Orchard Training Systems for Apples & Pears

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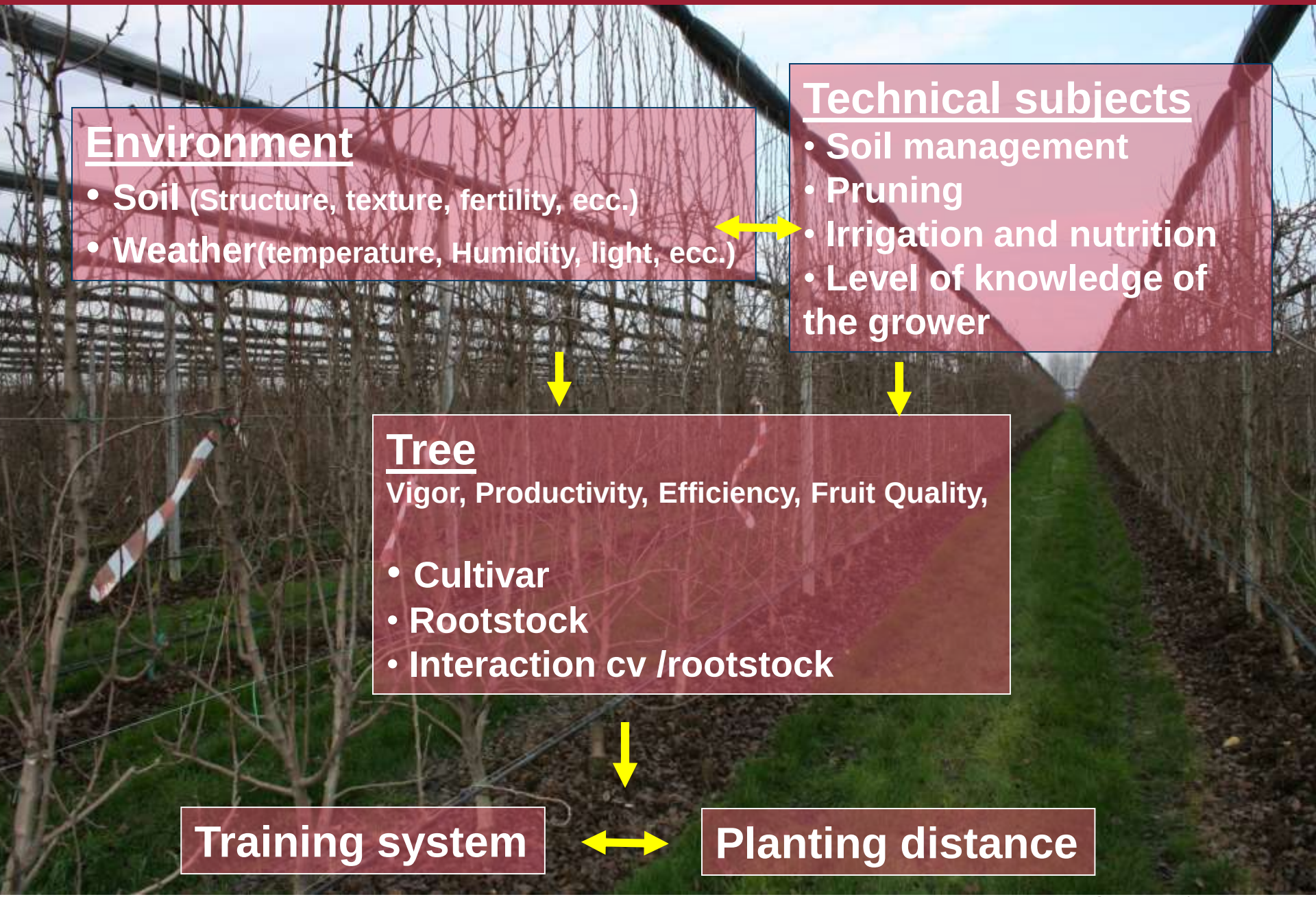
World Class. Face to Face.

What we have to consider for a precise orchard management ?



Environment

- Soil (Structure, texture, fertility, ecc.)
- Weather(temperature, Humidity, light, ecc.)

Technical subjects

- Soil management
- Pruning
- Irrigation and nutrition
- Level of knowledge of the grower

Tree

Vigor, Productivity, Efficiency, Fruit Quality,

- Cultivar
- Rootstock
- Interaction cv /rootstock

Training system ↔ **Planting distance**

Different apple needs different training system

GOLDEN DELICIOUS

GRANNY SMITH

RED DELICIOUS

GALA (bicolor)

Fruit exposure to the light and effect of leaves shadow

Apple habit

Spur type= Starkrimson

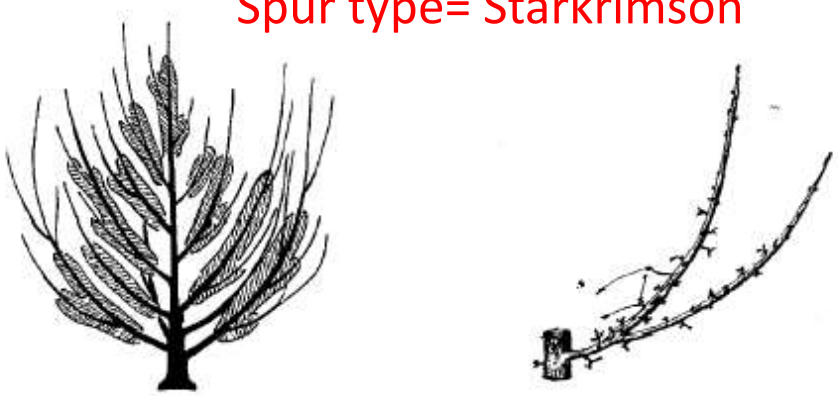


Fig. 3.10- Fruiting habitus type I (modified from Lespinasse, 1980).

Red Delicious

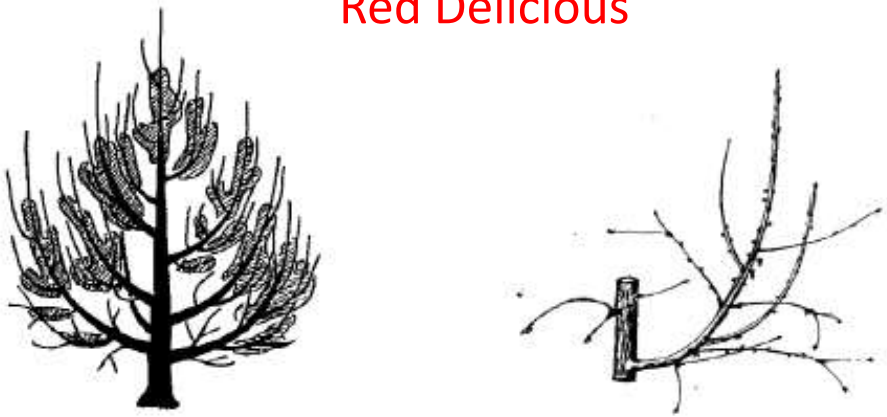


Fig. 3.11- Fruiting habitus type II (modified from Lespinasse, 1980).

Golden Delicious

Fig. 3.13- Fruiting habitus type III (modified from Lespinasse, 1980).

Rome Beauty

Fig. 3.15- Fruiting habitus type IV (modified from Lespinasse, 1980).

Apple training system

Apple orchard design

The last decade has seen pronounced innovation in apple orchard design marked by the success of new training systems developed as function of planting density.

Orchard density can range between 1,500 (Solaxe) trees/ha up to 10,000 trees/ha (Super spindle).

High density orchard trained at Super spindle induces early bearing starting from the second year.

Its weaknesses are:

- need of high level of technology;
- excess of vigor especially in fertile soil (high organic matter);
- lifespan less than 15 years.

Planting density:

Training system	Spacing (m)	Spacing (feet)	Planting density (trees/ha)	Planting density (trees/acre)	Cultivar
Spindle intensive	3.3 x 0.9	(11 x 3)	3,367	1,367	Gala. Rosy Glow Fuji
Spindle standard	3.6 x 0.9	(12 x 3)	3,086	1,249	Gala, Fuji and Rosy Glow
Bi-axis	3.3 x 0.9-1.2	(11 x 3-4)	2,525-3,367	1,022-1,367	Gala, Fuji and Rosy Glow

Canopy shape Bi-axis vs Spindle and V-system

WSU TREE FRUIT ENDOWMENT

Solaxe

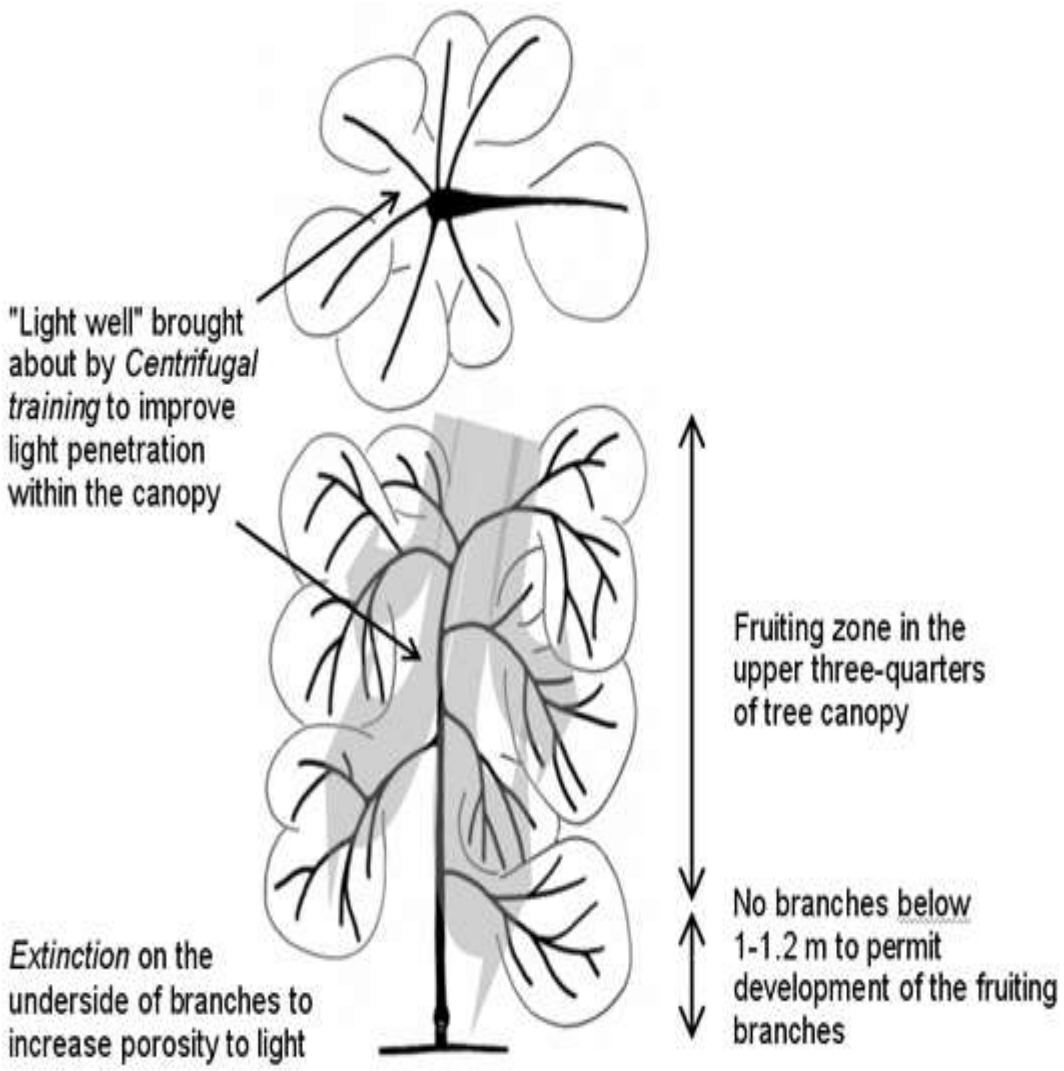
The solaxe is the combination of two training systems; the “Solen” (Lespinasse, 1989) and the “Axe vertical” (Lauri and Lespinasse, 2000).

This training system is based on the progressive formation of the tree structure, to establish an equilibrium between vegetative and fruiting activity.

This situation can be obtained with the use of permanent fruiting branches.

