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Task 9.1: Socio-economic impact assessment of copper-free production systems and strategies

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Summary

In this report the economic impact of minimization of copper use is assessed for four typical commercial production systems (potato, tomato, apple and grape) by partial budgeting. In this, the incremental effects on costs and returns of copper minimization compared to current practices (including the use of copper), are estimated, based on expert estimates.

This analysis shows that minimization of copper use by replacement with alternative PPP's is expected to be impossible or to have a major negative economic impact in most production systems, except for IPM-tomato production, mainly because of negative effects on (marketable) yields. Even if copper replacement strategies including resistant varieties are used, the economic impact is expected to be negative for most situations. Only for potato production and medium yielding grape production systems, the economic impact is expected to be positive if resistant varieties are used.

Sensitivity analysis shows that changes in the costs of disease control are not of major importance, with the exception of tomato production. It also shows that price effects might be highly important: if price premiums of 10% for 'copper-free' products will be attained, the economic impact of copper replacement by alternative PPP-spraying becomes positive for apple and potato production in low risk situations, besides IPM-tomato production. For strategies including resistant varieties, a 10% price premium is more than sufficient to attain a positive economic impact in all production systems.

It is concluded that, besides the development of good resistant varieties with comparable yields and qualities as current varieties, major marketing efforts, along with the introduction of 'copper-free' crop products and varieties, are an essential element of a strategy to minimize the use of copper.

1. Introduction

In organic farming, copper is one of the few fungicides with proven effectivity against several fungal and bacterial diseases (Dagostin et al., 2011). Also in most Integrated Pest Management (IPM) systems, copper is still used in addition to synthetic fungicides, mainly in order to avoid or delay the development of resistance. Because of negative environmental impacts of copper (on biodiversity, beneficial organisms, etc.), the European Union has restricted its use in organic agriculture but not banned it due to the increased risk of crop diseases and associated economic losses for organic producers (Ghorbani and Wilcockson, 2007).

In the CO-FREE-project several alternative plant protective products (PPP), varieties and strategies, to reduce or minimize the use of copper as e.g. fungicide in potato, tomato, apple and grape production, were tested during three consecutive years (2012-2015). Technical results on efficacy and production are and will be published elsewhere (see www.co-free.eu). In this report the socio-economic impact of these alternative measures to minimize copper use will be assessed. For this, the effect on costs and returns of alternative PPP-sprayings and strategies compared to the current practices (including the use of copper) on commercial farms will be assessed for four production systems in which copper is used: potato, tomato, apple and grape production.

2. Methodology

In 2012 a protocol was developed to evaluate the effect of CO-FREE treatments and strategies, to facilitate expert judgements of likely incremental effects compared to a standard production system. Partial budgeting (Tigner, 2006) is used to analyse the effects of CO-FREE treatments. In all cases examined in this paper, this is a gross margin analysis as no investments were assumed to be necessary. In such analysis, widely used since 1960's, output (marketable yield*market prices) is subtracted by variable costs for seeds, fertilizer, pesticides, variable labour costs, etc. (Defra, 2010). Gross margin analysis is seen as a useful tool to analyse changes if farm characteristics and production systems and thus fixed costs, are not fundamentally changed (Firth, 2002). In case more sprayings are expected to be required, extra costs are all assumed to be variable costs (thus disregarding the possibility of using extra family labour as a source), similar to the procedure of Speiser et al. (2013).

Based on preliminary information, a draft cost-benefit analysis for the different production systems was designed during a workshop with 29 experts (20th October 2015, Amsterdam). Simple production systems were chosen as a standard instead of averages, while the variation in production methods, production levels, costs and returns in Europe is enormous and accurate data not easily accessible. Thus, total variable costs and margins[1] shown are not meant as accurate indications of profitability but merely as a basis for the economic impact assessment and illustration of the relative importance of various issues.

These draft cost-benefit analyses were send to the experts for adjustments and additional information. Based on the responses and literature checks, a second draft was submitted for further comments.

[1] This margin, the result of deducting variable costs from total returns, is available to cover fixed costs for land, overhead labour and investments (machinery, etc.).

