Agroecology for IPM (I)

Weed Management

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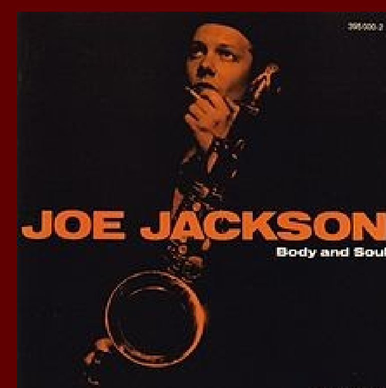
Lecture outline

- The importance of weed management in the context of IPM (and organic agriculture)
- Integrated Weed Management System (IWMS): the agroecological approach to weed management
- A snapshot on weed biology, ecology and community dynamics: essential knowledge for IWM
- A snapshot on preventive, cultural and direct methods
- Case study on system approach to IWM
- Going wider: weed/insect functional interactions and habitat diversity

'You can't get what you want (till you know what you want)'

Joe Jackson (Body and Soul, A&M Records, 1984)



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An *ante-litteram* definition of system approach

Then, in natural sciences, is the composite thing, the thing as a whole that mainly interests us, and not its components, that cannot be taken aside from the thing itself

Aristotles

(after Altieri, 1995)

The theoretical framework

Deep knowledge
of agro-ecosystem
structure and components

System approach

Agroecology
Sustainable agriculture
True IPM

DIVERSIFICATION

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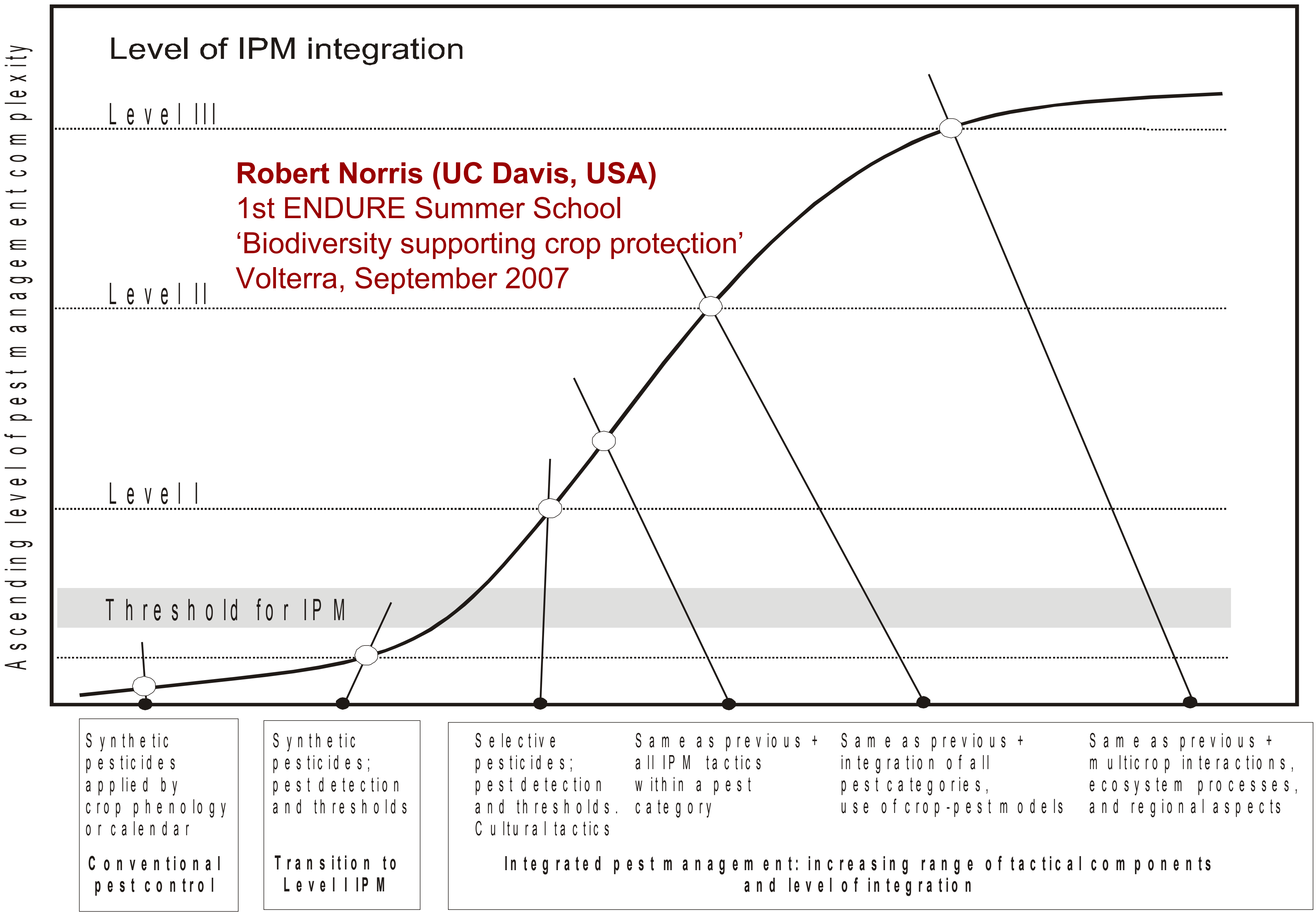
Level of IPM integration
Ascending level of pest management complexity
Level III
Level II
Level I
Threshold for IPM
Robert Norris (UC Davis, USA)
1st ENDURE Summer School
'Biodiversity supporting crop protection'
Volterra, September 2007
Synthetic pesticides applied by crop phenology or calendar
Conventional pest control
Synthetic pesticides; pest detection and thresholds
Transition to Level I IPM
Selective pesticides; pest detection and thresholds. Cultural tactics
Same as previous + all IPM tactics within a pest category
Same as previous + integration of all pest categories, use of crop-pest models
Same as previous + multicrop interactions, ecosystem processes, and regional aspects
Integrated pest management: increasing range of tactical components and level of integration

The importance of weed management in agricultural crops

Fruit crops ☹

Leys and pastures ☹ ☹

Field crops ☹ ☹ ☹

Vegetable and medicinal crops ☹ ☹ ☹ ☹

Integrated Weed Management (IWM)

- A **strategy** to maintain weed abundance below a ‘threshold’ of acceptable damage through the integration of **preventive, cultural, genetic, mechanical, biological and chemical tactics** (control means)

Shaw, 1982

Walker & Buchanan, 1982

Regnier & Janke, 1990

(modified)

Theoretical basis of IWM

- None of the **tactics** *per se* can provide adequate weed control
- Systemic approach (**Integrated Weed Management System - IWMS**): the **cropping system** defines the spatial and temporal framework of an IWM strategy
- An IWMS is not aimed to obtain outstanding weed control in the short term but **constant good weed control in the long-term**

Theoretical basis of IWM

- An IWM **strategy** is composed of several **tactics** to:
  - Reduce on-field weed emergence by acting before the onset of the crop growing season (***preventive weed management***)
  - Increase crop competitive ability against weeds (***cultural weed management***)
  - Eliminate weeds emerging during the crop growing season (***direct weed management***)
  - Terminology: Management *vs* Control

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Tactics usable in an IWM strategy