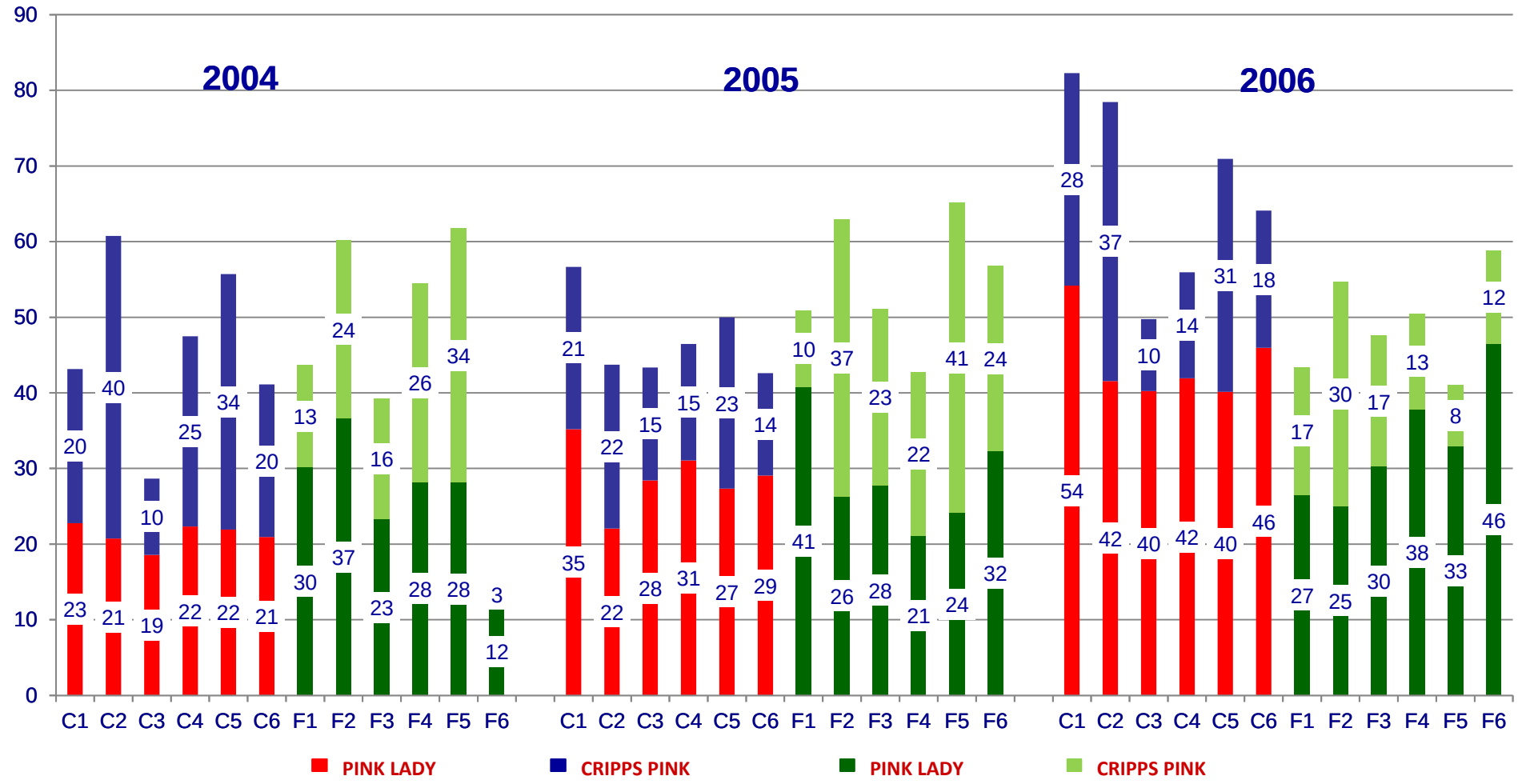
Central axis and the fruiting branches grow freely, whereas competing vegetative shoots are removed.

As the branch ages, secondary fruiting formations like brindles and fruiting spurs will develop.



CRIPPS PINK/M9 - FERRARA PLANTING YEAR 2003. YEAR 2007

CRIPPS PINK: COMPARISON BEWTEEN SOLAXE (CENTRIFUGE) AND SLENDER SPINDLE IN THE PO VALLEY (FERRARA)



Cripps Pink: effect of fruit position in the canopy

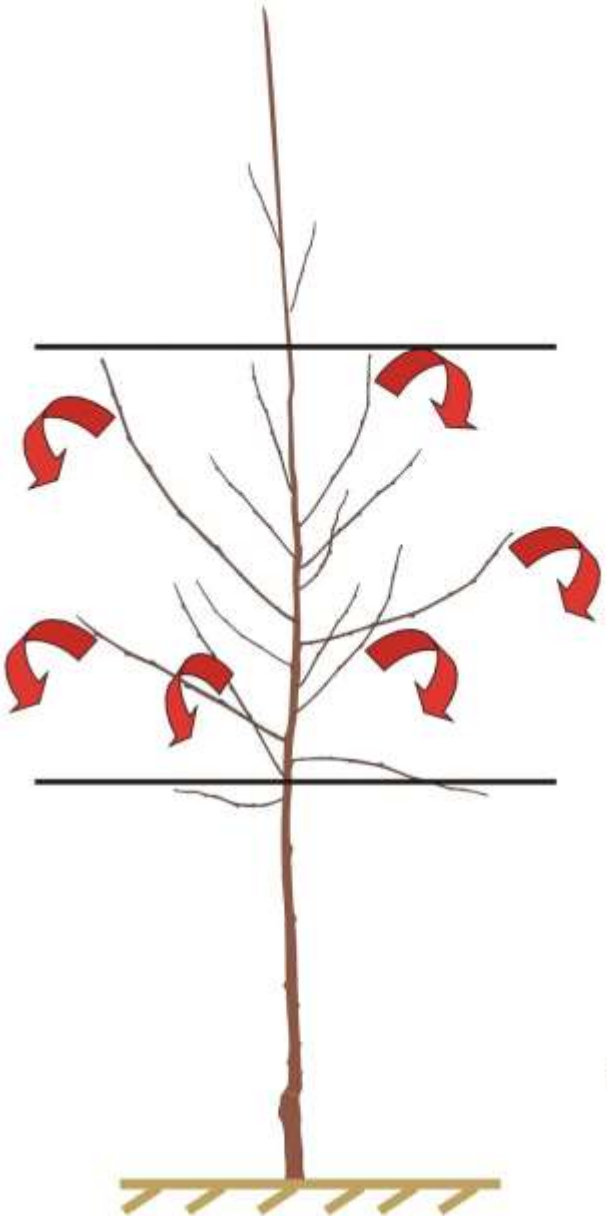
SpindleFuji/M9 2nd leaf 3.3 x 0.9 m (10.8’ x 2.95’)

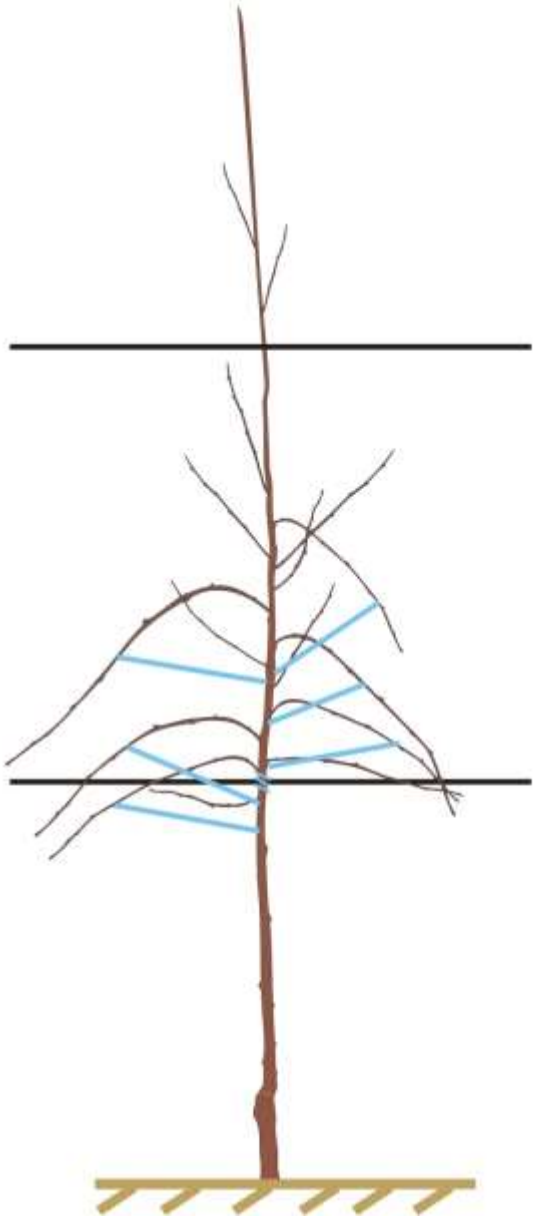
FUJI/PAJAM2 – SPINDLE 2nd leaf

3.3 x 0.9 m (10.8’ x 2.95’)

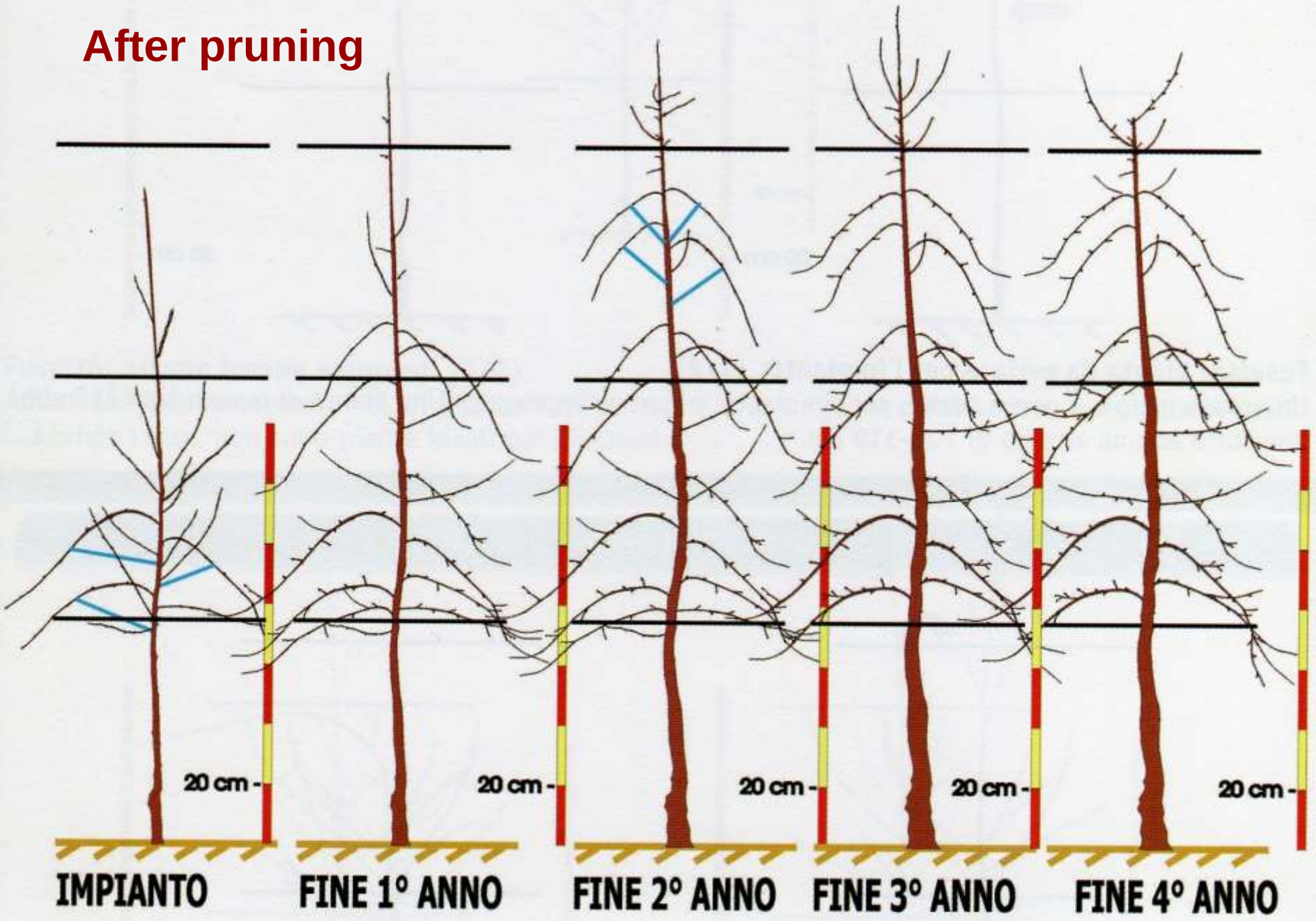
Cripps Pink/M9 2nd year

After planting





After pruning



V TRELLIS – ANGLE CANOPY

V TRELLIS - ANGLE CANOPY

Apple orchard design

New ideas regarding tree shape include plants with 2 or 3 axis so as to divide the vigor over more branches.

The innovative 'Bibaum®' system is a in nursery -pre-formed split-branches tree that obviates the delay of canopy formation.

Bi-axis

New ideas regarding tree shape include plants with 2 or 3 axis so as to divide the vigor over more branches.

WSU TREE FRUIT ENDOWMENT

Bi-axis system – Tree production

Bi-axis trees can be created in three possible ways:

1) **Nursery.**
2) **Heading back the tree in the field** (however, one more year is necessary to develop the canopy structure if the bi-axis is created in the field).
3) **Top graft** an existing orchard.

The nursery technique to produce bi-axis trees utilizes a double chip budding or a bench-graft and has been patented as "Bibaum®".

