INTEGRATED WEED MANAGEMENT SYSTEMS IN VEGETABLES IN THE MEDITERRANEAN AREA

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EWRS WG "Weed Management Systems in Vegetables"

Most vegetable crops are characterised by a:

- low plant density
- wide row distance
- slow initial growth

poor competitive ability

high-income crops

very low threshold weed densities
pretty long critical periods of weed competition

Vegetable crop	Plant density (n. plants m^{-2})	Row distance (cm)	Sowing-emergence (d)	Emerg./traspl. - canopy closure (d)	Growth cycle (d)	Critical period (weeks from emerg. or transpl.)	
						ETC	LTC
carrots	100 - 160	15 - 35	10 - 30	35 - 45	120 - 210	4-5	10-12
cabbage	2.5 - 6	50 - 70		35 - 50	60 - 120	3	5-6
cucumber	1.5 - 3.0	100 - 150	7 - 15	30 - 40	50 - 60	2	6
onions	40 - 100	20 - 30	15 - 25	35 - 50	120 - 240	3	13
water melon	0.3 - 1.0	150 - 250		30 - 4 0	70 - 100		4-6
french bean	35 - 50	30 - 45	7 - 10	15 - 20	50 - 60	1-2	5
fresh bean	35 - 50	45 - 60	7 - 10	15 - 20	65 - 70	1-2	5
lettuce (sown)	6 - 14	25 - 40	7 - 14	45 - 50	70 - 75	1-2	
lettuce (transplanted)	6 - 14	25 - 40		30 - 35	45 - 55		
melon	0.8 - 2.0	100 - 250		30 - 40	70 - 100		4-6
potato	3 - 5	60 - 80	10 - 20	45 - 60	120 - 150	6	9
sweet pepper	2.5 - 3.5	80 - 100		45 - 55	120 - 150	3	7
peas	80 - 100	15 - 30	10 - 15	35 - 45	90 - 120	1 - 2	3-4
tomato (transplanted)	2 - 5	80 - 150		35 - 40	75 - 100	3	5
leak	20 - 40	30 - 50			120 - 240		7-8
courgettes	0.8 - 2.0	100 - 150	7 - 15	20 - 30	80 - 100		4-6

ETC = Early Threshold Competition

LTC = Late Threshold Competition

(source: Tei & Pannacci, 2005; modified)

Vegetable cropping systems

- high number of species
- little crop acreage
- little farm size
- variable farming systems
- variable growing systems
- variable crop growth cycle
- variable product destination

WEED FLORA COMPOSITION

HIGH VARIABILITY

in function of

- crop rotation
- growth cycle (onset & length)
- cropping growth system
- farming system (conventional, integrated, organic)
- agronomic practices
- soil-climate conditions
- ...

A case study

CARROTS: production timing

- **Year-round crops** **UK F NL I E P MA TR**
- **Spring sowing (March to June)**

other countries in EU

summer-autumn harvests

Growth cycle 3 to 7 months

- **root size**
- **season (spring-summer 4-5 m winter 5-7 m)**

(source: Tei et al., 2002)

A case study

CARROTS: SOILS

- sandy — mostly
- clay-loam to silty loam — I MA
- organic — FIN UK

↓

low activity of residual herbicides

(source: Tei et al., 2002)

A case study

(source: Tei et al., 2002)

CARROTS: growing systems

FLAT FIELD single rows at 0.25 - 0.50 m

FLAT BED 1-2 m 3-8 single rows at 0.20 - 0.30 m

BAND 2-3 rows at 5-8 cm 0.30-0.45 m between bands

on RIDGE 0.45-0.50 m single row per ridge

on RIDGE 0.60-0.75 m 2-3 rows or a band per ridge

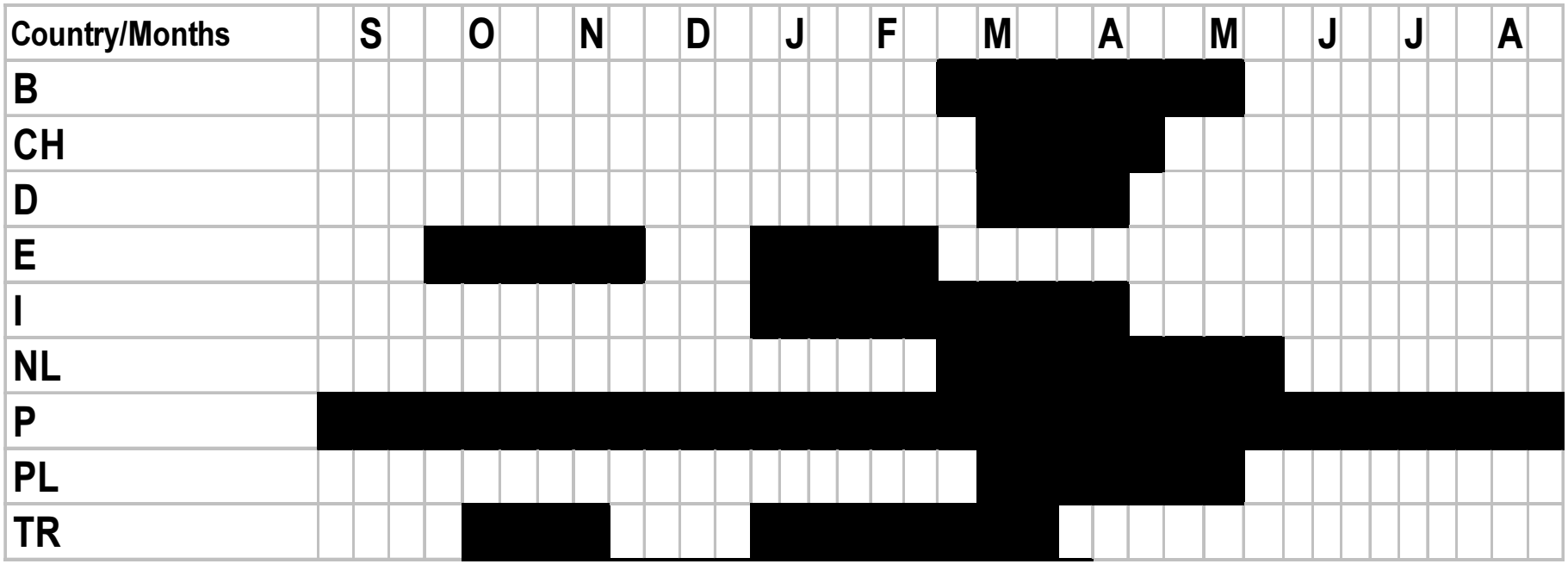
A case study

ONIONS
planting systems

mostly direct drilled	S, PL, UK, F, CH, I, E, IL
mostly from sets	FIN, P and MA
transplants	E and I.

(source: Tei et al., 1999)

Sowing period of green peas in relation to country



(source: Uludag et al., 2003)

2 MAIN WEED GROUPS

- autumn-early spring emergence species
  field vegetables: autumn-winter growth cycle
  early spring planting

- spring- summer emergence species
  field vegetables with spring-summer planting
  protected cultivations

Main “micro-thermal” species

- *Alopecurus myosuroides*
- *Lolium* spp.
- *Phalaris* spp.
- *Avena* spp.

- *Cruciferae*
- *Compositae*
- *Fumaria officinalis*
- *Anagallis arvensis*
- *Stachys annua*
- *Lamium* spp.
- *Veronica* spp.