1. PREVENTIVE

2. CULTURAL

3. DIRECT

Tactics usable in an IWM strategy

Tactic	Category	Main effect	Example	Applicability to fruit tree crops
Crop rotation	Preventive	Reduction of weed emergence	-	No
Soil tillage	Preventive + direct	Reduction of weed emergence + weed destruction	Ploughing, discing, hoeing, cultivation	Yes
Cover crops	Preventive + cultural	Reduction of weed emergence and/or competition	Green manuring prior to orchard planting, between-rows living mulch	Yes
Mulching	Preventive + cultural	Reduction of weed emergence and/or competition	In-row plastic mulches	Yes
Flame-weeding	Preventive + direct	Reduction of weed emergence + weed destruction	Use of shielded LPG-propelled burners	Yes (scarce)
Soil solarisation	Preventive	Reduction of weed emergence	Use before orchard planting	Yes (scarce)
Genotype choice	Cultural	Reduced weed competition	Use of stress-tolerant cvs (e.g. higher ability to take up soil water and nutrients)	Yes
Planting pattern	Cultural	Reduced weed competition	Reduced between-rows or in-row distance	Yes (scarce)
Fertilisation	Cultural	Reduced weed competition	Localised (in-row) application of fertilisers	Yes
Irrigation	Cultural	Reduced weed competition	Trickle/drip irrigation	Yes

Weed biology and ecology

- Knowledge of the basic biological and ecological features of **major weeds** and of **weed communities** is an **essential** prerequisite for designing any sustainable weed management strategy

- The more we want to reduce reliance on pesticides, the more we need to surrogate them with biological and ecological knowledge

Cousens & Mortimer (1995)

Weed **ecophysiological groups** and **false seedbed technique**

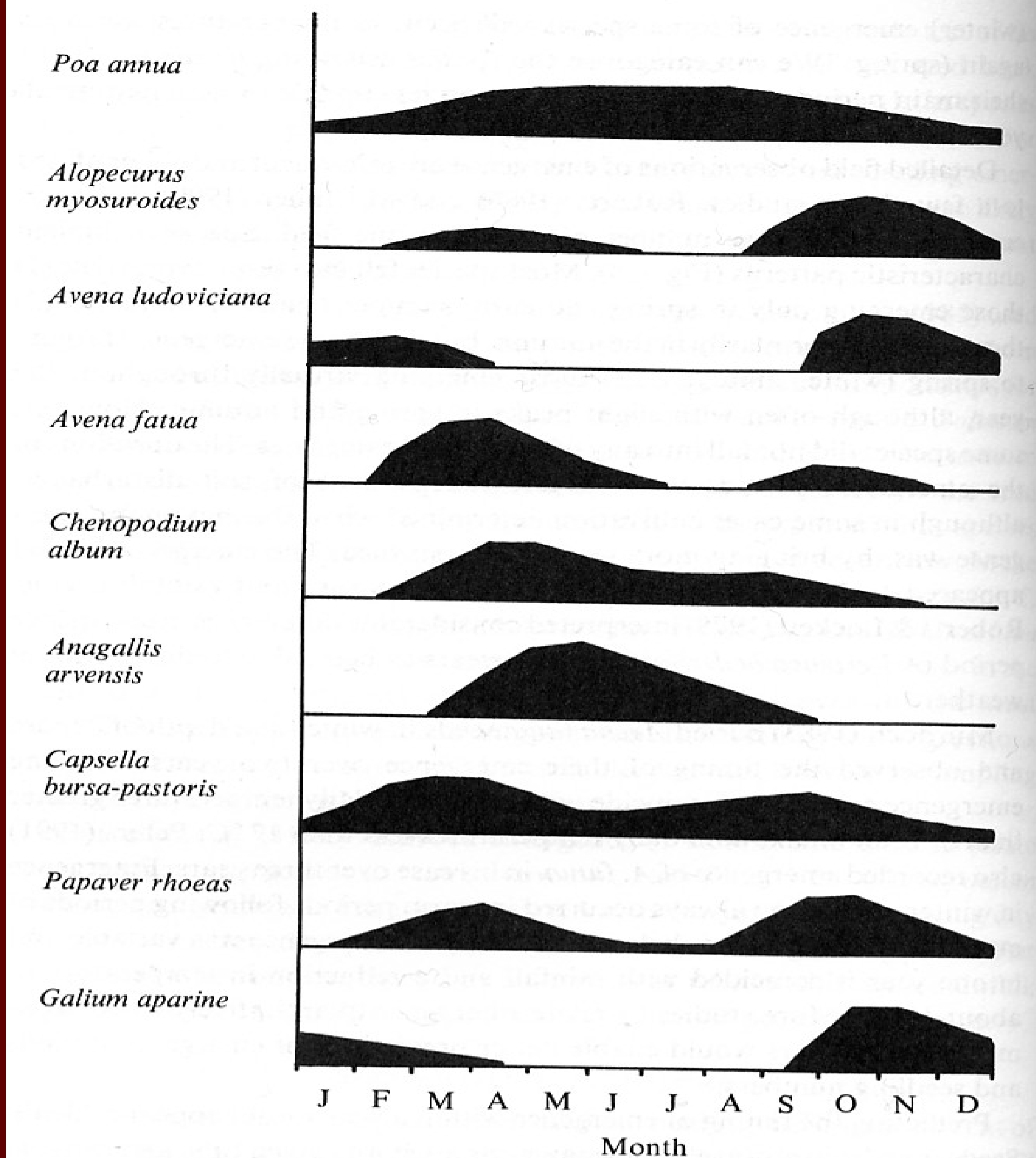
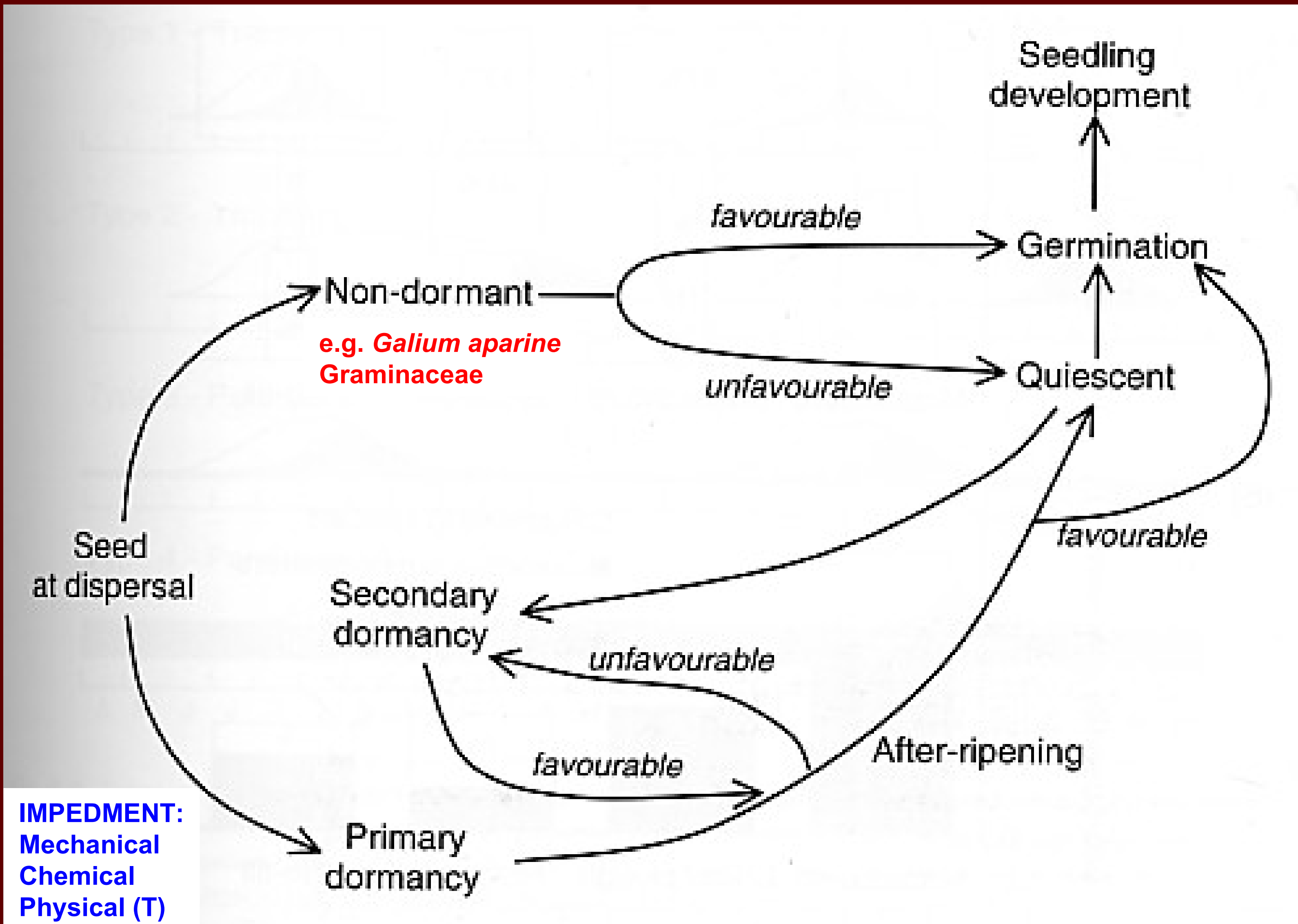