(Musacchi, 2008; Musacchi et al., 2009)

WSU TREE FRUIT ENDOWMENT

Double chip budding

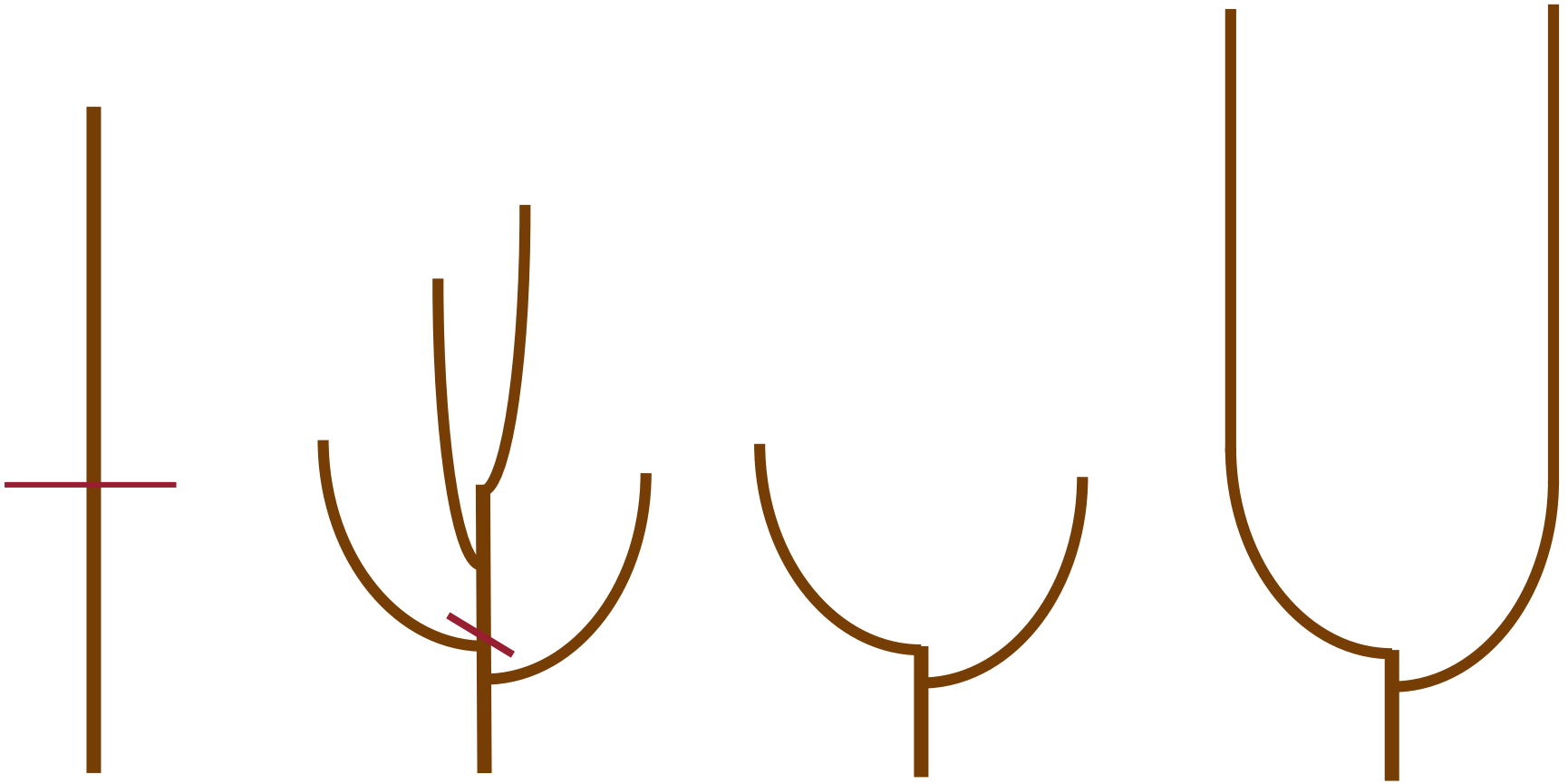
Bench graft

WSU TREE FRUIT ENDOWMENT

The innovative 'Bibaum®' system is a pre-formed, split-branch trees in nursery that obviate the delay of canopy formation.

Heading back the tree in the field

Heading back at planting



1st Head back
50 cm or 1.5 feet

2nd Head back
Just above the selected axis 20- 30cm 0.6-1 feet

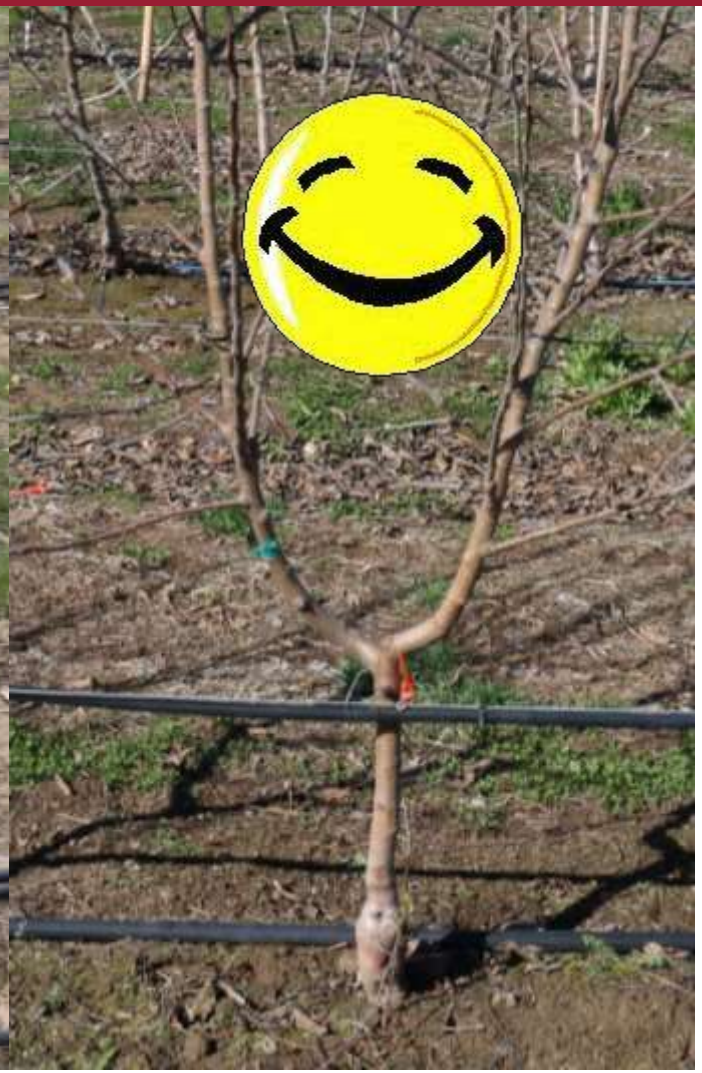
End of the first year at least 2 m (7 feet) of new growth.

Heading back the tree in the field

Heading back the tree in the field

Possible mistakes:

- Head back to high
- Use existing lateral to build the axis



Top Graft

WSU TREE FRUIT ENDOWMENT

Tri-axis

Bi-axis system - Planting

- This system requires a **trellis structure** with posts and **4 wires** equally spaced at a distance of **70 cm (2.5 feet)** between wires.
- Trees are planted with the **double axis oriented in the direction of the row** which results in a flat and narrow canopy with a **depth of 70 cm (2.5 feet).**
- At planting, the two axes will bend in opposite directions and with a **crotch angle of 30-40 degrees** to make the basal angle of insertion wider.
- When vegetative growth starts, the two axes will be **oriented vertically to build a "double axis" tree**.

Bi-axis

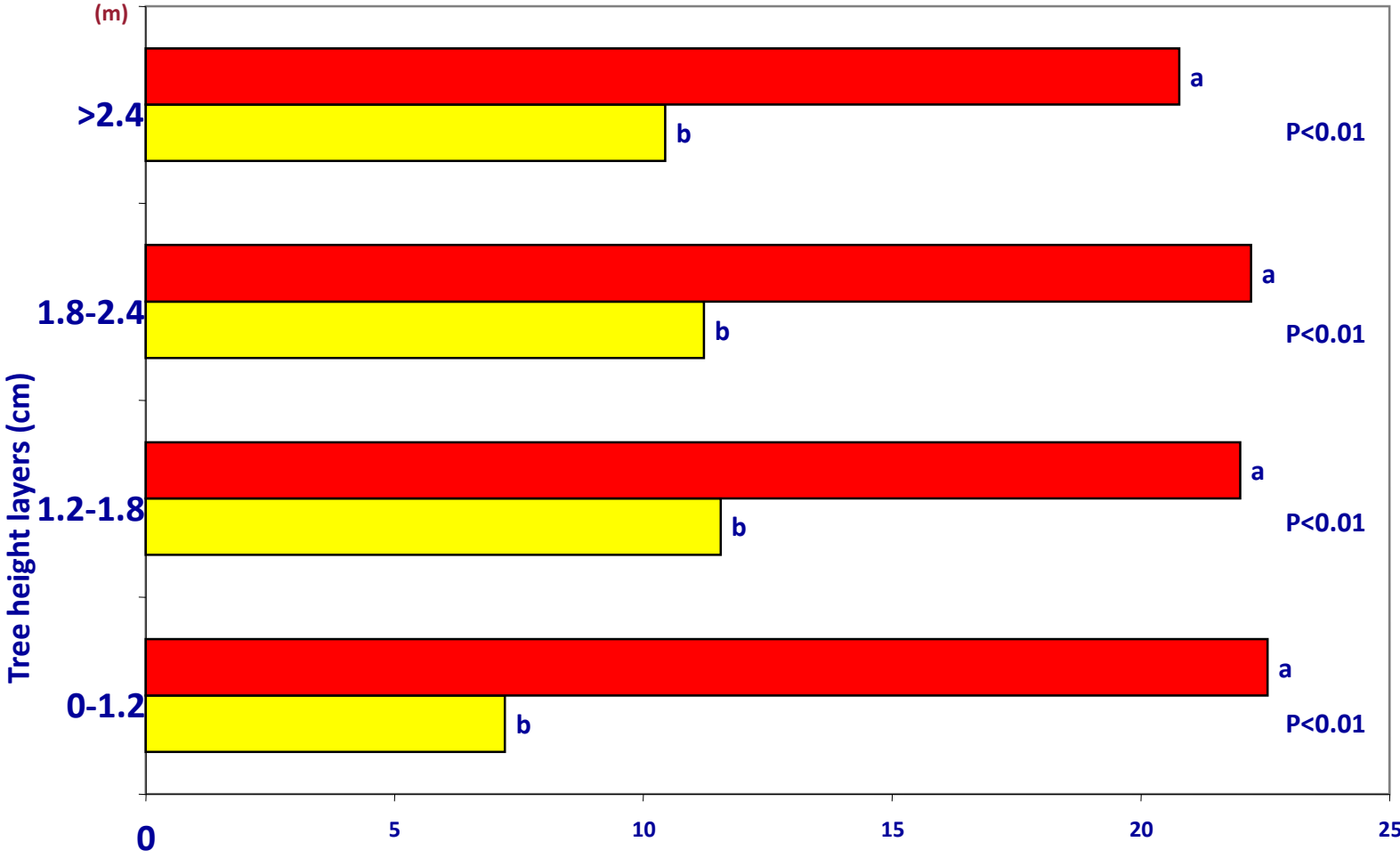
- Ideally, we need **20-25 small branches on each axis.**
- **It is not recommended to top the tree axis on apple.**

WSU TREE FRUIT ENDOWMENT

Bi-axis - Advantage

This system doubles the number of shoots and reduces their length to half compare to spindle planted at the same distance.

Fuji: Year 4 (Ravenna) - Data 2006 – Shoots number at various tree heights



Bi-Axis: an Alternative to Slender Spindle for Apple Orchards

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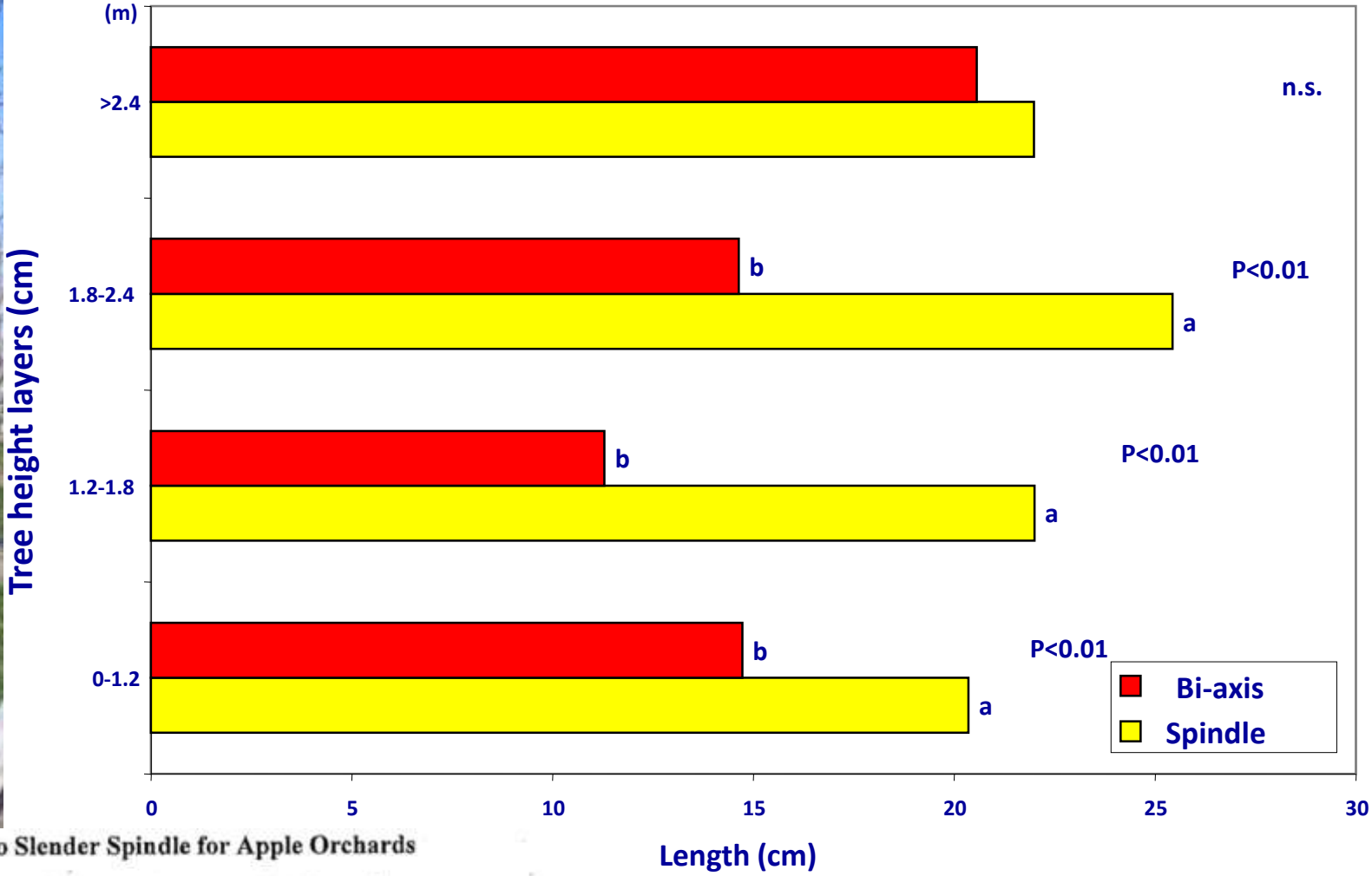
Fuji: Year 4 (Ravenna) - Data 2006 – 1–year shoot lenght at various tree heights



