total yield and tuber grading :

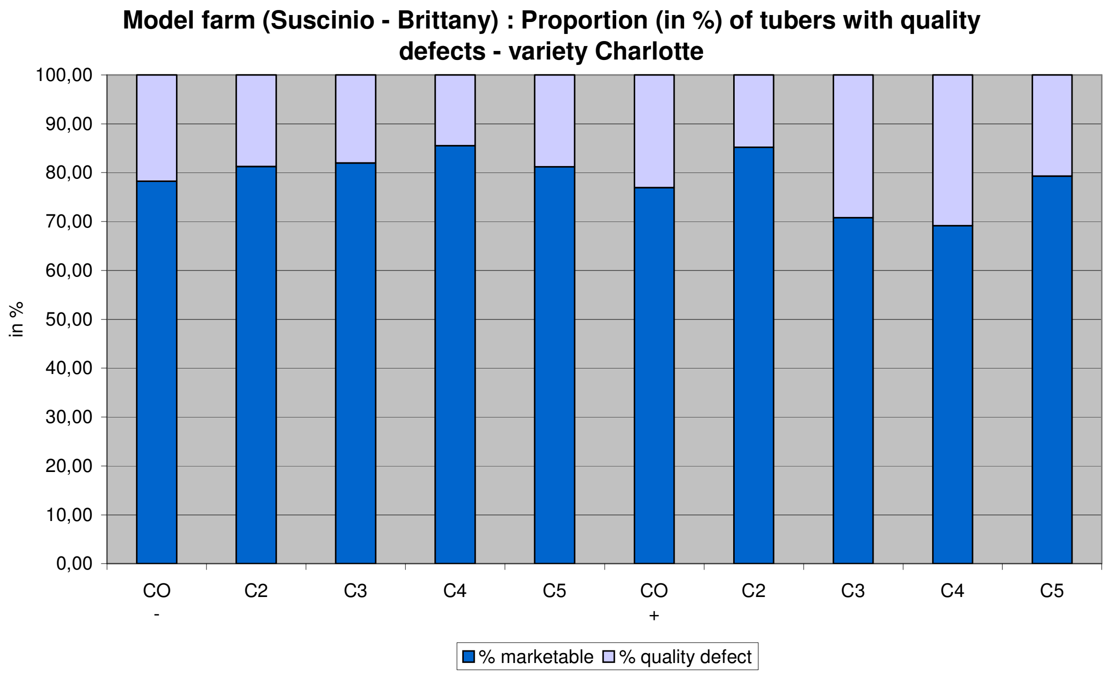


Total yields are very low. Proportion of small tubers is very high.
Total yield with copper treatments is not different from without any copper treatment.
Without any copper treatment, for Charlotte, alternating rows with a resistant variety has led to a total yield increase. Other added CS have no effect. With copper treatments, there is no difference between the modalities

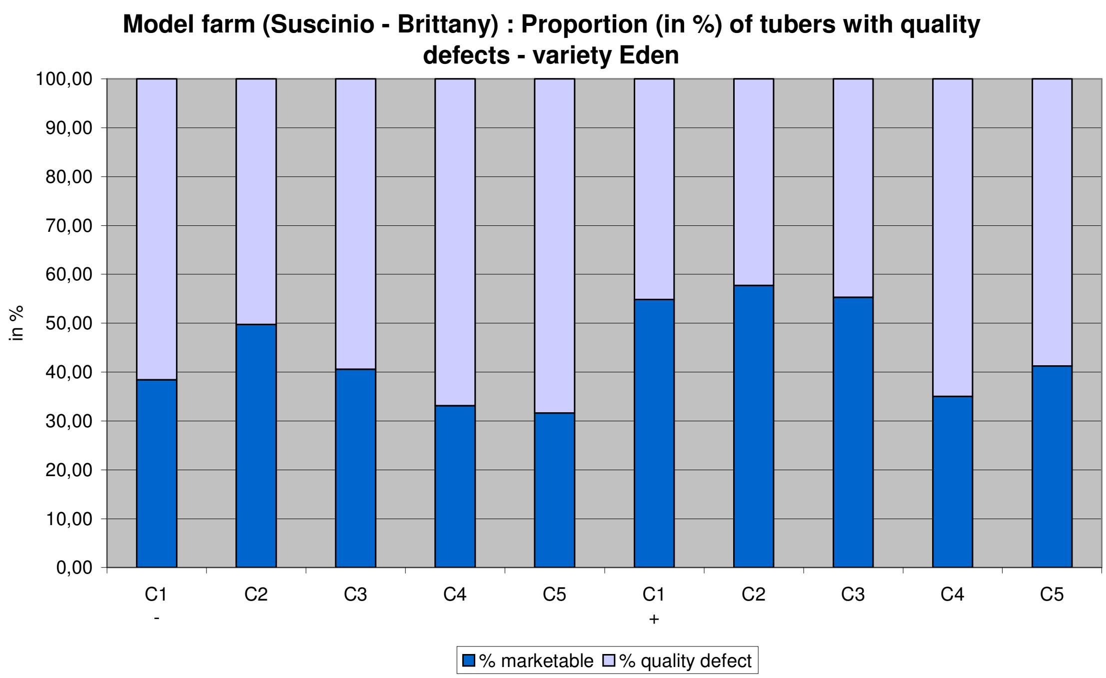


Total yields are very low. Proportion of small tubers is very low compared to Charlotte.
Total yield with copper treatments is higher than without any copper treatment.
Without any copper treatment, for Eden, alternating rows with a susceptible variety has led to a total yield decrease. Other added CS have no effect. With copper treatments, alternating rows with a susceptible variety has led to a total yield decrease. Added CS have no effect.

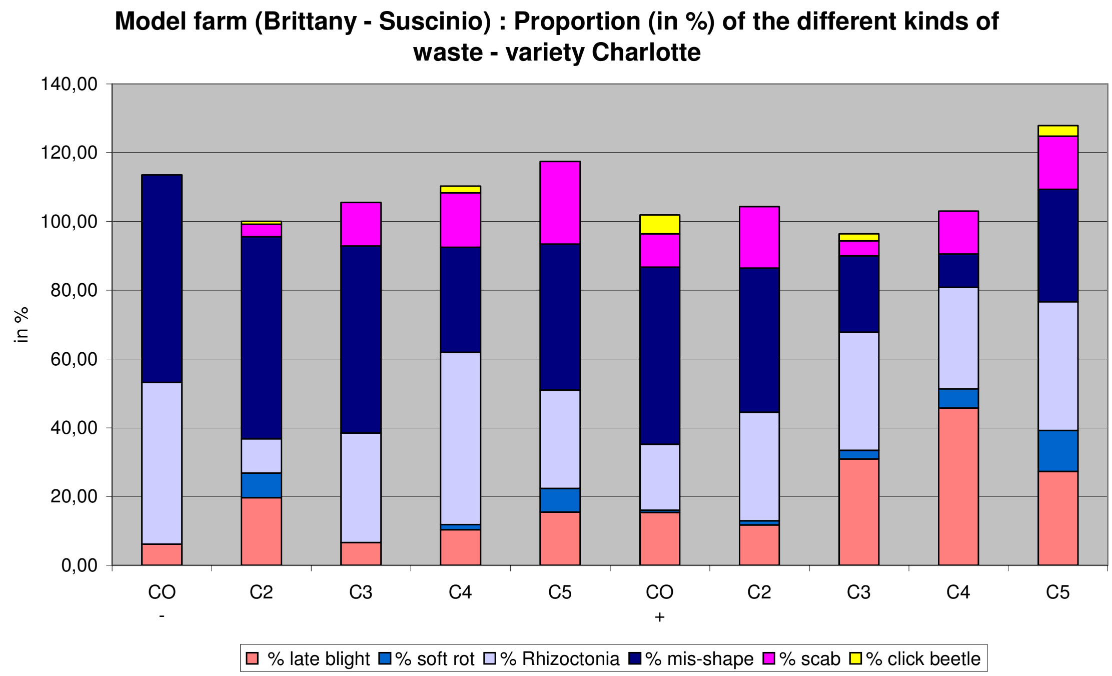
123- Proportion of waste and kind of waste