Fig. 4.8. Emergence periods of a range of temperate arable annual weeds in the UK (after Mortimer, 1990). The height of the shaded area indicates the relative frequency of emergence.

Seed dormancy cycle



Foley (2001)

Weed seeds: production

• Number of seeds **per plant** produced with lack of competition		No. viable seeds remaining with 95% control
Avena fatua	500	25
Stellaria media	2,400	120
Papaver rhoeas	17,000	850
Solanum nigrum	178,000	8,900
Amaranthus retroflexus	196,000	9,800

Speranza & Catizone (2001, modified)

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Weed seeds: germination

- Optimum and maximum depth for weed seedling emergence (cm)

	Optimum	Maximum
Chenopodium album	0.5-1	5
Digitaria sanguinalis	1	4
Sinapis arvensis	1	6
Setaria viridis	2.5	7.5
Avena fatua	2.5	17.5

King (1966, modified)

Germination cues, surface residues and landscape position

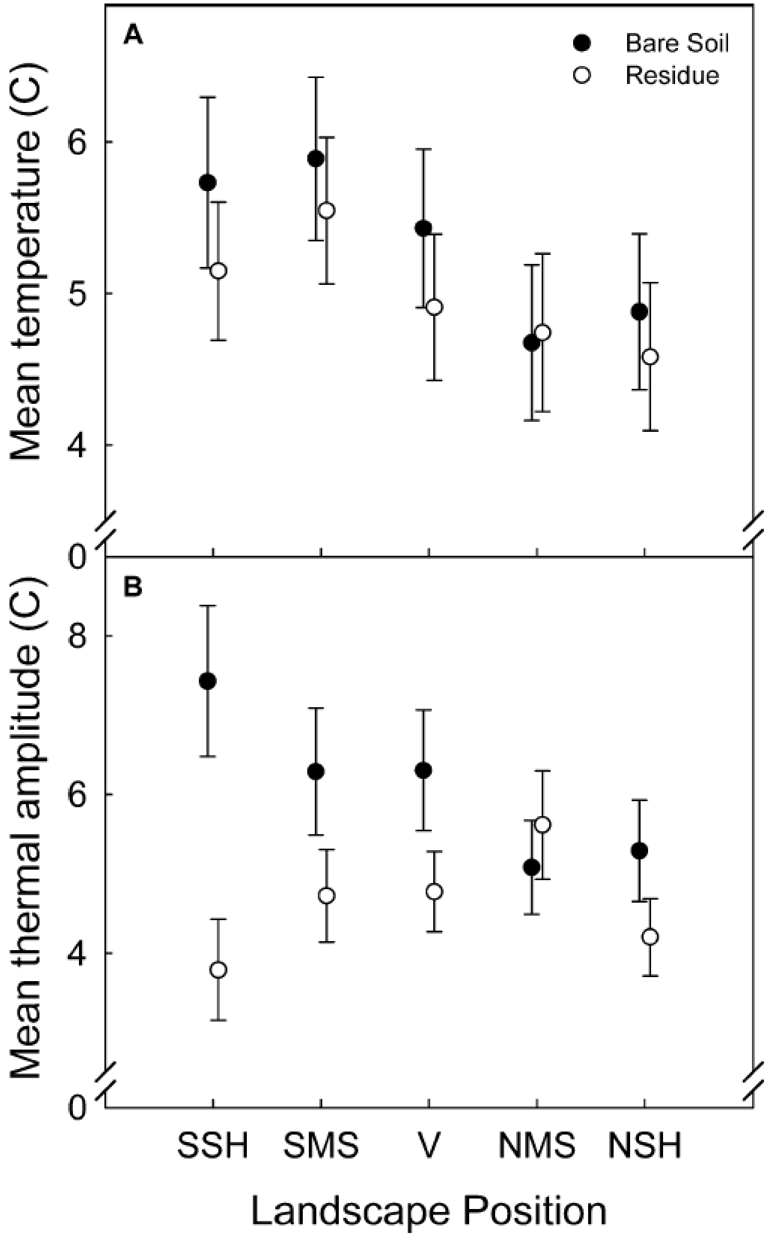

FIGURE 4. (A) Mean soil temperature and (B) thermal amplitude (± SE) in March 2003 from two residue levels, at five landscape positions: south shoulder (SSH), south midslope (SMS), valley (V), north midslope (NMS), and north shoulder (NSH). Thermal amplitude was calculated by subtracting the daily minimum temperature from the daily maximum temperature and averaging across days.