Main “macro-thermal” species

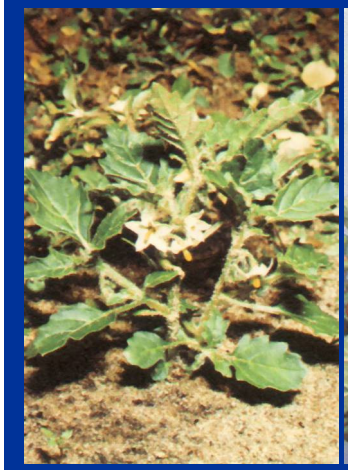
- *Echinochloa crus-galli*
- *Setaria* spp.
- *Digitaria sanguinalis*

- *Amaranthus* spp.
- *Chenopodium album*
- *Polygonum* spp.
- *Portulaca oleracea*
- *Solanum nigrum*

(source: Tei et ., 2003)

A case study: PROCESSING TOMATO

Solanum nigrum is a key weed



S. sarrachoides	Spain
S. physalifolium	Spain
S. luteum	France
S. eleagnifolium	Israel

Species	HR	F	IL	I	MA	PL	P	SLO	E
A. albus				+++					
A. blitoides			+++				+++		
A. cruentus			+						
A. deflexus				+			+++		
A. graecizans			+	+					
A. hybridus		+++							
A. lividus				++					
A. palmeri			+						
A. retroflexus	+++	+++	++	+++	+++	+++	+++	+++	+++

A. retroflexus

A. deflexus

A. hybridus

(source: Tei et al., 2003)

Species	HR	F	IL	I	MA	PL	P	SLO	E
C. album	+++	+++	+	+++	+++	+++	+++	+++	+++
C. ficifolium				+					
C. hybridum				+					
C. opulifolium				+			+++		
C. murale					+++				
C. polyspermum		++		++					
C. vulvaria				++					

C. album

C. opulifolium

C. polyspermum

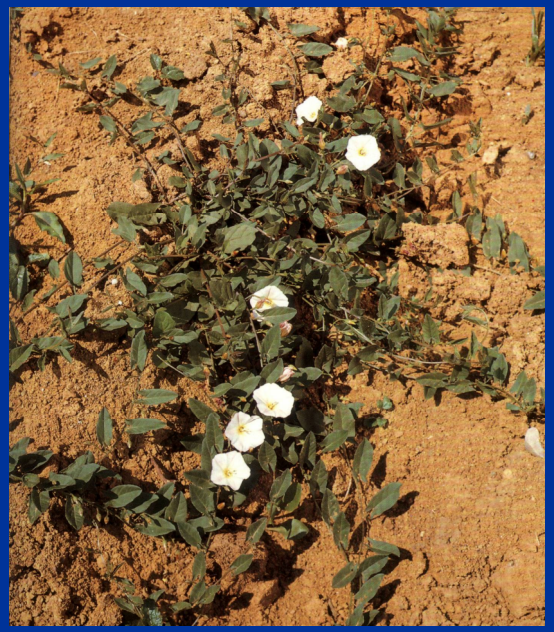
(source: Tei et al., 2003)

Perennial weeds

- *Sorghum halepense*
- *Cynodon dactylon*

- *Cyperus spp.*

- *Convolvulus arvensis*
- *Cirsium arvense*
- *Rumex spp.*



A case study: PROCESSING TOMATOES

(source: Tei et al., 2003)

Parasitic weeds

Species	IL	I	MA	P	E
Orobanche aegyptiaca	+++				
Orobanche crenata	+			+++	
Orobanche ramosa	+	+++	+++		+++
Cuscuta campestris	+++	+			+++

CARROTS: new & increasing weeds

Croatia	***Abutilon theophrasti, Datura stramonium, Hibiscus trionum***
Italy	***Cirsium arvense, Rumex* spp.**
Slovenia	***Cirsium arvense***
Hungary	***D. stramonium*, *Ambrosia artemisiifolia*, *Sorghum halepense***
Poland	***Anthemis* spp., *Rorippa sylvestris***
Finland	***Cirsium arvense, Galeopsis* spp., *Rorippa sylvestris, Sonchus arvensis***

(source: Tei et al., 1999)

CABBAGES: becoming important weeds

CH	*Rorippa sylvestris*
I	*Calystegia sepium*, *Rumex* spp., *Sorghum halepense*
SLO	*Amaranthus* spp., *Cirsium arvense, Convolvulus arvensis, Cruciferae*
HR	*Abutilon theophrasti*, *Panicum* spp., *Setaria viridis, Xanthium strumarium*
P	*Chenopodium album, Cuscuta* spp., *Galinsoga parviflora*
H	*Ambrosia artemisiifolia*
NL	*Urtica urens*
FIN	*Chenopodium album* and *Polygonum* spp.

(source: Tei et al., 2005)

ONIONS

Species are becoming an increasing problem

France	*Convolvulus arvensis*, *Equisetum arvense*, *Fumaria* spp., *P. aviculare*, *P. annua*
Spain	*P. aviculare*, *Coniza* spp.
Portugal	*Amaranthus* spp., *Cyperus esculentus*, *Datura stramonium*, *Galium* spp., *P. annua*
Italy	*C. arvensis*, *Cirsium arvense*, *Euphorbia* spp., *E. arvense*
Croatia	*Ambrosia artemisiifolia*, *D. stramonium*
Morocco	*Chrysanthemum* spp.
Israel	*Ammi* spp., *Daucus aureus*, *Fumaria* spp., *Ridolfia segetum*, *Cyperus rotundus*
Switzerland	*P. annua*, *Polygonum* spp. and *S. media*
UK	*Artemisia vulgaris*, *P. annua*
Sweden	*Galium aparine*, *Poa annua*, *P. aviculare*, *Stellaria media*
Finland	*Polygonum aviculare*, *Viola arvensis*

New weeds

Israel	*Euphorbia prostrata*, *Cuscuta campestris*
Finland	*Rorippa sylvestris*, *Bidens tripartita*

(source: Tei et al., 1999)

WEED COMPETITION reduces YIELD

but it can also decrease quality product

- less quality
- contamination of product

Weeds interfere with mechanical harvesting operations

Weeds as host for virus

(source: Conti et al., 1996)

e.g.: virus disease in tomato

Weeds	Virus			
	CMV	PVY	TMV	TSWV
Amaranthus retroflexus				+
Borago officinalis	+			
Calendula officinalis	+			+
Cichorium intybus	+			+
Cirsium spp.		+		
Convolvulus spp.	+			
Datura stramonium				+
Lamium purpureum	+			
Malva silvestris	+			
Mercurialis annua	+			
Picris hieracioides	+			
Plantago spp.			+	
Portulaca oleracea	+	+		+
Ranunculus spp.				
Solanum dulcamara	+	+	+	
Solanum nigrum	+	+	+	
Stellaria media	+			+

Weeds as host for bacterial disease

e.g.: bacterial diseases in tomato

Weeds	Bacteria		
	Corynebacterium michiganense pv. michiganense	Xanthomonas campestris pv. vesicatoria	Pseudomonas syringae pv. tomato
Brassica campestris			+
Brassica nigra			+
Datura stramonium		+	
Lamium amplexicaule			+
Solanum nigrum	+	+	
Stellaria media			+

(source: Conti et al., 1996)