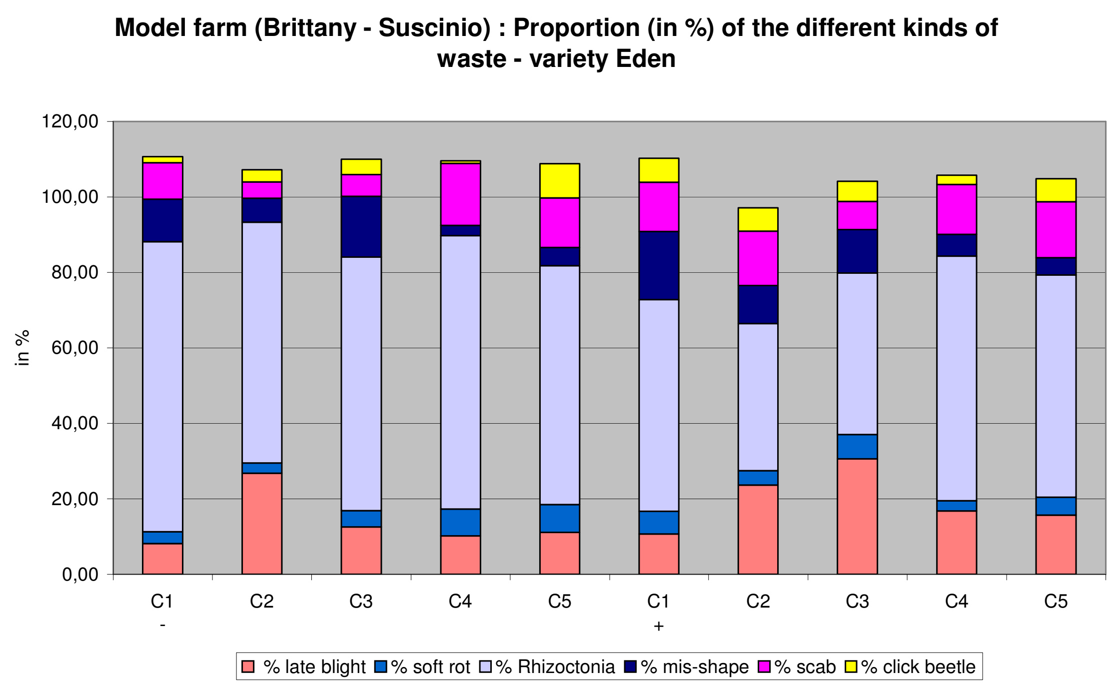
Proportion of discarded tubers for Charlotte is homogenous for all modalities



For Eden, proportion of discarded tubers is very high. Copper treatments have reduced the incidence of tubers with quality defects. Added CS have no effect on proportion of discarded tubers.

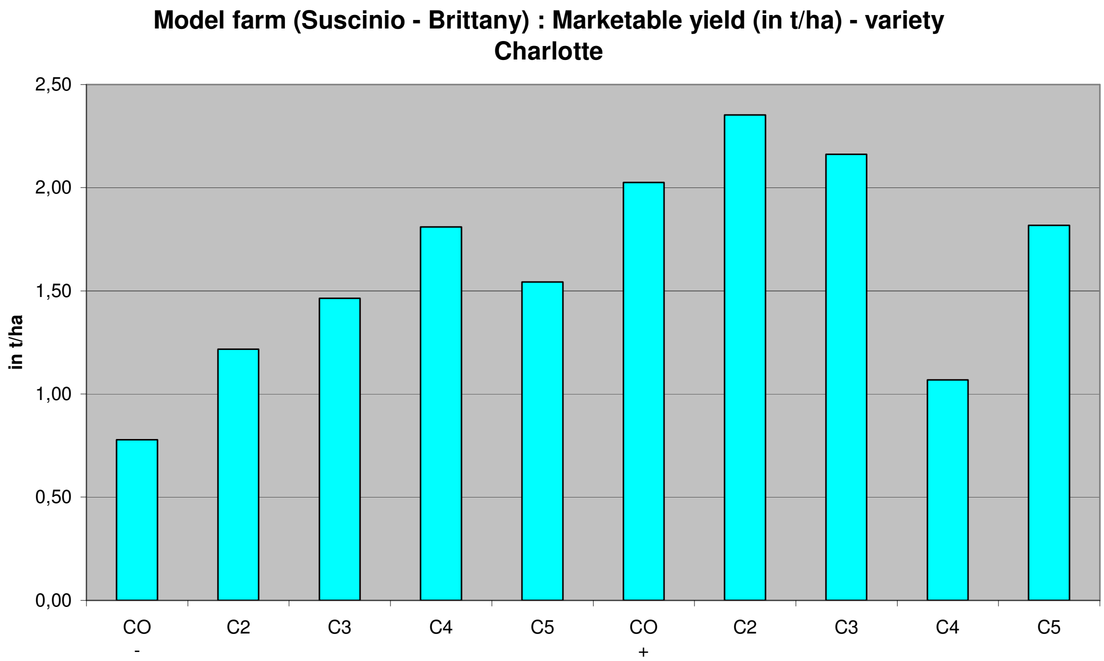


For Charlotte, there is no clear difference between modalities, concerning the proportion of the type of waste. Proportion of discarded tubers because of bacterial or fungal affection is not reduced by copper treatment on foliage.

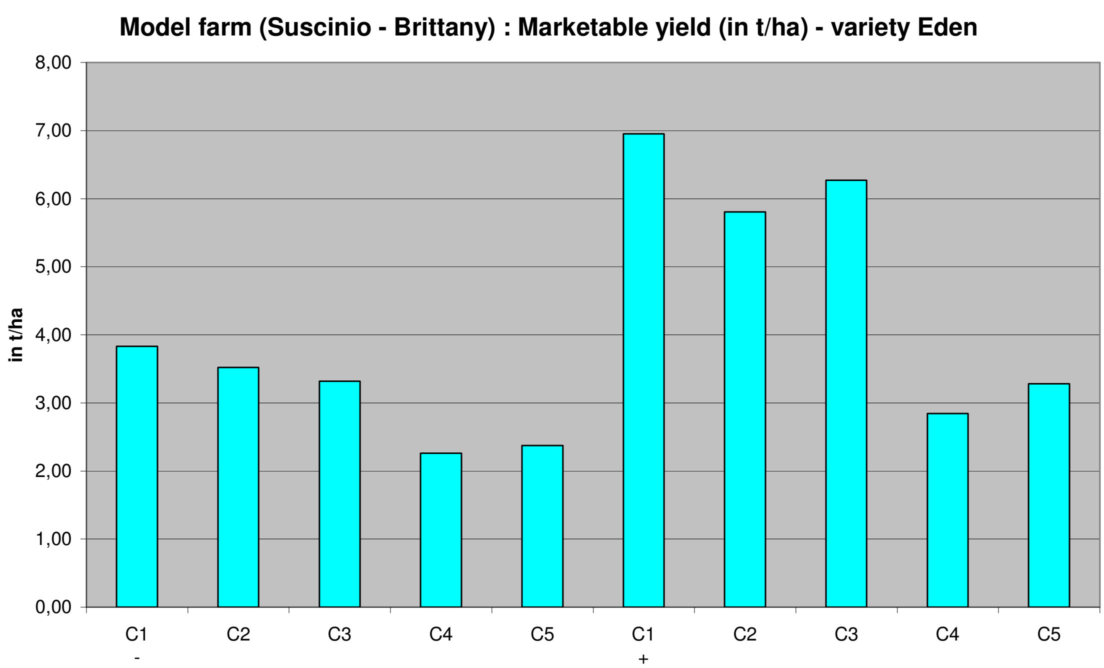


Eden is very susceptible to Rhizoctonia. There is no difference between the different modalities.