Page et al. (2006)
Weed Sci. 54 (5), 838-846

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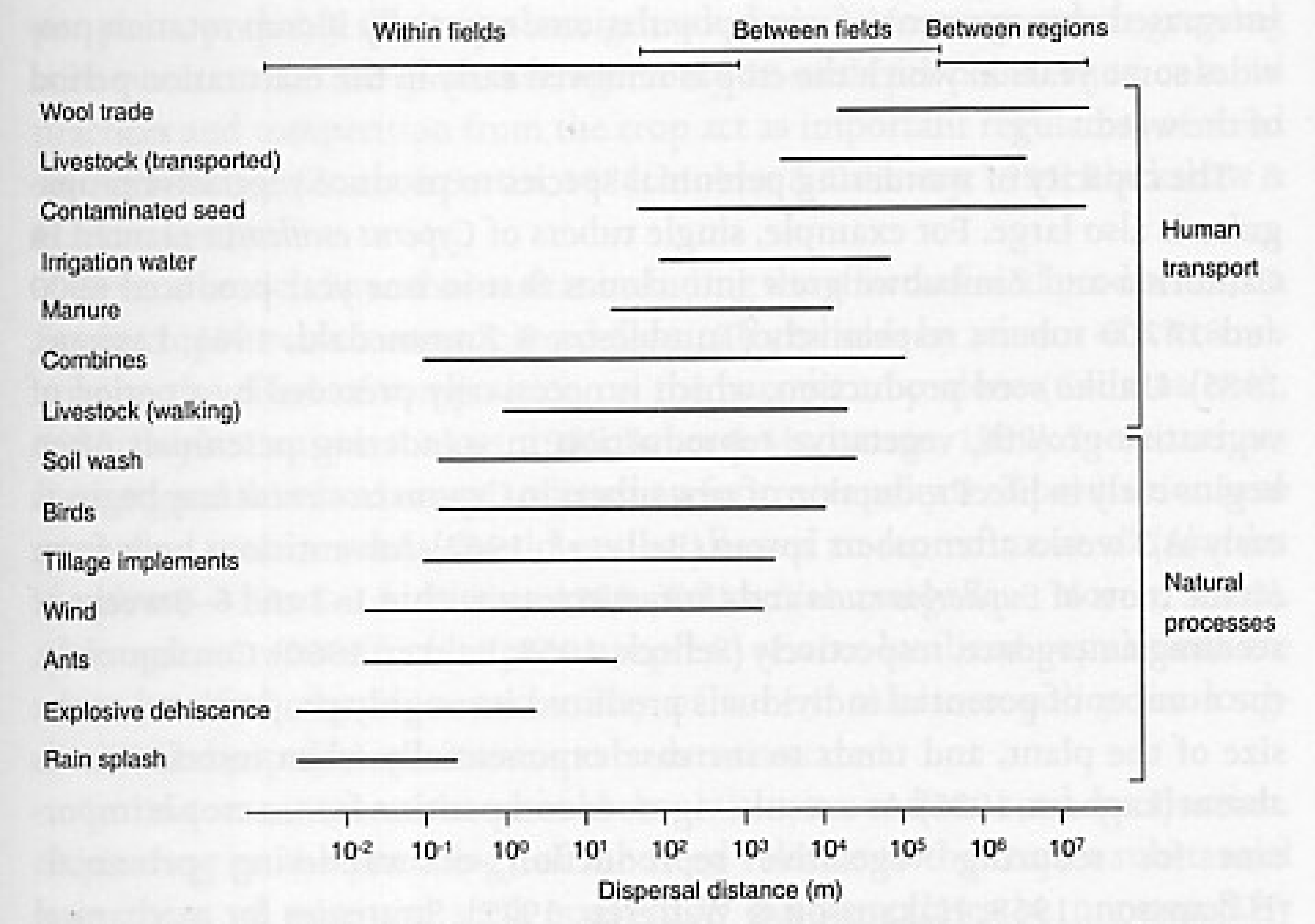
Weed seeds: germination cues

Factor	Species	+Factor (%)[a,b]	−Factor (%)[a,b]
Light	*Alopecurus myosuroides*	86	0
	Amaranthus retroflexus	98	14
	Brassica arvensis	78	53
	Datura ferox	96	1
	Lolium multiflorum	95	82
	Poa annua	89	1
	Portulaca oleracea	28	12
Alternating temperature	*Poa annua*	92	47
	Rumex crispus	100	0
	Sonchus arvensis	57	3
	Sorghum halepense	20	7
	Stellaria media	93	47
Nitrate	*Chenopodium album*	92	55
	Erysimum cheiranthoides	89	57
	Plantago lanceolata	48	25
	Plantago major	93	3

Mohler (2001), modified

Weed seeds: dispersion



Mohler (2001)

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RGR: Relative Growth Ratio

plant weight increase/plant weight/day

SLA: Specific Leaf Area

leaf area/leaf weight

RWR: Root Weight Ratio

root weight/plant weight

Weeds early growth

RLI: Root Length Increase

root length increase/root length/day

- Seed size and growth parameters (first 28 DAE)

SPECIES	Seed weight (mg)	RGR (g/g/d)	SLA (cm^2/g)	RWR (g/g)	Root diam. (mm)	RLI (cm/cm/d)
A. retroflexus	0.41	0.349	326	0.189	0.22	0.343
C. album	0.44	0.335	329	0.153	0.20	0.285
A. theophrasti	7.8	0.244	326	0.214	0.46	0.274
X. strumarium	38	0.187	237	0.217	0.35	0.227
Sunflower	61	0.197	276	0.272	0.42	0.227
Soyabean	158	0.155	242	0.241	0.64	0.201
Correlation with ln (seed weight)		-0.99**	-0.86*	0.86*	0.86*	-0.93**

Seibert & Pearce (1993), modified

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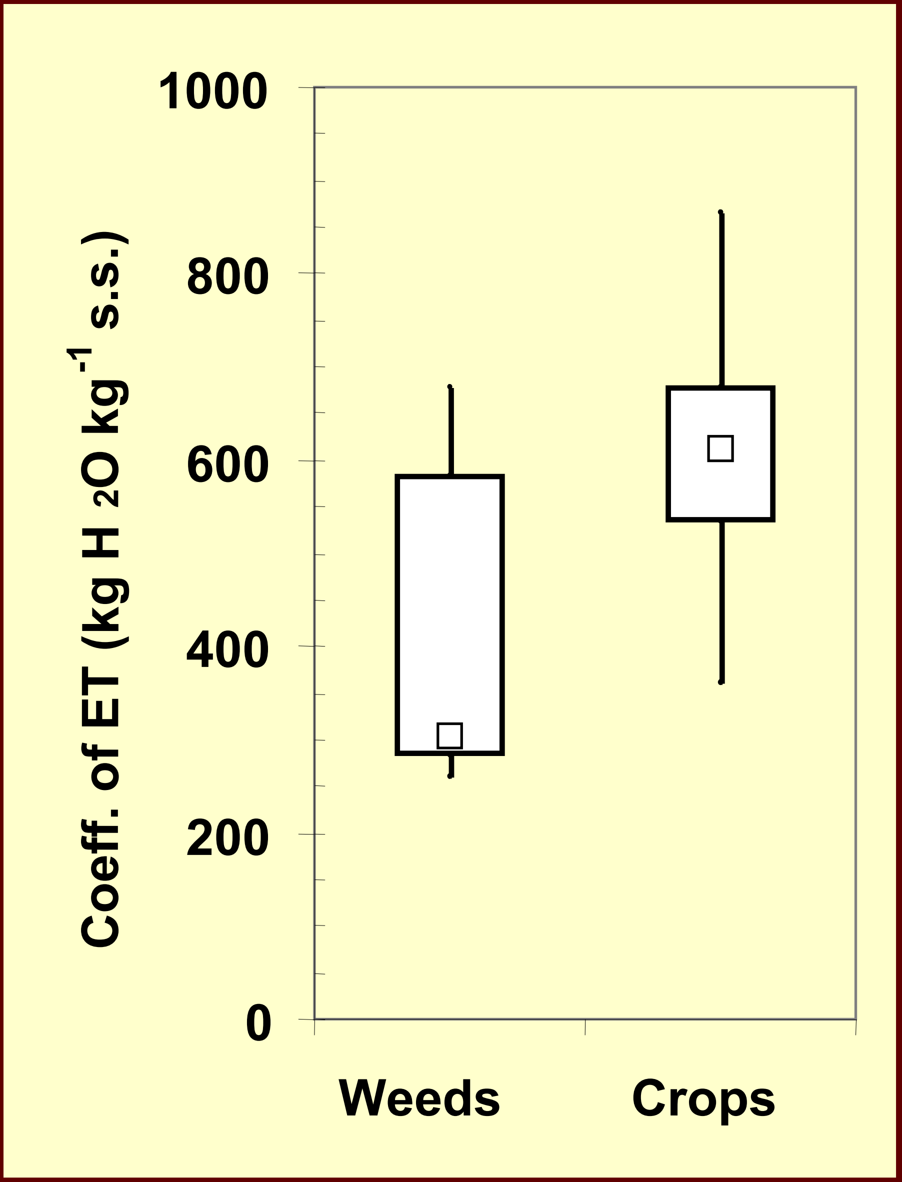
Coefficient of evapotranspiration