3. Results

3.1 Potato

Potato production in major part of Europe is prone to early blight and particularly late blight, but the importance (incidence and earliness) varies between regions and years. In organic agriculture, regular spraying with copper solution is used to extend the number of growing days, up to approximately 3kg Cu per ha per year, depending on the timing and severity of the infection.

Assumptions on current situation are based on data from KTBL "Leistungs-Kostenrechnung Pflanzenbau" (www.daten.ktbl.de) and expert information. Relevant expert estimations and assumptions are:

- There is a huge difference between low risk situations (mainly continental regions with low humidity during the growing season and/or low density of potato cultivation) and high risk situations (mainly temperate regions and high density of potato cultivation). In low risk situations replacing copper with alternative PPP-sprayings will result in only minor yield reductions, but in high risk situations it is insufficient to control late blight: under these conditions marketable yield is expected to be reduced by ±42%, due to a combination of lower total yield and a higher proportion of off-sized potatoes. In some cases (years with high incidence) cultivation might even fail completely.
- Cost of disease control will be increased if only alternative PPP-sprayings are used, particularly because more frequent spraying is required (e.g. due to limited rain fastness). Although not yet available on large scale, the costs of these products are expected to similar to copper.
- Resistant varieties are expected to have higher yields, particularly in high risk situations where diseases are the major limiting factor for potato production. These increased yields are slightly counterbalanced by a lower marketability due to higher losses, resulting in 8% and 13% higher marketable yields respectively for low and high risk situations.
- Prices of seed and ware potatoes of resistant varieties are expected to be similar to the current varieties (after successful introduction).
- No investments in new equipment, decision support systems, etc. are needed.

Table 1a: Expert estimates on relevant changes in the economic performance of ware potato production in low risk situations.

	Reference	**Best alternative PPP-sprayings**	**Resistant varieties and alternative sprayings**
Marketable yield (ton/ha)	33,3	30,9	35,8
Price (€ per ton)	400	400	400
Total returns (€ /ha)	13300	12369	14322
Total variable costs (€/ha)	3380	3455	3305
of which: Disease control (€/ha)	150	225	75
Margin (€/ha)	9920	8914	11017
impact (€/ha)		-1006	1097
Impact as % of variable costs		-30%	32%

Table 1b: Expert estimates on relevant changes in the economic performance of ware potato production in high risk situations.

	Reference	Best alternative PPP-sprayings	Resistant varieties and alternative sprayings
Marketable yield	25,2	14,7	28,6
Price (€ per ton)	400	400	400
Total returns (€ /ha)	10080	5880	11424
Total variable costs (€/ha)	3665	3840	3490
of which: Disease control (€/ha)	350	525	175
Margin (€/ha)	6415	2040	7934
Impact (€/ha)		-4375	1519
Impact as % of variable costs		-119%	41%

Replacement of copper by alternative PPP-sprayings will have a negative economic impact in low risk situations (30% of the variable costs; Table 1a). In high risk situations (Table 1b) this will be even more explicit with a negative impact of 119% of the variable costs (Table 1b). Using the available resistant varieties, copper replacement will have a positive economic impact (Table 1a and 1b), as yields of these varieties are expected to be higher, particularly in high risk situations.

Sensitivity analysis shows that a reduction of the cost of disease control (e.g. by fewer sprayings) will improve the economic impact of copper replacement by alternative PPP-sprayings only marginally (Table 2). A price premium for 'copper-free' potatoes of 10% will be enough to attain a positive economic impact of copper replacement by alternative PPP-sprayings in low risk situations. In high risk situations, however, the effect of a price premium will be small: the economic impact of an alternative PPP-spraying strategy will remain highly negative (>100% of the variable costs).

Table 2 also shows that the economic impact of using resistant varieties is expected to remain positive even if the yields of these varieties will be 10% lower than expected. However, this positive economic impact of resistant varieties is highly dependent on the market prices payed for these new varieties: a 10% lower price for these resistant varieties will result in a negative economic impact in low risk situations.

Table 2: Sensitivity analysis of the economic impact of copper replacement (in % of variable costs) by different strategies in organic potato production in low and risk situations.