124- marketable yield



For Charlotte, the marketable yield is very low. With copper treatments, marketable yield for C0 (pure stand) is 3 times as much as without copper treatment.
Without copper treatment, marketable yield increases with the added CS. C5 (treatment with Mycosin has no positive effect on marketable yield.
With copper treatments, alternating rows allows a light increase of commercial yield. Added CS have no clear effect.



For Eden, copper treatments have allowed an increase of marketable yield for C1, C2, C3. For C4 and C5, copper treatments have no effect.
Added CS have no impact on commercial yields, neither with copper treatments nor without.

2- Link Farm 1 :

Location : Taulé (Brittany – Western France)
Climate : oceanic
Plantation : 3rd May
Harvest : 1st September 2004

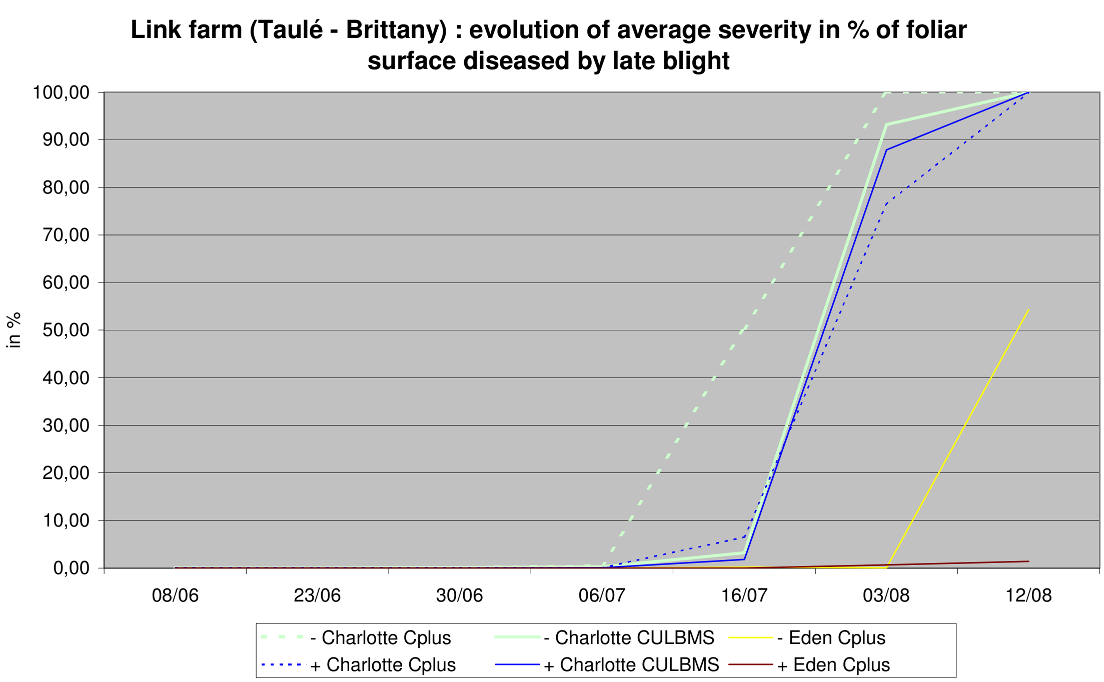
21- protocole :

	CULBMS	Cplus
Copper -	Pure stand : Charlotte No treatment	alternating rows : Charlotte, Eden (4x4) no treatment
Copper +	Pure stand : Charlotte Copper treatment (total copper dose : 4 kg/ha)	alternating rows : Charlotte, Eden (4x4) Copper treatment (total copper dose : 4 kg/ha)

products	Bordeaux mixture and Kocide
copper compound	copper sulfate and copper hydroxyde
doses	5 kg/ha and 3 kg/ha
dates	2 with Bordeaux mixture and 2 with Kocide

22- Results :

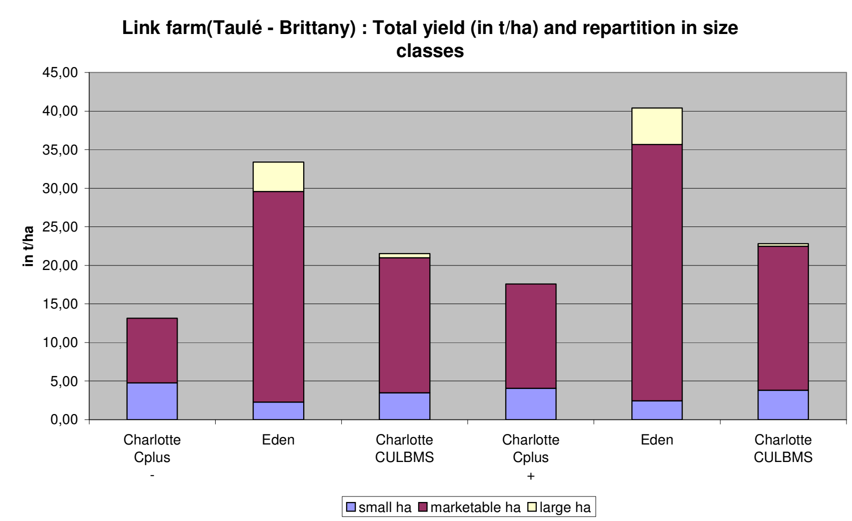
221 : Foliar late blight :



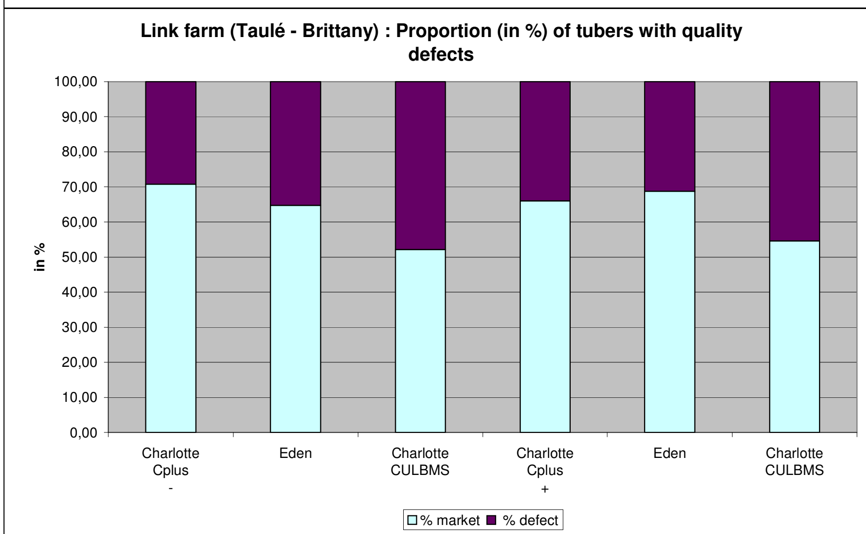
Calculation of St AUDPC

copper	variety	treatment	AUDPC
-	**Charlotte**	**Cplus**	38,60
		CULBMS	27,02
	Eden	**Cplus**	3,79
+	**Charlotte**	**Cplus**	24,20
		CULBMS	25,57
	Eden	**Cplus**	0,24