Weeds	*Amaranthus graecizans*	260
	Amaranthus retroflexus	305
	Avena spp.	583
	Chenopodium album	658
	Panicum miliaceum	267
	Polygonum aviculare	678
	Portulaca oleracea	281
	Setaria italica	285
	Sorghum spp.	304

Kale	518	Crops
Sweet pepper	865	
Melon	686	
Watermelon	577	
Soyabean	646	
Tomato	645	
Common bean	700	
Potato	575	
Common wheat	500	
Maize	361	



Perennial weeds

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Perennial weeds

- They possess organs for vegetative reproduction
- Simple (stationary) perennials
  - *Plantago* spp. (plantains)
  - *Rumex crispus* (curly dock)
  - *Taraxacum officinale* (dandelion)
- Creeping (dynamic) perennials
  - *Cirsium arvense* (thistle)
  - *Convolvulus arvensis/Calystegia sepium* (bindweeds)
  - *Cynodon dactylon* (bermudagrass)
  - *Sorghum halepense* (johnsongrass)

Tactics usable in an IWM strategy

1. <u>PREVENTIVE</u>

2. CULTURAL

3. DIRECT

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IWM: Component #1
Preventive weed management

- *Aim*: to reduce density of **actual weed vegetation**
- *Mean*: exhaustion of **potential weed vegetation**:

1. Reduce in-crop weed emergence
2. Reduce weed seeds dispersal (*seed rain*)

- *Necessary knowledge*
  - Weed community composition
  - Ecophysiology of weed seeds germination
  - Mechanisms of weed colonisation in a cropped field
  - Mechanisms of weed reproduction and survival
- *Practical applications*
  - Crop rotation, soil tillage, false seedbed technique, cover crops and mulching, soil solarisation

IWM: Component #1
Preventive weed management

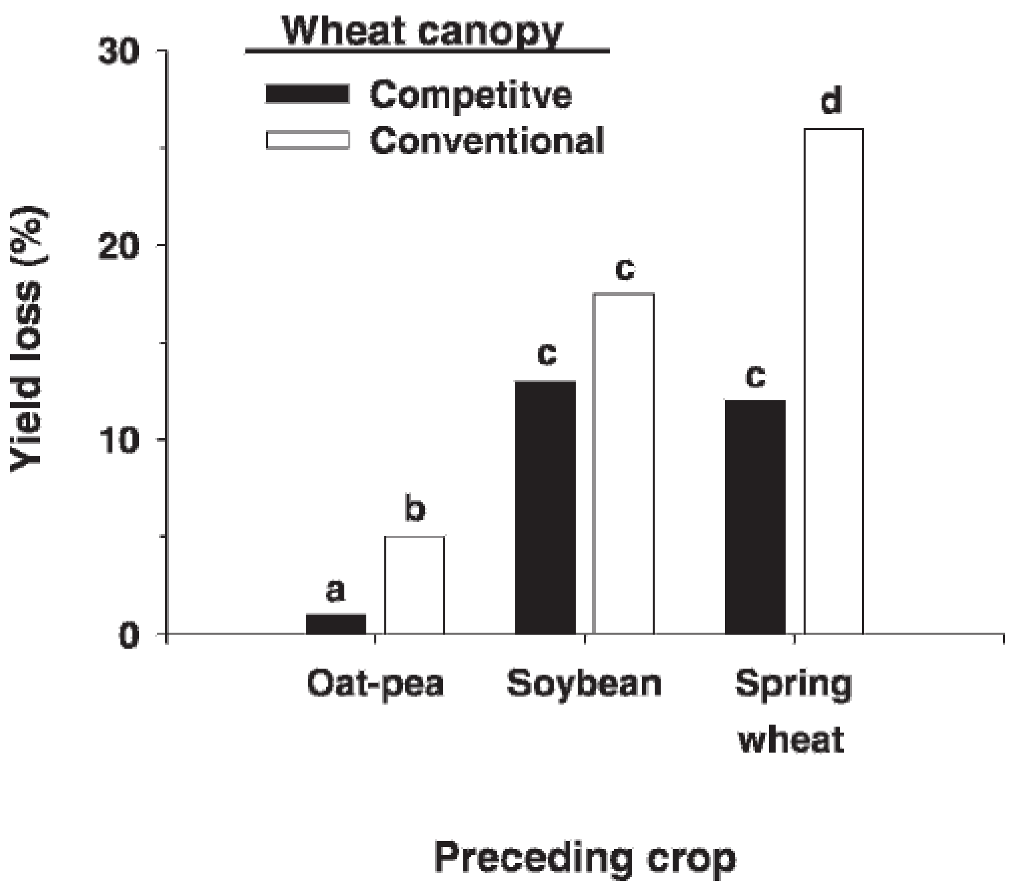

Figure 1. Yield loss in winter wheat due to rye interference, as affected by preceding crop and canopy treatment in winter wheat. Data pooled across years. Bars with identical letters are not significantly different as determined by Fisher's Protected LSD (0.05).

Anderson (2009). Weed Tech. 23, 564-568

Competitive = 67% increase in seeding rate + banded seed fertilisation

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Cover crops

Mechanisms of weed suppression by cover crops

- **Resource competition**
  - light, water, nutrients, space
- **Release of phytotoxins (allelochemicals)**
  - from live plants
  - from residue decomposition
- **Alteration of soil physical conditions**
  - reduction of soil temperature amplitude
  - conservation of soil moisture
  - reduction of quantity and quality of transmitted radiation

Cover crops

Effect on weed seedbank (seedlings m^{-2})

Cover type	CS	LIS	Mean
Crimson clover	5809 (9%)	29806 (6%)	13152 ab (7%)
Rye	4835 (24%)	31089 (2%)	12274 ab (14%)
Subterranean clover	5208 (18%)	23605 (26%)	11092 a (22%)
Crop stubble	6365	31688	14191 b