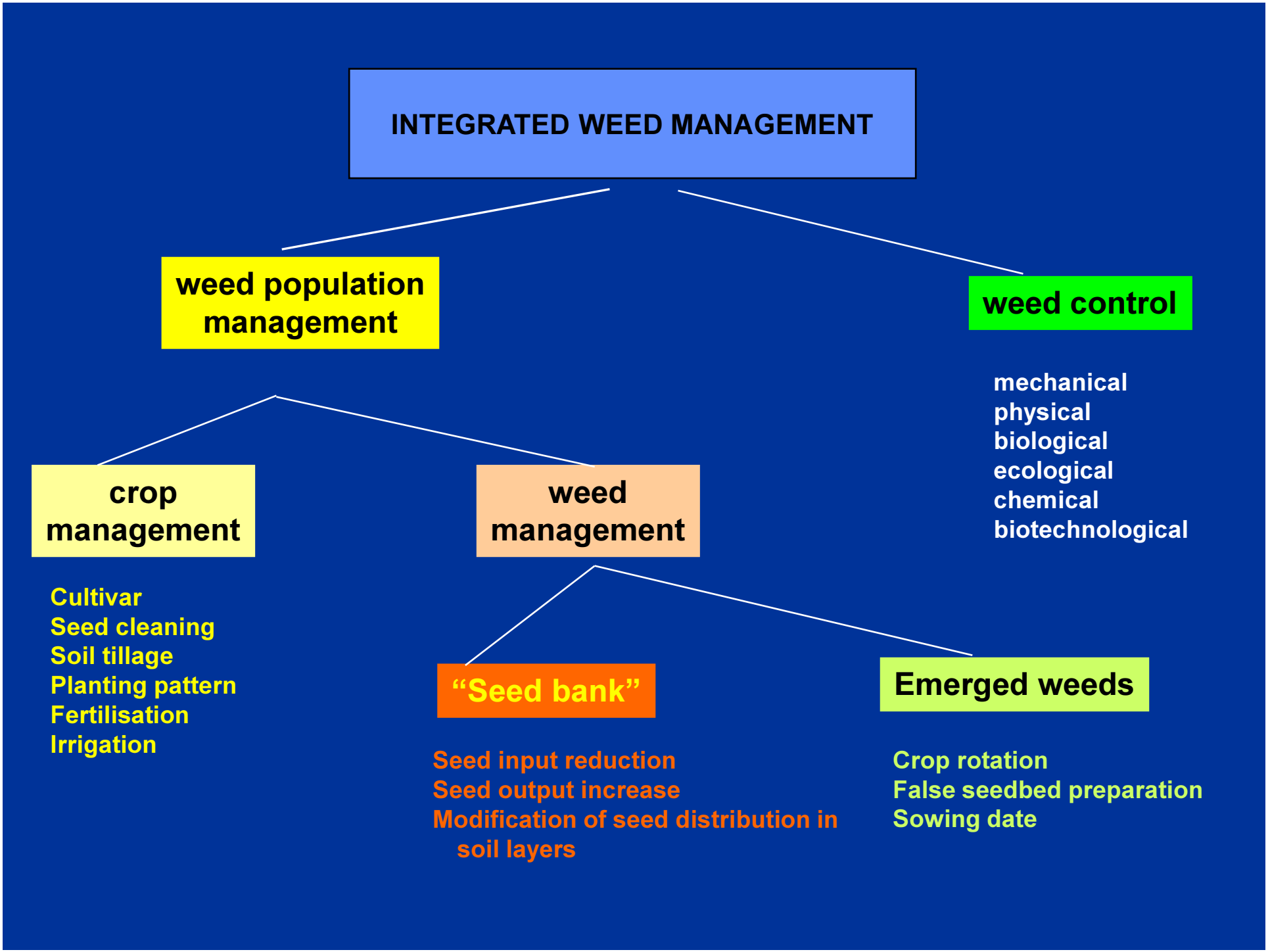
INTEGRATED WEED MANAGEMENT

...The challenge today is to develop a truly integrated crop management system in which preventive measures are taken first, followed by precision control…

(Kropff & Walter, 2000)

IWM Principles

- avoiding the weed eradication
  - ecological niche is promptly filled by other species
- improving crop competitive ability
- promoting competition between weeds
- avoiding production and dispersal of seed and propagules
- disturbing weed “regenerative niches”
- interacting with weed dynamics


INTEGRATED WEED MANAGEMENT
weed population management
weed control
mechanical
physical
biological
ecological
chemical
biotechnological
crop management
weed management
Cultivar
Seed cleaning
Soil tillage
Planting pattern
Fertilisation
Irrigation
“Seed bank”
Emerged weeds
Seed input reduction
Seed output increase
Modification of seed distribution in soil layers
Crop rotation
False seedbed preparation
Sowing date

1. **Prevention (indirect)**
   - Farming- and cropping system
   - Crop choice, varieties, sanitation, cover crops, etc.

2. **Decision making**
   - Necessity: when, where, how?

3. **Weed Control**
   - physical (mechanical, thermal, mulching)
   - biocontrol (insects, pathogens, etc.)
   - chemical

The success of weed management strategy depends on the most effective combination of **Prevention**, **Decision making** and **Control Measure**

(after Baumann, 2003)

IWM

WEED CONTROL

integration of different direct measures

physical

mechanical

biological

organic farming

chemical

conventional and low input agriculture

low selection pressure

density and period thresholds

rate optimization and environmental sustainability of herbicides

Cultural (preventive) measures

Preventive measures

Crop rotation

- unstable environment that prevents the proliferation and dominance of a particular weed
- more equilibrated composition of weed flora
- easier control of key weeds
- possible use of trap crops for parasitic weeds
- however, maintaining a particular rotation solely for weed suppression may be difficult to justify when economic and market forces also influence the cropping sequence

PROCESSING TOMATO

Herbicides and crops for the control of *Solanum nigrum* in the crop rotation in Italy

(after Montemurro and Preziosa, 2000)

Active ingredients	Crops
acifluorfen	soyabean
alachlor	maize
bentazone	maize, soyabean, peas
bromoxynil	maize
chloridazon	sugarbeet
chlorpropham	sugarbeet, carrot, onion, garlic
chlorthal-dimethyl	carrot, onion, cucurbits, cabbages, lettuce, artichoke, asparagus
clopyralid	sugarbeet, maize
cycloate	sugarbeet, spinach
desmedipham	sugarbeet
ethofumesate	sugarbeet, tobacco
imazethapyr	soyabean, bean
linuron	soyabean, bean, carrot, fennel, sunflower, artichoke, potato, maize
metamitron	sugarbeet
metazachlor	artichoke, potato, oilseed rape
methabenzthiazuron	maize, potato, peas, sunflower
naptalam	cucurbits
nicosulfuron	maize
oxyfluorfen	sunflower, onion, cabbages, artichoke
phenmedipham	sugarbeet
primisulfuron	maize
prometryn	carrot, soyabean, bean, peas, potato, artichoke, sunflower, maize, sorghum
propachlor	onion, cabbages, sorghum
propyzamide	lettuce, sugarbeet, artichoke
terbutryn	maize, potato, sunflower, peas, bean
triflursulfuron	sugarbeet

Trap crops for parasitic weeds

- They stimulate seed germination of parasitic weeds but are not parasitised

For example in processing tomato:

- *Orobanche* spp.
  peas, soyabean, bean, alfalfa, garlic, sorghum, maize
- *Cuscuta campestris*
  cereals, maize, garlic, cotton

Prevention: cover crops, living mulch systems

- Reduction of pests and weeds
- Suppression of weeds
- Reduction of
  - Soil erosion
  - Nitrogen leaching
  - Soil compaction
- Enhancement of
  - Organic matter
  - Water retention
  - Soil moisture and nutrient content

