Maize based cropping systems
« Results and lessons learnt from PURE »

February 2015

OBJECTIVES

The general objective of WP3 was to identify, test and validate innovative IPM solutions for maize based cropping systems for the most important European maize producing areas. This was achieved by :

- Identifying candidate IPM solutions and testing them in on-station and on-farm experiments,
- Evaluating the sustainability of tested IPM solutions.

APPROACH (EXPERIMENTS, ASSESSMENT TOOLS)

The experiments were carried out in three major maize growing regions in Europe: Southern Europe (Italy, South-France), Eastern Europe (Hungary, Slovenia) and (North West) Central Europe (Germany, The Netherlands).

In the experimental work on-station and on-farm experiments were distinguished. In the *on-station* experiments two IPM strategies (packages of measures) were compared with the conventional strategy (Table 1), the latter being the current farmers' practice in the region. In the 1st IPM strategy (ADV) crop rotation is more diversified (grain maize is substituted partly by soybean or peas) and the crop management measures were relatively close to current practice (e.g. cultivar choice, using selective pesticides, combination of chemical and mechanical weed control). In the 2nd IPM-strategy (INN) crop rotation is extended with cover crops (only Italy) and more innovative measures (e.g. biological ECB control) are applied. The experiments were conducted in Italy, Hungary and France. Additionally, in a Dutch experiment chemical and mechanical weed control (harrowing + hoeing) were compared in different reduced tillage systems (not included in Table 1).

In the *on-farm* experiments separate IPM tools were tested for weed control (combinations of chemical and mechanical weed control) and ECB control (biological treatment by *T. brassicae* or *B. thuringiensis)* (Table 1). The tested tools had to be applicable with the available machinery in the region. The experiments were conducted in Italy, Germany, France, Hungary and Slovenia.
Additionally, in Italy and Slovenia, the need of chemical treatment against soil pests (granule applied at sowing in Italy, seed dressing in Slovenia) was tested.

Based on the technical results of the experiments the sustainability of the different tools and strategies was evaluated. Important indicators taken into account were the economy (total variable costs and gross margin) and the environmental impact (assessed with the model SYNOPS). Overall sustainability of the on-station experiments was evaluated with the model DEXiPM.

Table 1. Tested IPM solutions in on-station and on-farm experiments (DE = Germany, IT = Italy, SI = Slovenia, HU = Hungary, FR = France; M = maize, WW = winter wheat, SB = soybean, PE = peas, CC = cover crop).

On station	***CON***	***IPM1 (ADV)***	***IPM2 (INN)***
Crop rotation			
- IT+HU	M-WW-M	M-WW-SB/PE	M-WW+CC-SB/PE+CC
- FR	M-M	M-SB	M-SB
Weed control			
- *Broadcast spraying*	IT,HU,FR		
- Band spraying + hoeing		IT,HU,FR	IT,HU,FR
ECB control			
- *No treatment*	FR	FR	FR
- *Broad spectrum Insecticide*	IT,HU		
- Selective Insecticide not harming beneficials		IT,HU	
- Bacillus thuringiensis-spraying			IT,HU
Soil pests			
- Granule at sowing	IT		
- Seed dressing	FR	FR	
- No treatment	HU	IT,HU	IT,HU,FR
On farm	***CON***	***IPM-WEED***	***IPM-ECB***
Weed control			
- *Broadcast spraying*	DE,IT,HU,SI		
- Band spraying + hoeing		DE,IT,HU,SI	
- Spraying based on scouting and predictive model + hoeing		IT	
- Harrowing + low dose spraying		SI	
ECB control			
- *No treatment*	HU,FR,SI		
- *Broad spectrum Insecticide*	IT,HU		
- *Trichogramma brassicae* release			IT,FR,HU,SI
- *Bacillus thuringiensis*-spraying			IT,HU,SI

PESTS

The major crop protection problems in European maize growing areas are weed control and attacks by European Corn Borer (ECB, *Ostrinia nubilalis*).

 *Chenopodium album*	 *Solanum nigrum*
 *Echinochloa crus-galli*	 *Amaranthus retroflexus*
 *ECB pupa (Ostrinia nubilalis)*	 *ECB imagos (Ostrinia nubilalis)*

TECHNICAL RESULTS

On-station experiments

General remark

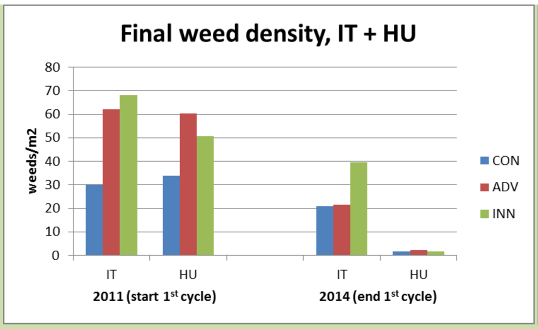
The on-station experiments include crop rotation effects. In Italy and Hungary not all crops were present each year. This means that calculated effects on rotation level can also be affected by differences in climatic conditions between the years.