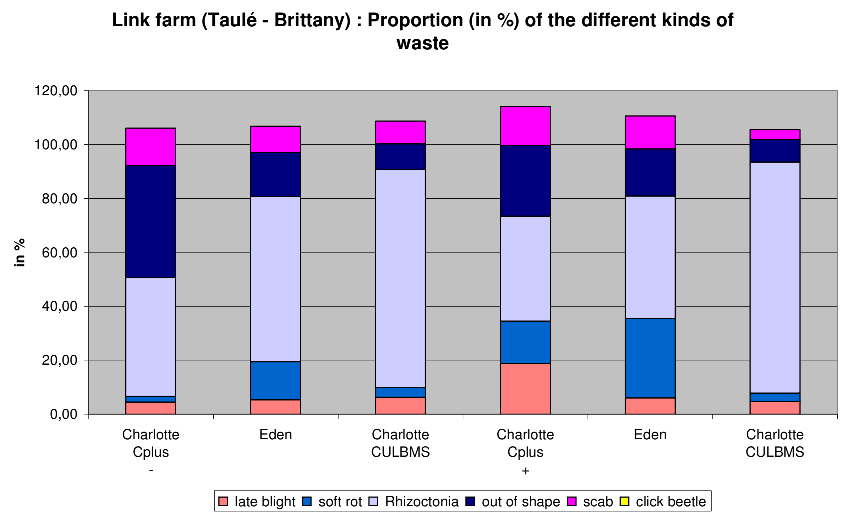
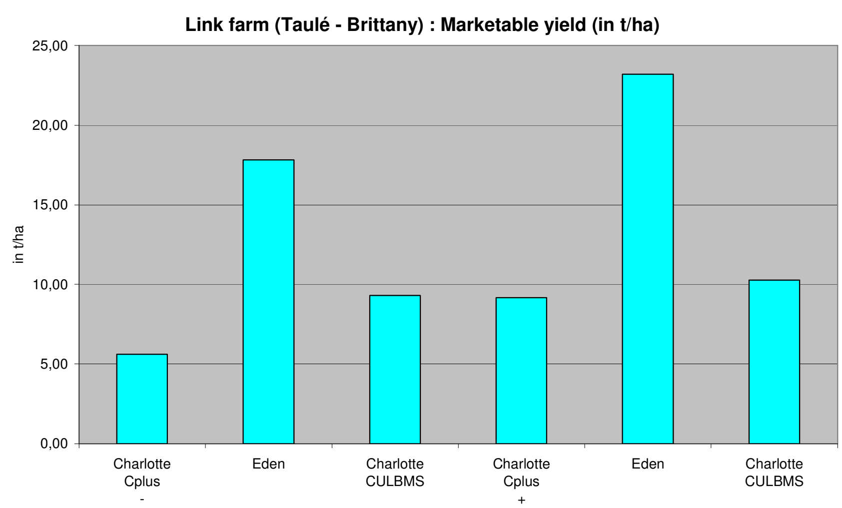
Concerning Charlotte, reduction of AUDPC by copper treatments is higher for Cplus than for CULBMS.
Cplus does not lead to a lower AUDPC.
Eden is less susceptible than Charlotte.



Copper treatments have led to an increase of total yield, for all treatments.
For Charlotte, Cplus has no effect on yield of tubers of marketable size.
Total yield and yield of tubers of marketable size is higher for Eden.



Copper treatments have no effect on proportion of waste.
For Charlotte, Cplus leads to an increased proportion of waste.

	Copper treatments seem to reduce incidence of Rhizoctonia. For Charlotte, Cplus reduces incidence of Rhizoctonia but increase proportion of mis-shapen tubers. Eden is more susceptible to soft rot than Charlotte.
	Copper treatments have no effect on commercial yield of Charlotte in pure stand. Copper treatments show effects on commercial yield of Eden and Charlotte in alternating rows.

3- Link Farm 2 :

Location : Lanvellec (Brittany – Western France)
Climate : oceanic
Plantation : 8th April
Harvest : 1st October 2004

31- Protocole :

	CULBMS	Cplus
Copper -	Pure stand : Charlotte No treatment	alternating rows : Charlotte, Eden (4x4) Mycosin treatment
Copper +	Pure stand : Charlotte Copper treatment (total copper dose : 2 kg/ha)	alternating rows : Charlotte, Eden (4x4) Copper treatment (total copper dose : 2 kg/ha)

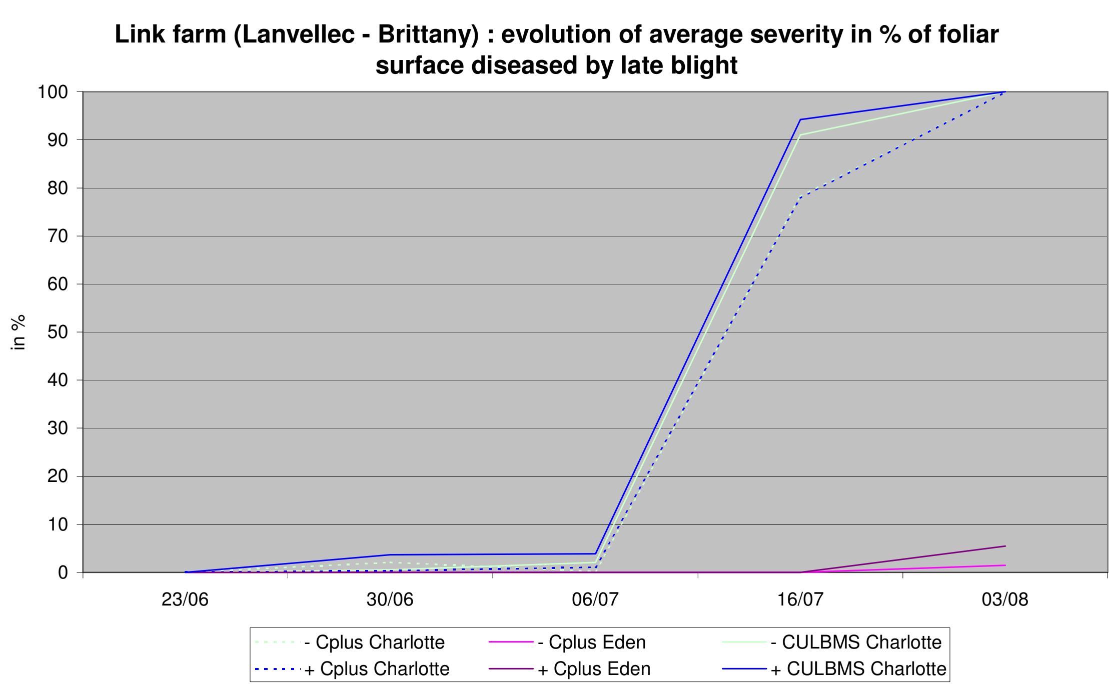
copper - : **no copper treatment but treatment with Mycosin**

product	Mycosin (Andermatt)
copper compound	Mineral clay + equisetum extracts
doses	0,9 kg /ha
dates	2 treatments

copper + : **copper treatment**

product	Bordeaux mixture
copper compound	copper sulfate
doses	5 kg/ha
dates	2 treatments

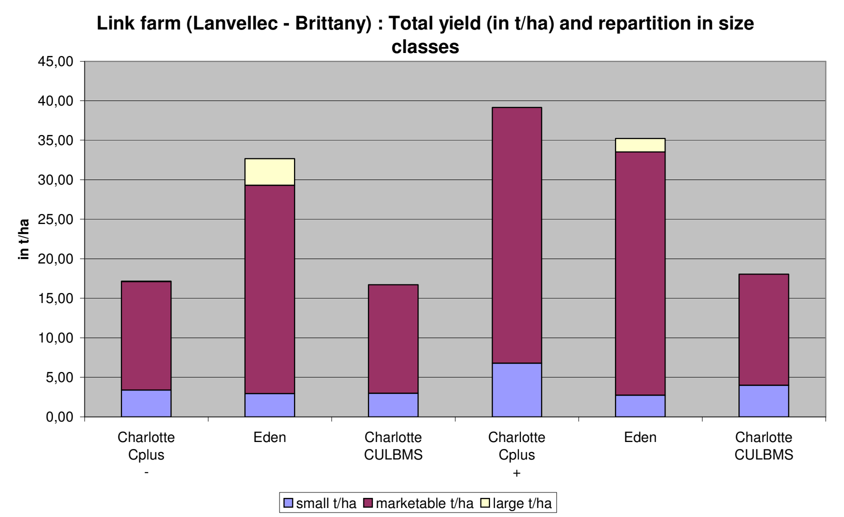
32- Results :