The strategic importance of the cover crops seems low
in environments characterised by
limited availability of irrigation water or where water cost is high

Prevention: intercropping

Allelopathy

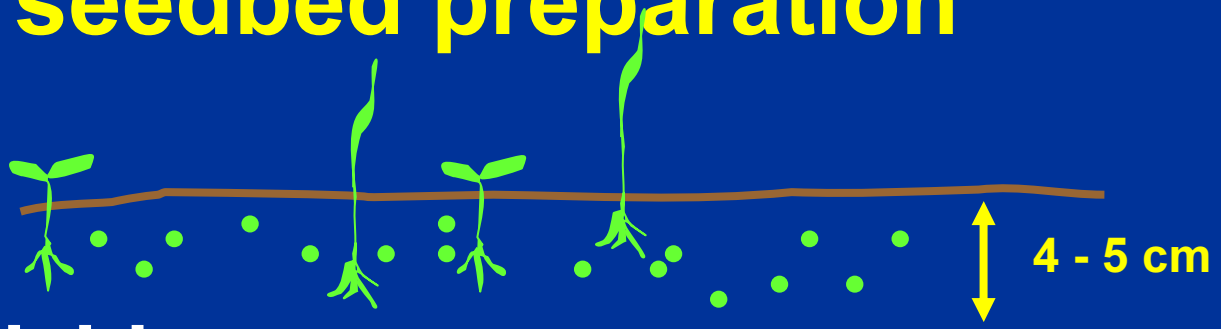
- **Allelopathy may be a promising weed management tool in IWMS in vegetables**

- **Vegetables with allelopathic activity against weeds: cucumber, squash, onion, leek, garlic, pea, pepper, watermelon**

- **Potential problems to use allelopathy as a practical tool for weed management:**
  - ✓ ***Information about which crops are effective against which weeds is limited;***
  - ✓ ***Information about which are the most allelopathic varieties of a particular crop is not available;***
  - ✓ ***there are no effective allelopathic crops management recommendations to provide maximum weed suppression.***

False seedbed preparation

followed by:



- total herbicides
- shallow harrowing
- flaming

Prevention: competitive cultivar

the breeding of competitive cultivars
is not yet enough developed
even if experimental results seem to be encouraging

GREEN PEAS (source: Grevsen, 2003, modified)

Cultivar	Weed biomass at harvest g m^{-2}	Pea biomass at 28 DAS g m^{-2}	Pea dry yield t ha^{-1}
Greenshaft	80 a	130 a	4.9 a
Ambassador	80 a	125 a	4.1 b
Bella (semi-leafless)	136 b	109 ab	1.9 c
Kemit (semi-leafless)	140 b	94 b	2.4 c
Argona	154 b	89 bc	1.0 d
Dinos	160 b	63 c	1.0 d

PLANTING SYSTEM

- direct seeding
- transplanting

***Solanum nigrum* threshold density**

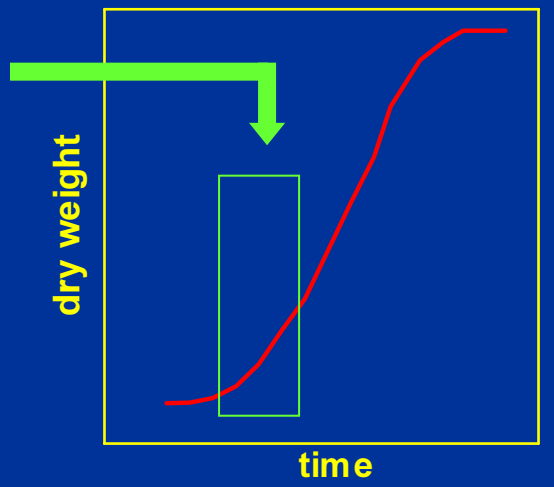
transplanted crops: 1 plant per linear meter

direct-sown crops: < 1 plant (close to zero)

Critical period of competition

transplanted crops: from 24 to 40 DAT

direct-sown crops: from 30 to 60 DAE



Preventive measures

PLANTING PATTERN & DENSITY

Single rows – Twin rows

Row distance

Flat field - Flat bed – Band – on ridge

increase of crop plant density
narrower row distance or of twin rows

increase the crop competitivity...but

WEAKNESSES

- cost of transplants (e.g. peppers, processing tomatoes, melons…)
- negative effects of a higher crop density on quality product (e.g. size of marketable product of cauliflower, lettuce…)
- need to have “well-spaced” crop rows for the application of mechanical weed control (e.g. in onions, carrots, fennels…)

