Large-Scale, Whole-Bed, Scion-Rootstock Trial, Indiantown

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CREC Citrus Plant Improvement

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Whole-Bed Rootstock Trial, Indiantown - Description

The primary objective in this project was to demonstrate the purported benefits of size-controlled trees planted at spacings appropriate to expected tree vigor. To that end, Hamlin or Valencia trees on various rootstocks were planted in whole beds at moderate to close spacing. The treatments [scion-rootstock-spacing combinations] were planted in single multi-row beds with spacing ranging from 12 x 20 ft. to 7 x 12 ft. or 181 to 518 trees/acre. Tree count was between 144 and 332 trees/bed. Some treatment combinations were replicated.

Part of the original plan was to test windbreaks. Thus, each scion block of 20-acres was subdivided into 4 sections and surrounded by a two-layer windbreak consisting of a fast-growing tree [*Corymbia torelliana*] and a short, yellow-flowering shrub [sterile, Gold lantana].

Whole-Bed Rootstock Trial, Indiantown – Summary [see following narrative details]:

- Location: Indiantown, Martin county
- Scion: Hamlin and Valencia
- Rootstocks: see Table 1
- Date planted: November 2009; March & September 2010
- Design: Whole beds planted with one scion-rootstock-spacing combination with some replication; also, 2 beds with Hamlin and 2 with Valencia were included to observe the performance of advanced plant breeding selections and other promising rootstocks.
    - Spacing: variable
    - Drip irrigation
- Data:
    - 2012/13: Tree height and canopy width
    - 2012/16: Juice quality, yield [boxes/acre] for 2012/13; 2013/14; 2014/15; 2015/16; 4-year cumulative yield
- ***Trial was terminated in 2016. Change in ownership.***

SITE DEVELOPMENT: The trials were established on land previously planted to citrus growing on 60-ft beds. Two adjacent 20-acre blocks were selected for planting with Hamlin or Valencia. The broad beds were retained, but renovated to their original condition. A drip irrigation/fertigation system was designed and installed by Arapaho Citrus Management. Prior to or after planting, a layer of chicken manure-based organic material was added to each row except the western-most 5 or 6 beds in each block.

PLANTING: The citrus trees were produced in a commercial nursery. The beds in each block were numbered consecutively from east to west and 3 or 4 rows/bed were staked off depending on the rootstock-spacing plan [Fig. 2]. The planting plan was developed in conjunction with the soil map [Fig. 1] to minimize soil series as a factor affecting trial outcomes. Planting commenced in November 2009 and continued until September 2010. The first trees were planted in bed 1 and continued to the west [Table 2]. About 2/3 of the trees were planted in 2009.

The windbreaks were planted before the citrus. Management proved to be a bit problematic. The *C. torelliana* trees grew off satisfactorily, but the lantana plants did not compete well with weeds. They were difficult to maintain and, thus, did not provide the yellow color intended to distract psyllids.

DATA: Yield measurements, by bed, began when the trees were about 3 years old and continued for 4 consecutive seasons. Tree canopy size was measured in the first year when yield data were obtained. No data were taken from the research beds. No juice quality data were collected from each bed; however, to provide a overview of the general quality, data are presented from the official test house facility at the processing plant where the trailer loads of fruit were delivered from the trials.

HLB and COLD WEATHER: Visible symptoms of HLB began to appear among the trees after several years, but those symptoms were not widespread or more apparent among the trees of one treatment versus any other scion-spacing-rootstock combination**.**

A freeze occurred soon after planting in 2009. Many of the newly planted trees were injured. Badly damaged trees were replaced where possible.

The trial was terminated and removed in 2016.

Table 1. Whole-Bed Rootstock Trial, Indiantown - List of rootstocks, parentage and number of trees

Hamlin		
Rootstock	**Parentage**	**Number of Trees**
PxM 1584	*Poncirus trifoliata* x Milam	159
C-35	Ruby swt. x WF TF	938
FDT	Flying Dragon TF	960
Kinkoji	Citrus obovoidea hort. ex I. Takah. RUTACEAE	168
RxT	Rangpur lime x Troyer citrange	560
Swingle	Swingle citrumelo	868
US-812	Sunki x Benecke TF	141
US-897	Cleo x TF	560
Willits	Ruby swt. x TF	280

Valencia		
Rootstock	**Parentage**	**Number of Trees**
C-35	Ruby swt. x WF TF	1280
FDT	Flying Dragon TF	2960
Swingle	Swingle citrumelo	560
US-897	Cleo x TF	1280

Whole-Bed Rootstock Trial, Indiantown - Interpretative summary [as of August 2016]:

Hamlin. The trees were only 6-7 years old when the trial was terminated and removed. In that span of time, 4 years of yield data provided evidence supporting the "Sweet Spot" concept , i.e., proper selection of tree spacing is dictated by the vigor of a scion-rootstock combination, site conditions and cultural practices. Rootstock examples illustrating this concept are:

- **Willits citrange**. This rootstock produces small trees that when planted close together are productive early on leading to high cumulative yields [projected 1,000 boxes/acre; Figs 12 and 13]. That confirms the benefit of such trees and that early yields with trees on any rootstock bear in direct relationship to tree count: Higher tree counts lead to higher yields.
- **Swingle citrumelo**. Most commercial scions on this rootstock produce trees of medium vigor. Thus, to balance long-term and short-term performance, trees on Swingle are best planted at medium density like 10 x 20 ft. The Hamlin data support this contention: Those planted at 8 x 12 ft. yielded a projected 1,000 boxes/acre cumulatively; those planted at slightly lower densities of 8 x 20 and 12 x 20 ft. were not as productive as they had yet to fill the canopy space available.
- **C-35 citrange**. Trees on this rootstock are similar to, but usually less vigorous than those on Swingle. The cumulative yield differences among the C-35 trees reflected the same pattern as those on Swingle except the closest spaced trees on C-35 had the lowest yields. Those trees were planted at 8 x12 ft. and were a year younger.
- **Flying Dragon trifoliate orange.** This rootstock is well-known for producing small-sized trees that were the closest planted ones in the trial at 7 x 12 ft. Their projected yields indicated the planting density selected was a good match to tree vigor although yield varied among Flying Dragon beds because of differences in tree age. Canopy crowding was not apparent after 6 years.

Whole-Bed Rootstock Trial, Indiantown - Interpretative summary [as of August 2016]:

Valencia. The cumulative yields among many of the Valencia trees were higher than those for the same combination with Hamlin which is unusual because of the generally smaller, less vigorous growth habit of Valencia. Rootstock examples illustrating the Sweet Spot concept are:

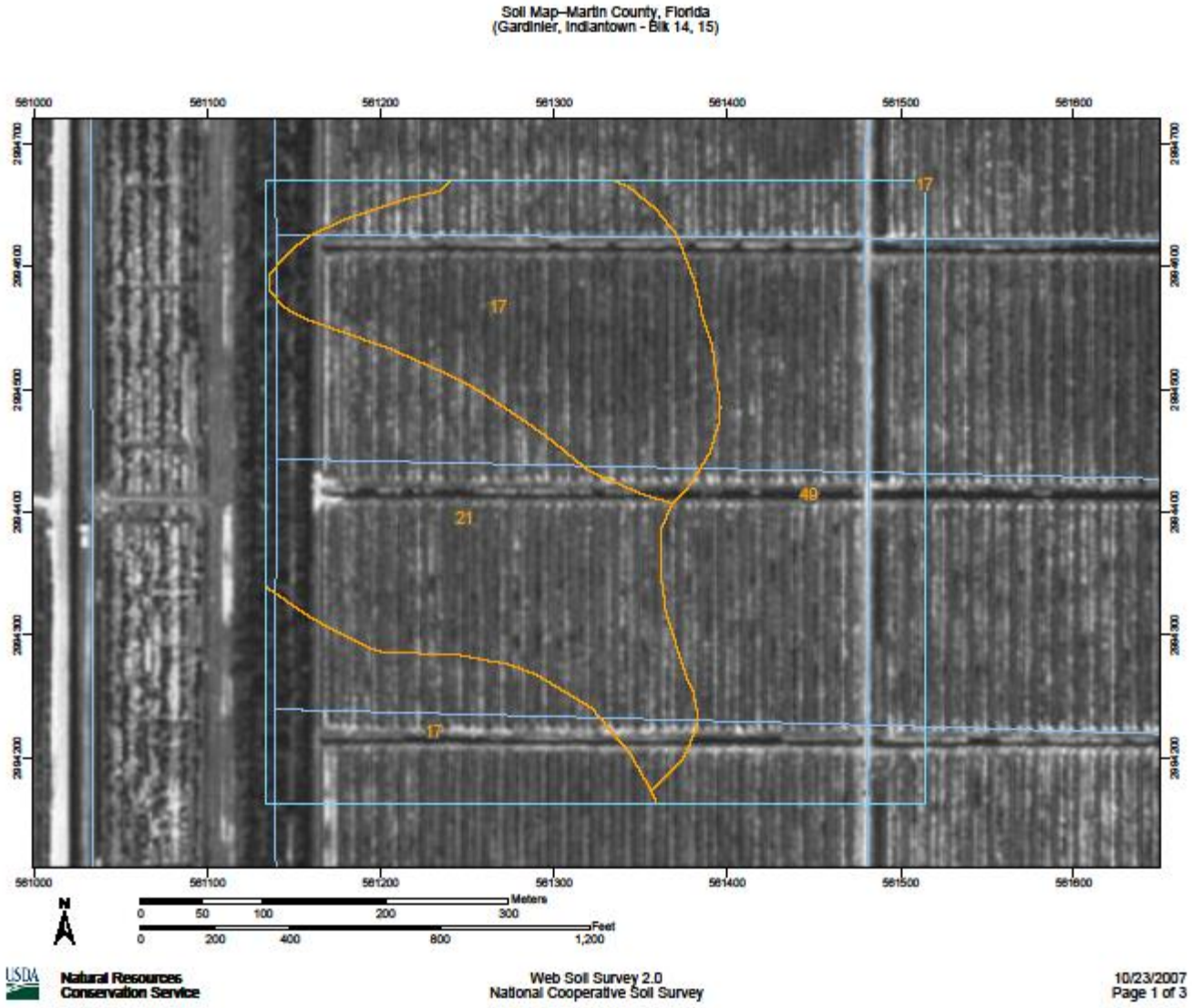
- **Swingle citrumelo**. There were only two beds of Valencia trees planted with Swingle, both at 8 x 12 ft. They yielded between a projected cumulative 1,000 to 1,350 boxes/acre. Those yields were among the highest in the trial regardless of the scion. These good yields are not the result of smaller tree size as they were similar in height to the tallest Hamlin trees.
- **C-35 citrange**. We anticipated that Valencia/C-35 would produce a good-yielding smallish tree that would perform best at 8 x 12 ft. As a result, 3 beds at only 8 x 12 ft were planted. Our expectation appeared to be true as in the first 4 years of bearing the cumulative yields were projected out to 1,100 to 1,400 boxes/acre. However, it is questionable how long such performance would continue. The Hamlin trees had formed a hedgerow [Fig. 4] after 6 years as had the Valencia trees [Fig. 7].
- **Flying Dragon trifoliate orange.** Nearly 50% of the Valencia beds were planted with trees on Flying Dragon TO at 7 x 12 ft. Their actual and projected yields indicated that the planting density selected was a good match to tree vigor although yield varied among Flying Dragon beds because of differences in tree age. Canopy crowding was not apparent after 6 years [Fig. 8].

Whole-Bed Rootstock Trial, Indiantown - Interpretative summary [as of August 2016]:

General conclusions.

- The **Sweet Spot** concept was validated by this trial. Excellent yields were obtained among most of the scion-rootstock combinations as a result of their vigor under the trial's site conditions and management. The concept is based on tree canopy expansion continuing until the trees are about 8 years old at which time canopy closure occurs in-row; thereafter, bearing continues at high numbers.
- However, the high yields obtained in the first 6 years were largely a result of tree count/acre. For high yields to be maintained, [which we were not able to determine because of an ownership change], the successful use of the Sweet Spot concept requires that the trees not be crowded to the point that yield declines early in the life of a given scion-rootstock-spacing combination.
- Once canopy closure is reached, the effect of tree count/acre is being replaced by the long-term benefits of having selected a proper sweet spot spacing.
- The Hamlin and Valencia data support the conclusion that in this trial, the Hamlin trees/Willits represented the best application of the Sweet Spot concept; among the Valencia trees, those of Swingle and C-35 performed better than most of the other rootstocks at 8 x12 ft, but the degree of canopy closure illustrated in the photos shows that 8 x 20 ft would likely be a better longer-term spacing.
- The trees on Flying Dragon TO illustrate the point that a "successful" application of the Sweet Spot concept to efficient bearing trees [high yield/unit of canopy volume] may still fall short in performance when compared to lower-density plantings of less efficient, but highly productive trees like Swingle and C-35.

Fig. 1. Soil map of the whole-bed rootstock trial, Indiantown. The site consists of two 20-acre blocks planted to Hamlin [upper section] or Valencia [lower section].



Note that among the soil series mapped at the trial site, the better one, Wabasso, occurs virtually only in the Hamlin [upper] block, a factor that may have influenced tree behavior when making comparisons among the Hamlin beds and between Hamlin and Valencia.

Map Unit Legend

Martin County, Florida [FL085]

Map Unit	Symbol Map Unit Name	Acres in AOI	% AOI
17	Wabasso sand	23.1	34.3
21	Pineda & Rivera fine sands	19.7	29.2
49	Rivera fine sand	24.6	36.5

Fig. 2. Planting map of whole-bed rootstock trial, Indiantown.

Rootstocks

US 812
1584: *P. trif.* x Milam
C-35 citrange
SwC: Swingle citrumelo
Experimental*
Kinkoji
RxT: Rangpur x Troyer
Willits citrange
US 897
FDT: Flying Dragon trif.

* A mixture of selections from the CREC plant breeding program.

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Table 2. Whole-bed rootstock trial, Indiantown – Planting dates.

Planting Dates [color coded for planting dates]

Block	Bed	Date[1]	Date [2]	Block	Bed	Date[1]	Date [2]
14	1	Nov 09	Mar 10	15	1	Nov 09	Mar 10
Valen.	2	Nov 09	na	Hamlin	2	Nov 09	Mar 10
	3	Nov 09	na		3	Nov 09	na
	4	Nov 09	na		4	Nov 09	na
	5	Nov 09	na		5	Nov 09	Mar 10
	6	Windbreak			6	Windbreak	
	7	Nov 09	na		7	Nov 09	na
	8	Mar 10	na		8	Nov 09	Mar 10
	9	Mar 10	na		9	Mar 10	Sep 10
	10	Sep 10	na		10	Nov 09	na
	11	Sep 10	na		11	Nov 09	na
	12	Nov 09	na		12	Nov 09	Mar 10
	13	Windbreak			13	Windbreak	
	14	Nov 09	Mar 10		14	Nov 09	na
	15	Sep 10	na		15	Nov 09	Mar 10
	16	Mar 10	na		16	Sep 10	na
	17	Nov 09	Mar 10		17	Nov 09	na
	18	Nov 09	na		18	Nov 09	na
	19	Windbreak			19	Windbreak	
	20	Nov 09	na		20	Nov 09	Mar 10
	21	Mar 10	na		21	Nov 09	Mar 10
	22	Nov 09	na		22	Sep 10	na
	23	Nov 09	na		23	Sep 10	na
	24	Sep 10	na		24	Sep 10	na
	25	Windbreak			25	Sep 10	na

Fig. 3. General size and appearance of those trees that had been planted for nearly 1 year [Valencia/C-35 @ 8 x 12 ft. as of Oct 2010].

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Fig. 4. Hamlin/Swingle - [Upper left] age 2 years @ 8 x 20 ft.; [Upper right] age 6 years @10 x 20 ft.; [Lower left] age 6 years @ 8 x 12 ft.

Fig. 5. Hamlin/Swingle @ 8 x 20 ft. - [L] age 2 years; [R] age 6 years.

Fig. 6. Hamlin/C-35 @ 10 x 20 ft.; [UL] 2 years old; [LL] 6 years old; [UR] @ 8 x 20 ft., 6 years old.

Fig. 7. Valencia/C-35 @ 8 x 12 ft. [L] 2 years old; [R] 6 years old.

Fig. 8. [L] Hamlin/Willits citrange , age 4 years, @ 8 x 12 ft.; [R] Valencia/Flying Dragon trifoliate orange, age 6 years, @ 7 x 12 ft.

Fig. 9. Valencia/U.S. 897, @ 8 x 12 ft. [L] age 2 years; [R] age 6 years.

Fig. 10. Valencia/Swingle, 8 x 12 ft., [L] 2 years old; [R] 6 years old.

Fig. 11. [Left]. Chicken manure-based organic material applied to most beds prior to or at the time of planting. [Right]. Young windbreak consisting of *Corymbia torelliana* trees [rear] and Gold lantana [front].