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Materials and Methods

Location: Marrara (Ferrara)

Graft combination: Toshiro/M9 T337

Training system: Bi-axes and Spindle

Year of planting: 2005

Planting distance and density:

Spindle 4.0 x 0.9 m (2,778 trees/ha)

Bi-axes 4.0 x 1.2 m (2,083 trees/ha)

TOSHIRO/M9 T337: Marrara (FERRARA) Year of planting 2005. Productive and vegetative traits (Years 2006-08). Comparison: Spindle *vs* Bi-axes

Training system 2006	Planting density	Fruit number	Yield /tree (kg)	Fruit weight (g)	TSA (cm2)	Yield effic. (kg/cm2)	Calc. Yield (t/ha)
Bi-axes	2083	61	15,67	258 a	7,9	1,99	32,6
Spindle	2778	61	14,6	241 b	7,3	2,01	40,6
Significatività		ns	ns	*	ns	ns	*

Training system 2007	Planting density	Fruit number	Yield /tree (kg)	Fruit weight (g)	TSA (cm2)	Yield effic. (kg/cm2)	Calc. Yield (t/ha)
Bi-axes	2083	57,8	12,51	224	11,25	1,13	26,1
Spindle	2778	44,8	9,99	222	10,71	1,05	27,8
Significatività		ns	ns	ns	ns	ns	ns

Training system 2008	Planting density	Fruit number	Yield /tree (kg)	Fruit weight (g)	TSA (cm2)	Yield effic. (kg/cm2)	Calc. Yield (t/ha)
Bi-axes	2083	111,9 a	25,7 a	230	12,46	2,11 a	53,5
Spindle	2778	88,7 b	20,3 b	229	11,79	1,74 b	56,5
Significatività		**	**	ns	ns	*	ns

TOSHIRO/M9 T337: Marrara (FERRARA) Year of planting 2005. Bi-axes productive and vegetative traits. Large branch *vs* Small branch

Bi-axes 2006	Fruit number	Yield /tree (kg)	Fruit weight (g)	TSA (cm2)	Yield effic. (kg/cm2)	Calc. Yield (t/ha)	Calc. Yield (%)
Large branch	26,6 b	6,72 b	256	4,76 a	1,48 b	14,0	42,8
Small branch	34,5 a	8,95 a	261	3,29 b	2,89 a	18,6	57,2
Significance	**	***	ns	***	***	32,6	100,0

Bi-axes 2007	Fruit number	Yield /tree (kg)	Fruit weight (g)	TSA (cm2)	Yield effic. (kg/cm2)	Calc. Yield (t/ha)	Calc. Yield (%)
Large branch	29,1	6,30	220	6,91	0,98	13,1	50,4
Small branch	28,7	6,20	231	4,92	1,33	12,9	49,6
Significance	ns	ns	ns	***	*	26,1	100,0

Bi-axes 2008	Fruit number	Yield /tree (kg)	Fruit weight (g)	TSA (cm2)	Yield effic. (kg/cm2)	Calc. Yield (t/ha)	Calc. Yield (%)
Large branch	59,2	13,57	229	7,12 a	1,91	28,3	52,8
Small branch	52,7	12,12	230	5,37 b	2,25	25,2	47,2
Significance	ns	ns	ns	***	*	53,5	100,0

Fuji (Ravenna):

different overcolor in the bottom part of the tree – Year 4

Spindle

Bi-axis

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WSU TREE FRUIT ENDOWMENT

Materials and Methods

Location: Migliaro (Ferrara)

Graft combination: Rosy Glow/M9T337

Training system: Bi-axes and Spindle

Year of planting: 2006

Planting distance and density:
Spindle: 3.3 x 0.8 m (3,788 trees/ha)
10.8’ x 2.6’ (1,534 trees/A)
Bi-axis: 3.3 x 0.8 m (3,788 trees/ha)
10.8’ x 2.6’ (1,534 trees/A)

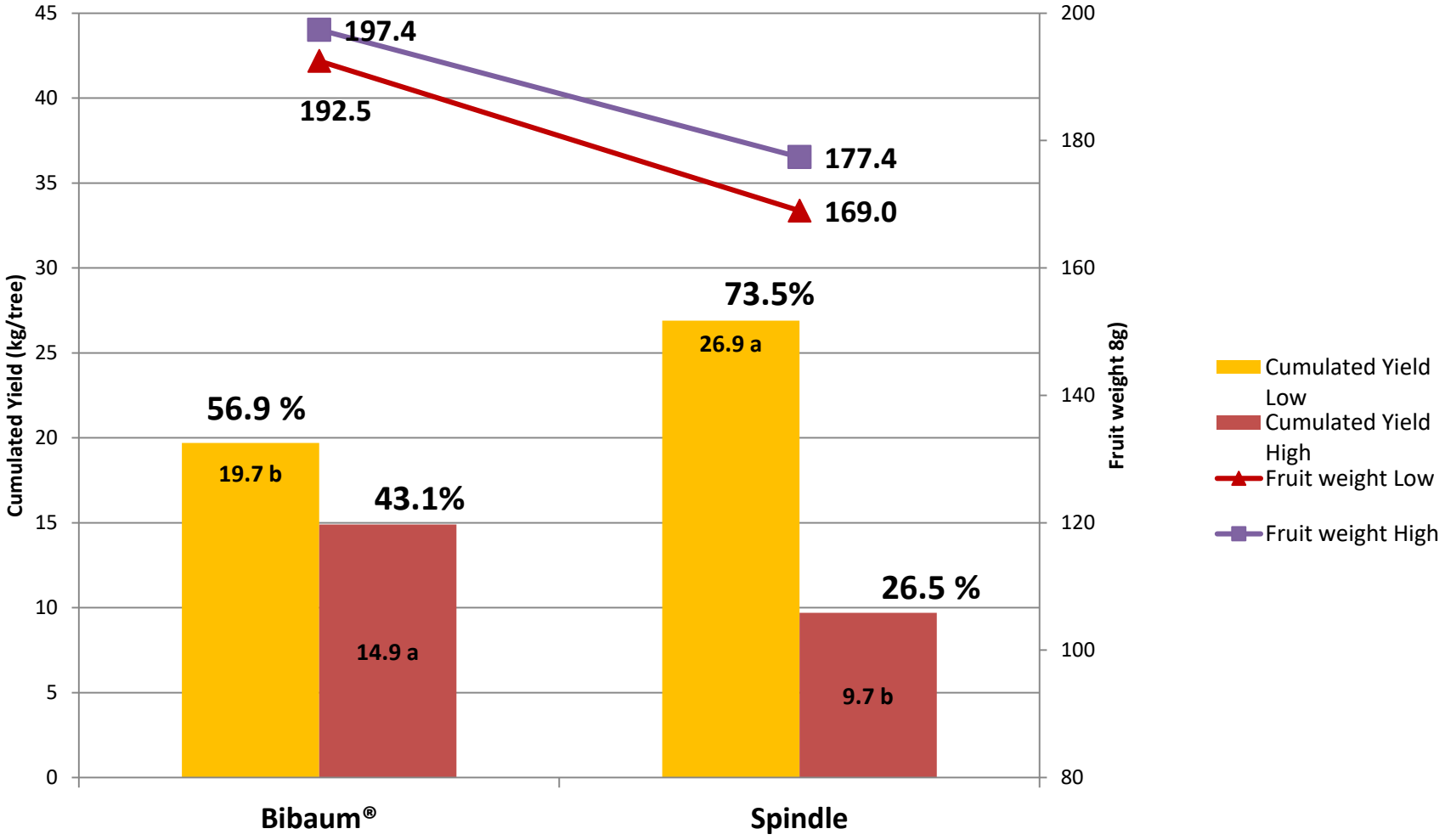
Rosy Glow/M9 T337 – Medelana (FERRARA) Planting year 2006. Productive and vegetative traits 2007

Training system	Planting density (trees/ha)	Planting density (trees/A)	Fruit number	Yield kg/tree		Avr. fruit weight (g)		TCSA (cm^2)		Yield effic. (kg/cm^2)	Calc. Yield (t/ha)	Calc. Yield (tonne/A)
Bi-axis	**3,788**	**1,533**	21.2	5.02	a	238	a	5.34	a	0.97	19.0	7.7
Spindle	**3,788**	**1,533**	23.2	5.18	b	226	b	4.27	b	1.24	19.6	7.9
Significance			ns	ns		*		*		ns	ns	ns

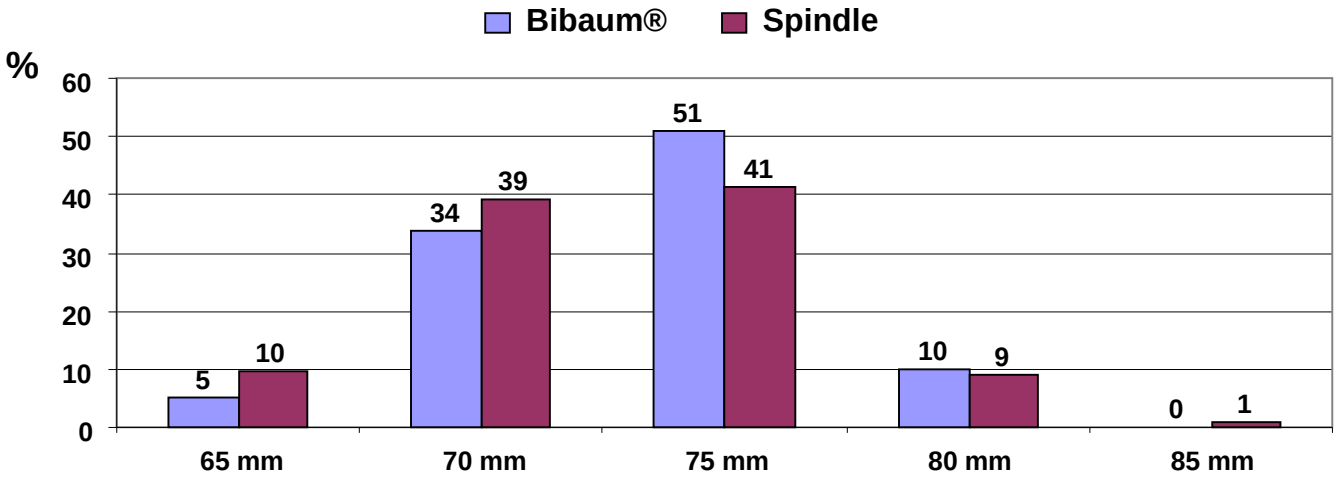
Bi-axes	Planting density (trees/A)	Fruit number		kg/tree		Avr. fruit weight (g)	TCSA (cm^2)		Yield effic. (kg/cm^2)	Calc. Yield (t/ha)	Calc. Yield (%)
Large branch	**1,533**	8.8	b	2.07	b	238	3.41	a	0.61 b	7.8	41.2
Small branch	**1,533**	12.4	a	2.95	a	239	2.25	b	1.37 a	11.2	58.8
Significance		*		*		ns	*		*	19.0	100.0