Prevention: irrigation and fertilization

early RGR negative correlation with

seed mass
seed storage compounds

↓

seed size: weeds << crop

↓

high soil fertility

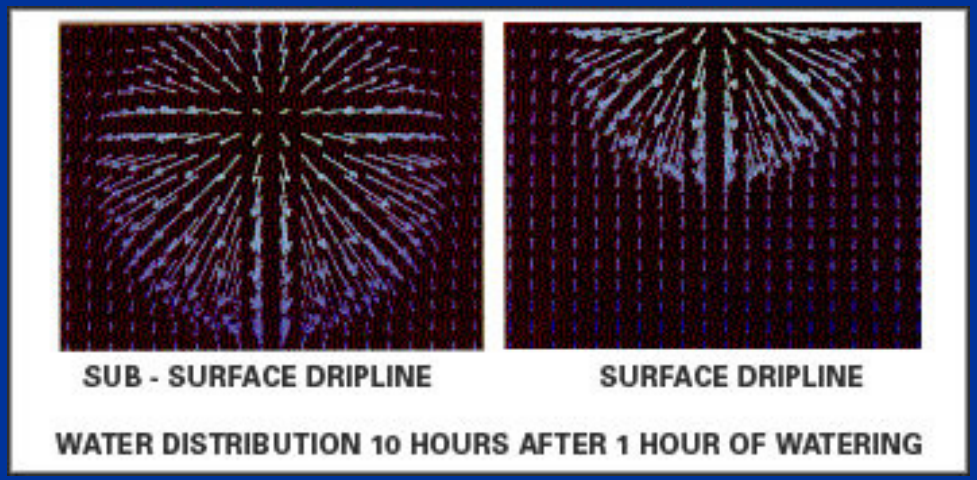
high relative growth and uptake rates

↓

localization → stress *vs* weeds

Use of surface drip fertigation and subsurface drip fertigation

determine a different water distribution…



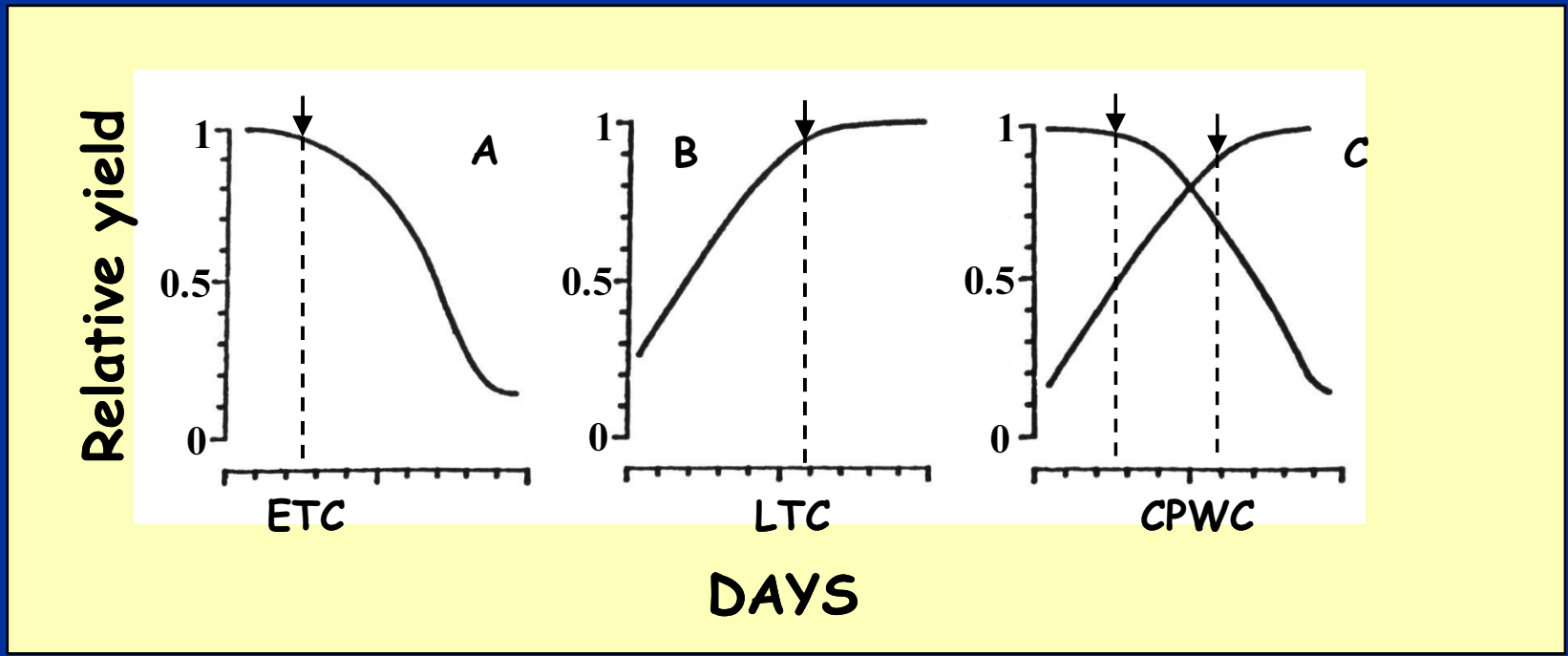
….with possible effects on:

- weed germination, growth and competition
- herbicides distribution into the soil

Decision making

Decision making: control when?

period thresholds



Relative yield in function of the duration of competition:
(A) early threshold competition, ETC
(B) late threshold competition, LTC
(C) critical period for weed control, CPWC

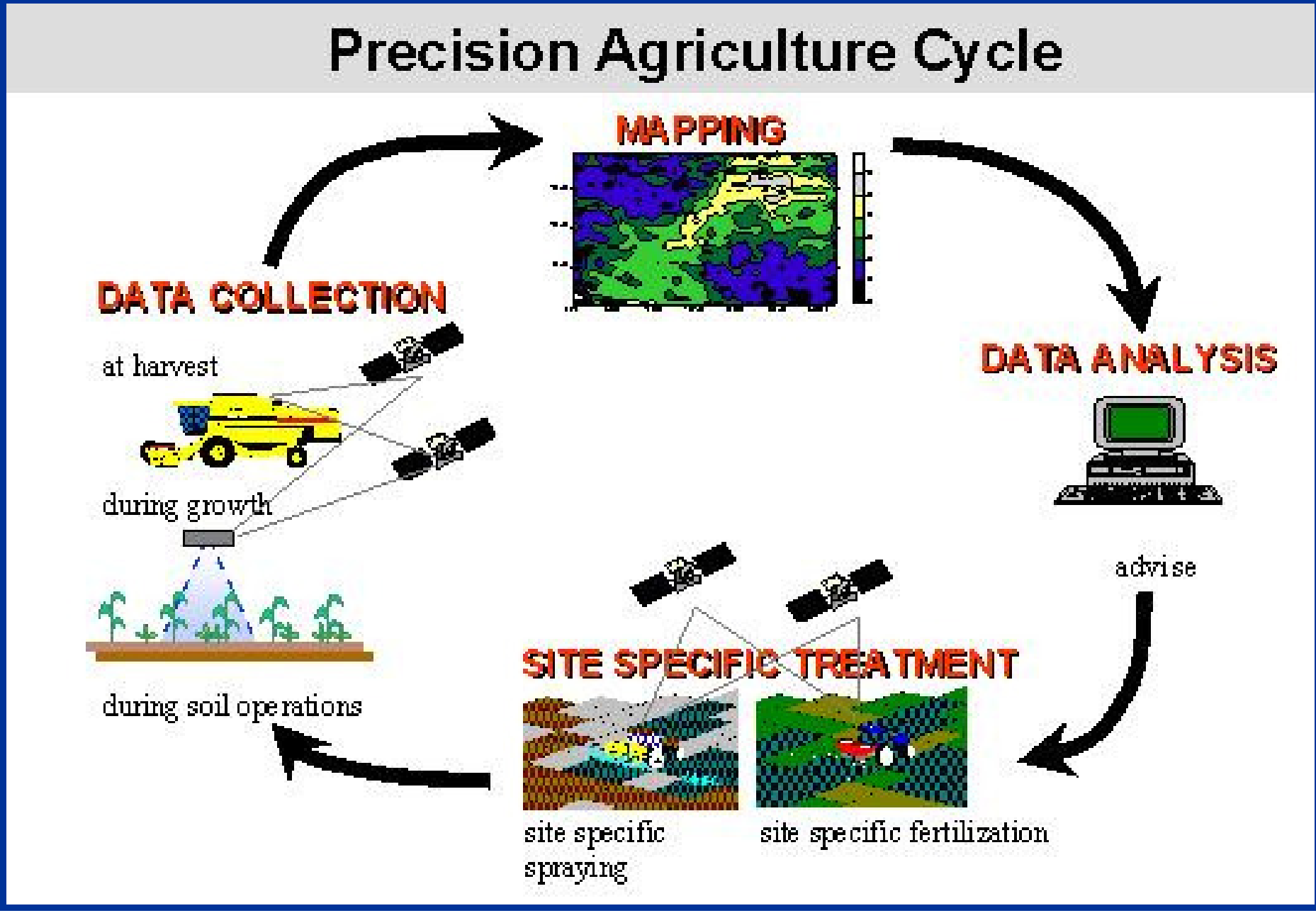
(after Sattin & Tei, 2001)

period thresholds

crop	weeks ETC	LTC
carrots	4 - 5	10 - 12
cabbage	3	5 - 6
onion	3	13
fresh bean	1 - 2	5
potato	6	9
sweet pepper	3	7
peas	1 - 2	3 - 4
tomato	3	6