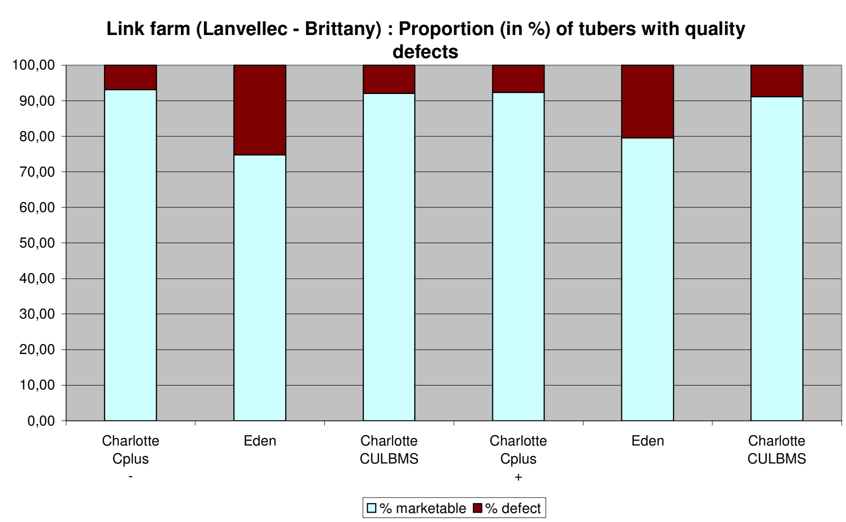
Calculation of st AUDPC

copper	treatment	variety	AUDPC
-	**Cplus**	**Charlotte**	49,03
		Eden	0,32
	CULBMS	**Charlotte**	53,52
+	**Cplus**	**Charlotte**	48,79
		Eden	1,20
	CULBMS	**Charlotte**	55,46

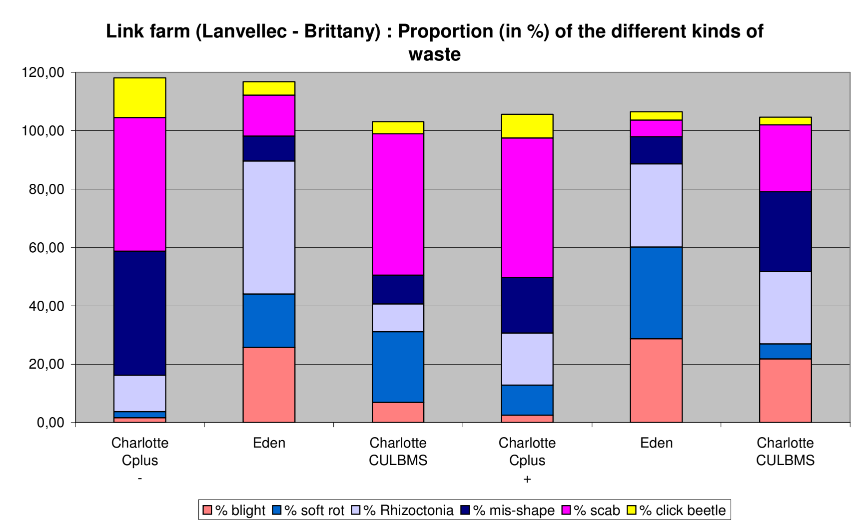
Copper treatments reduce foliar blight.
Cplus reduces lightly foliar blight.
Eden is less much susceptible to foliar blight than Charlotte.



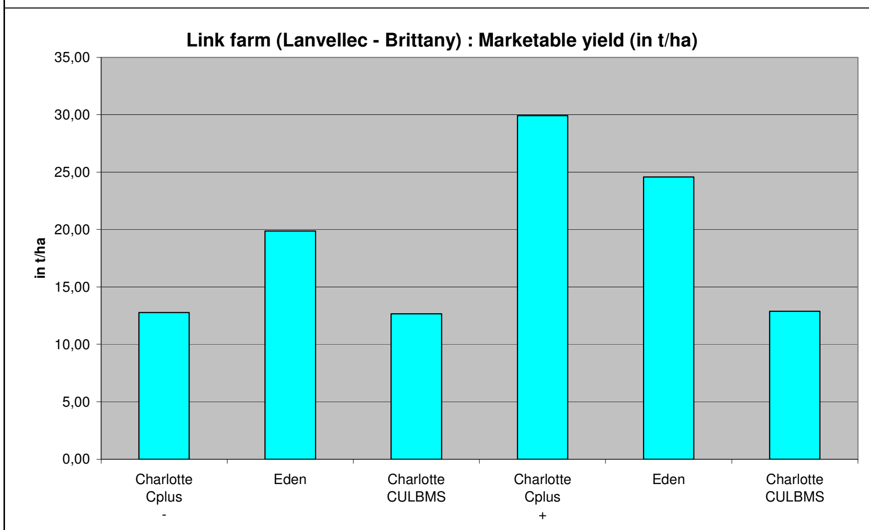
Copper treatments have an important effect on total yield and yield from tubers of marketable size, for Charlotte Cplus. Copper treatments have no effect for Eden and Charlotte CULBMS.
For Charlotte, Cplus leads to a increased total yield and yield from tubers of marketable size, when copper is applied. Without copper applied, no effect is observed.
Without copper, total yield in Cplus for Eden is much higher than for Charlotte. With copper, total yield for Cplus are equivalent for both varieties.



Proportion of discarded tubers is low.
Copper and Cplus have no effect on proportion of waste.
Eden presents a higher proportion of waste.



Copper treatments have no clear effect on proportion of different kinds of waste. Copper does not seem to reduce incidence of diseases on tubers such as late blight, Rhizoctonia, soft rot... Eden seems to be more susceptible to tuber blight than Charlotte.



Copper treatments have an important effect on commercial yield, for Charlotte C plus and Eden. Copper treatments have no effect Charlotte CULBMS.

For Charlotte, Cplus leads to a increased commercial yield, when copper is applied. Without copper applied, no effect is observed.

Without copper, commercial yield in Cplus for Eden is higher than for Charlotte.

4- Link Farm 3 :

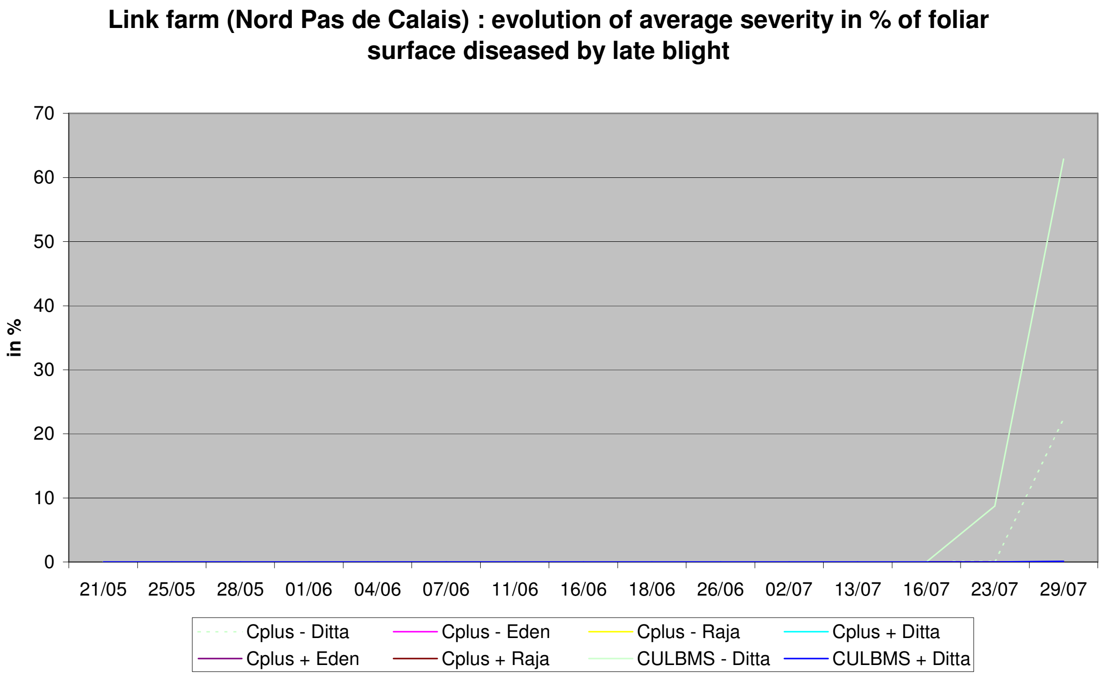
Location : Northern France (Nord Pas de Calais)
Climate : oceanic
Plantation : 23rd April 2004
Harvest : 27 August 2004