Efficacy weed control

Figure 1 shows the final weed density for the Italian and Hungarian experiments in the maize crop at the start and at the end of the 1st rotation cycle. Although at the start efficacy of weed control was lower for both IPM strategies, at the end a significant reduction of weed density was observed for the IPM-strategies as compared to the start of the 1st cycle.

In the French experiment the ADV strategy showed equal weed control to CON in all years, for the INN strategy this applied to two out of three years.

In the Dutch experiment mechanical weed control overall gave a comparable efficacy than the chemical weed control (data not shown).



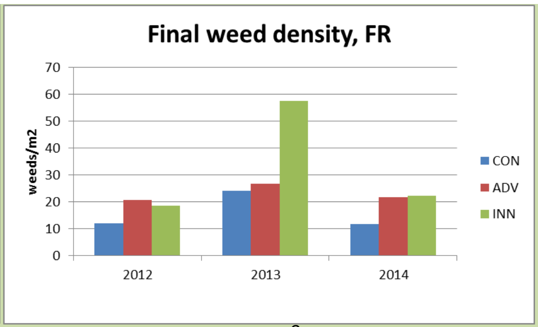


Figure 1. Final weed density maize in the maize crop (weeds/m^2) as affected by the CON and IPM-strategies in Italy and Hungary (left) and France (right). Weed assessments were done before harvest except for France 2013 (end of August).

Efficacy ECB control

Only in Italy ECB pressure was significant. Biological control (INN strategy) resulted in a higher crop damage (more broken plants below ear) than in the CON and ADV strategy (spraying with a non-selective and selective insecticide, respectively) (Figure 2).

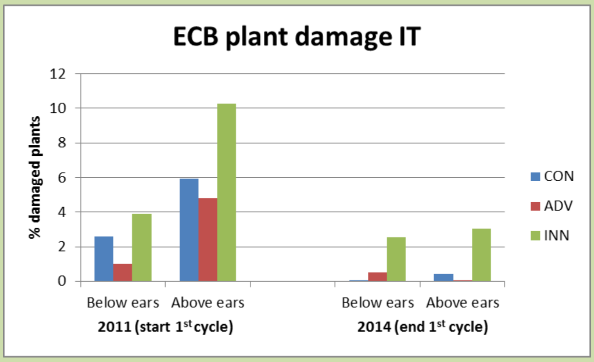


Figure 2. ECB broken maize plants below and above maize ears in 1st (2011) and 2nd rotation cycle (2014) as affected by IPM-strategy in Italy.

Soil pests

In Italy and France in the CON strategy a treatment is done against soil pests. In the IPM strategies no insecticides are used (in France this only applies to IPM2/INN). The lack of significant plant damage (data not shown) shows that an insecticide application was not necessary.

Mycotoxin content grain

Mycotoxin content of maize grain (only assessed in Italy) tends to be higher in IPM plots than in CON plots. This might be explained by a higher plant stress (known as a key factor increasing mycotoxin production by fungi) caused by an higher weed density and by an higher plant damage by ECB in IPM plots.

Yields

In Italy and Hungary (only in 2011) maize grain yields were significantly lower in both IPM strategies as compared to the CON strategy, in France only the INN strategy had lower yields (Figure 3).

The Dutch experiment showed that for both the conventional and reduced tillage systems mechanical weed control did not decrease yields significantly compared to the chemical weed control (data not shown).

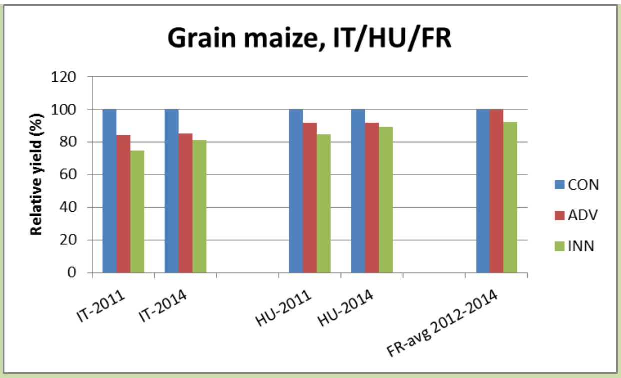


Figure 3. Relative maize yields of the on station experiments in Italy, Hungary and France (100 = yield CON).