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Fig. 12. Whole-bed rootstock trial, Indiantown – Hamlin 4-year cumulative Yield by bed [tree age 3-6 years; 2012/13 to 2015/16, boxes/acre] sorted by yield.

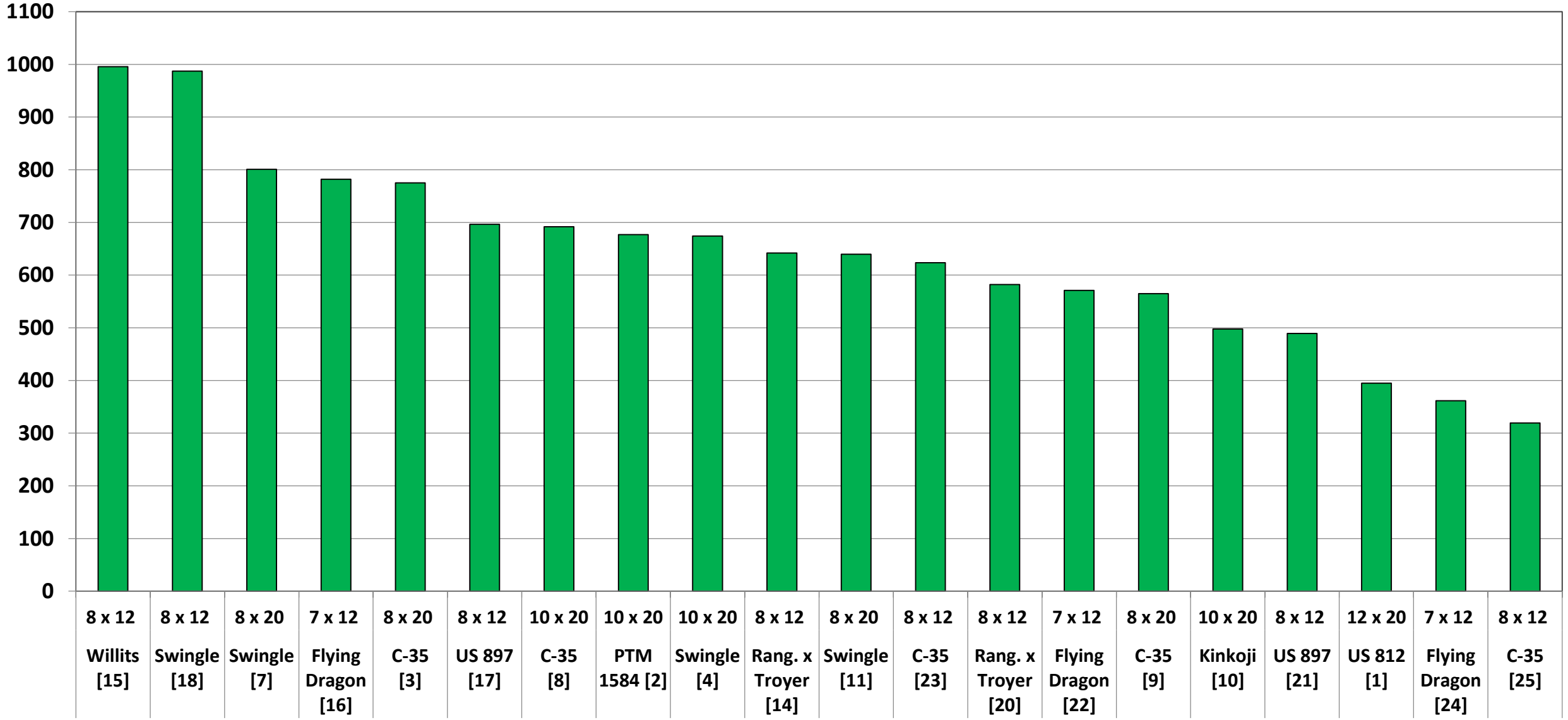

Fig. 13. Whole-bed rootstock trial, Indiantown – Hamlin 4-year cumulative Yield, mean + std. dev. [2012/13 to 2015/16, boxes/acre] by spacing – rootstock combination, sorted by yield.

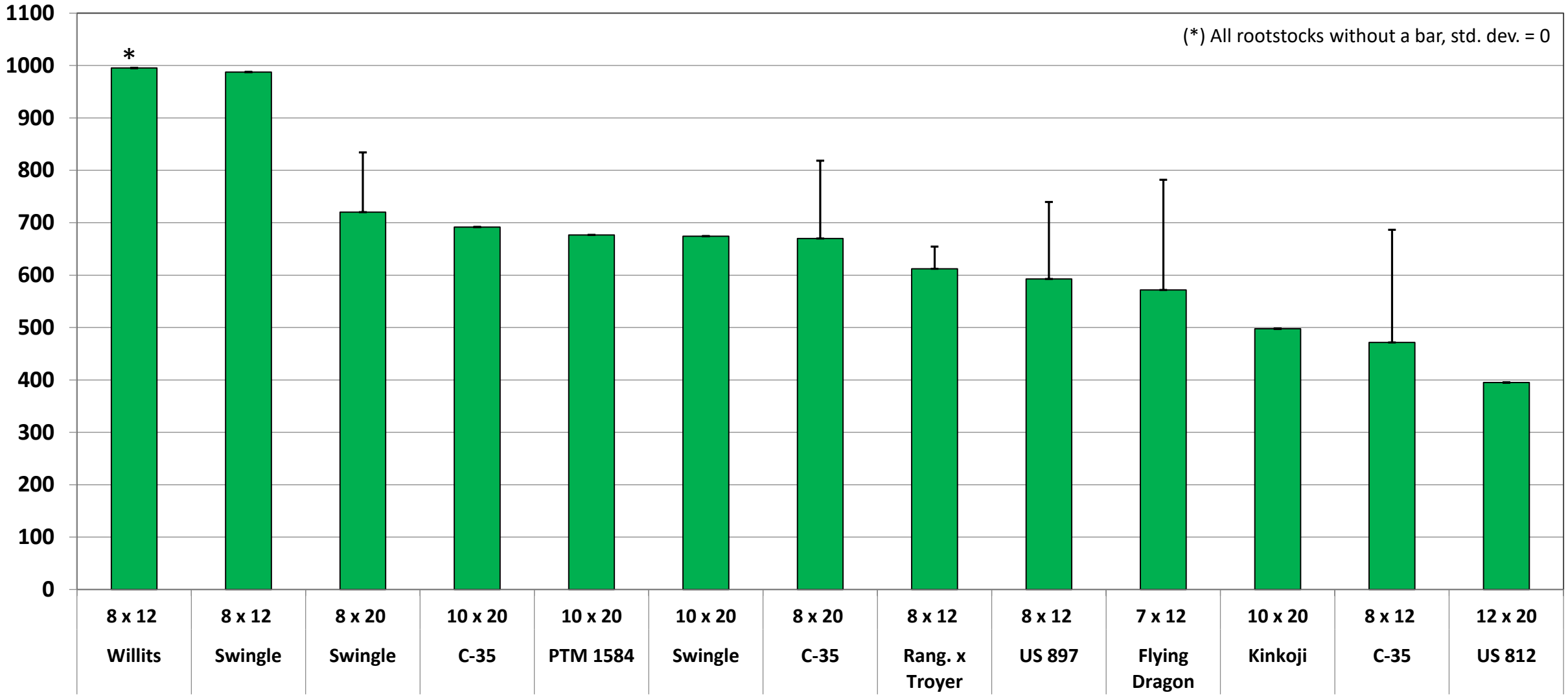

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Fig. 14. Whole-bed rootstock trial, Indiantown – Valencia 4-year cumulative Yield by bed [2012/13 to 2015/16, boxes/acre] sorted by yield.