Copper replacement strategy		Low risk	High risk
Alternative PPP-sprayings	Best estimate	-30	-119
	Lower cost of disease control (equal to reference)	-28	-115
	Higher prices for 'copper-free' potatoes (+10% instead of 0%)	7	-103
Resistant varieties and alternative sprayings	Best estimate	32	41
	Lower yield (0 and 10% instead of 10 and 20% resp.)	2	15
	Lower price (-10% instead of 0%)	-10	10

3.2 Tomato

Tomato production in Europe can be subdivided in distinct production systems, e.g. greenhouse or open field production, for sauce, fresh or processed tomatoes. Particularly open field production is prone to fungal diseases like late blight. Copper sprayings are used in 'Integrated Pest Management' (IPM) agriculture as disease control up to a rate of approximately 1,5kg Cu per ha per year, besides 5-7 other sprayings with fungicides and insecticides. In organic agriculture typically 8-10 copper sprayings are used (often mixed with oils etc.) up to a rate of 6kg Cu per ha per year, depending on the infection risk.

Assumptions on current situation are based on expert-guesses for plum tomatoes from Greece, checked with additional economic information from Engindeniz (2006), Klonsky (2012) and Garming et al. (2014). Few reliable information sources have been identified for organic tomato production, but yields are likely to be 25-35% lower, whereas prices are 10-20% higher than IPM. Relevant expert estimations and assumptions are:

- Effective disease control without copper but with alternative PPP-sprayings is possible, with no major differences in yield expected compared to the current situation.
- Most effective CO-FREE-products are likely to be much more expensive than copper (+300%).
- Most effective products even seem to have a positive product quality effect (higher Brix), which might result in a higher market price for the tomatoes.
- No investments in new equipment, decision support systems, etc. are needed.
- No acceptable resistant varieties are available.

Table 3a: Expert estimates on relevant changes in the economic performance of processed IPM-tomato production.

	Reference	**Alternative PPP-sprayings**
Marketable yield (ton/ha)	100	100
Price (€ per ton)	80	84
Total returns (€ /ha)	8000	8400
Total variable costs (€/ha)	2300	2600
of which: Disease control (€/ha)	1200	1500
Margin (€/ha)	5700	5800
Impact (€/ha)		100
Impact as % of variable costs		4%

Table 3b: Expert estimates on relevant changes in the economic performance of processed organic tomato production.

	Reference	**Alternative PPP-sprayings**
Marketable yield (ton/ha)	63	63
Price (€ per ton)	92	96,6
Total returns (€ /ha)	5796	6086
Total variable costs (€/ha)	1870	2470
of which: disease control (€/ha)	770	1370
Margin (€/ha)	3926	3616
Impact (€/ha)		-310
Impact as % of variable costs		-17%

In IPM (Table 3a) replacement of copper by alternative PPP-sprayings has only a small economic impact as copper constitutes only a small part of the disease control costs. Reducing the cost of PPP-spraying to a level comparable to the reference situation will further improve the economic impact (Table 4). Preliminary calculations for organic tomato production (Table 3b) indicate that the economic impact of copper replacement is likely to be more negative compared to IPM, due to the greater importance of copper in the disease control. A more positive price premium is crucial in organic systems to neutralise the economic impact of copper replacement by alternative PPP-sprayings (Table 4).

Table 4: Sensitivity analysis of economic impact of copper replacement (in % of variable costs) in IPM and organic plum tomato production.

	IPM	Organic
Best estimate	4	-17
Lower cost of disease control (equal to reference)	17	15
Higher price premium (10% instead of 5%)	22	-1

3.3 Apple

Apple production in Europe is based on a few varieties, vulnerable to various diseases like downy and powdery mildew, scab, etc. Copper sprayings are used in organic agriculture as disease control at a rate of ±3 (1,5 - 6) kg Cu per ha per year, depending on the region and infection risk.