On-farm experiments

Weed control

In a part of the experiments (Germany, Slovenia) the efficacy of the tested IPM-tools was lower than in the CON treatment (Figure 4, left) while in Italy and Hungary no differences were observed. The decreased level of weed control was mainly due to unfavourable weather conditions not allowing timely hoeing operations. However, grain yield was not significantly affected by the weed competition (Figure 4, right).

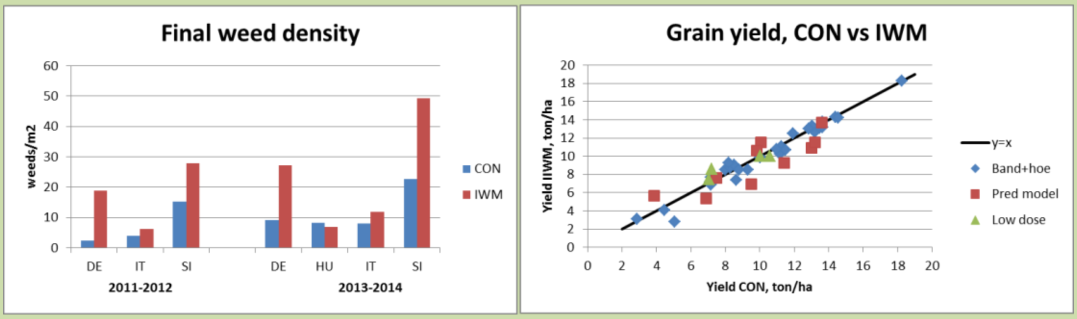


Figure 4. Final weed density for the IPM-tool (IWM) and the corresponding CON treatment in the on farm experiments (left) and maize grain yield of CON versus IWM (right) (band+hoe = band spraying + 1-2 hoeings, pred model = spraying when indicated by predictive model, low dose = harrowing + low dose spraying).

ECB control

The ECB pressure was significant only in Italy and Slovenia. The results showed that in these countries no significant differences in crop damage between both IPM tools and the CON treatment (insecticide spraying in IT and no treatment in SI) (Figure 5, left) were observed and grain yield was also comparable (Figure 5, right). However, it has to emphasized that in general economic thresholds for ECB pressure were not exceeded making it difficult to evaluate the efficacy of the tested biological tools.

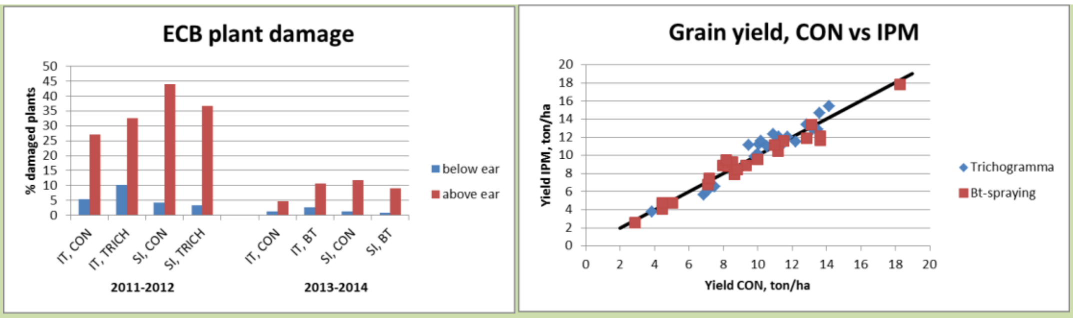


Figure 5. ECB broken maize plants below and above maize ears of the IPM-tool (Trichogramma brassicae, Bacillus thuringiensis) and the corresponding CON treatment in the on farm experiments (left) and maize grain yield of CON versus IPM (right).

Mycotoxin content grain

The climate conditions appeared to be the main driver of mycotoxin content differences between years, but there is a tendency to a slightly lower mycotoxin content in plots treated with chemical insecticides (CONV) in comparison with ECB (biological) treatments.

SUSTAINABILITY OF IPM SOLUTIONS

On-station experiments

The sustainability of the tested systems in the on-station experiments was evaluated with the model DEXiPM. The results are shown in Table 2.

For Italy and France the overall sustainability of the IPM systems was higher than for the conventional system while for Hungary the overall sustainability was the same for all three systems.