Bi-axis - Crop distribution

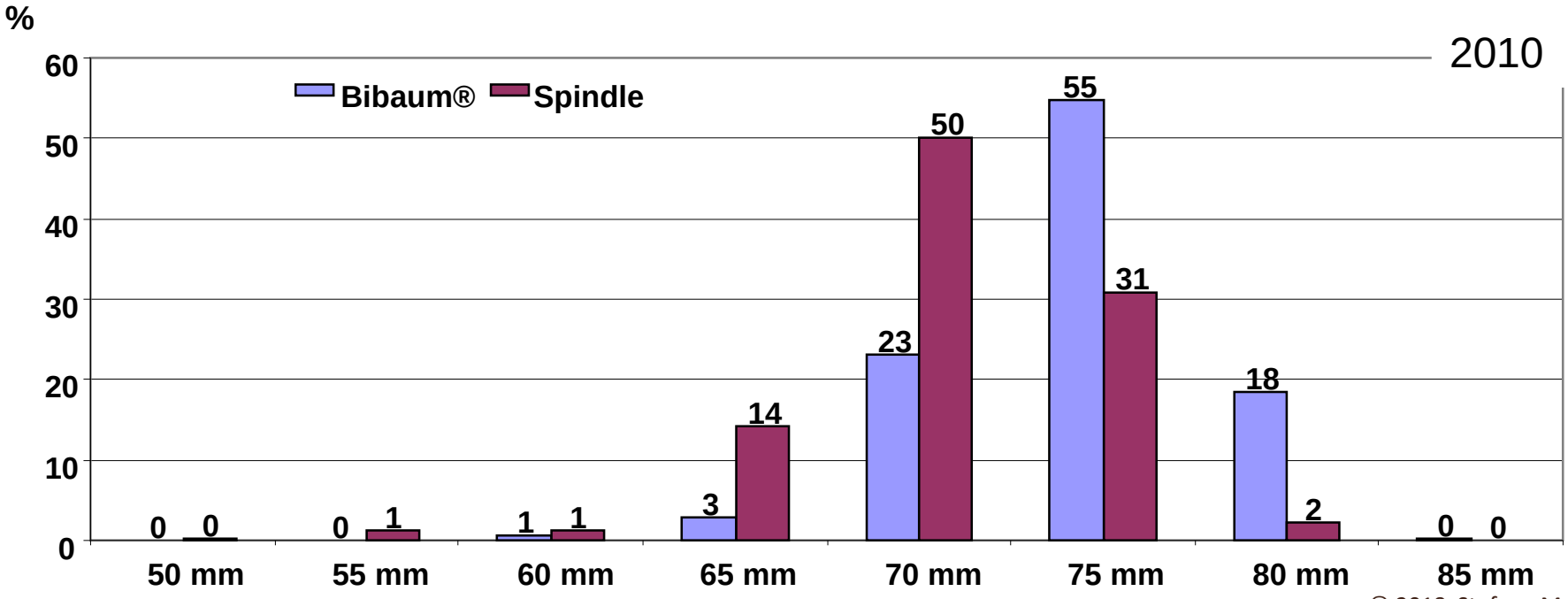
Cumulated yield and the average fruit weight in the canopy



Fruit size distribution (%) (yrs 2009-2010)

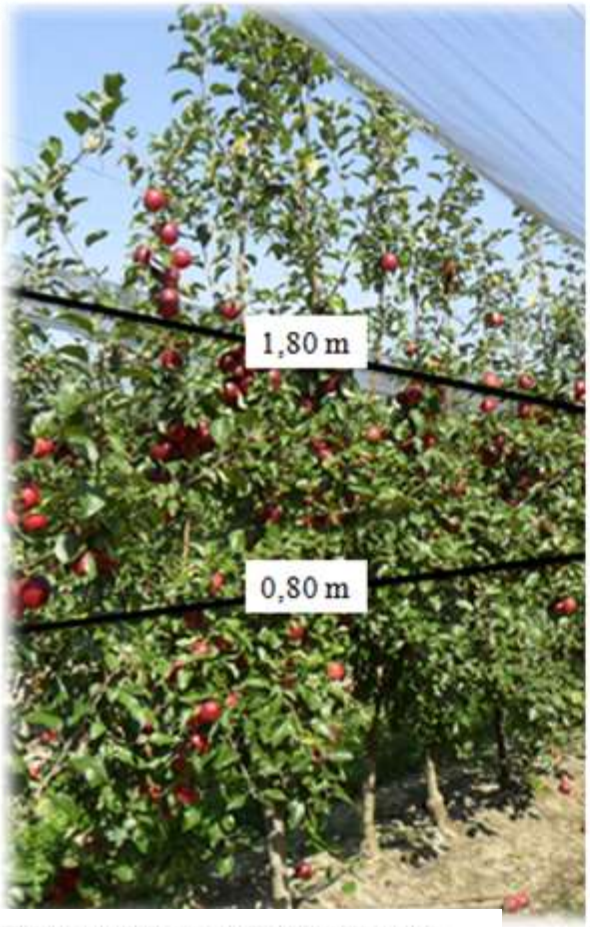


2009



MODI: Fruiting *habit* investigation

- **Single picking time**
- **Three canopy levels: < 0.8m = low, 0.8-1.8m = medium, >1.8m = high**



Spur on axis

Brindilla

Spur on 1-year-old shoot

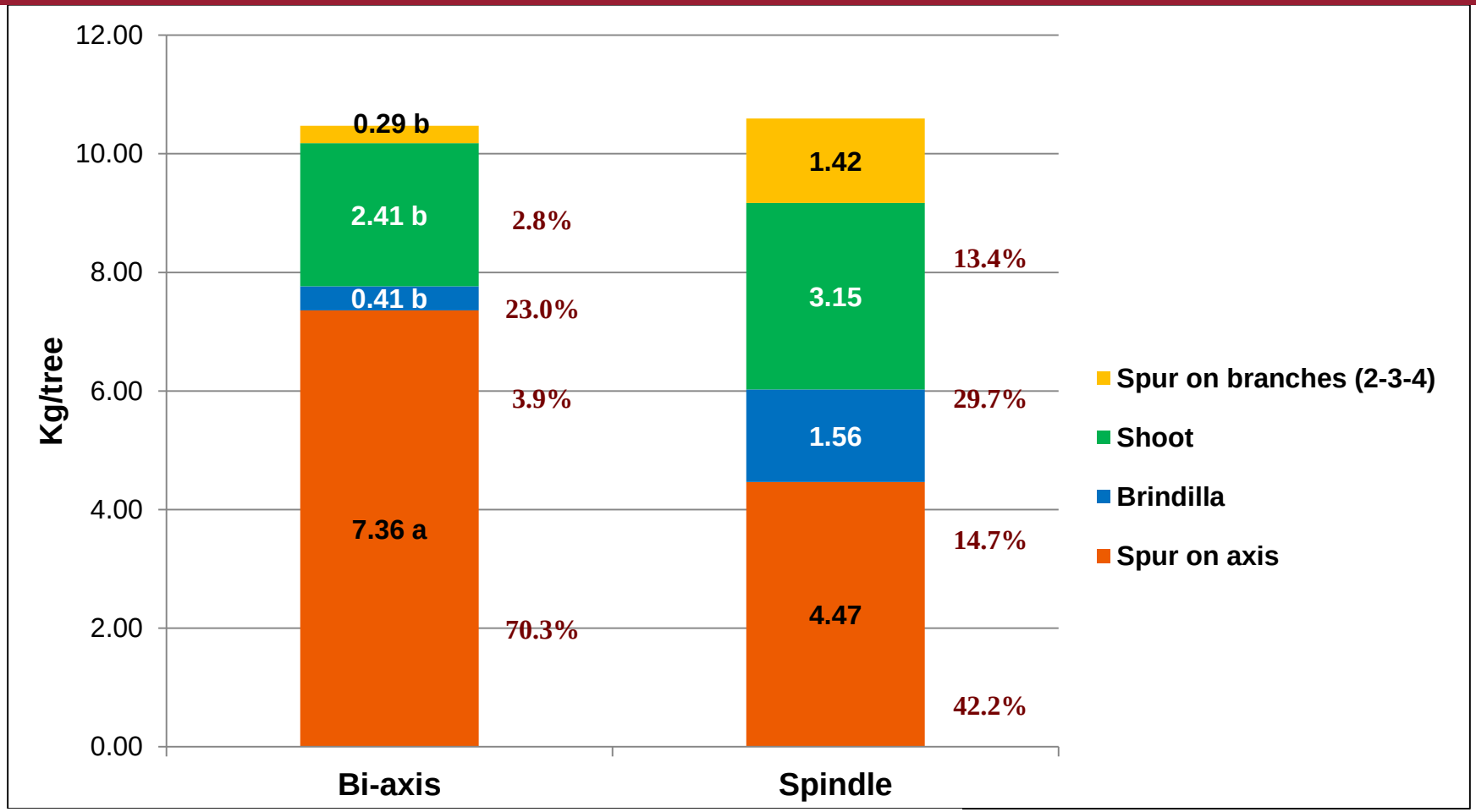
Spur on 2-years-old and over braches

Investigation of 'Modi®' Habitus in Relation to Training Systems

S. Musacchi[1,2], D. Bucci[1], V. Ancarani[1], F. Gagliardi[1] and S. Serra[1,2]
[1] DipSA, Alma Mater Studiorum, University of Bologna, Italy
[2] TFREC, Washington State University, Wenatchee, WA, USA

Proc. X[th] IS on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems
Ed.: K. Theron
Acta Hort. 1058, ISHS 2014

Modi: Habitus investigation
Results: comparison among training systems
Yield (kg) per training systems divided by bearing wood 2011