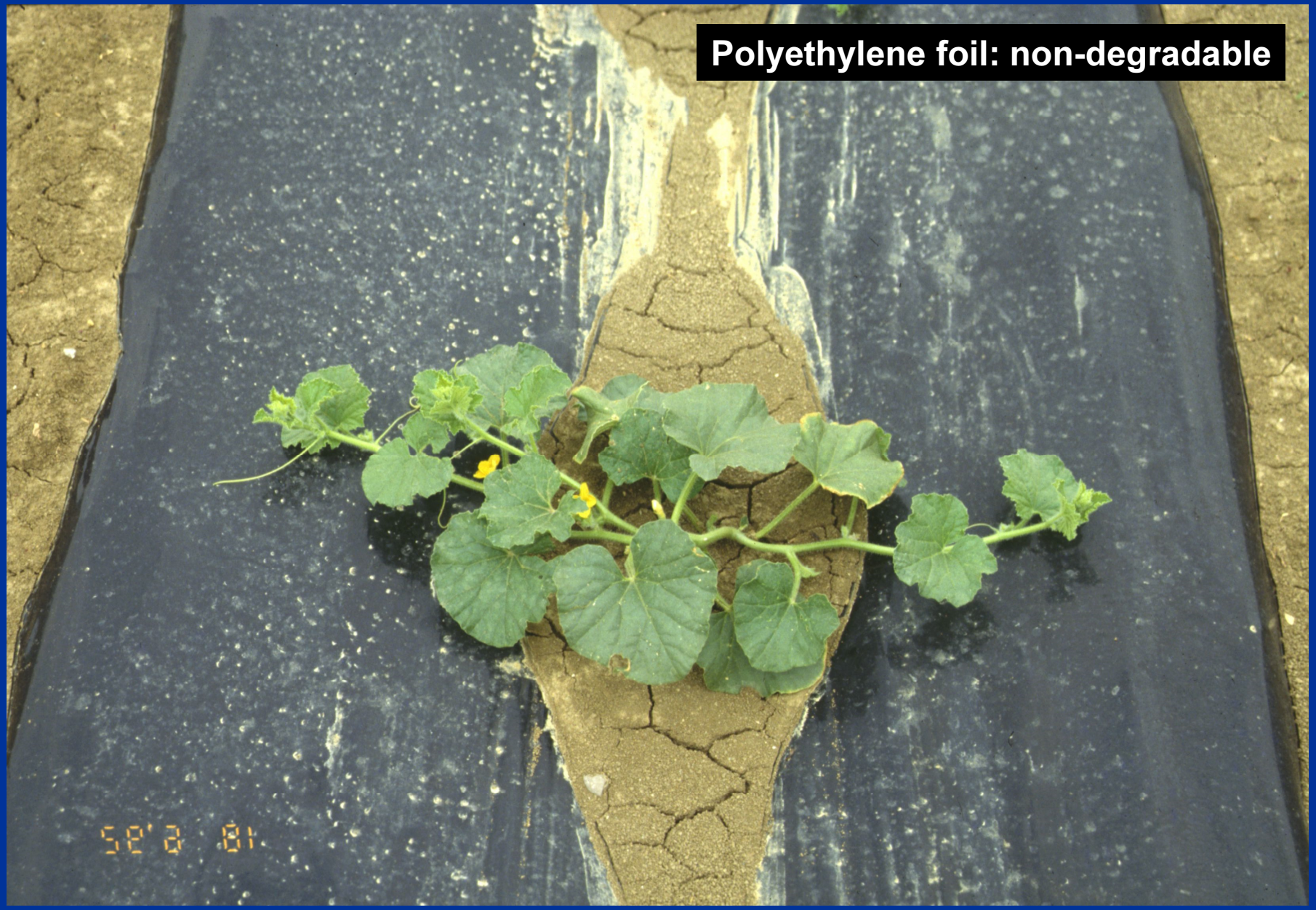
ETC = early threshold competition
LTC = late threshold competition

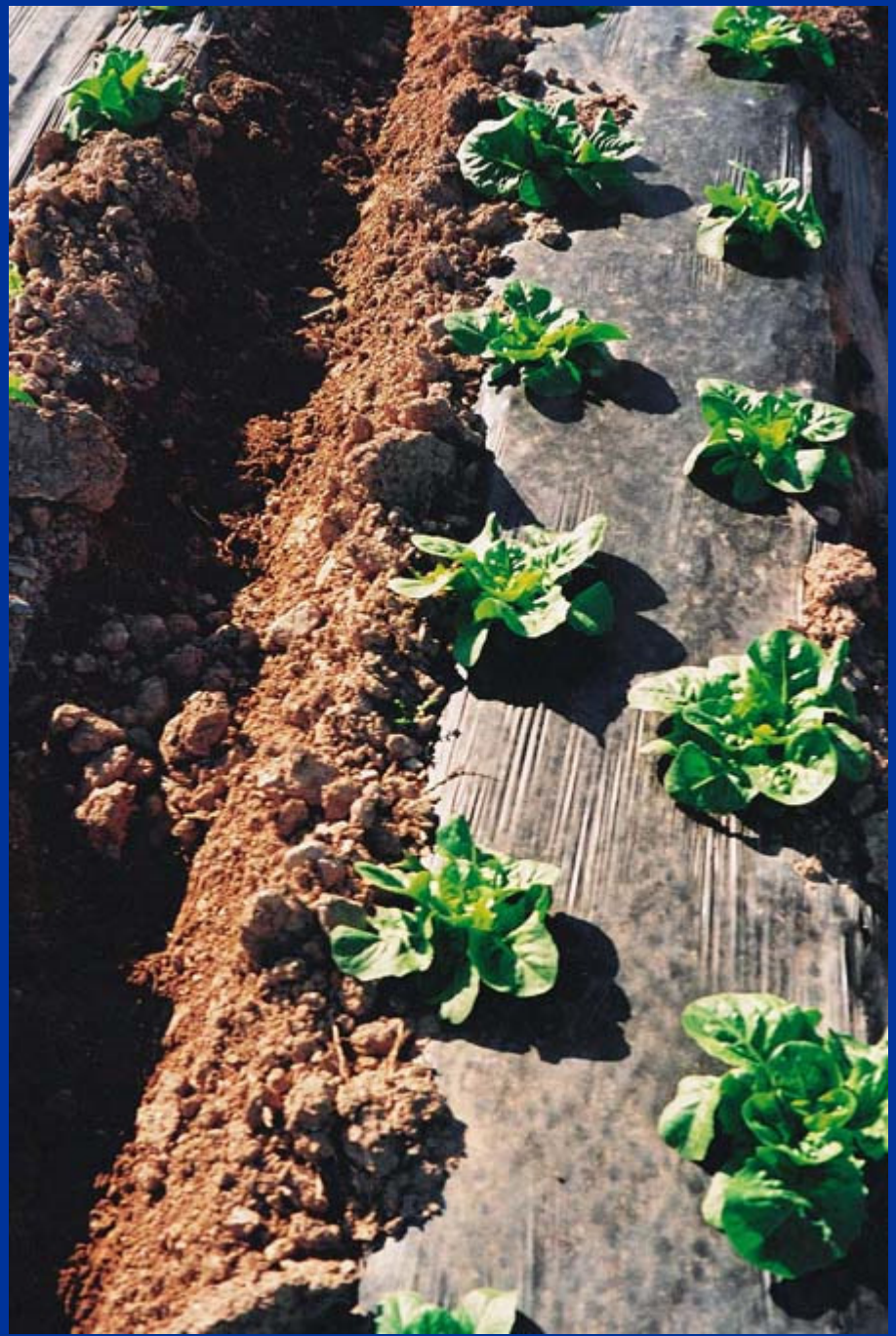
Decision making: control where?