Assumptions on the current situation are based on expert estimates for Germany and Northern Italy, and checked with literature (e.g. Mon and Holland, 2006). Relevant expert estimations and assumptions are:

- Simply replacing copper with alternative PPP-sprayings (including lime sulphur, acid clays and carbonates) is possible without a major yield reduction but risky. This is reflected in a lower grading of the apples, particularly in high risk situations, resulting in lower average prices. Moreover, apple production becomes more vulnerable to a gradual build-up of the infection risk for fungal diseases. Particularly in high risk situations, these might not be controlled adequately with alternative PPP-treatments without any copper spraying.
- An effect of this higher risk is also visible in the cost of disease control; the large number of sprayings will further increase (by 40% and 50% respectively in low and high risk situations) if only alternative PPP-sprayings are used.
- Resistant varieties are available, but have slightly lower yields. Market prices of resistant apple varieties are expected to be similar to the current varieties (after successful introduction). Availability of new plants is expected not to be problematic.
- No investments in new equipment are needed.

Table 5a: Expert estimates on relevant changes in the economic performance of apple production in low risk situations.

	Reference	Alternative PPP-sprayings	Resistant varieties and alternative sprayings
Total yield (ton/ha)	40	40	36
% of yield Class 1	75%	60%	75%
% of yield Class 2	15%	30%	15%
% of yield Class 3	10%	10%	10%
Total returns (€/ha)	31400	29600	28260
Total variable costs (€/ha)	17000	17800	16000
of which: Disease control (€/ha)	2000	2800	1000
Margin (€/ha)	14400	11800	12260
Impact (€/ha)		-2600	-2140
Impact as % of variable costs		-15%	-13%

Note: prices are assumed to be 900, 600 and 200€ per ton for Class 1, 2 and 3 respectively.

Table 5b: Expert estimates on relevant changes in the economic performance of apple production in high risk situations.

	Reference	Alternative PPP-sprayings	Resistant varieties and alternative sprayings
Total yield (ton/ha)	40	40	36
% of yield Class 1	70%	45%	70%
% of yield Class 2	20%	40%	20%
% of yield Class 3	10%	15%	10%
Total returns (€/ha)	30800	27000	27720
Total variable costs (€/ha)	17400	18600	16200
of which: Disease control (€/ha)	2400	3600	1200
Margin (€/ha)	13400	8400	11520
Impact (€/ha)		-5000	-1880
Impact as % of variable costs		-29%	-11%

Note: prices are assumed to be 900, 600 and 200€ per ton for Class 1, 2 and 3 respectively.

Replacement of copper by alternative PPP-sprayings is possible in apple production, but it has a negative economic impact (15% of the variable costs; Table 5a). In high risk/unfavourable situations, diseases might become uncontrollable without some well-timed copper-sprayings. Within few years, this will result in a negative economic impact of 29% of total variable costs (Table 5b). Moreover, high frequent spraying with alternative treatments (up to ±40 times in a few months' period) will contribute to the stress of farmers that is already apparent during this period. Currently available resistant varieties do reduce this stress but are not sufficient to minimize the negative economic impact of copper replacement (Table 5a and 5b), as yields are expected to be lower and quality (grading/price) is expected to be marginally altered. This, combined with the high investments necessary for orchard renewal, will render in a slow introduction of resistant varieties, mainly matching with a strategy to prolong the total harvest period to flatten peaks in labour requirements.

Sensitivity analysis shows that a reduction of the cost of disease control will improve the economic impact of copper replacement by alternative PPP-sprayings only marginally (Table 6). Moreover, this will not improve the stressful conditions of high frequent spraying.

The economic impact will improve if a premium is paid for 'copper-free' apples: a 10% higher product price is sufficient to attain a positive economic impact of copper replacement, except for high risk situations without using resistant varieties (Table 6). Also higher yielding resistant varieties (with yields comparable to the current varieties) would result in a positive economic impact of copper replacement.

Table 6: Sensitivity analysis of economic impact of copper replacement (in % of variable costs) by different strategies in organic apple production in low and risk situations.

Copper replacement strategy		**Low risk**	**High risk**
Alternative PPP-sprayings	Best estimate	-15	-29
	Lower cost of disease control (equal to reference)	-11	-22
	Price premium for 'copper-free' apples (10% instead of 0%)	2	-13
Resistant varieties and alternative sprayings	Best estimate	-13	-11
	Higher yield (0% instead of -10%)	6	7
	Price premium for 'copper-free' apples (10% instead of 0%)	4	5

3.4 Grape

Grape production in Europe can be subdivided in distinct production systems for wine, table/fresh and dried grapes. It is based on a few varieties, susceptible to various diseases like downy and powdery mildew, scab and Botrytis. Copper sprayings are used in organic agriculture as disease control up to a rate of ±6kg Cu per ha per year, depending on the infection risk and production system. Copper use in fresh grapes is often very low, due to coverage of the bunches.

