Integrated Weed Management, experiences from the Netherlands

Uppsala February 2019

Marleen Riemens et al.
Content

- Big trends and the impact on primary production
- Context: Towards AgroEcology & Technology
- Integrated Weed Management:
  - Diversified cropping systems
  - Cultivar choice: cover crops
  - Tillage and field management
  - Mechanical weed management & robotics
  - Monitoring
Our Research partners (both public and private) develop their vision, strategy and R&D policy to solve/address these issues.
The Netherlands 2nd

September 2017

October 2017
Continue on current path or sustainable innovation?

Continuation

More, more, more
New modes of action
Same system?

Transition to IWM

IWM

A systems approach

Diverse cropping systems (in space and time)
Cultivar choice & Establishment
Targeted control
Field/soil management
Monitoring & evaluation

WAGENINGEN UR
For quality of life
Challenges & Solutions

- 1 problem, 1 solution \(\rightarrow\) system approach
- Reactive \(\leftrightarrow\) pro-active: prevention
- Biodiversity poor \(\leftrightarrow\) biodiversity rich
- Ecology meets technology meets agronomy
Agro ecology with high tech support
Integrated Weed Management (IWM)

- focuses on the management of weed populations, extending the current growing system:
  - Reduction of seed rain;
  - Prevent establishment of weed seedlings;
  - Prevent seedlings to mature.
Transplanting
Sowing date
Seed rate
Cultivar choice
Spatial arrangement
Post-emergence herbicides
Mechanical weeding
Intercropping
Patch/band spraying
Biological control
Sowing depth
Nutrient placement
Seed vigour

Stale seedbeds
Timing and depth of cultivation
Cover crops
Pre-sowing herbicides
Pre-emergence herbicides
Allelopathic compounds
Flaming
Mulching (dead and living)
Field margin management
Clean seed

Mature plants
Reduce the impact of weeds on the crop
Prevent the establishment of weeds
Reduce seed return

Clean machinery
Stubble management
Weed seed collection & destruction
post-emergence herbicides
Crop destruction with herbicides
Hand weeding
Seed predation
Mowing
Flaming
Grazing

Seedlings
Seeds

IWMPRAISE
EU grant agreement № 727321
Five classes of IWM

- Diverse cropping systems (in space and time)
- Cultivar choice & establishment
- Field/soil management
- Targeted control
- Monitoring & evaluation
Five classes of IWM

- Diverse cropping systems (in space and time)
- Cultivar choice & establishment
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IWM
Experimental site: diversified systems

Proeftuin Agroecologie & Technologie
Agroecologische bouwstenen, ondersteund door technologie
Voor een toekomstbestendig, regeneratief landbouwsysteem.

Bouwstenen

- Landschapselementen & akkerranden
- Groenbemesters
- Organische stof aanvoer
- Stroketenteelt
- Robuuste rassen
- Gereduceerde grondbewerking
- Agroforestry
- Inzet van kleine, lichte machines
- Mengteelt
- Gezonde rotatie en bouwplan
- Vaste rijpaden systeem
- Vlinderbloemen (voor stikstofbinding)
- Slimme gewasbescherming, IPM 2.0
- Vogels, bestuivers & natuurlijke vijanden
- Beslissingsondersteuning & ICT
- Detectie & monitoring met sensoren

Agro-ecosysteem
integratie van agroecologische bouwstenen

In toenemende mate meer divers, weerbaar en regeneratief
Diversified systems in modern arable farming? Is that possible?

Temporal & Spatial

Strip cropping, Erf Almere: 40 ha
18 ha field trial on clay soil
Field experiment

- Temporal Crop diversification
- Varieties resistant or tolerant to pests and diseases, weed suppressive traits
- Biological, Green Control or reduced chemical control based on DSS
- Monitoring & Evaluation
- Flower strips

<table>
<thead>
<tr>
<th>4-jarig bouwplan</th>
<th>8-jarig bouwplan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aardappel</td>
<td>Aardappel</td>
</tr>
<tr>
<td>Uien</td>
<td>Uien</td>
</tr>
<tr>
<td>Suikerbiet</td>
<td>Suikerbiet</td>
</tr>
<tr>
<td>Graan</td>
<td>Graan</td>
</tr>
<tr>
<td>(Aardappel)</td>
<td>Aardappel</td>
</tr>
<tr>
<td>(Uien)</td>
<td>Gras-klaver</td>
</tr>
<tr>
<td>(Suikerbiet)</td>
<td>Kool</td>
</tr>
<tr>
<td>(Graan)</td>
<td>Peen</td>
</tr>
</tbody>
</table>
Start: 2018

Grote velden: 24 x 60 m

Total area ca 15 ha
10 ha netto field

Two management systems:

Integrated crop management (+) 
→ mechanical based weed management
reference (-) 
→ herbicide based treatment
- Crop Yields not significantly different in first year
- Weeds: not significantly different
- Higher costs for weed management (labour)
- Lower costs for disease control
Strip cropping, Erf Almere: 40 ha
Performance characterized by
Land Equivalent Ratio = sum of the relative yields

\[
\text{LER} = \frac{Y_1}{M_1} + \frac{Y_2}{M_2}
\]

\(Y_i\): yield crop \(i\) in intercrop
\(M_i\): yield crop \(i\) in sole crop

<table>
<thead>
<tr>
<th>Intercrop system</th>
<th>LER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat/maize</td>
<td>1.21-1.58</td>
</tr>
<tr>
<td>Wheat/soybean</td>
<td>1.23-1.26</td>
</tr>
<tr>
<td>Faba bean/maize</td>
<td>1.13-1.34</td>
</tr>
</tbody>
</table>

LER = land area that would be needed as sole crops to produce the same yield as a unit area of intercrop

Fang Gou, 2016
Crop diversity and CA increase population of soil dwellers

Shuang Xie, 2015. Master thesis WU-FSE

Tamburini et al 2015. , Journal of Applied Ecology 53(1):n/a-n/a ·
In strip lower *P. infestans* infection

Variety: Ditta
strip: 3m
Take home message:
1. Wider crop rotation leads to a strong reduction in weed seed bank density
2. Spatial diversity has positive effects on disease and pest incidence, effects on weed management unclear

(Liebman et al 2016.)
Five classes of IWM

- Diverse cropping systems (in space and time)
- Cultivar choice & establishment
- Monitoring & evaluation
- Targeted control
- Field/soil management
Cover Crops & weeds

1. Competition for light, water and space
2. Allelopathic effects

<table>
<thead>
<tr>
<th>Cover crop</th>
<th>Soil coverage</th>
<th>Cold tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tagetes</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Raphanus sativus</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Avena strigosa</td>
<td>10 (excellent)</td>
<td>5</td>
</tr>
</tbody>
</table>

Cultivar choice

For quality of life
Allelopathy

- Processes in which secondary metabolites are produced by plants, micro-organisms, and viruses that influence the growth of plants.
Cover Crops

- Two sources of allelochemical compounds:
  - Direct from (cover) crop residues
  - Indirect, produced by micro-organisms that grow on (cover) crop residues
Fases in the allelopathic proces:

1. Allelochemical compounds in the cover crop
2. Allelochemical compounds in the soil
3. Allelochemical compounds in the receptor plant (weed)
4. Effect of allelochemical compounds on the plant

(Kruidhof et al., 2007)
1. Allelochemical compounds in the cover crop

- Quantities vary between cover crop species
- Quantities are not stable during the growing season and vary with conditions and growth stage.
2. Allelochemical compounds in the soil

- Release of compounds:
  - Pre treatment of cover crop before soil incorporation
  - Brake down of cover crop residues after incorporation in the soil

- In the soil compounds are converted, transported, or bound to soil particles.

- This is influenced by:
  - Physical soil qualities
  - Chemical properties of the particles
  - Soil moisture and temperature
3. Allelochemical compounds in target plant

Uptake is determined by the distance of the compound to the root or the seed of the weed: good distribution in the soil is important.
4. Effect of allelochemical compounds on the weed

- Depends on:
  - Mode of action of the compound;
  - Possibility of the weed to brake down harmful compound;
  - Tolerance of the weed for the compounds;
  - Growth conditions
The use of cover crops

- In late summer and fall: prevent growth and seed production of weeds through competition

- In spring: residues can suppress or delay weed development.
Effect of cover crop on weed growth in fall and weed emergence in spring

- Soil: sandy, Organic matter: 4%.

<table>
<thead>
<tr>
<th>species</th>
<th>Sowing date</th>
<th>Sowing density (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>25 July</td>
<td>25</td>
</tr>
<tr>
<td>Lupine</td>
<td>24 July</td>
<td>160</td>
</tr>
<tr>
<td>Brassica napus</td>
<td>25 July</td>
<td>7</td>
</tr>
<tr>
<td>Raphanus sativus</td>
<td>25 July</td>
<td>15</td>
</tr>
<tr>
<td>Winter rye</td>
<td>25 July</td>
<td>150</td>
</tr>
<tr>
<td>Italian ryegrass</td>
<td>24 July</td>
<td>30</td>
</tr>
</tbody>
</table>

Incorporation of cover crops on March 31st.