41- protocole :

	CULBMS	Cplus
Copper -	Pure stand : Ditta no treatment	alternating rows : Raja, Ditta, Eden (4x4) treatment with Mycosin
Copper +	Pure stand : Ditta copper treatments (total copper dose : 2,6 kg/ha)	alternating rows : Raja, Ditta, Eden (4x4) reduced copper treatments (total copper dose : 2 kg/ha)

	Cplus copper +	Cplus copper -	CULBMS copper +
07/06	Bordeaux mixture 2kg/ha + copper hydroxyde 1 kg/ha	Mycosin 8 kg/ha	Bordeaux mixture 2kg/ha + copper hydroxyde 1 kg/ha
18/06	Bordeaux mixture 2kg/ha	Mycosin 8 kg/ha	Bordeaux mixture 2kg/ha
05/07			Bordeaux mixture 2kg/ha + copper hydroxyde 1 kg/ha
06/07		Mycosin 8 kg/ha	
11/07	Bordeaux mixture 2kg/ha		Bordeaux mixture 2kg/ha
13/07		Mycosin 8 kg/ha	
24/07	Bordeaux mixture 2kg/ha		Bordeaux mixture 2kg/ha
26/07		Mycosin 8 kg/ha	
02/08	defoliation	defoliation	defoliation

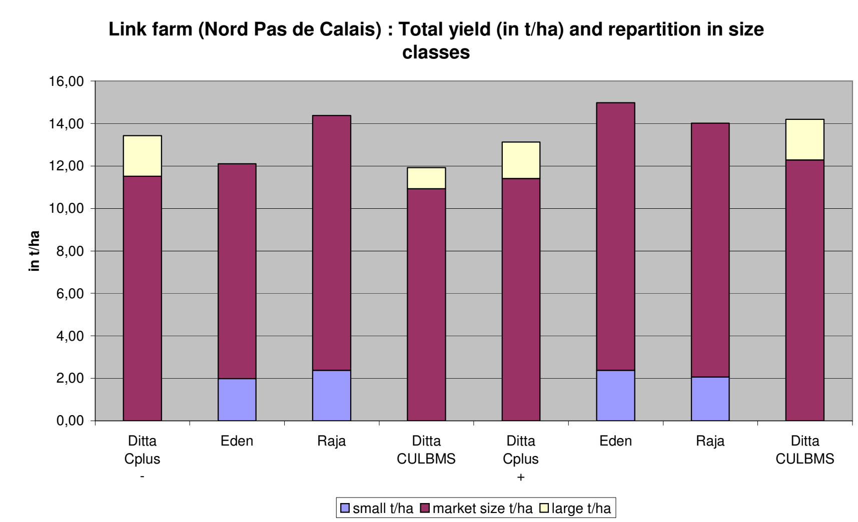
42- Results :



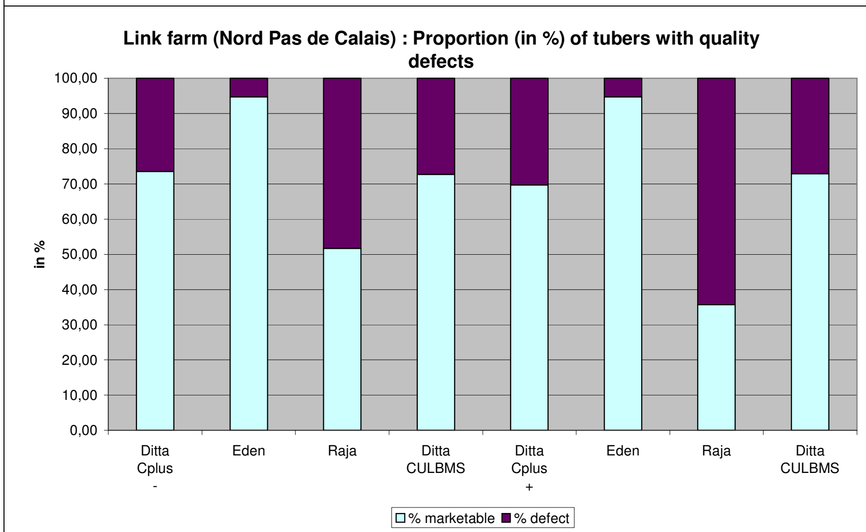
Calculation of St AUDPC

treatment	**Copper**	**Variety**	**AUDPC**
Cplus	-	Ditta	0,87
		Eden	0,00
		Raja	0,00
	+	Ditta	0,00
		Eden	0,00
		Raja	0,00
CULBMS	-	Ditta	3,09
	+	Ditta	0,01

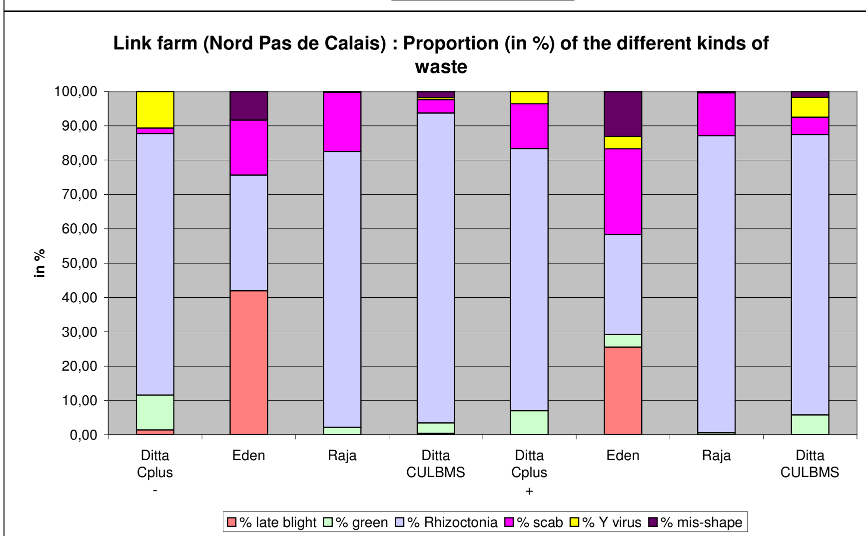
Late blight outbreak is weak this year. AUDPC are very low. The highest AUDPC is observed for Ditta in pure stand, without any copper treatment.