Generally, the IPM systems improved the environmental sustainability due to a lower use of pesticides and more diverse crop rotations. In the IPM systems the economic sustainability increased in Italy (for both the advanced and innovative system) while it decreased for Hungary (advance and innovative system) and France (innovative system). This is due to a lower gross margin of soybean/peas as compared to grain maize production and to the lower crop yields of especially maize in the ADV and INN strategy.

The social sustainability was improved in Hungary and France while in Italy it was not affected by the IPM system.

Table 2. Results DEXiPM calculations on-station experiments (VL = very low, L = low, M = medium, H = high, VH = very high).

Country	System	Sustainability			
		Economic	Environmental	Social	***Overall***
Italy	CON	M	VL	H	***M***
	ADV	H	M	H	***H***
	INN	H	H	H	***VH***
Hungary	CON	M	L	H	***M***
	ADV	L	L	VH	***M***
	INN	L	H	VH	***M***
France	CON	M	VL	M	***L***
	ADV	M	L	H	***M***
	INN	L	M	H	***M***

On-farm experiments

Weed control

<u>Cost benefit analysis</u>

- The difference in total variable costs between the IPM and conventional strategy ranged from -€80 to +€30/ha (Figure 6, left). Averaged over all tested tools the difference in costs was -€5/ha.
- The difference in gross margin between the IPM and conventional strategy ranged from -€105 to +€60 €/ha (Figure 6, right). Averaged over all tested tools difference in gross margin was -€30/ha.

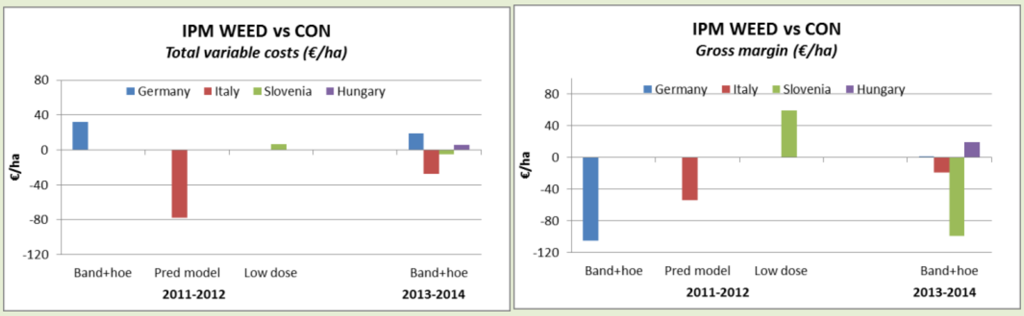


Figure 6. Difference in total variable costs (left, costs for herbicides and application) and gross margin (right) between the IPM-WEED and CON strategy.

<u>Environmental effects</u>

In all countries in the CON treatment the risks for terrestrial life are already low to very low (Table 3). In contrary, the risks for aquatic life are high across all the countries. The tested IPM tools decreased this risk, however, the risk was still on a high level. The tested IPM tool reduced the risk to a lower level mainly due to a decreased herbicide inputs.

Table 3. Environmental risks for aquatic and terrestrial life of CON and IPM-WEED in on farm trials as calculated by the model SYNOPS (average of tools, sites and years: red = high, yellow = medium, blue = low, green = very low;

		Acute		Chronic	
		Aquatic	Terrestrial	Aquatic	Terrestrial
GE	CON	0.60	0.00	5.32	0.01
	IPM	0.41	0.00	3.61	0.00
SI	CON	0.39	0.01	2.85	0.12
	IPM	0.19	0.00	1.24	0.02
HU	CON	0.32	0.00	3.06	0.02
	IPM	0.24	0.00	2.24	0.01
IT	CON	0.44	0.00	3.00	0.10
	IPM	0.27	0.00	1.39	0.03

ECB control

<u>Cost benefit analysis</u>

- The difference in total variable costs between the IPM and conventional strategy ranged between +€5 to +€140/ha (averaged over all tested systems +€70/ha) (Figure 7, left). If only the trials in which a pesticide spraying was done in the CON treatment (Italy and Hungary) were taken into account on

- average the total costs increase was +35/ha.
- The difference in gross margin between the IPM and conventional strategy ranged from -€155 to +€85 €/ha (averaged over all tested tools -€55/ha) (Figure 7, right). For the trials with a pesticide spraying in the CON treatment on average the gross margin decreased with 35/ha.