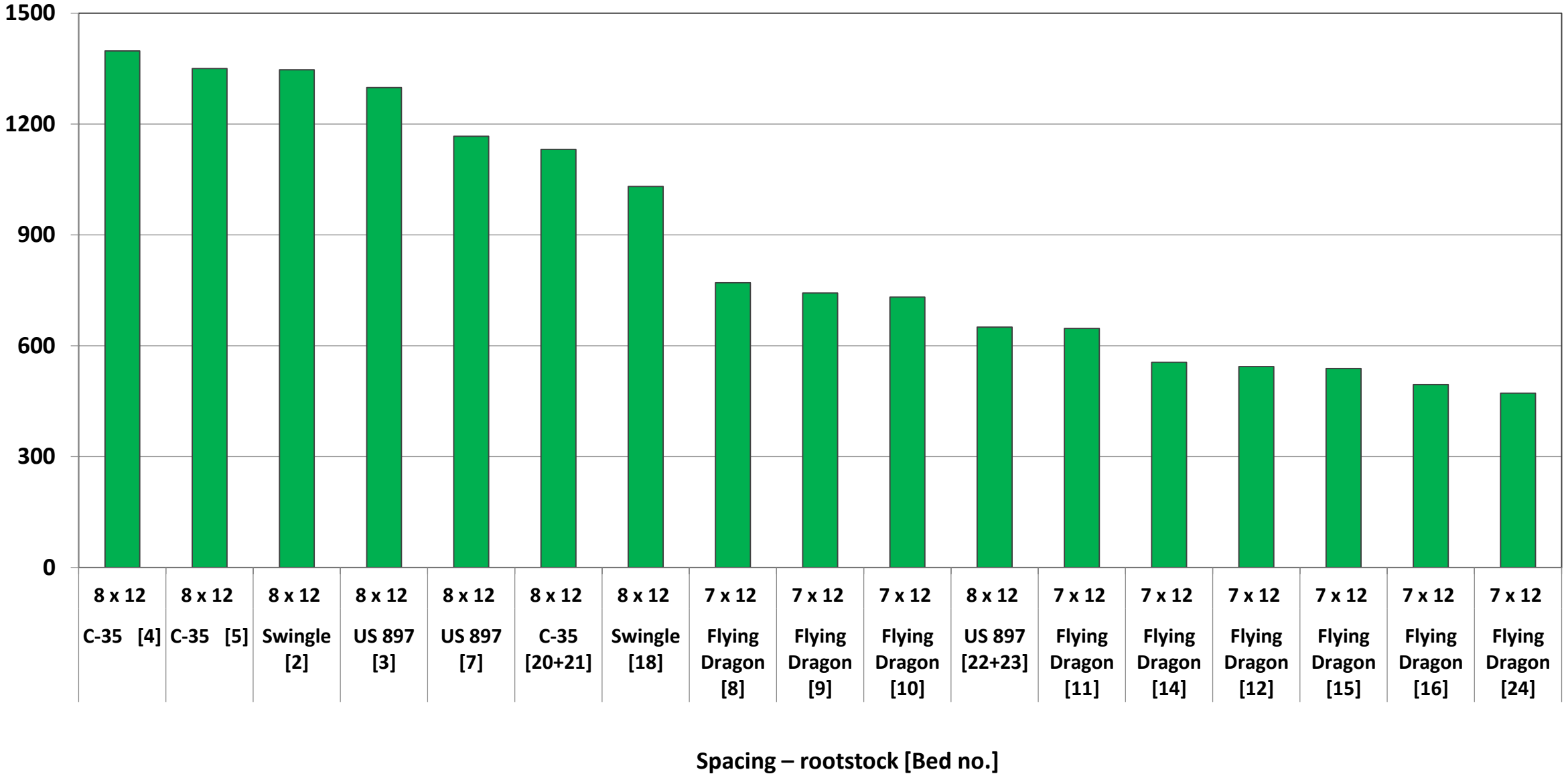

Fig. 15. Whole-bed rootstock trial, Indiantown – Valencia 4-year cumulative Yield, mean + std. dev. [2012/13 to 2015/16, boxes/acre] by spacing – rootstock combination, sorted by yield.

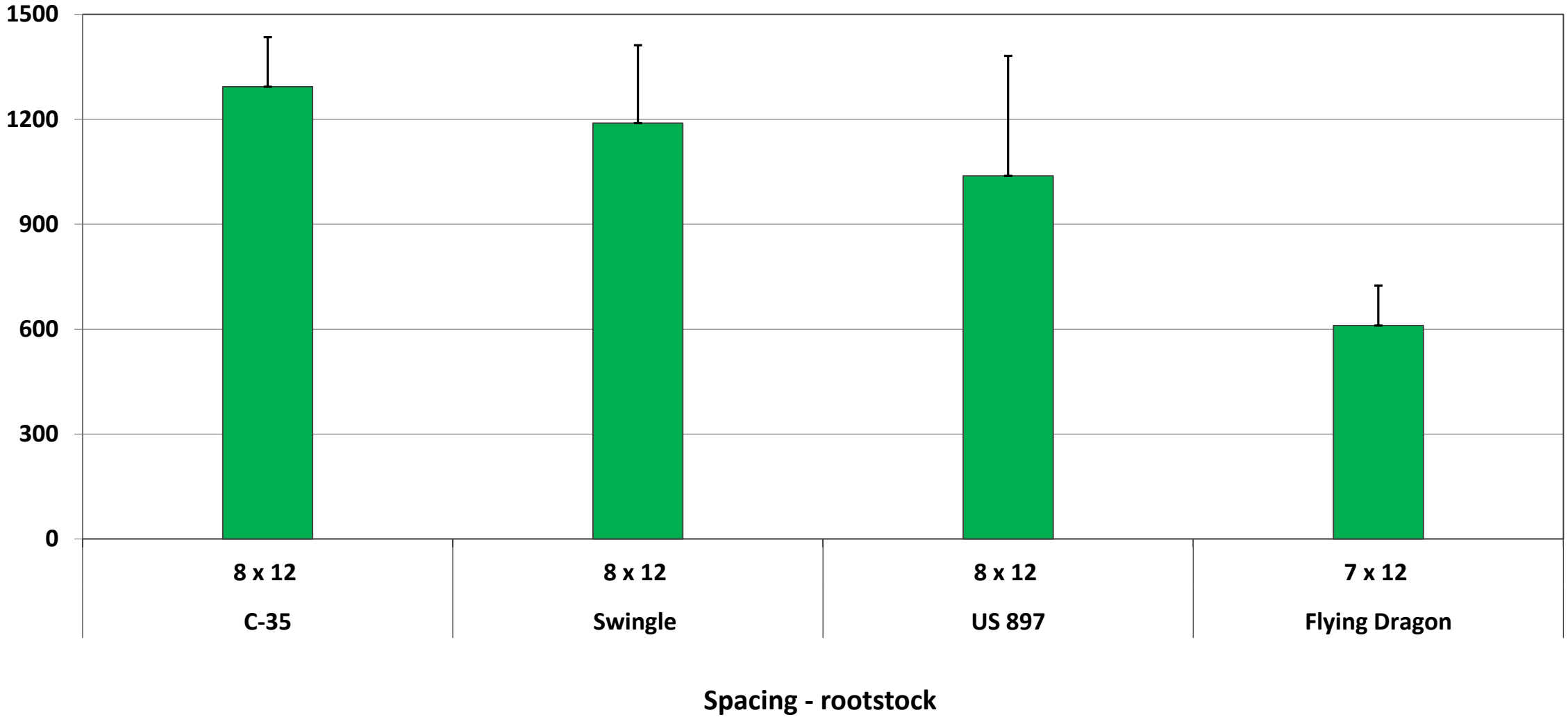

Fig. 16. Whole-bed rootstock trial, Indiantown – Hamlin, 4-year cumulative yield [boxes/acre], sorted by bed number.