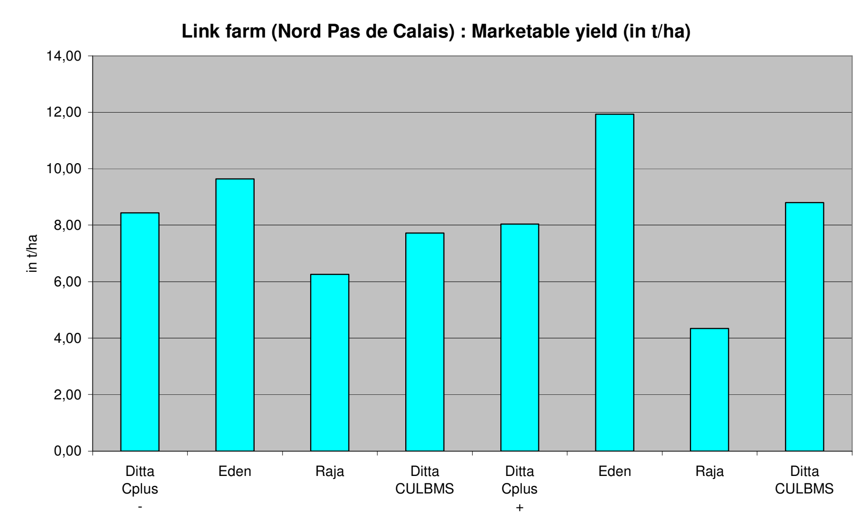
Copper treatments lead to an increase of total yield for Eden (Cplus) an Charlotte CULBMS.
Cplus have no effect on total yield and yield from tubers of marketable size for Ditta.
Yields for Eden and Raja are close to yield from Ditta.



Copper treatments have no effect on proportion of discarded tubers.
Cplus have no effect on proportion of discarded tubers.
Proportion of waste is low for Eden, intermediary for Ditta, high for Raja.



The outbreak of Rhizoctonia is hughe, especially for Raja.
Eden is the most susceptible variety to tuber blight, even if the foliage is poorly attacked.



Copper treatment have no effect on commercial yield, except for Eden (increase) and Raja (decrease).
Cplus has no effect on commercial yield.
Commercial yield is the highest for Eden, the lowest for Raja.

5- Link Farm 4 :

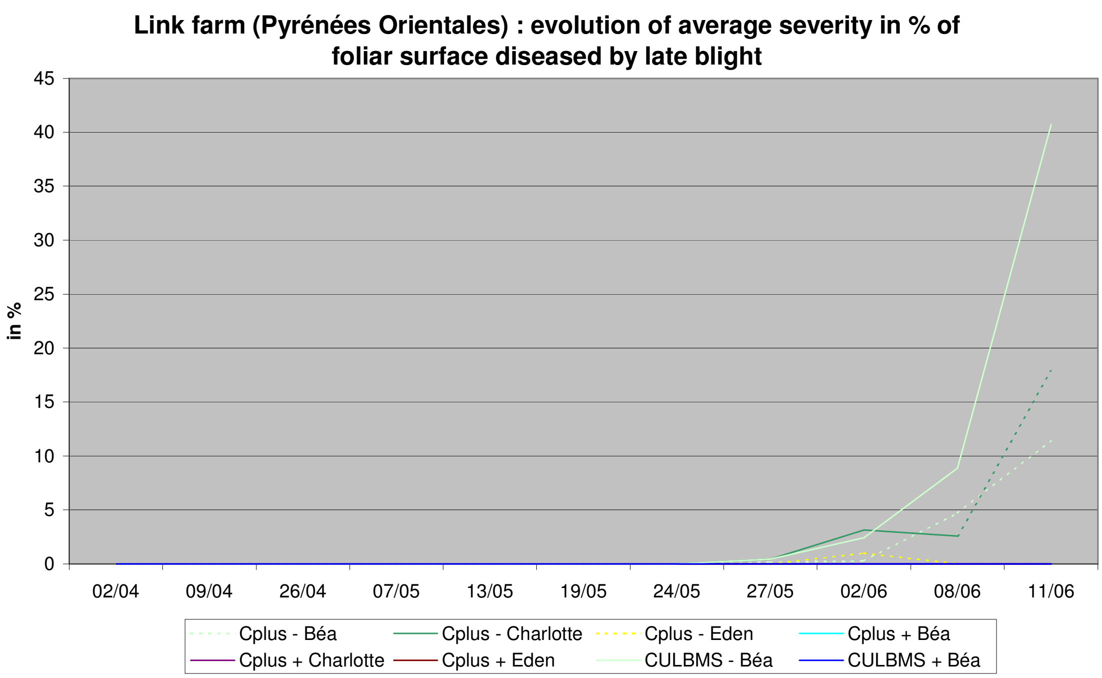
Location : Southern France (Pyrénées Orientales)
Climate : mediterranean
Plantation : 10th March
Inoculated : 19th May
Harvest : 11th June 2004

51- protocole :

	CULBMS	Cplus
Copper –	Pure stand : Bea No treatment	alternating rows : Béa, Charlotte, Eden (2x2) No treatment
Copper +	Pure stand : Bea Copper treatment (total copper dose : 4 kg/ha)	alternating rows : Béa, Charlotte, Eden (2x2) Copper treatment(total copper dose : 4 kg/ha)

product	Bordeaux mixture
copper compound	copper sulfate (20% of copper metal)
doses	4 kq/ha
dates	5 treatments (07/05 ; 14/05 ; 19/05 ; 24/05 ; 28/05)

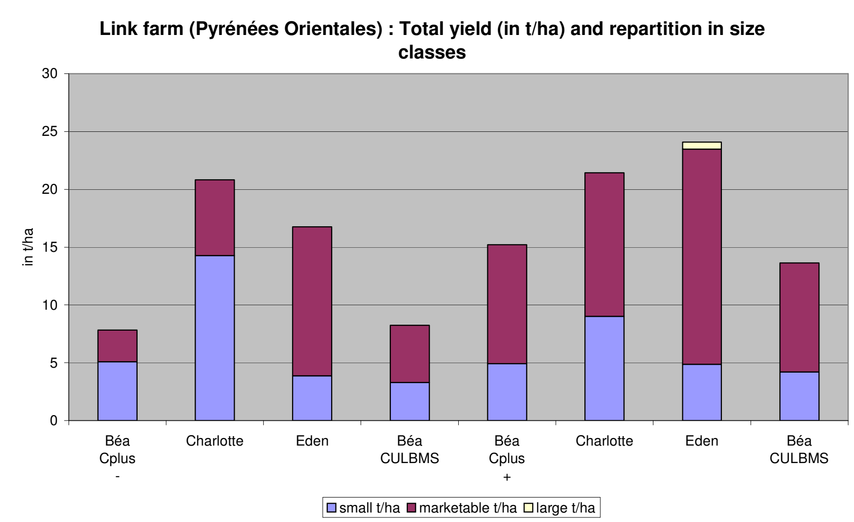
52- Results :



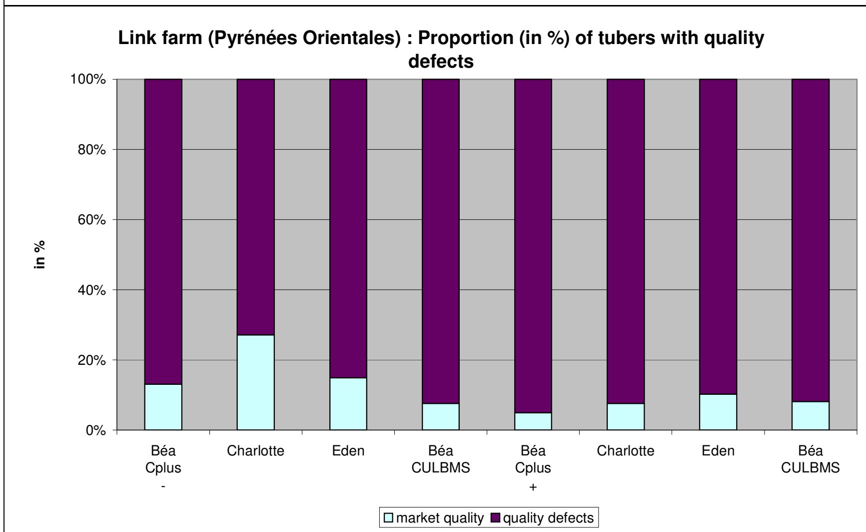
Calculation of St AUDPC

Copper	treatment	Variety	AUDPC
-	**Cplus**	**Béa**	2,26
		Charlotte	3,29
		Eden	0,33
	CULBMS	**Béa**	6,52
+	**Cplus**	**Béa**	0,00
		Charlotte	0,00
		Eden	0,00
	CULBMS	**Béa**	0,00