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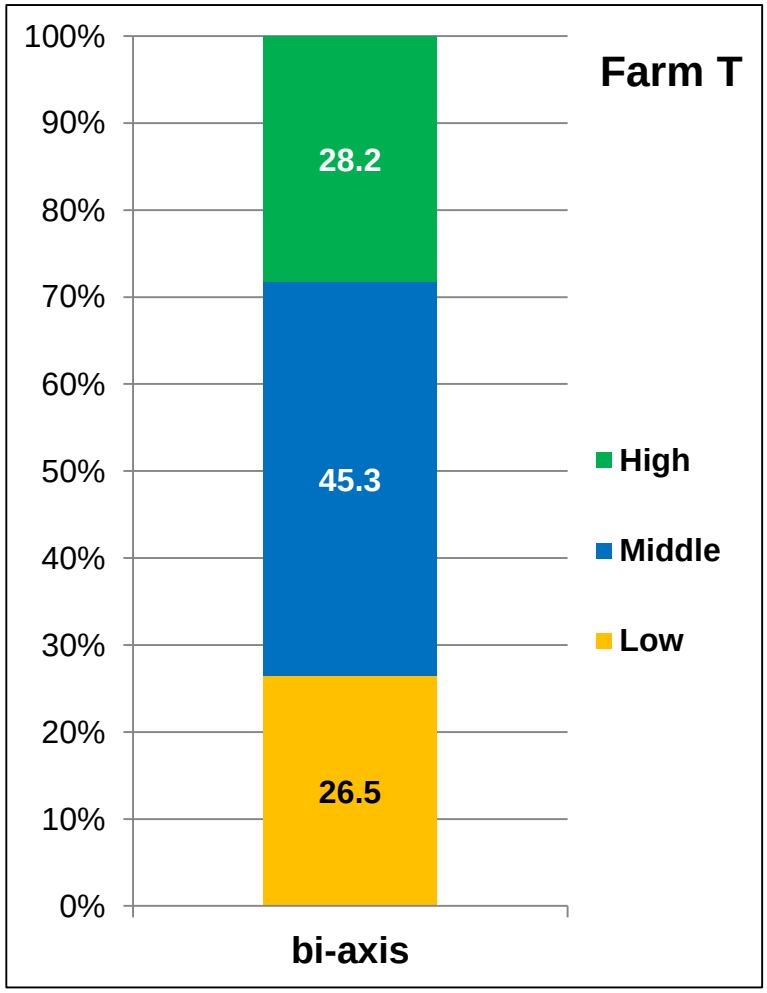
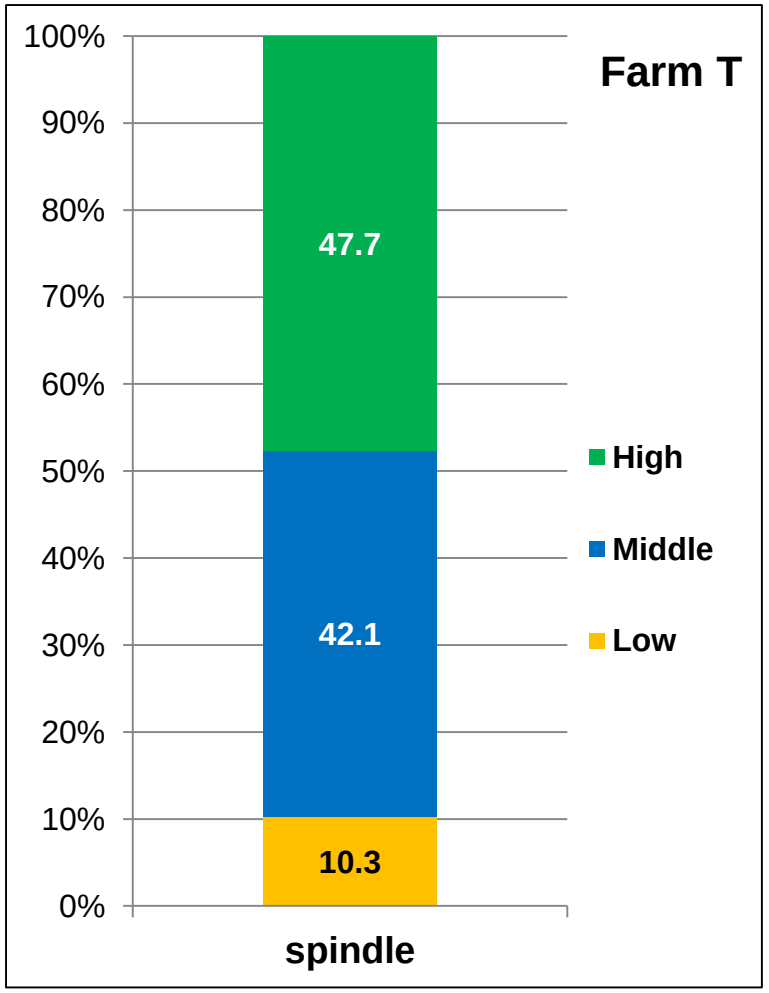
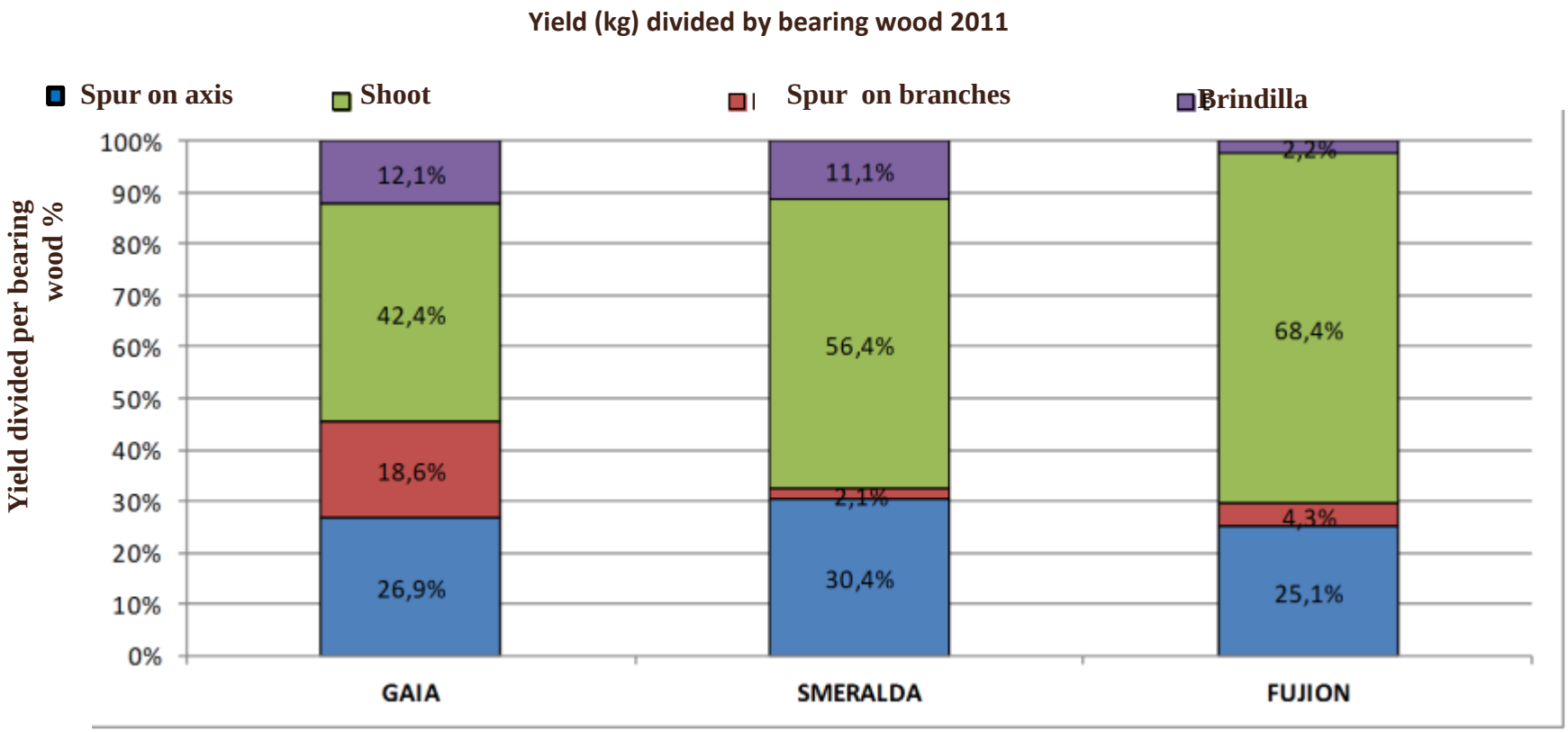
WSU TREE FRUIT ENDOWMENT

Percentage of spurs per canopy level





Distribution of fruits on different bearing wood in three cultivar



Pear training system

Pear cultivar

PASSA CRASSANA (1885)

BLANQUILLA (<1700)

ROCHA(1836)

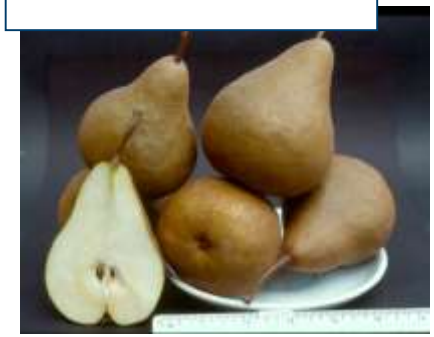
WILLIAM (1765)

CONFERENCE (1885)

DECANA DEL COMIZIO (1849)

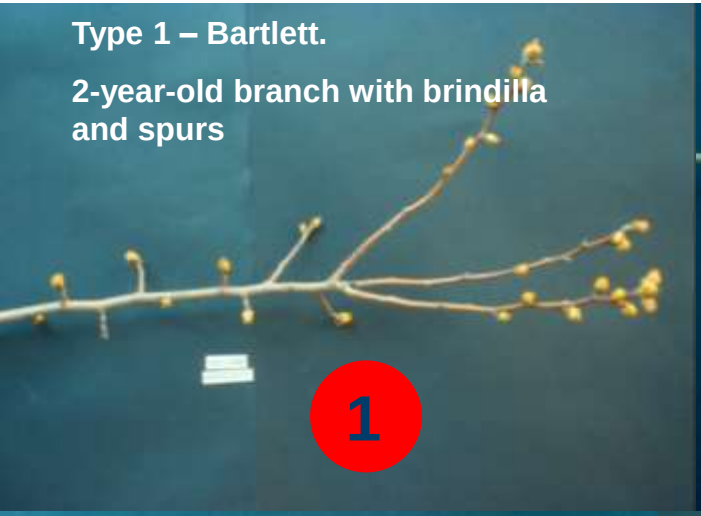
ABATE FETEL (1876)

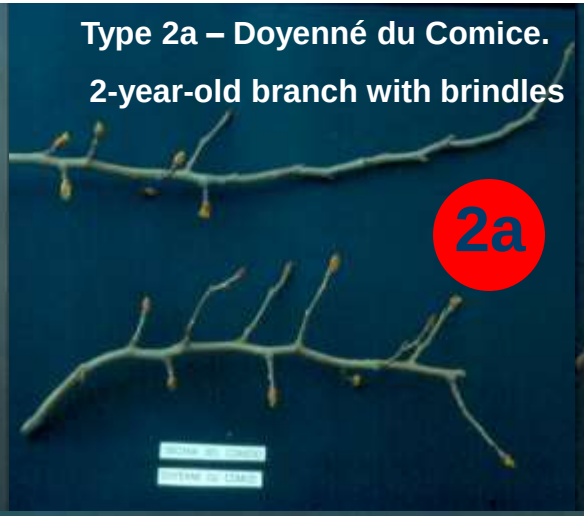
KAISER(1830)

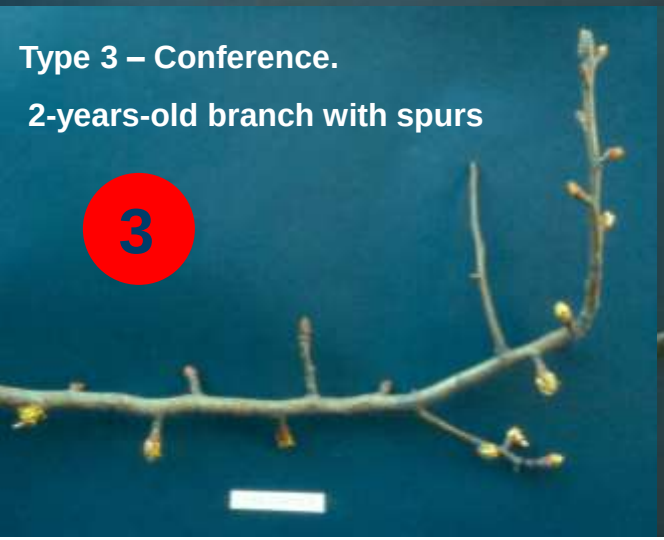


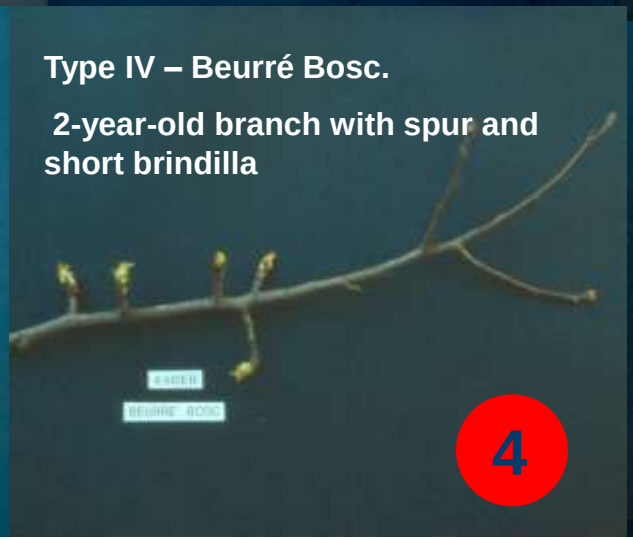
MAX RED BARTLETT (1938)

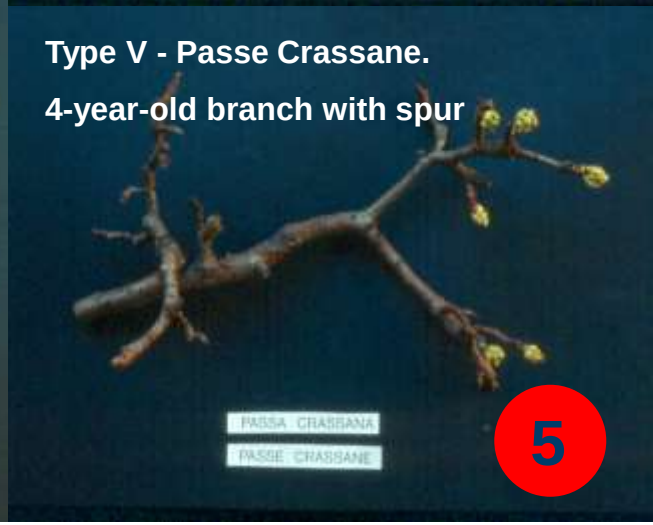
Pear fruit-bud models











Sansavini 1966 a e b

Training systems and spacings 2016

Training system	Spacing (m)	Density (tree/ha)	Density (tree/acre)	Cultivar
Free Palmetta	3,6 x 1,5 4,0 x 2,0	1,850 1,250	749 506	Main
Slender spindle	3,5 x 1,0 4,0 x 1,5	2,850 1,660	1,153 672	Main
Vertical axis	3,5 x 0,7	4,080	1,651	Abbé Fétel, Conference, Doyenné du Comice, Bosc
Y tatura	4,0 x 0,8 4,5 x 1,2	3,125 1,850	1,265 749	Main
Y longitudinal Bibaum®	3,3 x 1,0	3,030	1,227	Main
V system	3,5 x 0,7	4,080	1,651	Abbé Fétel, Conference, Doyenné, Bosc
Very high density				
V system intensive	3,5 x 0,50	6,000	2,429	Abbé Fétel, Conference, Doyenné du Comice, Bosc
Vertical axis	3,0 x 0,30 2,5 x 0,31	11,000 13,000	4,453 5,263	Abbé Fétel

Source: modified from Sansavini and Musacchi, 2000

Palmette

Abbe Fetel own-rooted 12-year-old

Palmette

Abbe Fetel grafted of Conference (own-rooted) 5-year-old

Spindle

Spindle

V system

Abbè Fètel/BH/MC Spacing 3.8 x 0.35- Planting density 7,518 trees/ha. Year of planting 2005

VERTICAL AXIS

Abbé Fétel/MC - Vertical axe. Year 5. Ferrara. 2005 Density 12,121 trees/ha. Spacing 2.75 x 0.30 m