Kruidhof et al 2007
Late summer and fall

Big differences in weed suppressive ability of cover crops

<table>
<thead>
<tr>
<th></th>
<th>T50</th>
<th>Dry weight weeds (g/plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winterhardy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winterrye</td>
<td>33</td>
<td>0.80</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>46</td>
<td>4.12</td>
</tr>
<tr>
<td>Brassica napus</td>
<td>28</td>
<td>0.22</td>
</tr>
<tr>
<td>Not winterhardy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Italian rye</td>
<td>50</td>
<td>2.54</td>
</tr>
<tr>
<td>White lupine</td>
<td>53</td>
<td>2.32</td>
</tr>
<tr>
<td>Brassica napus</td>
<td>27</td>
<td>0.27</td>
</tr>
</tbody>
</table>

T50= number of days until 50% soil coverage

Kruidhof et al 2007
- Dominant weeds: *Chenopodium album*
- Alfalfa had the strongest effect in spring, followed by Brassica napus and Lupine
- Winterrye and Raphanus did not suppress weed emergence in spring
Take home message:
Cultivar choice is relevant for
a) weed suppression and competition, look for soil coverage, early growth, winterhardy crops;
b) Use the allelopathic effects of crop residues. Best effect of incorporation just before rain
Five classes of IWM

- Diverse cropping systems (in space and time)
- Cultivar choice & establishment
- Targeted control
- Field/soil management
- Monitoring & evaluation
Cultivation

Field/soil management
Experience with tillage types in arable cropping system

Plough

Strip cultivation

‘Direct Sow

Start: 2009, maize based system

Experiences with soil cultivation effects on weed management

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Main cultivation</td>
</tr>
<tr>
<td>A</td>
<td>Plough Spring 25 cm</td>
</tr>
<tr>
<td>C</td>
<td>Deep tine cultivation</td>
</tr>
<tr>
<td>D</td>
<td>Strip rotary cultivation</td>
</tr>
<tr>
<td>E</td>
<td>Deep tine cultivation</td>
</tr>
<tr>
<td>I</td>
<td>Weed control</td>
</tr>
<tr>
<td>II</td>
<td>Conventional</td>
</tr>
<tr>
<td></td>
<td>Mechanical</td>
</tr>
</tbody>
</table>

- **Sowing bed preparation**
- **rotary harrow**
- **Conventional sowing**
- **rotary cultivator**
- **Conventional sowing**
- **Strip rotary cultivation**
- **Strip rotary cultivation**
- **Direct sowing**
- **None (direct sowing)**

For quality of life
Results

Seed bank in spring 2018

A: plough + rotary harrow seed bed,

C: Deep tine cultivation + rotary

D: Strip Rotary cultivation + strip rotary seed bed,

E: Deep tine cultivation + direct sow.

Treatment I: conventional herbicidal based weed control, Treatment II: mechanical weed control.
Trials with stale seedbed

- **Crop:** Lettuce
- **3 fields at** experimental farm

<table>
<thead>
<tr>
<th>eigenschap</th>
<th>jaar</th>
</tr>
</thead>
<tbody>
<tr>
<td>% klei</td>
<td>1</td>
</tr>
<tr>
<td>% organische stof</td>
<td>2</td>
</tr>
<tr>
<td>voorvrucht</td>
<td>Winter tarwe</td>
</tr>
<tr>
<td>plantdatum</td>
<td>June 15</td>
</tr>
<tr>
<td>oogstdatum</td>
<td>July 26</td>
</tr>
<tr>
<td>Afstand in de rij (cm)</td>
<td>35</td>
</tr>
<tr>
<td>Afstand tussen de rij (cm)</td>
<td>37</td>
</tr>
<tr>
<td>veldgrootte (m)</td>
<td>154 x 20</td>
</tr>
</tbody>
</table>

Riemens et al 2007
## Treatments

<table>
<thead>
<tr>
<th>treatment</th>
<th>Stale seedbed</th>
<th>Seedbed prep</th>
<th>Weed control before planting</th>
<th>Weed control after planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>Rotary harrow</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>Rotary harrow</td>
<td>chemical</td>
<td>torsionweeder</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
<td>Rotary harrow</td>
<td>-</td>
<td>fingerweeder</td>
</tr>
<tr>
<td>D</td>
<td>-</td>
<td>Rotary harrow</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>E</td>
<td>-</td>
<td>Rotary harrow</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>4 weeks, rotary harrow</td>
<td>-</td>
<td>chemical</td>
<td>-</td>
</tr>
<tr>
<td>G</td>
<td>4 weeks, rotary harrow</td>
<td>-</td>
<td>Rotary harrow</td>
<td>-</td>
</tr>
<tr>
<td>H</td>
<td>4 weeks, rotary harrow</td>
<td>-</td>
<td>Covered harrow</td>
<td>-</td>
</tr>
<tr>
<td>I</td>
<td>4 weeks, rotary harrow</td>
<td>-</td>
<td>Covered harrow</td>
<td>Far red light</td>
</tr>
<tr>
<td>J</td>
<td>-</td>
<td>Covered harrow</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>treatment</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>59.3</td>
<td>70.5</td>
<td>68.9</td>
</tr>
<tr>
<td>C</td>
<td>95.5</td>
<td>96.4</td>
<td>N.T.</td>
</tr>
<tr>
<td>D</td>
<td>98.7</td>
<td>99.2</td>
<td>N.T.</td>
</tr>
<tr>
<td>E</td>
<td>88.4</td>
<td>92.6</td>
<td>N.T.</td>
</tr>
<tr>
<td>F</td>
<td>69.2</td>
<td>67.5</td>
<td>74</td>
</tr>
<tr>
<td>G</td>
<td>43.2</td>
<td>59.9</td>
<td>70.7</td>
</tr>
<tr>
<td>H</td>
<td>73.7</td>
<td>71.1</td>
<td>80.2</td>
</tr>
<tr>
<td>I</td>
<td>N.T.</td>
<td>71.1</td>
<td>82.8</td>
</tr>
<tr>
<td>J</td>
<td>N.T.</td>
<td>63.1</td>
<td>61.5</td>
</tr>
</tbody>
</table>