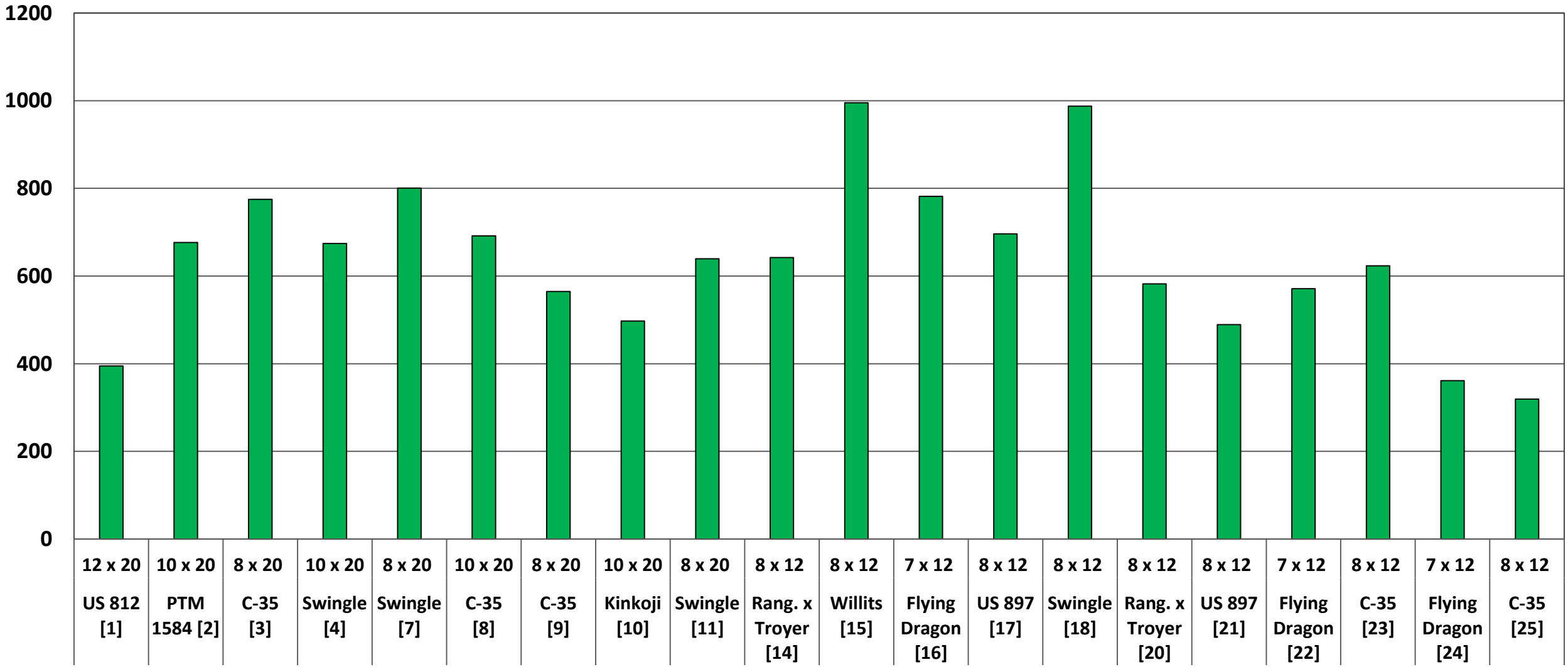

Fig. 17. Whole-bed rootstock trial, Indiantown – Valencia, 4-year cumulative yield [boxes/acre], sorted by bed number.

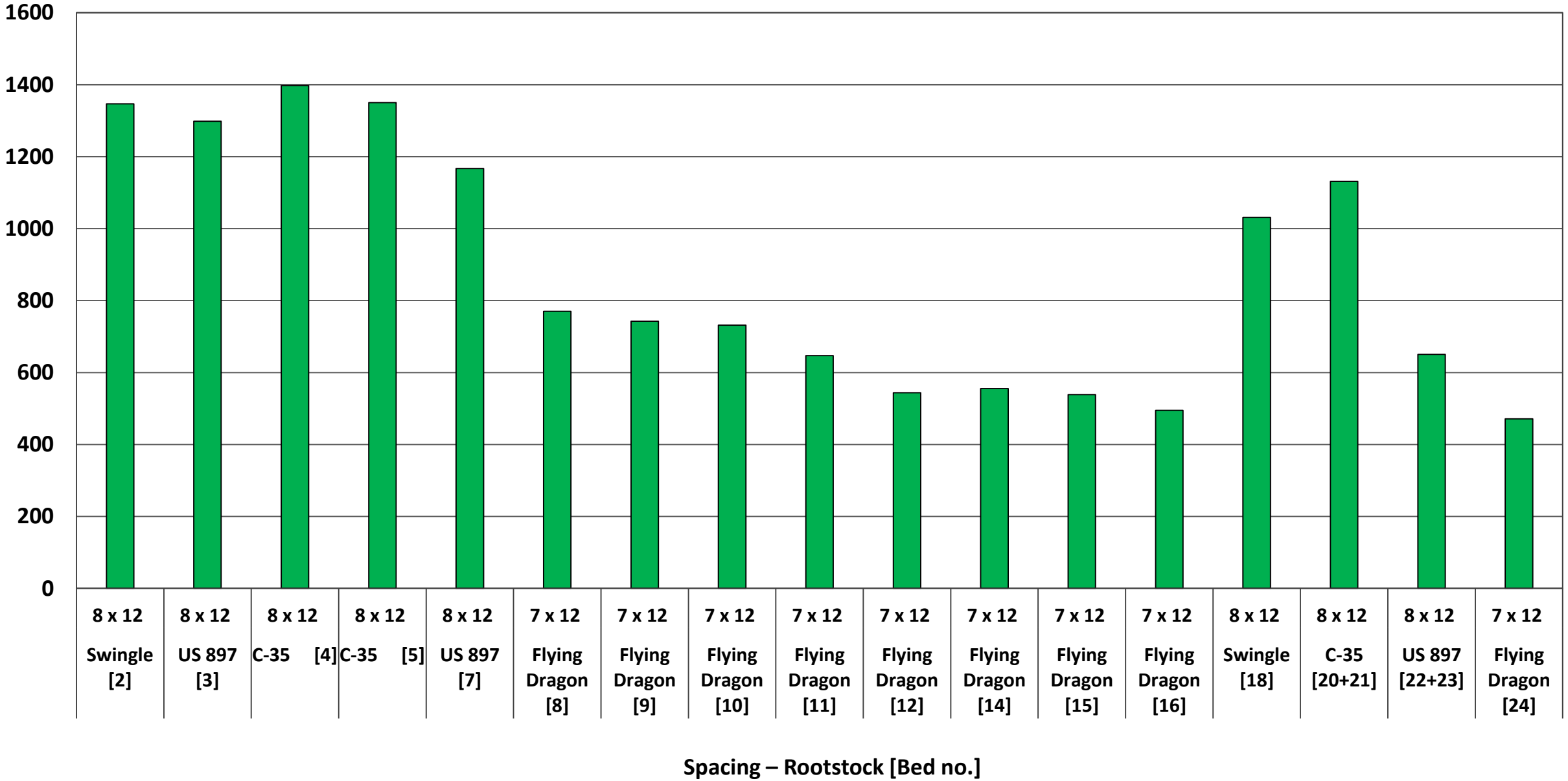

Fig. 18. Whole-bed rootstock trial, Indiantown – Tree height [ft.]: mean + std. dev. , age 3 years, sorted by spacing [data collected October 2012].