Direct control

Direct control: physical measures





Direct control: physical measures

Source: Polyeur (www.polyeur.it)

Non-degradable photoselective coloured plastic mulches

Mulch	colour	weed control	Soil temper.	IPM	season / crop	minimum thickness (mm)
Polydak	transparent	solari-zation	very high		any crop	0.015
Silver / Silver	silver	partial	medium	aphids, aleurodids	melon, strawberry	0.025
Al-Or	brown	yes	medium		vegetables, strawberry	0.020
Silver / SLT	silver / brown	yes	medium	aphids, aleurodids	strawberry	0.025
Yellow / SLT	yellow / brown	yes	low	aleurodids	spring-summer vegetables	0.028
Red / SLT	red / brown	yes	medium / high		tomato	0.025
Black	black	yes	low / medium		any crop	0.020
Silver / Black	silver / black	yes	low	aphids, aleurodids	any crop and season	0.025
Black / White	black / white	yes	very low	aphids, aleurodids	summer – any crop	0.025

Direct control: physical measures

starch-based biodegradable mulches

mulching activity
for 2-4 months

critical period
of competition

Direct control: physical measures

Flaming

pre-emergence

- carrots
- onion
- parsley

post-emergence

- onion
- head cabbage
- sweet corn
- artichoke

MECHANICAL CONTROL

- inter-row weeds are easily removed by inter-row cultivation (i.e. hoeing, harrowing, brushing, split hoe)
- intra-row weeds still constitute a major challenge aimed at minimising laborious hand weeding although new implements (i.e. finger weeder, torsion weeder, steering hoe) show a pretty good efficacy if their application is included in a sound IWM programme

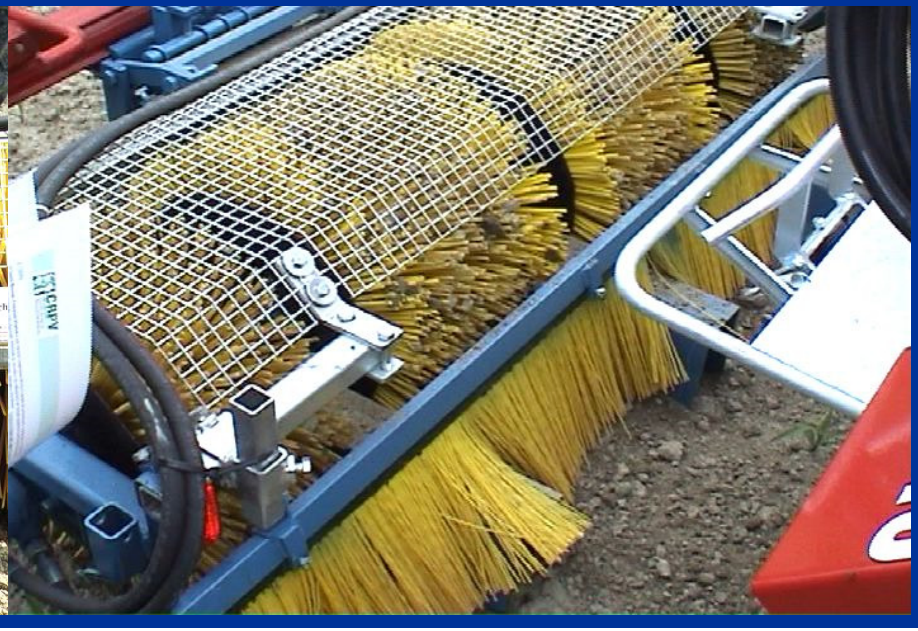
Direct control

INTER-ROW MECHANICAL WEED CONTROL

hoeing

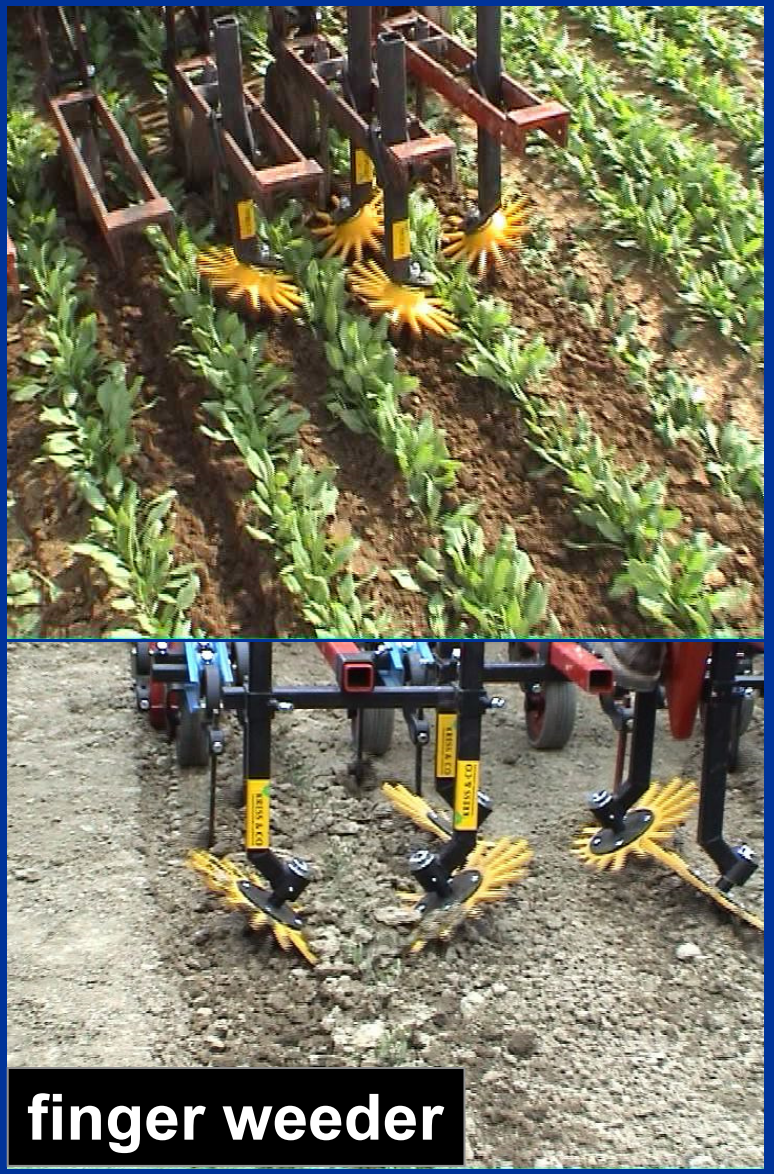
split-hoeing

brushing



Direct control

INTRA-ROW MECHANICAL WEED CONTROL



Mechanical weed control in organic onion seed production

(Pannacci et al., 2007)

Planting systems	Planting date	Crop density plants m^{-2}	Weed density plants m^{-2}	n. of applications
drilled	begin. AUG	3	220	3
from sets	end SEP	12	8	1

	weed control %		onion seed yield (kg ha^{-1})	
	drilled	sets	drilled	sets
spring tine harrowing	25		11	
hoeing	49	73	47	370
hoeing-ridging		71		321
split-hoeing	48	82	93	446
finger-weeding	51	49	77	406
split-hoeing + finger-weeding	69	86	28	370
weed-infested check			8	312

Direct control: physical measures

Labour requirement for hand weeding

carrots	100 - 500 h/ha
onion	100 – 300

Biological control

At present, biological control does not seem to be applicable on large scale and successfully in European vegetable crops systems:

- small fields
- a high number of crop species
- pluri-specific weed infestations

CHEMICAL WEED CONTROL

Most vegetables are

MINOR CROPS

thus

the availability of

approved herbicides for use

is scarce

due to

the low economic interest

by the chemical industries

In European Union

the already difficult situation has been worsening by the application of the directive 91/414/EEC concerning the authorization, placing on the market, use and control within the Community of plant protection products in commercial form

this restriction has already caused the expiration of the authorisation of several herbicides largely used in vegetables and minor crops and other ones will be withdrawn.