Assumptions on current situation are based on expert estimates for wine production in Northern Italy. Relevant expert estimations and assumptions are:

- Replacing copper with alternative PPP-sprayings seems impossible without major yield reduction. Some low copper dose sprayings (±0.8kg Cu per ha per year) are required to prevent severe economic impact.
- Fungi resistant varieties (PIWI) are available. Some sprayings with alternative PPP's are needed, also to slow down the process of declining resistance.
- No major investments are needed. Replacement of current varieties by resistant varieties will be only via regular orchard renewal, as replacement of young/productive orchards will require prohibitively high investments.
- Production systems vary widely in production level, quality and thus output prices. We will distinguish three typical production systems (high quality/low yields; medium quality/ yields; low quality/high yields) with large differences in yields and product prices and slightly different variable costs.
- In all production systems, using alternative PPP/low copper-sprayings is likely to result in yield reductions (of 15, 15 resp. 20%, due to higher losses), but price premiums (of ± 10%) for grapes with low copper use are expected to be possible, except for high quality systems.
- Resistant varieties might give lower yields (-10%) in high yielding systems, but are likely to give higher yields (+10%) in high quality/low yield systems.
- Although product prices are highly sensitive for (perceived) quality differences, it is assumed that the price premium for low copper use (+10%) is sufficient to balance the negative price

effect of the resistant variety use in medium and high yielding systems. In high quality/low yield systems a price premium for low copper use is unlikely and a negative price effect of 15% is assumed for resistant varieties.

Table 7a: Expert estimates on relevant changes in the economic performance of grape production in a high yielding/low quality wine production system (e.g. Veneto).

	Reference	**Alternative PPP-sprayings (incl. low Cu-dose)**	**Resistant varieties and alternative sprayings**
Marketable yield (kg/ha)	25000	20000	22500
Price (per kg)	0,6	0,66	0,6
Total returns (€/ha)	15000	13200	13500
Total variable costs (€/ha)	7200	9400	6700
of which: Disease control (€/ha)	1800	4000	1300
Margin (€/ha)	7800	3800	6800
Impact (€/ha)		-4000	-1000
Impact as % of variable costs		-56%	-14%

Table 7b: Expert estimates on relevant changes in the economic performance of grape production in a medium yielding/medium quality wine production system (e.g. Trentino).

	Reference	**Alternative PPP-sprayings (incl. low Cu-dose)**	**Resistant varieties and alternative sprayings**
Marketable yield (kg/ha)	17000	14450	17000
Price (per kg)	1,1	1,21	1,1
Total returns (€/ha)	18700	17485	18700
Total variable costs (€/ha)	8100	9600	7600
of which: Disease control (€/ha)	1500	3000	1000
Margin (€/ha)	10600	7885	11100
Impact (€/ha)		-2716	500
Impact as % of variable costs		-34%	6%

Table 7c: Expert estimates on relevant changes in the economic performance of grape production in a low yielding/high quality wine production system (e.g. sud-Tirol).

	Reference	**Alternative PPP-sprayings (incl. low Cu-dose)**	**Resistant varieties and alternative sprayings**
Marketable yield (kg/ha)	6000	5100	6600
Price (per kg)	3,3	3,3	2,81
Total returns (€/ha)	19800	16830	18513
Total variable costs (€/ha)	9900	11400	9400
of which: Disease control (€/ha)	1500	3000	1000
Margin (€/ha)	9900	5430	9113
Impact (€/ha)		-4470	-787
Impact as % of variable costs		-45%	-8%

Table 7 shows that minimization of copper use by the adoption of alternative PPP-sprayings will have a major negative economic impact in all production systems, even if combined with a price premium for grapes with low copper-use. A reduction of the disease control costs, to a similar level as the current level, will be insufficiently effective: the economic impact will improve but remains negative (Table 8). Table 7 also shows that the economic impact of strategies including resistant varieties is much better but still negative, except for the medium quality/yield production systems.