Moonen & Bàrberi (2004), modified

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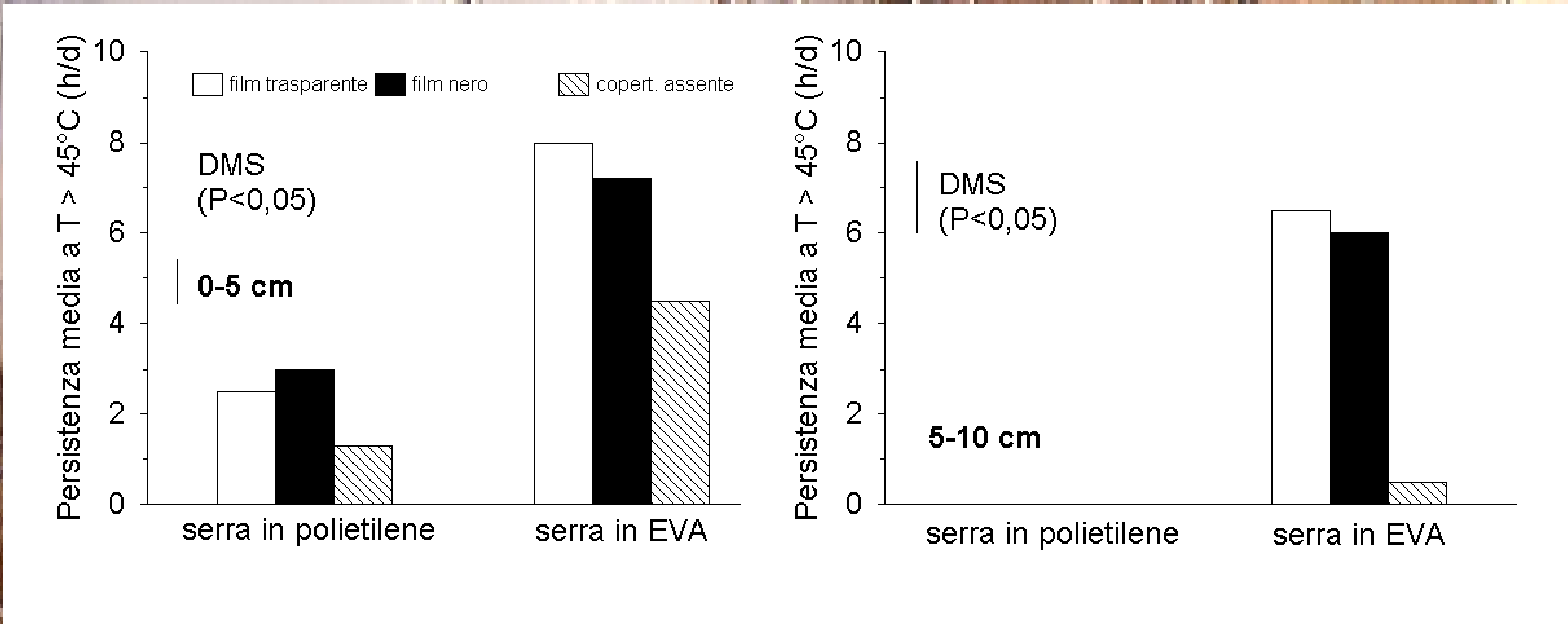
Soil solarisation

Weed biomass at harvest (g m^{-2})

Crop	Soil cover type		
	Transparent PE film	Black PE film	No cover
Lettuce (13 WAS)	0.1 b	0.1 b	2.7 a
Radish (24 WAS)	0.3 b	0.4 b	21.5 a
Rocket (25 WAS)	0.4 b	2.0 b	46.9 a
Tomato (46 WAS)	82.7 b	72.2 b	146.0 a

Bàrberi & Moonen (2002)

Soil solarisation
Persistence of high T at two soil depths



Temperini *et al.* (1998)

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Tactics usable in an IWM strategy

1. PREVENTIVE

2. CULTURAL

3. DIRECT

IWM: Component #2
Cultural weed management

- *Aim*: to reduce the need for use of **direct** weed control methods (e.g. herbicides) and increase their effectiveness
- *Mean*: choose **cultural practices** as to **increase crop competitive ability** against weeds
- *Necessary knowledge*
  - Crop/weed competitive relationships
  - Crop/weed biology and ecophysiology
  - **Critical period** for crop/weed competition
- *Practical applications*
  - Crop genotype choice, planting pattern, polycultural systems, localised fertilisation/irrigation

Crop genotype choice

- More competitive cvs. are characterised by:
  - higher height (not in all species)
  - higher attitude to tillering/branching
  - faster development (e.g. emergence)
  - higher CGR at earlier stages
- Fixation of higher crop *competitive ability* traits via genetic improvement?
- *Competitive ability* and *productivity* are often uncorrelated traits

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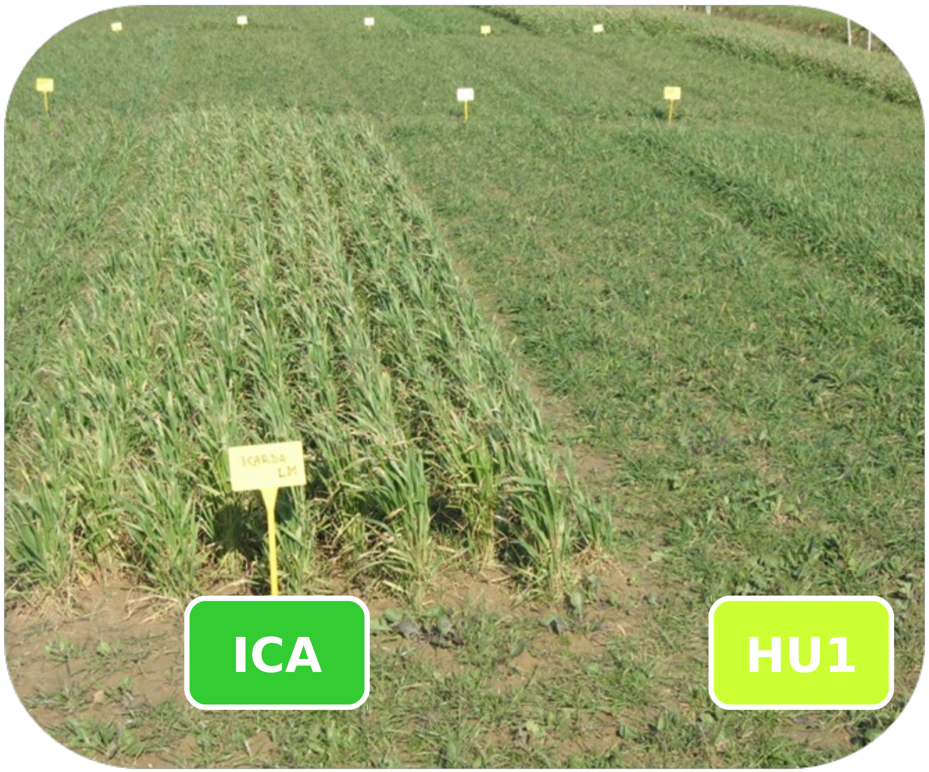
Crop genotype choice

Common wheat: height

Early differences: growth habit



Late differences: straw height

Competitive varieties

Competitive Balance Index (C_b) in potato and chickpea varieties

Crop	Variety	% yield loss	C_b
Potato	Desiré (L)	2.6	2.88
"	Kuroda (L)	3.6	2.76
"	Agata (E)	9.4	1.34
Chickpea	C136	67.2	-0.62
"	C118	97.9	-2.00

Competitive Balance Index (Wilson, 1988)

$C_b = \log (B_{cw}/B_c)/(B_{wc}/B_w)$

Mirabelli et al. (2003)

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Sowing/transplanting technique

- Increase the time interval between crop and weed emergence
- Increase the crop/weed density ratio (*sowing method/time/rate*)
  - Risk: sub-optimum yields
- Transplanting (e.g. vegetable crops)
- Crop spatial arrangement

Polycultural systems

- Increase soil cover with vegetation in both space and time

↓

- Exploitation of free ecological niches by useful species
- Need to have resource use complementarity between polyculture components in both space and time
- Examples: living mulches, intercropping, mixed farming systems