Moreover

the availability of

approved herbicides for use

is very variable among countries

PROCESSING TOMATO

Active ingredients	Efficacy against	Application timing				Country									
		PRES	PREE	PRET	POSTE POSTT	HR	F	IL	I	MA	PL	P	SLO	E	CH
Aclonifen	B		+	+					x						
Butralin	G + B			+										x	
Chlorthal-dimet.	B + G			+	+		x	x							x
Dinitramine	G + B		+	+	+							x		x	
Diphenamid	G + B	+	+	+		x									
Ethalfluralin	G + B		+	+										x	
Flufenacet	G + B			+					x		x				
Flurochloridone	B + G			+			x								
Metolachlor	G + B			+							x				
Metribuzin	B + G	+	+	+	+	x	x	x	x	x	x	x	x	x	x
Napropamide	B + G	+	+	+		x					x		x	x	
Oxadiazon	B			+	+				x						
Oxyfluorfen	B + G			+				x						x	
Oxadiargyl	B + G		+	+				x							
Pendimethalin	G + B			+		x	x		x	x	x	x	x	x	
Prometrine	G + B			+										x	
Rimsulfuron	G + B				+			x	x			x		x	
Trifluralin	G + B			+	+ (1)	x		x	x		x	x	x	x	

G = grasses B = broad-leaved weeds
PRES = pre-sowing PREE = pre-emergence PRET = pre-transplanting
POSTE = post-emergence POSTT = post-transplanting
(1) Inter-row soil incorporated post-emergence

(source: Tei et al., 2003)

CARROTS

Active ingredients	PPI	PRE	POST	HR	DK	FIN	F	D	G	HU	I	MA	NL	PL	P	SLO	E	S	CH	TR	UK
Aclonifen		x			+	+		UR			+							+			
Butralin																					
Chlorbromuron		x	x							+											
Chlorpropham		x	x								+										+
Chlortal-dimethyl		x							+		+										
Clomazone		x											UR								
Dinitramine	x										+										
Fluorochloridone		x								+	+			+						+	
Ioxynil			x																		OL
Isoxaben			x																		OL
Linuron		x	x	+	+	+	+		+	+	+	+	+	+	+	+	+		+	+	+
Linuron + Monolinuron												+							+		
Metamitron		x											UR								
Metolachlor																					
Metoxuron		x	x				+						+						+		+
Metribuzin			x			+		UR	+		+		UR					+			OL
Metribuzin + Orbencarb		x																	+		
Pendimethalin		x		+	+	UR		+	+	+	+		UR	+	+				+		+
Pentanochlor			x																		+
Prometryne		x	(x)	+					+	+	+			+	+		+			+	+
Sulphosate		x		+										+							
Trifluralin	x			+					+	+	+			+		+	+			+	+

PPI = pre-sowing
PRE = pre-emergence
POST = post-emergence

UR = Under Registration
OL = Off-Label

(source: Tei et al., 2002)

LETTUCE

Active ingredients	Application time (1)	UK	PL	NL	D	CH	SLO	I	E	P	HKJ
trifluralin	pres / pret	x						x			x
chlorpropham	pree / poste / postt	x		x				x			
pendimethalin	pree / pret / postt	x			x	x		x	x		x
propachlor	pret / postt	x						x			
propyzamide	any application time	x	x		x	x	x	x	x	x	
carbetamide	pree			x							
benfluralin	pres / pree / pret							x	x		
chlorthal	pree / postt							x	x		
oxadiargyl	pret								x		
oxadiazon	pret							x			
oxyfluorfen	pret										x
graminicides	poste / postt				x		x	x	x	x	x

pres = pre-sowing pree = pre-emergence pret = pre-transplanting

poste = post-emergence postt= post-transplanting.

No pre- or post-emergence/transplanting herbicides are registered in Turkey.

(source: Tei et al., 2007)

CABBAGES

Active Ingredients	Application time	HR	FIN	D	H	I	NL	PL	P	SLO	E	CH	UK
trifluralin	pre	+		+	+	+		+	+		+	+	+
napropamide	pre	+	+*			+		+		+		+	
oxyfluorfen	pre	+				+		+	+	+			
pendimethalin	pre	+		+	+	+		+		+	+		
metazachlor	pre / post	+	+	+	+	+	+	+		+	+	+	+
propachlor	pre / post					+		+			+	+	+
pyridate	post		+	+						+	+		+
clopyralid	post		+			+		+					+
graminicides	post	+	+	+	+	+	+	+	+	+	+	+	+

*under registration

(source: Tei et al., 2005)

A repeated use of herbicides with similar mode of action

may lead to a strong and quick selection of weed flora

- *Compositae* in lettuces and chicory
- *Umbelliferae* in carrots
- *Solanum nigrum* in processing tomatoes

Chemical weed control

in vegetables shows

peculiar environmental and health concerns

due to

- relatively short growth cycle
- fresh edible parts of vegetables
- a coarse soil texture of main production areas

Chemical weed control: concerns

- Food safety
- Weed population dynamics
  - dominant species (i.e. non-equilibrated populations)
  - herbicide resistance
- Environmental sustainability
  - environmental indeces (e.g. GUS, LogJ of Hartley...)
  - toxicological indeces (NOEL, DL50, CL50...)
- Cost

IWM in transplanted tomato

<table>
<tr><th rowspan="2">IWM</th><th rowspan="2">False seedbed preparation</th><th rowspan="2">Pre-planting</th><th colspan="2">Post-planting</th></tr>
<tr><th>1st application</th><th>2nd application</th></tr>
<tr><td>A</td><td></td><td>Residual herbicides</td><td rowspan="4">Intra-row
low split-dose
+
inter-row
mechanical control</td><td rowspan="4">Intra-row
low split-dose
+
inter-row
mechanical control</td></tr>
<tr><td>B</td><td rowspan="2">Harrowing + residual herbicides
or
total + residual herbicides</td><td></td></tr>
<tr><td>C</td><td></td></tr>
<tr><td>D</td><td>Harrowing or total herbicides</td><td></td></tr>
<tr><td>E</td><td colspan="2">Harrowing or flaming</td><td colspan="2">Inter-row / intra-row mechanical control</td></tr>
</table>

A. Crop infested by grass and broadleaved weeds without any specific problem
B. Crop infested by grass and broadleaved weeds with high presence of *Solanum nigrum*
C. Areas with risk of virus attacks
D. Organic soils
E. Organic farming systems

CARROTS
INTEGRATED WEED MANAGEMENT

- false seedbed preparation
- glyphosate, gluphosinate
- sowing in single rows 0.45-0.50 m
- pre - emergence treatment
  - band spraying
- post - emergence control
  - Low Dosage System
  - inter-row hoeings or rotary cultivation
  - in-row control: ridging

CARROTS: ORGANIC PRODUCTION

- false seedbed preparation
- sowing in single rows 0.45-0.50 m
- pre - emergence flaming
  - 50 - 80 kg gas ha^{-1}
- in-row brush weeding
  - crop at 2 - 3 true leaves
- 5 - 8 intra-row mechanical passes
  - hoeing, rotary cultivation, finger weeding
  - combined with ridging
- hand weeding (100 - 500 h ha^{-1})

THANK YOU FOR YOUR ATTENTION