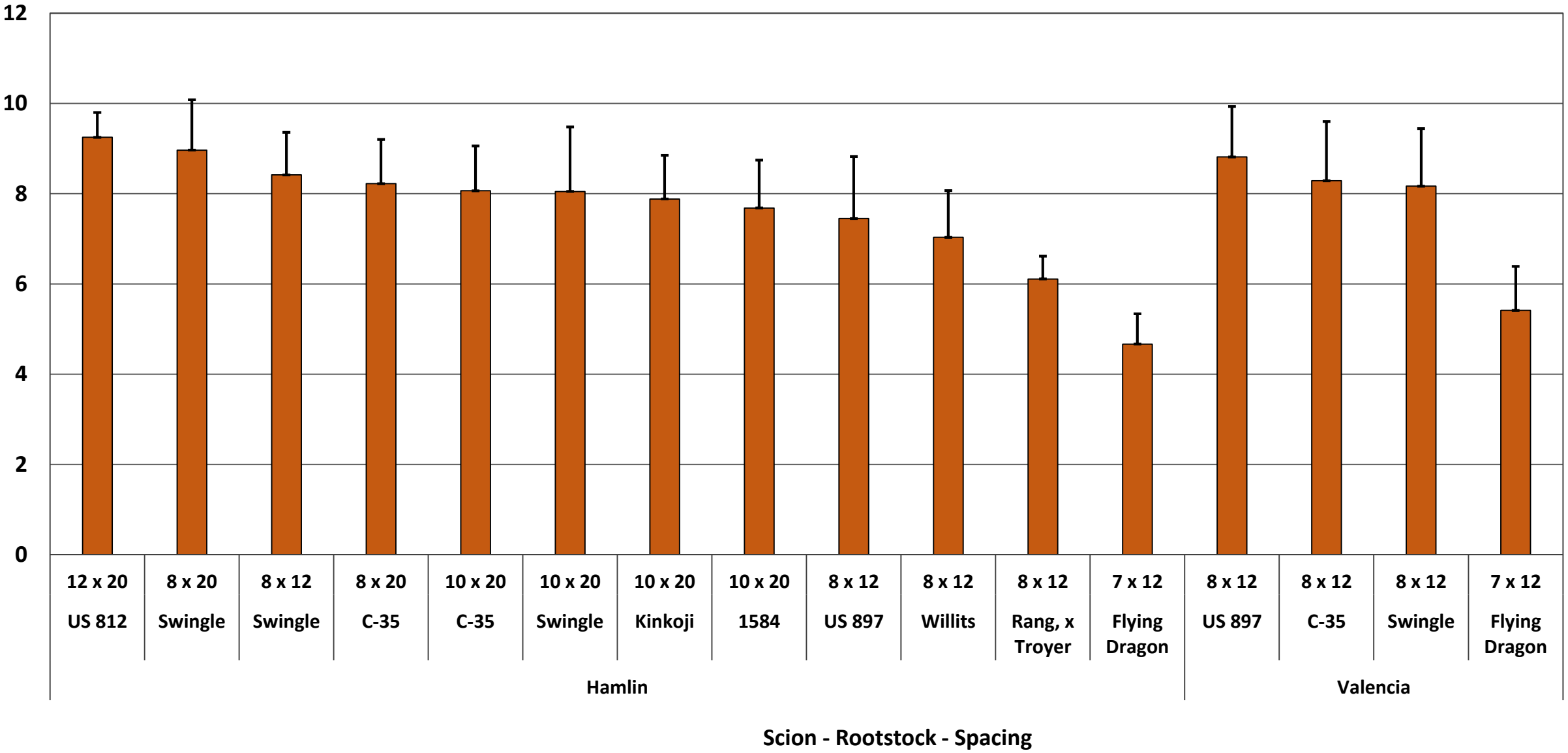

Fig. 19. Whole-bed rootstock trial, Indiantown – Canopy width [ft.]: mean + std. dev., age 3 years, sorted by spacing [data collected October 2012].

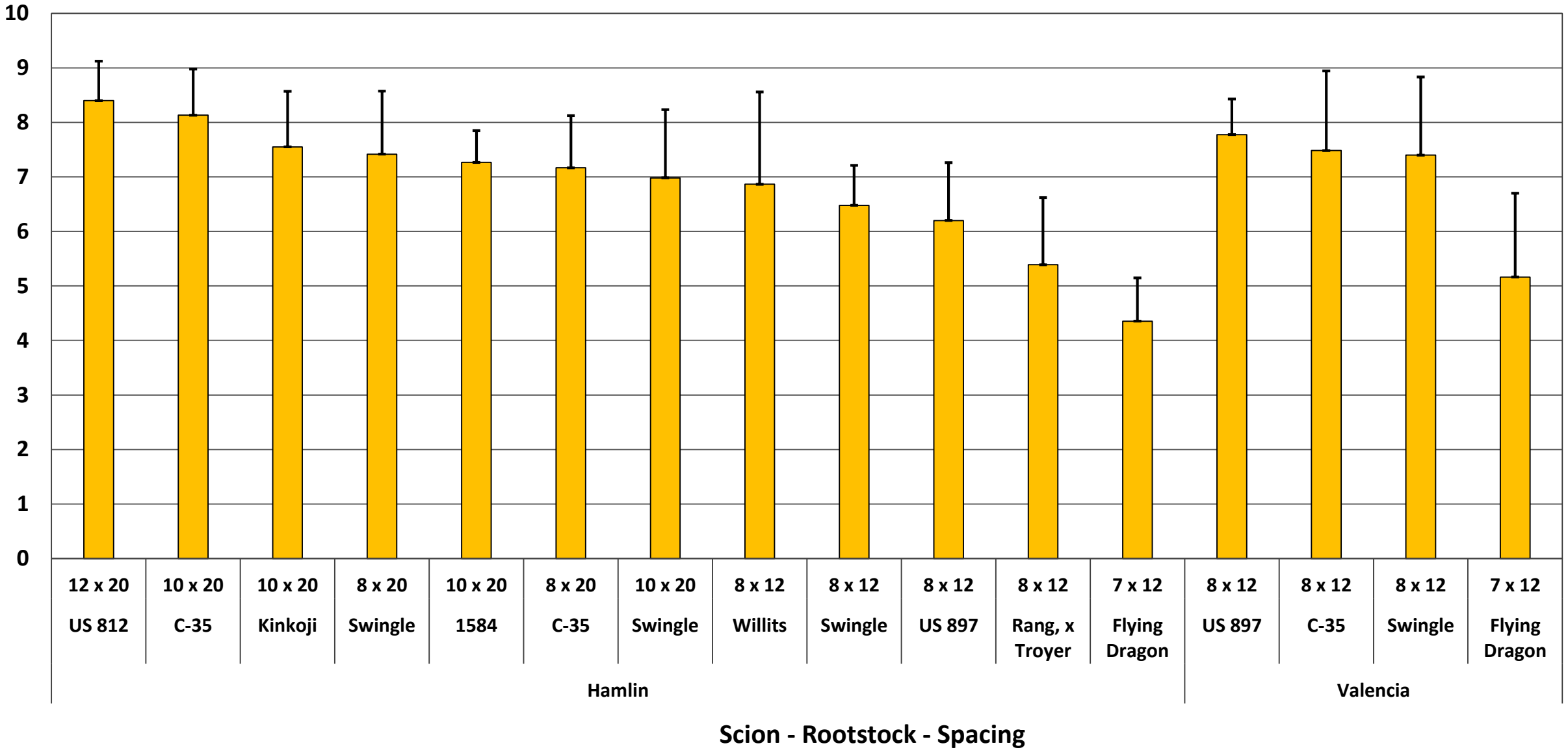

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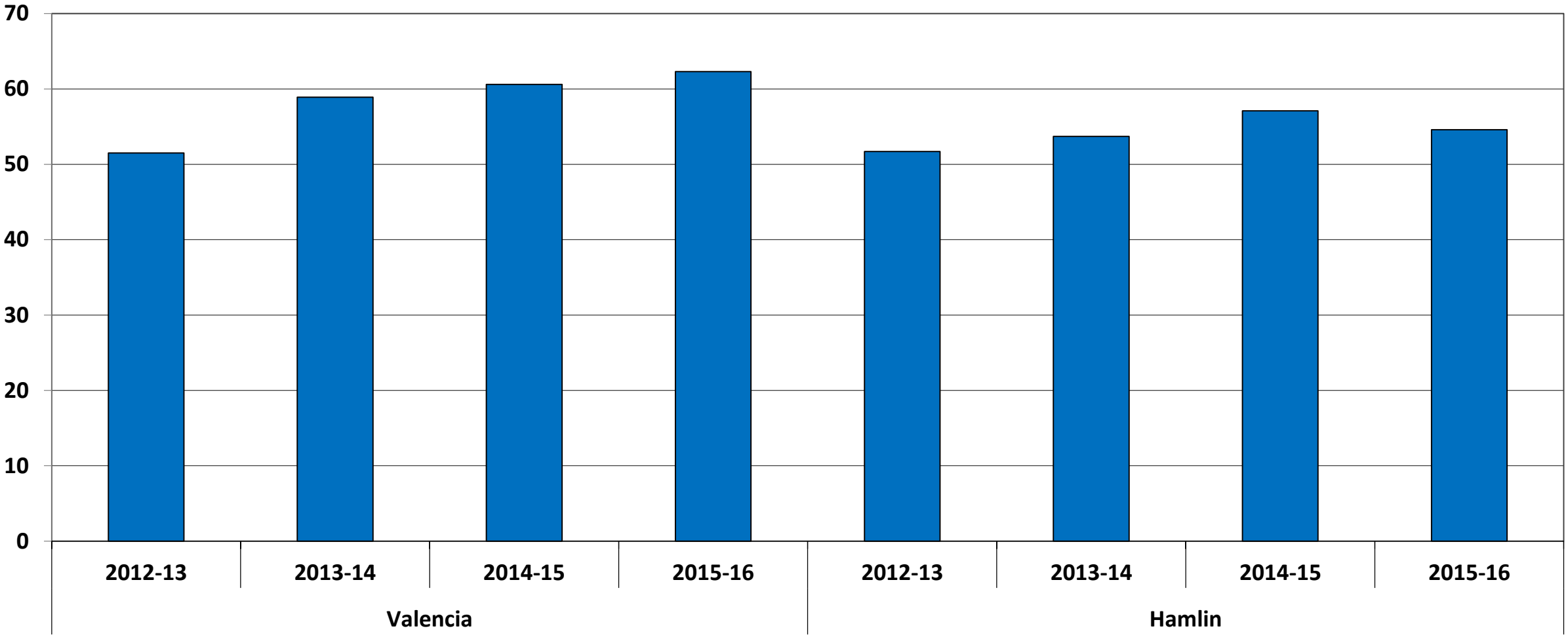
Table 3. Whole-bed rootstock trial, Indiantown – Juice quality of standard loads of fruit brought from the trial to a commercial processing facility: mean and range*.