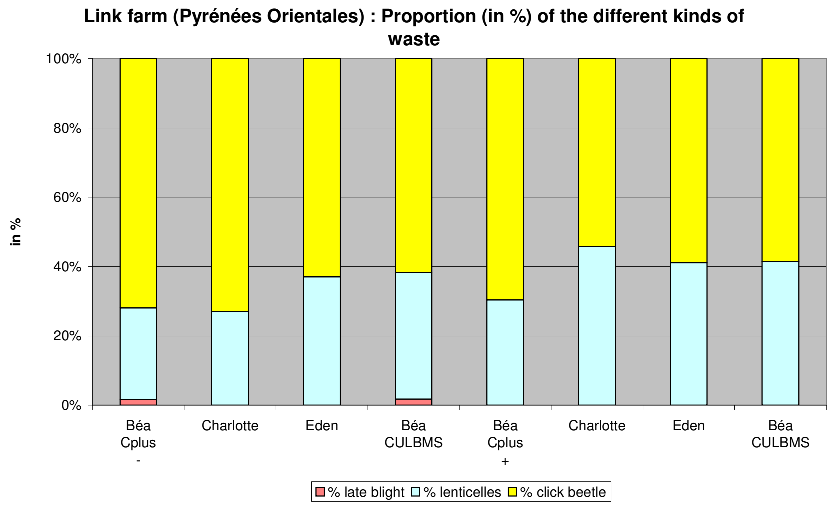
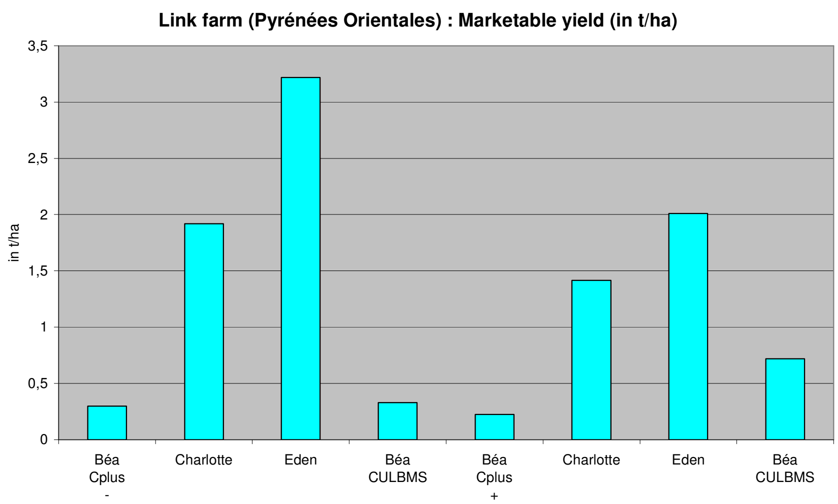
Outbreak of late blight in this farm is late and weak. No late blight is observed when copper is applied. Cplus reduces AUDPC on Béa. Charlotte and Béa are more attacked than Eden.



Total yield is very low. Copper treatments have a light effect on total yield for Béa Cplus, Eden, Béa CULBMS but not for Charlotte.
Cplus has no effect on total yield for Béa.



Proportion of discarded tubers is enormous (between 80% and 90%), for all the modalities.

	This plot has been settled on a previous fallow. This could explain the great incidence of click beetle on the harvested tubers. Click beetle is one of the major phytosanitary problems on organic potato crop is Southern France.
	Commercial yields are very low. Copper treatments do not lead to a yield increase. Cplus has no effect on the commercial yield.

Conclusion :

The effects of the introduced Component Strategies (resistant varieties, alternating rows, presprouting, early plantation, alternative treatments) is not obvious. In the Model farm, CS had no direct effect on foliar late blight, except for Eden. On the marketable yield, each CS had an additive positive effect for Charlotte, without any copper treatment. On Eden, no clear effect was observed.
Copper treatments reduced AUDPC on both Charlotte and Eden. Copper treatments led to an increase of marketable yield for Charlotte but also for Eden. At harvest, both varieties were indeed burnt off because of the large late blight outbreak.

On Link farms, conclusions are a bit different : on 3 out of 4 farms, the introduced CS reduced late blight on the foliage and copper did not seem to have a strong impact on commercial yield. One observation can be done on 2 sites (Taulé, Lanvellec) : it seems that positive effect of copper treatments on marketable yield for the susceptible variety is enhanced if this variety is settled in alternating rows with a resistant variety.

On 3 sites out of 5, marketable yields for the susceptible variety for CULBMS with copper treatments and for the best Cplus without copper treatments are not that different.

Statistical analysis

For each variety, on each site, ANOVA have been made to test effect of copper treatments and effect of the component strategies.

		St AUDPC	Too small t/ha	marketable size t/ha	Too large t/ha	% marketable	Marketable yield t/ha	% late blight	% soft rot	% Rhizoctonia	% mis-shape	% scab	% click beetle	green	Yvirus
Model farm	**c**	->+ C4a C5a C0b C2b C3b	NS NS	+>- NS	na	NS NS	+>- NS	+>- NS	NS NS	NS NS	NS NS	NS NS	NS NS	na	na
	e	->+ C1a C2a C3a C4ab C5b	NS NS	+>- C1a C3ab C2ab C5b C5b	NS NS	+>- C2a C3ab C1ab C5ab C4b	+>- C1a C3a C2a C5b C1b	NS C2a C3ab Cab C5ab C1b	NS NS	->+ NS	NS C1a C3a C2ab C5b C1b	NS NS	NS NS	na	na
Taulé	**c**	->+ Cplus>CULBMS	NS Cplus>CULBMS	+>- CULBMS>Cplus	NS CULBMS>Cplus	NS Cplus>CULBMS	NS CULBMS>Cplus	NS NS	+>- Cplus>CULBMS	NS CULBMS>Cplus	NS Cplus>CULBMS	NS Cplus>CULBMS	na	na	na
	e	->+ NS	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS	na	na
lanvellec	**c**	NS CULBMS>Cplus	+>- Cplus>CULBMS	+>- Cplus>CULBMS	NS NS	NS NS	+>- Cplus>CULBMS	NS NS	NS NS	NS NS	NS NS	NS NS	NS Cplus>CULBMS	na	na
	e	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS	->+ NS	NS NS	NS NS	NS NS	na	na
Nord Pas de Calais	**d**	->+ CULBMS>Cplus	na	NS NS	NS NS	NS NS	NS NS		na	NS NS	NS CULBMS>Cplus	NS NS	NS NS	NS NS	NS NS
	e	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS		na	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS
	r	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS		na	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS
Pyrénées Orientales	**b**	->+ CULBMS>Cplus	na	na	na	na	na	na	na	na	na	na	na	na	na
	c	NS NS	na	na	na	na	na	na	na	na	na	na	na	na	na
	e	NS NS	na	na	na	na	na	na	na	na	na	na	na	na	na

Varieties :   b = Béa, c= Charlotte, d = Ditta, e = Eden, r = Raja

na : non applicable
NS : non significant
First lign : effect of copper treatments :
->+ : average without copper treatment significantly higher (Fisher 5%) than average with copper treatments
Second lign : effect of the late blight management strategies
for the Model farm : the component strategies have been classified through an ANOVA (Newman-Keuls 5%)
for the Link farms : CULBMS>Cplus : average for the Currently Used Late Blight Management Strategies significantly higher (Fisher 5%) than average for the Cplus (Proposed Late Blight Management Strategies)

No statistical analysis was made for the Link farm in Pyrénées Orientales because of the lack of repetitions