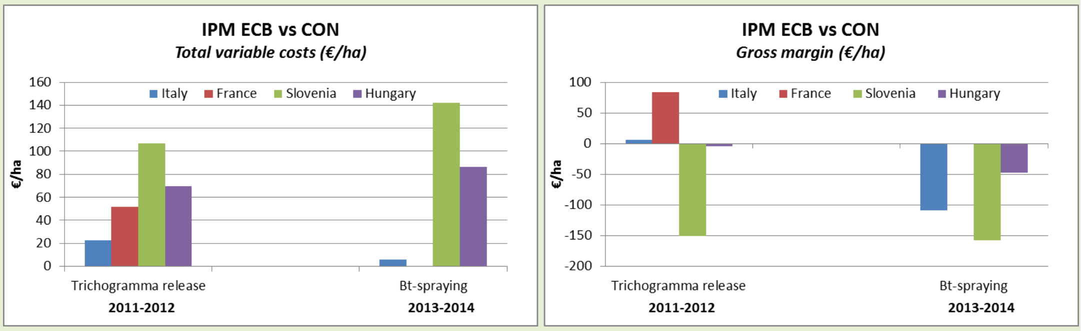


Figure 7. Difference in total variable costs (left, costs for pesticides/biological agents and application) and gross margin (right) between the IPM and CON strategy.

<u>Environmental effects</u>

Since only biological agents were used in the IPM tools the environmental risks were strongly decreased compared to a situation in which a conventional spraying is done (Table 4).

Table 4. Environmental risks for aquatic and terrestrial life of insecticide spraying against ECB in on farm trials as calculated by the model SYNOPS (average of tools, sites and years: red = high, yellow = medium, blue = low, green = very low;

	Acute		Chronic	
	Aquatic	Terrestrial	Aquatic	Terrestrial
Broad spectrum insecticide	0.54	0.00	31.51	0.01
Selective insecticide	0.01	0.09	0.02	0.78

LIMITS AND CONDITIONS OF SUCCESS, ADAPTATIONS (LESSONS LEARNT)

The results of the experiments show that IPM-solutions are available but for implementation in practice attention has to be paid to the following points:

- Sometimes IPM solutions are economic less attractive than the conventional strategy e.g. biological ECB control. For cash crops, like maize, currently, no higher prices are paid for IPM produced maize. In order to motivate farmers to adopt IPM tools subsidy schemes can be considered to compensate for possible economic drawbacks. Alternatively traders could try and find market niches that pay higher prices, e.g. food industry parties hat implement sustainability policies.
- For (new) IPM strategies training and demonstration will be necessary in order to build up experience and have IPM adopted by farmers.
- For weed control the IPM tools consist of mechanical operations. The observed variable efficacy can be overcome by essential elements like correct timing, experience and appropriate machinery.
- Band spraying of pre-emergence herbicides combined with hoeing was a frequently applied tool in the experiments. However, environmentally it can be more beneficial to apply a decision support system or a combination of early mechanical control (e.g. harrowing) combined with low dose spraying

	preferably with environmentally sound herbicides. • Crop rotation was a major measure in the IPM strategy in the on station experiments. The results showed that on the short term a diversification of the rotation may economically be less attractive. However, the experimental period allowed only one complete rotation to be studied. Ideally, the experiments should be continued in order to assess the possible long term effects of and adjusted rotation (lower weed pressure, increased soil fertility, higher crop yields). • The results showed that the need of insecticide applications against soil pests is rare and that monitoring methods are reliable; therefore soil insecticides or insecticide seed dressing should only be done when monitoring indicates this. This offers opportunities to improve farmers' income while reducing crop environmental impact at the same time.
REFERENCES	• D 3.1. First list of tested IPM solutions which improve the sustainability of maize based systems. • D 3.2 Updated list of tested IPM solutions which further improve the sustainability of maize based systems. • Annual Report Period 1 (1st March 2011 to 31st August 2012). WP 3 Innovative IPM solutions for maize based cropping systems. • Annual Report Period 2 (1st September 2012 to 28st February 2014). WP 3 Innovative IPM solutions for maize based cropping systems. • Vasileiadis, V.P., S. Otto, W. van Dijk, G. Urek, R. Leskovsek, A. Verschwele, L. Furlan, M. Sattin, 2015. European Journal of Agronomy 63, p. 71-78. • Razinger, J., V.P. Vasileiadis, M. Giraud, W. van Dijk, S. Modic, I.J. Holb, A. Vamos, M. Sattin, G. Urek, 2015. On-farm evaluation of inundative biological control of *Ostrinia nubilalis* (Lepidoptera: Crambidae) by *Trichogramma brassicae* (Hymenoptera: Trichogrammatidae) in European maize production (Accepted with major revision).