				Juice, %		Brix		Acid		Ratio		PS/box	
Variety	Season	Harvest date	Total boxes harvested	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Valencia	2012-13	Apr 25 2013	1,060	51.5	50.1-52.7	11.4	11.3-11.4	0.59	0.58-0.60	19.3	19.2-19.4	5.87	5.85-6.06
	2013-14	Apr 25 2014	1,686	58.9	58.0-60.7	12.3	12.1-12.7	0.80	0.73-0.84	15.6	14.4-17.3	6.54	6.41-6.61
	2014-15	Apr 04 2015	4,343	60.6	59.0-61.9	12.2	11.3-12.8	0.73	0.68-0.81	16.7	14.9-18.1	6.00	5.92-6.07
	2015-16	Mar 08 2016	4,048	62.3	61.2-63.3	12.0	11.6-12.2	0.80	0.77-0.84	15.0	14.4-15.8	6.71	6.55-6.84
Hamlin	2012-13	Dec 19 2012	377**	51.7		9.9		0.59		16.71		4.58	
	2013-14	Jan 07 2014	1,001	53.7	52.1-54.9	10.7	10.6-10.8	0.55	0.54-0.56	18.5	18.3-19.7	5.18	4.99-5.30
	2014-15	Dec 11 2014	2,981	57.1	5.8-58.7	10.0	9.5-10.1	0.6	0.58-0.63	16.7	15.9-17.8	5.13	4.75-5.33
	2015-16	Jan 09 2016	3,060	54.6	52.3-56.2	11.4	10.8-12.0	0.49	0.47-0.53	23.3	22.2-24.9	5.57	5.30-5.84

*The 4 years of juice data herein are the same years yield was measured by bed. As yield was recorded in each bed, the fruit were placed [combined] in a commercial fruit trailer which when full [ca. 500-600 boxes] was hauled to a processing facility for standard fruit sampling and analysis.

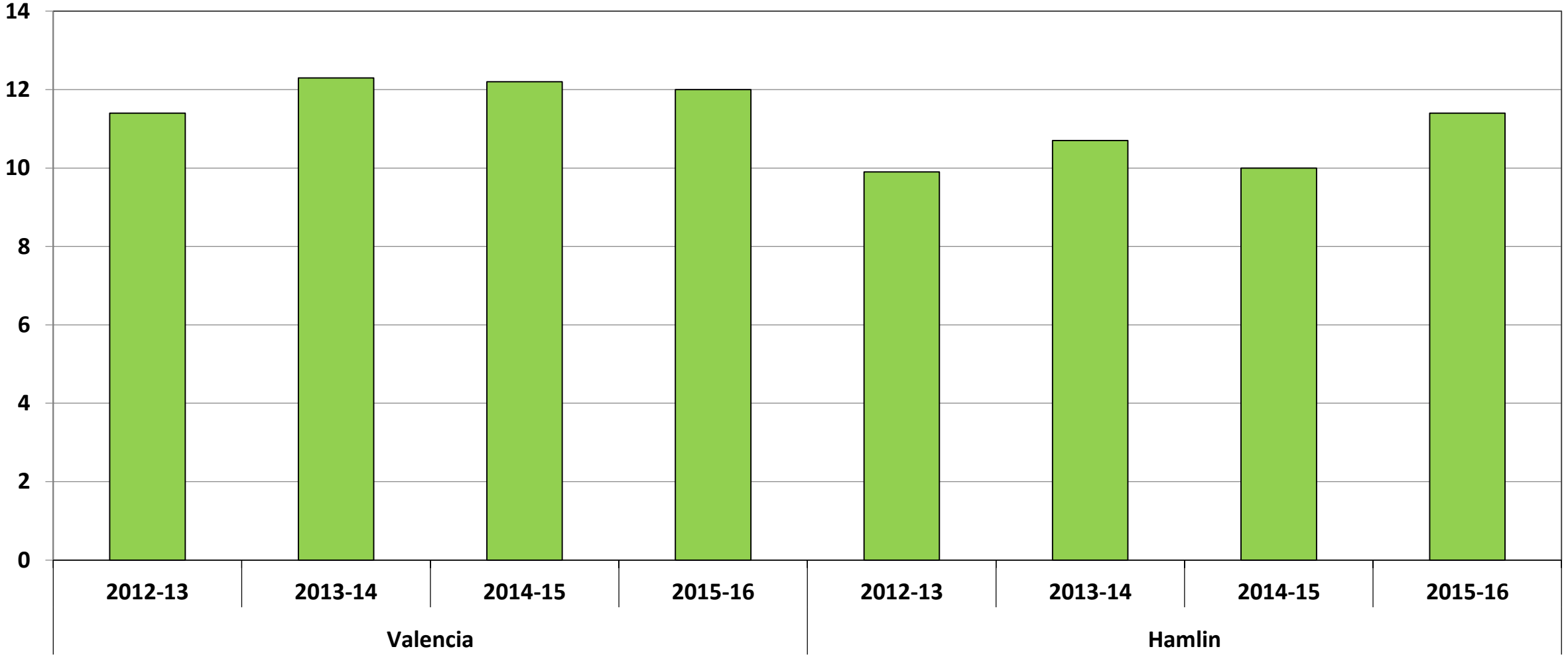
**Only one load of fruit was harvested, thus, there is no range of results.

Fig. 20. Whole-bed rootstock trial, Indiantown – Percent juice: mean of standard loads of fruit brought from the trial to a commercial processing facility by scion and by season*.



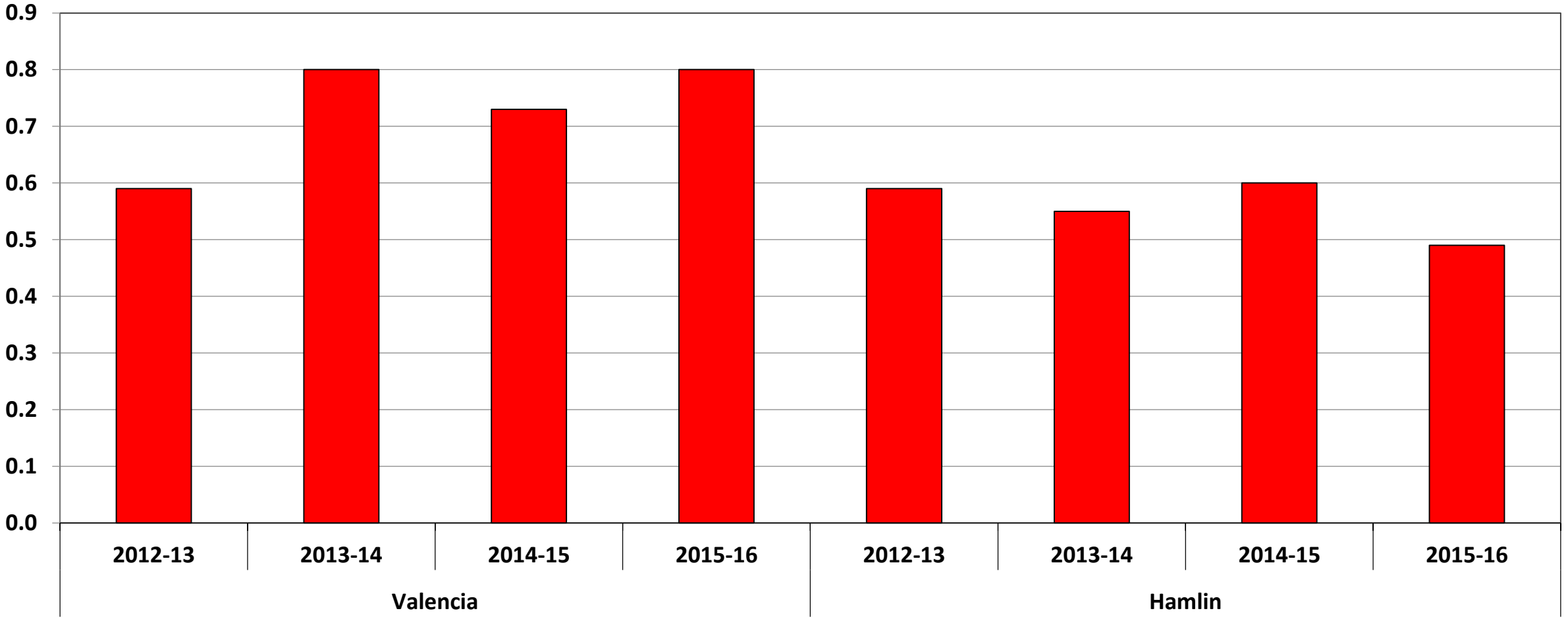
*The 4 years of juice data herein are the same years yield was measured by bed. As yield was recorded in each bed, the fruit were placed [combined] in a commercial fruit trailer which when full [ca. 500-600 boxes] was hauled to a processing facility for standard fruit sampling and analysis.