Cv Abbé Fétel/Syd g distance 3.3 x 1.0 m. Planting de

Bi-axis

From old to new orchards in Washington and Oregon

From a globe shape to a Bi-axis system

NEW ORCHARDS

Two-axis

Three- axis

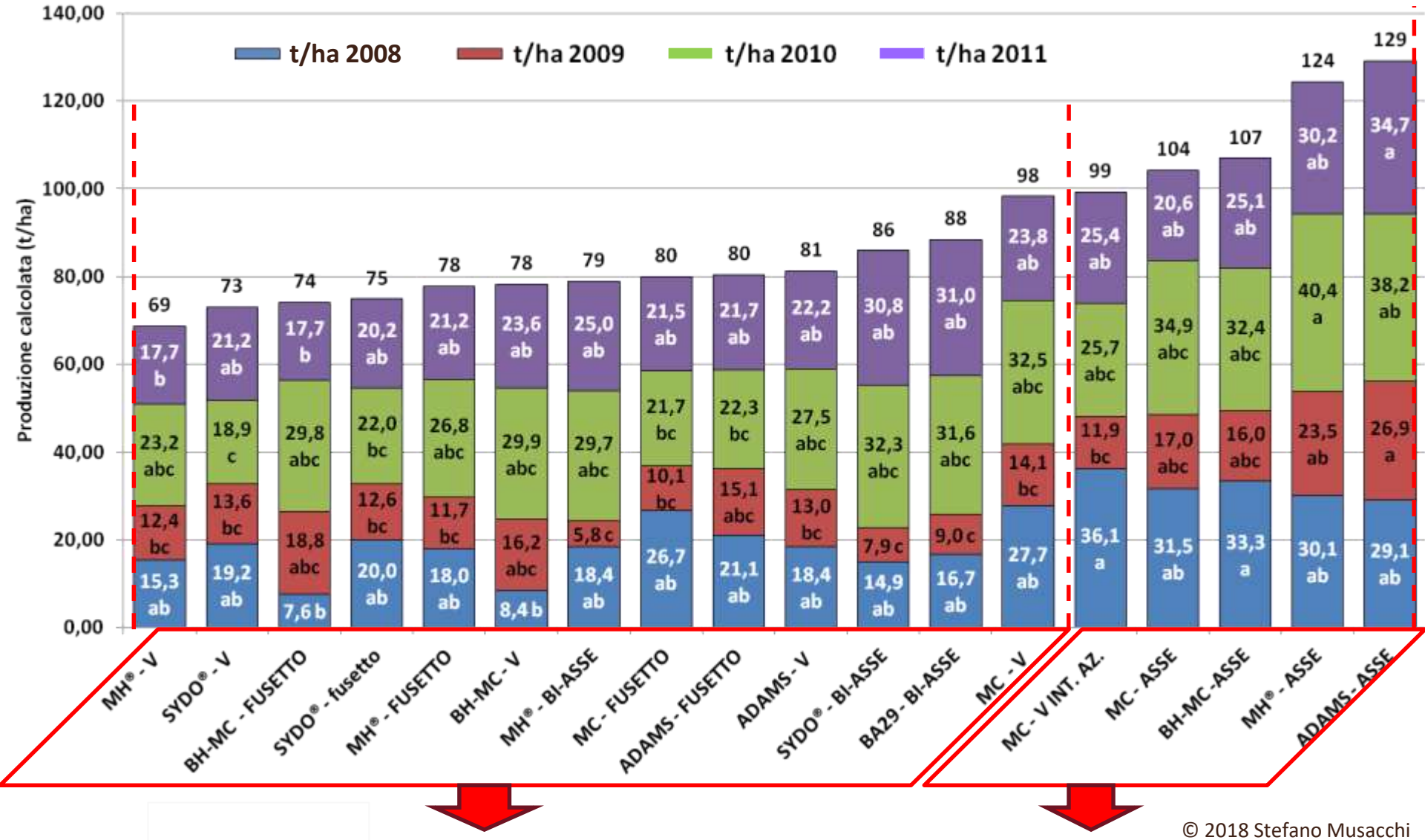
Comparison among orchard systems for Abbé Fétel cultivar

Training system	density	Rootstock					
		ADAMS	Sydo®	MC	BH-MC	MH®	BA29
Spindle	Spacing (m)	3,5x0,9	3,5x1	3,5x0,8	3,5x0,8	3,5x0,9	/
	Density (tree/ha)	3,175	2,857	3,571	3,571	3,175	
Bi-axis	Spacing (m)	/	3,5x1	/	/	3,5x1	3,5x1
	Density (tree/ha)		2,857			2,857	2,857
"V" system	Spacing (m)	3,5x0,7	3,5x0,8	3,5x0,5	3,5x0,5	3,5x0,7	/
	Density (tree/ha)	4,082	3,571	5,714	5,714	4,082	
Vertical axis	Spacing (m)	3,5X0,4	/	3,5x0,3	3,5x0,3	3,5X0,4	/
	Density (tree/ha)	7,143		9,524	9,524	7,143	
Intensive "V" system	Spacing (m)	/	/	3,5X0,4	/	/	/
	Density (tree/ha)			7,143			

Every combination rootstock-training system was rapresented by three randomized repetitions.

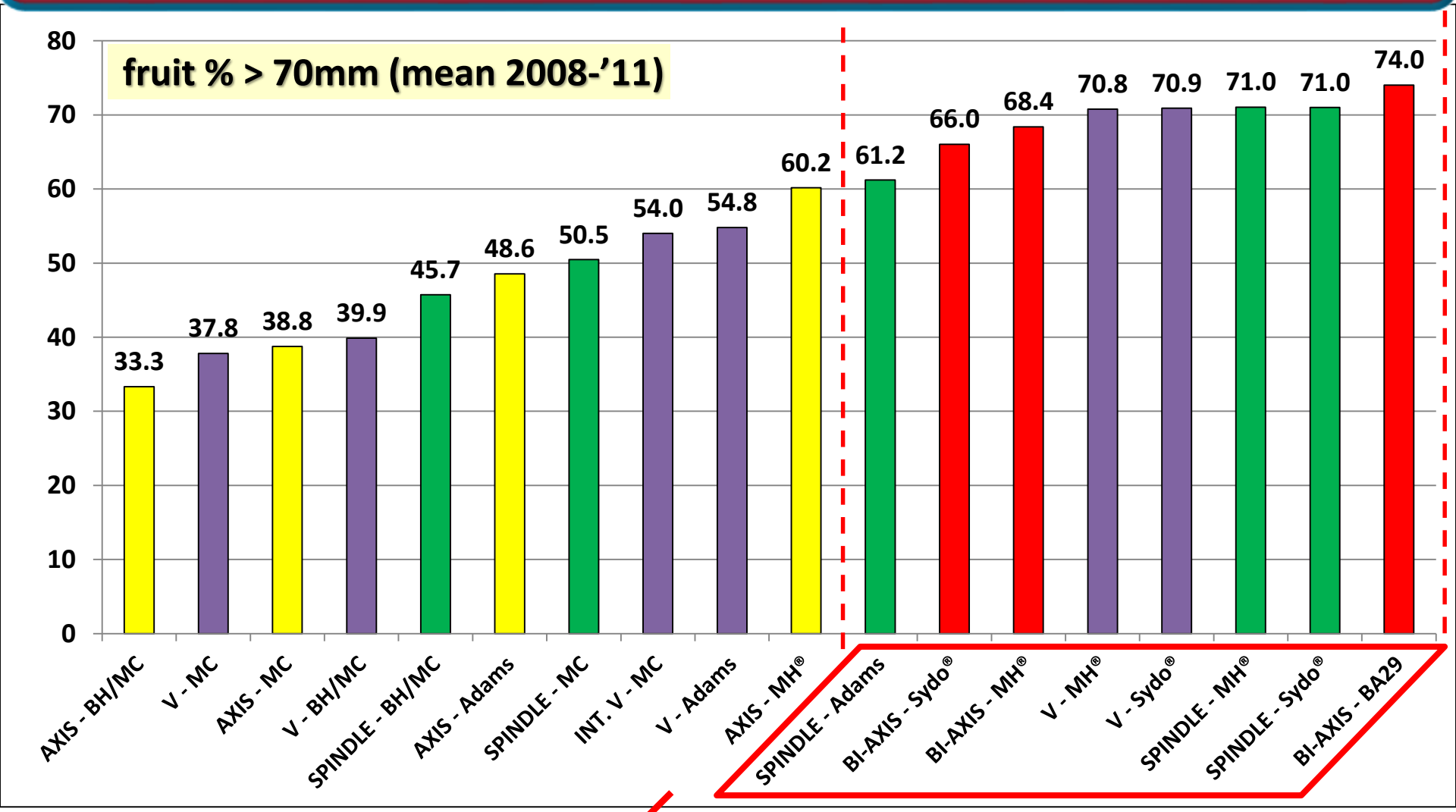
Comparison among orchard systems for Abbé Fétel cultivar: productive results.

Calculated Yield/ha (2008-2011)



Density: 2,857 ÷ 5,714 trees/ha **Density: 7,143 ÷ 9,524 trees/ha**

Comparison among orchard systems for Abbé Fétel cultivar: Fruit size: % over 70 mm



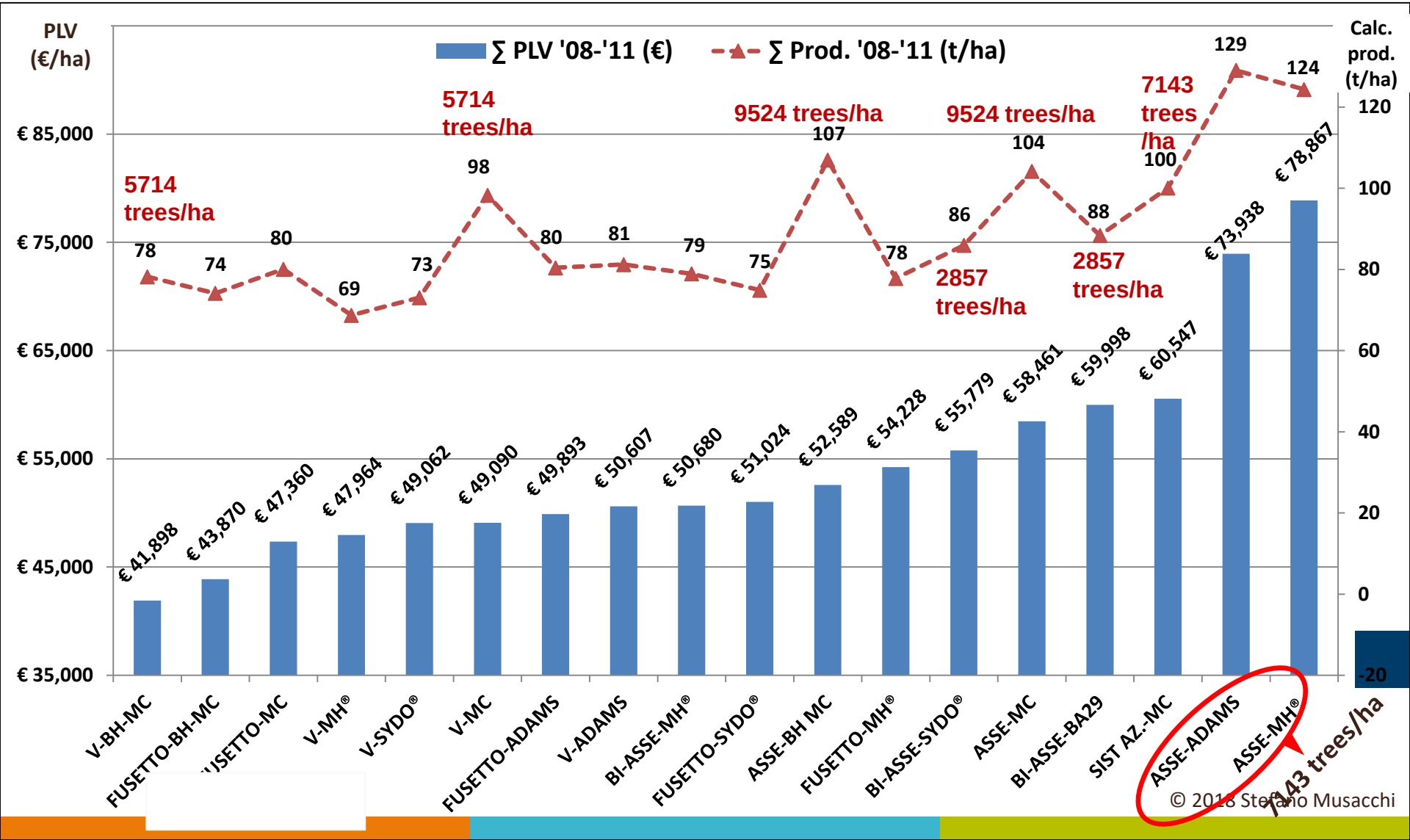
7,143 trees/ha

Density: 2,857 ÷ 4,082 trees/ha

Value of the production

	Size	- 60	60/65	65/70	70/75	75+
Year	2008	0,05	0,45	0,68	0,87	0,93
	2009	0,05	0,35	0,55	0,70	0,80
	2010	0,05	0,55	0,75	0,92	1,00
	2011	0,05	0,15	0,20	0,40	0,52

Prices per size
Source:
Fondazione
F.lli Navarra



Pruning
Bi-axis

WSU TREE FRUIT ENDOWMENT

Bibaum® - First year early spring (left) second year (right)

Bi-axis system

- If the trunk presents blind areas in the second year, it is possible to girdle the trunk or notch over the dormant buds to induce bud break. In the third year, the tree should completely fill the space.