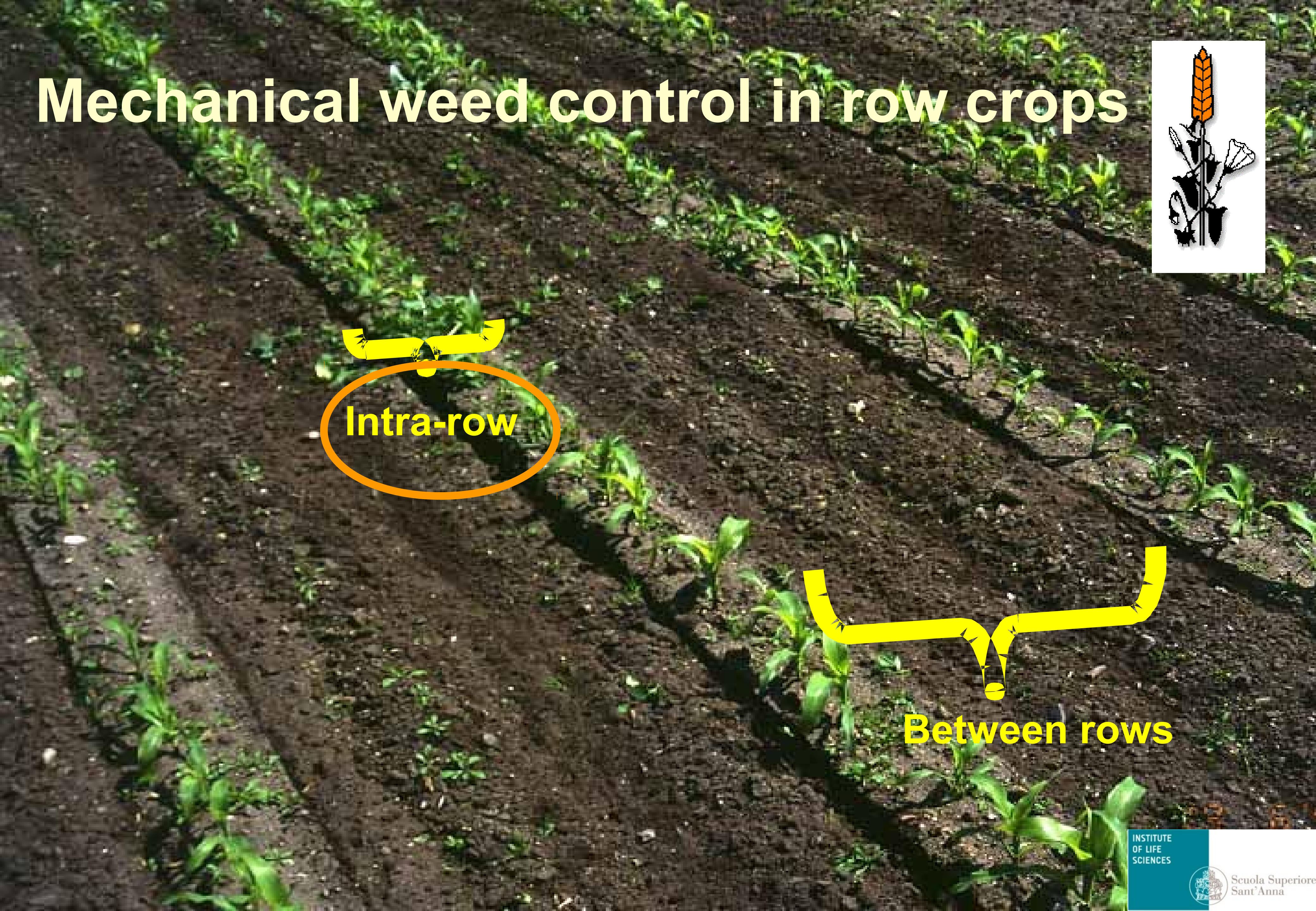
Tactics usable in an IWM strategy

1. PREVENTIVE

2. CULTURAL

3. DIRECT

Mechanical weed control in row crops



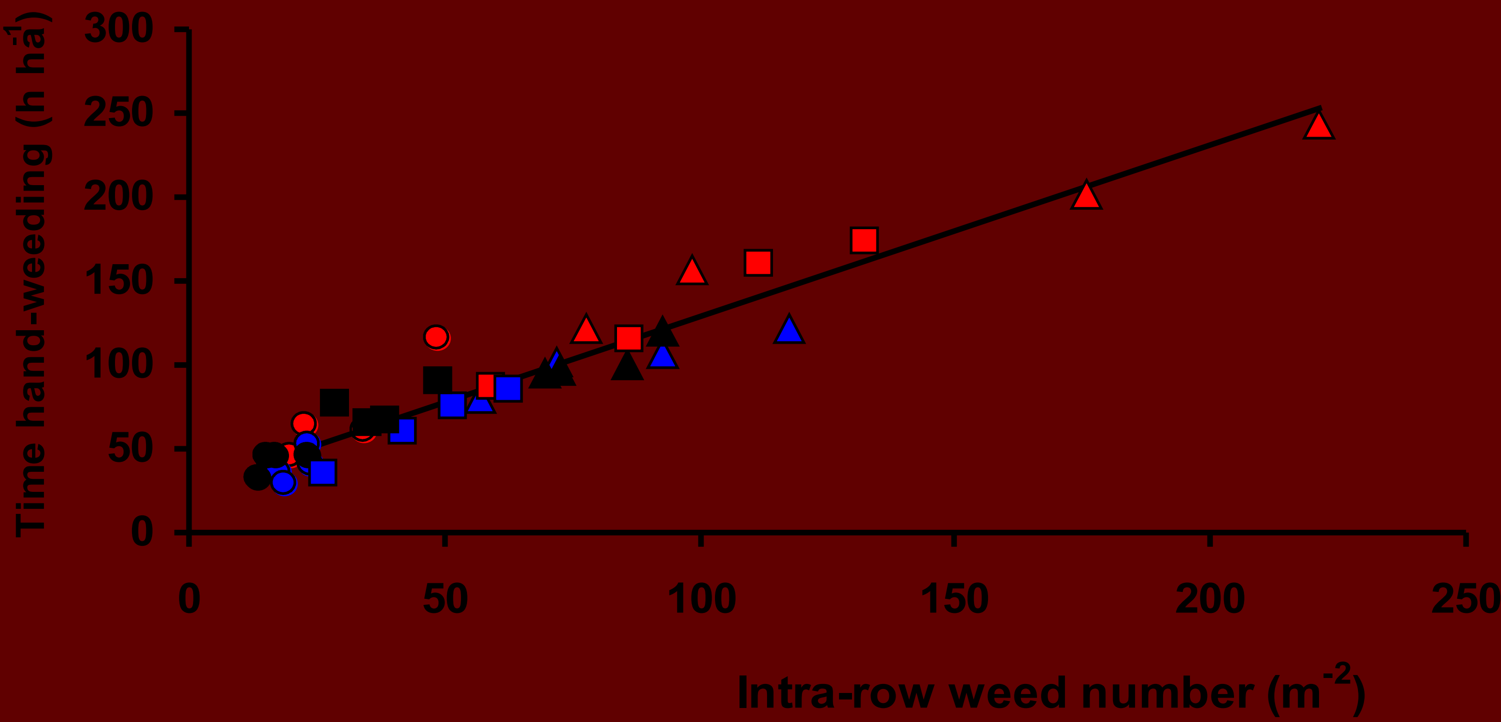
Bed-weeding platform

Time needed for intra-row hand-weeding:

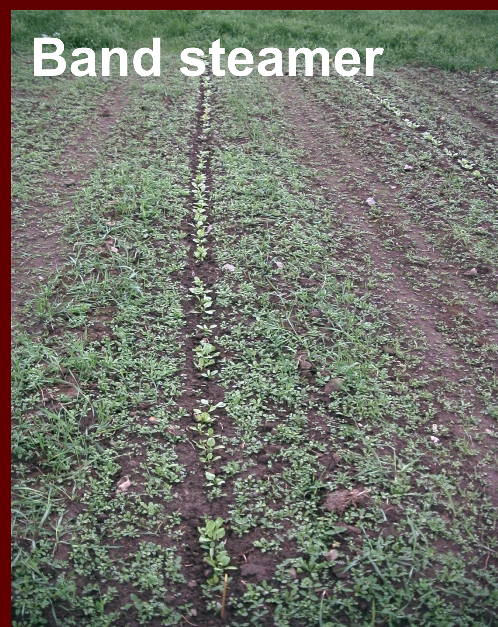
200-500 h ha^{-1} in carrot, onion and leek

Relationship between intra-row weed density and time needed for hand-weeding

Melander & Bàrberi (2004)



Solutions for intra-row weeding



Unconventional biological weed control

A recipe for resistance

- Huge fields on huge farms across a continent
- 100% minimum tillage (often zero till)
- Minimum crop diversity – mainly wheat
- The same herbicides persistently used
- genetically diverse *L rigidum* at high density across 60 million hectares

Stephen Powles, University of Western Australia (2005)

An example of ‘holistic’ weed management in organic farming

Melander & Rasmussen (2000)

Year 1
Winter wheat
or barley

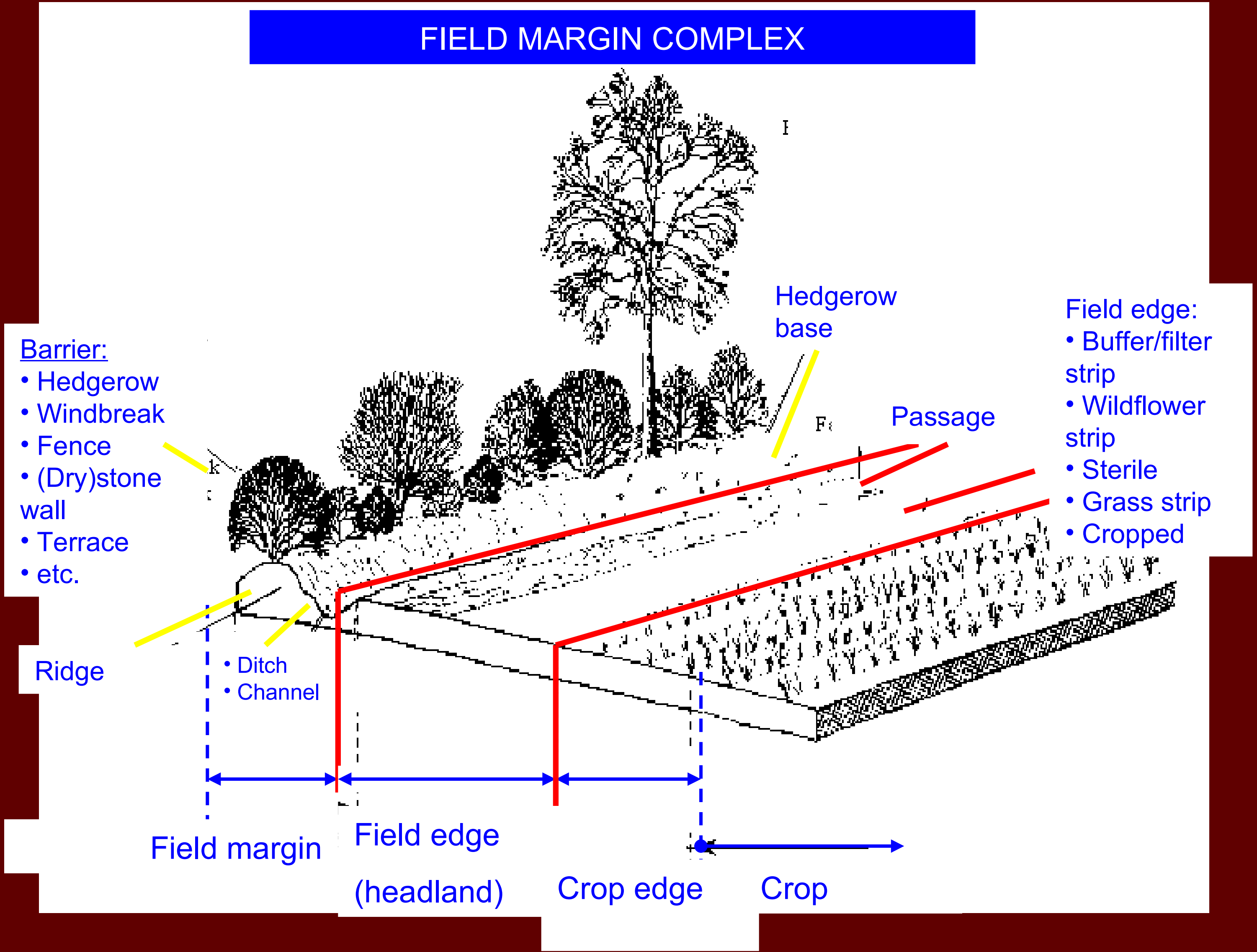
Interrow distances:
12.5 and 25.0 cm

Year 2
Row crop
(sugar beet or
vegetable)

Interrow distance:
50 cm

The Field Margin Complex (FMC)

(adapted from Greaves & Marshall, 1987)



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Examples of FMCs

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A functional biodiversity study

- To study the inter-relations between:
  - Field Margin Complex (FMC, = boundary) structure
  - Richness and abundance of:
    - plants
    - beneficial insects (Coccinellidae, Syrphidae, Chrysopidae)

in the arable part of the farm

Functional analysis

- Vegetation in the FMC

- Classification in 5 groups
  - woody species
  - grasses
  - herbaceous dicots
  - grass weeds
  - dicot weeds

  } WEEDINESS

- FMC ⇒ INTEGRITY

  { structural complexity (niches)
  management
  disturbance

FMCII

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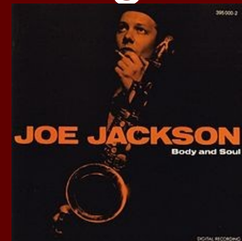
Results

X	Y	a	b	r	n	P
Plant species richness	% Weediness	-0.53	72.15	-0.47	62	0.0001***
FMCII	% Weediness	-0.16	62.46	-0.30	62	0.019*
FMCII	Plant species richness	0.17	23.93	0.35	62	0.005**
Plant species richness	% Weediness	-0.88	87.13	-0.76	8	0.030*
FMCII	% Weediness	-0.36	73.57	-0.75	8	0.033*
FMCII	Plant species richness	0.27	21.05	0.65	8	0.081
FMCII	Insect density	-0.14	16.06	-0.66	8	0.076
% Weediness	Insect density	0.33	-8.83	0.75	8	0.033*
% Weediness	Insect density	0.44	-14.47	0.93	7	0.002**

What would you prioritise? Biological pest control or weed invasion risk?



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Moonen *et al.* (2006)

Concluding remarks

- Agroecologically-based IWM is the best approach
- Cropping system diversification

- Weed management diversification
  - Conventional farming: ensures long-term sustainability of direct control measures (herbicides)
  - Organic farming: increases effectiveness of (less effective) direct non-chemical control measures
- Unravelling multitrophic interactions at different scales: the next challenge