Fig. 21. Whole-bed rootstock trial, Indiantown – juice Brix: mean of standard loads of fruit brought from the trial to a commercial processing facility by scion and by season*.



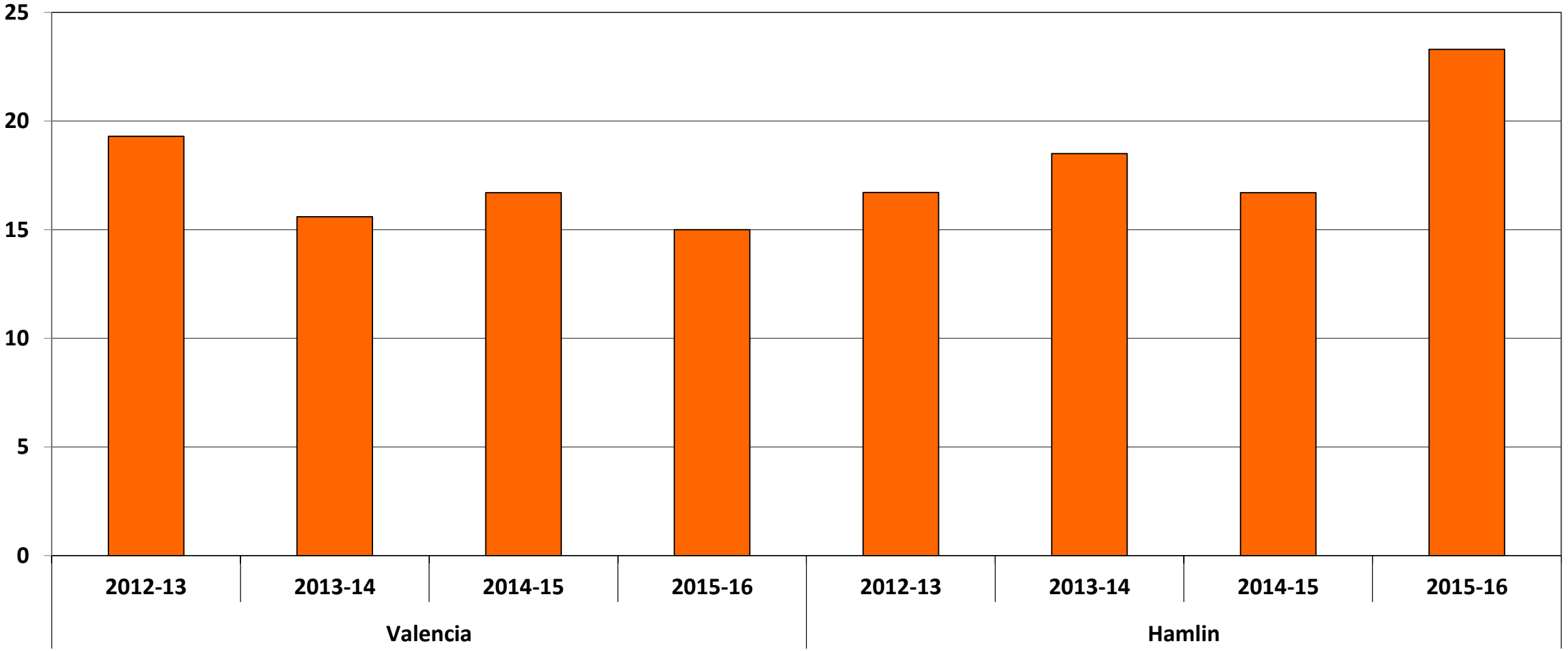
*The 4 years of juice data herein are the same years yield was measured by bed. As yield was recorded in each bed, the fruit were placed [combined] in a commercial fruit trailer which when full [ca. 500-600 boxes] was hauled to a processing facility for standard fruit sampling and analysis.

Fig. 22. Whole-bed rootstock trial, Indiantown – juice Acid: mean of standard loads of fruit brought from the trial to a commercial processing facility by scion and by season*.



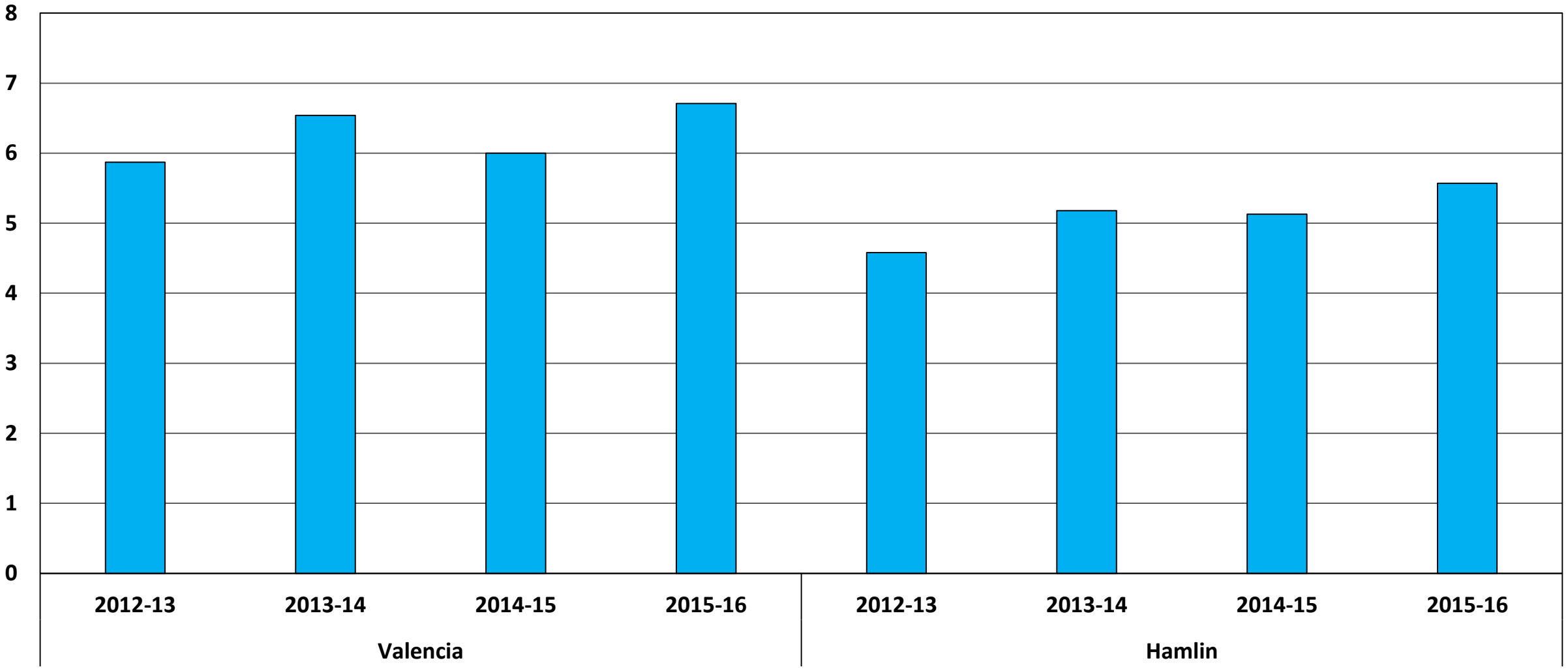
*The 4 years of juice data herein are the same years yield was measured by bed. As yield was recorded in each bed, the fruit were placed [combined] in a commercial fruit trailer which when full [ca. 500-600 boxes] was hauled to a processing facility for standard fruit sampling and analysis.

Fig. 23. Whole-bed rootstock trial, Indiantown – juice Ratio: mean of standard loads of fruit brought from the trial to a commercial processing facility by scion and by season*.



*The 4 years of juice data herein are the same years yield was measured by bed. As yield was recorded in each bed, the fruit were placed [combined] in a commercial fruit trailer which when full [ca. 500-600 boxes] was hauled to a processing facility for standard fruit sampling and analysis.

Fig. 24. Whole-bed rootstock trial, Indiantown – PS/box: mean of standard loads of fruit brought from the trial to a commercial processing facility by scion and by season*.



*The 4 years of juice data herein are the same years yield was measured by bed. As yield was recorded in each bed, the fruit were placed [combined] in a commercial fruit trailer which when full [ca. 500-600 boxes] was hauled to a processing facility for standard fruit sampling and analysis.