Girdling:
Precise shoots formation

Girdling, notching and Promalin application can help to promote shoot growth

WSU TREE FRUIT ENDOWMENT

Notching and girdling effects on blind wood

Girdling, notching and Promalin application can help to promote shoot growth

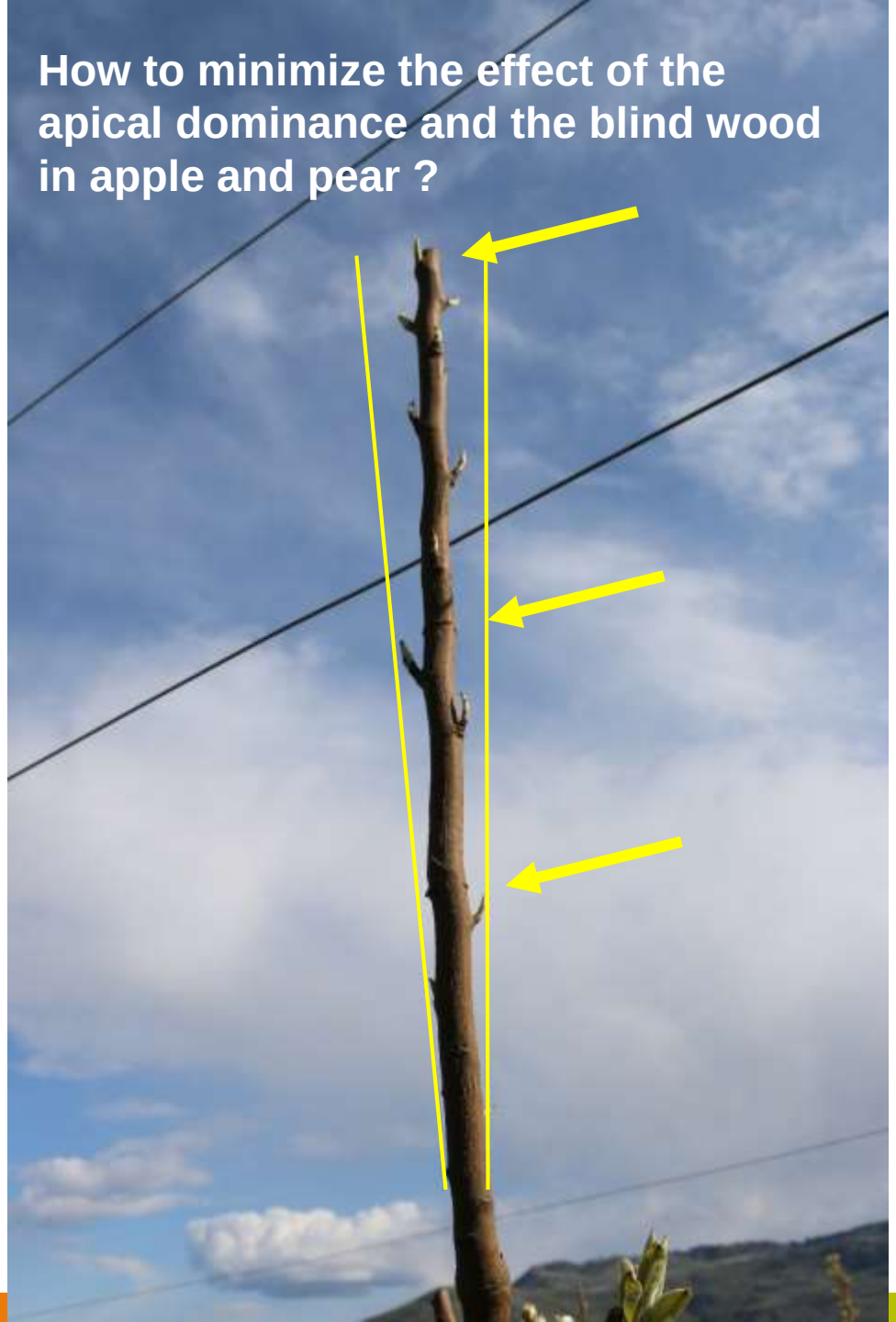
Notching and girdling effects on blind wood

Notching and girdling effects on blind wood

WSU TREE FRUIT ENDOWMENT

Girdling effects on Fuji

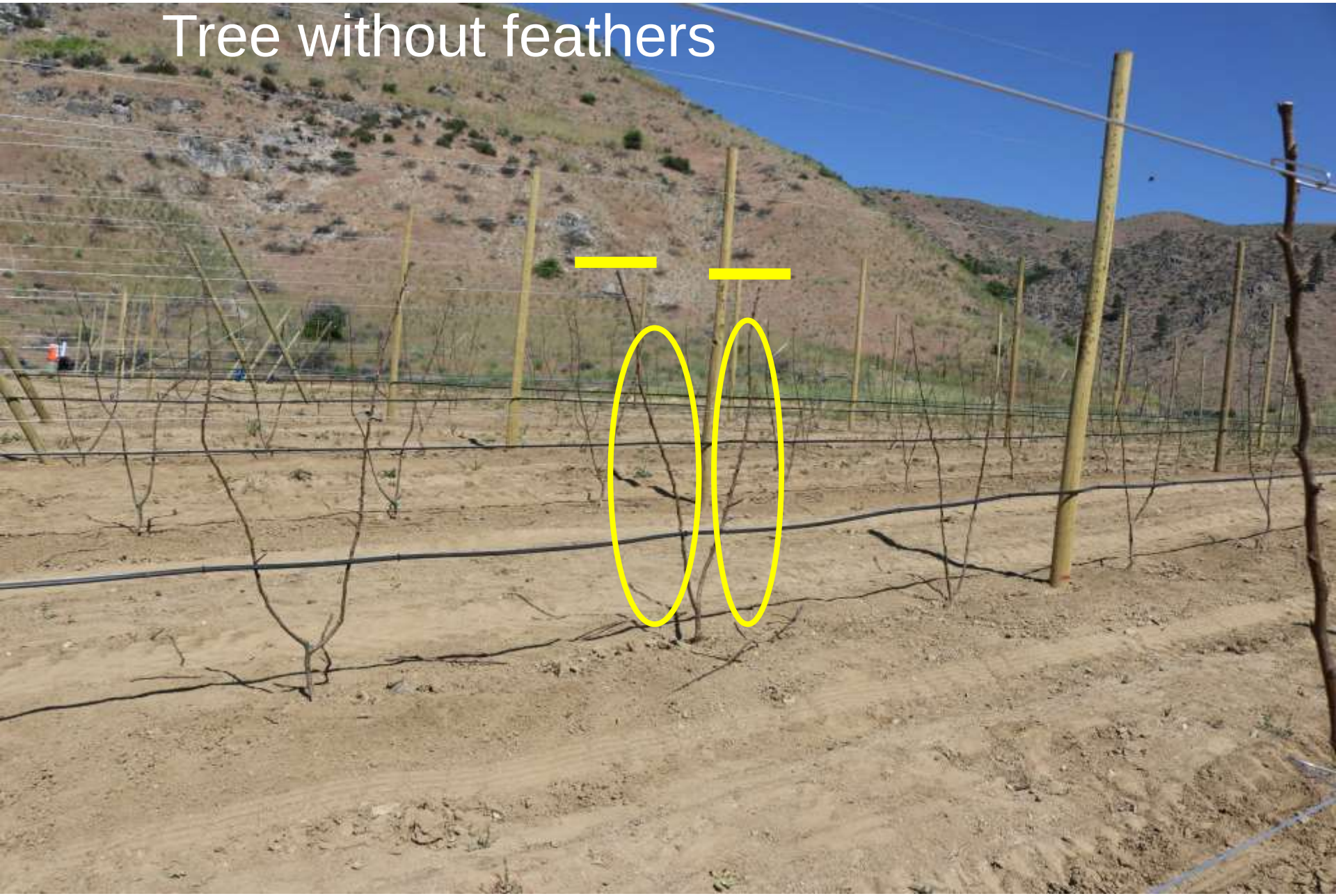
How to minimize the effect of the apical dominance and the blind wood in apple and pear ?



WSU TREE FRUIT ENDOWMENT

Tree with feathers

Tree without feathers



Starting operations

- Head back the tree 3 inches above the third wire. All the tree will be at the same level
- Girdling every feet the part of the tree in the ellipse. After planting
- Notching at least 4 buds between two girdling, the bottom part is more important. After planting
- Start the feathers production 1.5 feet above the ground. Don’t move to high…….please.

Bi-axis system - Pruning

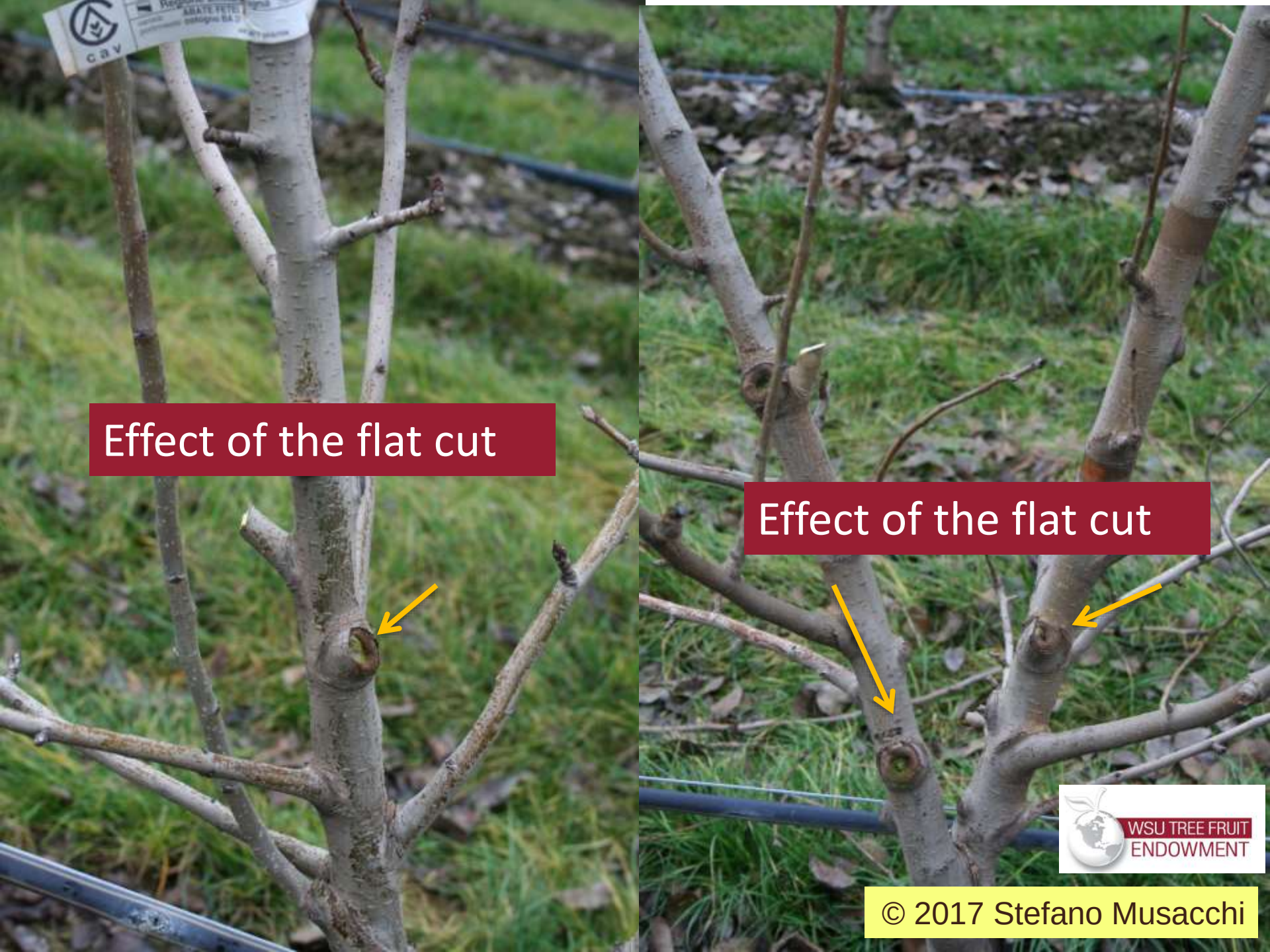
- Click pruning help to maintain the cropping zone close to the stem
- Pruning is simple and is required to eliminate the shoots that are too vigorous and remove branches oriented towards the inside.
- In the basal zone a good rule is to eliminate all the shoots that have a diameter 30% greater than that of the trunk where they are inserted.
- It is strongly recommended to leave a stub to avoid producing blind wood.
- Prefer to It is recommended to renew 20 % of the structure annually to minimize branches aging.

Click = Tira savia

Click = Tira savia

Click effect on shoot growth

Click pruning effects on buds swelling



Effect of “Dutch cut”

Pruning of the top

- We need to maintain only the twigs closed with a flower bud.
- Later cut when the final height of the tree is achieved.
- Short the top on 1-year old shoot. ONLY IF NECESSARY- SPECIES DEPENDENT (PEAR)

Click pruning of the top in apple

WSU TREE FRUIT ENDOWMENT

Cut back on lateral 1-year-old shoot with a flower bud

Cut back of the top on 1-year-old shoot

Thank you for your attention !!

Thank you!

WSU TREE FRUIT ENDOWMENT

YouTube Videos

WSU CAHNRS Channel; WSU Tree Fruit playlist

Recorded and Being Edited:

Pruning Bartlett Pears to Optimize Fruit Size and Quality (Musacchi)

WSU Expert Videos

Direct link to the WSU Tree Fruit playlist:
https://www.youtube.com/playlist?list=PLajA3BBVyv1zjkicqf3Of_Ka_PTSAddqu