Table 8: Sensitivity analysis of economic impact of copper replacement (in % of variable costs) by different strategies in organic grape production in three different production systems.

Copper minimization strategy		**High yielding**	**Medium yielding**	**Low yielding**
Alternative PPP-sprayings (incl. low copper dose)	Best estimate	-56	-34	-45
	Lower cost of disease control (equal to reference)	-25	-15	-30
	Lower prices for 'copper-free' grapes (10% lower than expected +10%, +10% and 0% resp.)	-72	-53	-62
Resistant varieties and alternative sprayings	Best estimate	-14	6	-8
	Yields of resistant varieties equal to reference (instead of -10%, 0 and +10% resp.)	7	6	-25
	Higher prices for resistant variety-grapes (10% higher than expected 0%, 0% and -15% resp.)	5	29	14

In high quality/low yield systems the impact of resistant varieties is likely to be negative and if assumed yield increases will not substantiate the impact even becomes more negative (-25%; Table 8). However, this is highly dependent on the product price effect: a less negative product price effect (of 95% instead of 85% of the original price) is already sufficient to gain a positive impact of 14% of the total variable cost.

Sensitivity analysis also shows that if resistant varieties are able to produce equal yields of the same quality in low quality/high yield systems, a positive economic impact is possible (+7%; Table 8). A price premium for 'copper-free' grapes of resistant varieties will have a similar effect.

4. Discussion and conclusions

Though reduction of copper use is possible (by using improved disease control strategies, timing of sprayings and alternative PPP's), minimization of it by replacement with alternative PPP's is expected to be impossible or will have a major negative economic impact in most production systems, except for IPM-tomato production. No literature was identified on the economic impact of copper minimization to check these results, but they are in line with earlier conclusions that resistant varieties are essential for minimizing copper use (Ellis et al., 1998; Leifert and Wilcockson, 2005).

But even if resistant varieties are used, the economic impact is expected to be negative for most situations. Only for potato production and medium yielding grape production systems, the economic impact is expected to be positive if resistant varieties are used. For the other production systems considered, suitable resistant varieties are not available (tomato) or the economic impact of copper replacement is expected to be negative, due to the lower yields of the resistant varieties (apple) or lower product prices (low yielding grape production systems).

Sensitivity analysis show that the costs of disease control, though increasing, are not of major importance: even if the cost of disease control with alternative PPP-sprayings is reduced to levels comparable with the current situation, the economic impact of copper replacement by alternative PPP-sprayings will remain negative, mainly due to expected reductions in (marketable) yield. Tomato production seems to be the exception of this, as economic margins will improve substantially if the disease control costs become comparable with the cost level in the current situation, due to both the high increase of the disease control cost that is expected when replacing copper with alternative PPP-sprayings and the expected subsequent product price increase.

Sensitivity analysis shows that also for other production systems, price effects are highly important. If price premiums of 10% for ‘copper-free’ products might be attained, the economic impact of copper replacement by alternative PPP-spraying becomes positive in low risk situations. For strategies including resistant varieties, a 10% price premium is more than sufficient to attain a positive economic impact in all production systems.

Thus price premiums for ‘copper-free’ products or better resistant varieties, with similar yields and qualities as current varieties, are essential to neutralise the negative economic impact of copper replacement. However, the introduction of new varieties is often problematic (e.g. Weibel et al., 2007; Nuijten et al., forthcoming). Consumers, retailers and/or traders seem hesitant to buy unknown varieties and/or reluctant to value intrinsic values like a ‘copper-free’ production, implying uncertain market perspectives and thus lower product prices for these new varieties, whereas stable prices, or in most production systems even price premiums for ‘copper-free’ products, are an important precondition for gaining a positive economic impact. These uncertain market perspectives make the seeding/planting of resistant varieties unattractive, particularly in perennial systems like grape and apple, where the possible breakdown of the (monogenetic) resistance makes high investments in early orchard renewal highly risky. Therefore, in addition to the development of good resistant varieties, major marketing efforts, along with the introduction of ‘copper-free’ crop products and varieties, are an essential element of a strategy to minimize the use of copper.

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