- A: control
- B: herbicide
- C: torsionweeder
- D: fingerweeder
- E: hoe
- F: herbicide
- G: rotary harrow
- H: covered harrow
- I: covered harrow + far red light
- J: covered harrow

**Without stale seedbed**

- Mechanical control before planting
- Mechanical control after planting

**Stale zaai bed behandelingen**

- Mechanical control after planting
- Mechanical control before planting
Take home message

- Inversion tillage valuable basis for weed management
- Stale seed bed reduces weed growth during crop growth - 43 tot 83%
- Mechanical control of weeds emerging after stale seedbed treatment causes new flushes → better to use non soil disturbing tools (eg flame weeder)
- Mechanical control with fingerweeder, torsionweeder and harrow reduced weed pressure with 88 to 99% relative to control.
From full field control to control on the spot

"That's your idea of weed control?"
Full field; Harrow

- Non selective
- Small seedlings

Application:
- Between sowing and crop emergence
- Firmly rooted crop
Interrow; Hoe

- Every cm closer to the crop row ways out a reduction in driving speed.

- Application possibilities
  - Vertually unlimited
  - Combined with ridges
Intrarow: Torsionweeder
Fingerweeders
More precision with guidance systems

- Physical guidance
  - Rosko
- Optical
  - Robocrop Garford
  - Steketee IC Weeder
  - Auto-pilot Kress
Mechanical: Rosko

- Based on physical guidance from the crop
- Cheap
- Engineered for maize, but several applications possible
- Based on high speed
Optical systems

- Robocrop
Roterende schoffel
Steketee IC weedmachine

Cameras view the crop from above

Camera is activated with a support wheel mounted to the machine

Special software “traces” the plants

- Colour algorithm (Excessive Green)
- $2 \times G - R - B$
- Binar image
How does the software works?

Practical problem: weeds are also “plant pixels”

However: Location/pattern of weeds deviates

Solution: Detect the consistency of the seed pattern

Method: Fast-Fourier Transformation (patent Wageningen UR)
Intelligent intra-row weeding
Robovator Poulsen in lettuce

www.visionweeding.com
Intrarow flame weeding
Broadleaf weeds in grassland

- Robot Ruud: dock in grassland

www.ruud.wur.nl
Plant level, on-the-go, autonomous
IWM
Diverse cropping systems (in space and time)

Cultivar choice & establishment
Field/soil management
Targeted control
Monitoring & evaluation

Seed vigour
Spatial arrangement

Inter cropping
Rotation
Mulching alive
Field margin management

Reducing impact of weeds on crop
Reduce seed return
Prevent establishment
Supportive tactics

COMPLEX & KNOWLEDGE INTENSIVE

www.IWMPRAISE.EU
Vision provides new possibilities for DSS

- Weed recognition and image processing

- Calculation of in-field weed pressure & mapping

www.akkerweb.nl: platform for farmers, also in English
Farmers are the key: success of IWM in practice

What's going on here?

What can I do?

What should I do?

What's going on here?

What would I like to do?

Weather
Soil
Crop
Weed
Biophysical
Economic
Technological
Financial
Cost-benefit
Time investment
Efficacy
World view
Technological means
Regulations
Individual
Public perception
Socio-cultural
Experience
Flexibility
IWMPIRAISE partners

www.iwmpraise.eu
Physical and Cultural Weed Control - European Network

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Thanks are due to Rommie van der Weide, Hilfred Huiting, Pieter Blok, Frits van Evert, Dirk van Apeldoorn, Leendert Molendijk, Corne Kempenaar, Paula Westerman, Mout de Vrieze, Huub Schepers, Fogelina Cuperus, Wijnand Sukkel, Bram Veldhuisen, Johnny Visser