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Production and Productivity of Elite Avocado Trees in a Commercial Orchard in Spain

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Introduction

In a previous work (Olalla, unpublished data), the production of 2603 avocado trees, over a ten year period, was studied. Factors related to phenotypic variation were detected as well as a high variability presumably of genetic origin, which suggests the existence of elite trees, *e.g.,* trees well adapted to their environment, and which in comparison to nearby trees, present very good production traits (3-6X the standard deviation, for normalized values, after correction of environmental effects). Considering the importance of productivity (production per trunk area) as well as the possibility of supplying data to explain differences in production/productivity among individual trees, this research was undertaken. Along this line, a comparison between elite and nearby average adjacent trees is shown. This comparison includes several factors, *e.g.,* size, and productivity of the trees under study.

Material and Methods

Description of the orchard

The commercial orchard is located in low hills of the east part of Málaga province, at four kilo-meters from the coast. This orchard is under irrigation and was established throughout the 1970's. It presents different microclimates, mainly determined by orientation and protection from winds (Olalla, unpublished data). Elite trees are located in specific terraces, mainly those planted at the beginning of orchard establishment; seeds used at that time had very different origins and that could be the basis for the high variability encountered.

In the cited work, the terrace and year effects were eliminated of the original data obtaining production data p_{ij} (i as tree subindex and j, year subindex). On this data the average production per tree, the standard deviation of these averages $s(p_i)$ as well as the standard deviation of data per each tree $s_i(p_{ij})$ were calculated. With these parameters, we could first undertake the normalization of p_i (average of each tree for the 10 years period) by obtaining the production of each tree as standard deviation units $s(p_i)$ - Normalised Corrected Production, NCP-, and secondly, assuming that $s_i(p_{ij})$ could be considered as irregularity production index -IPI-(higher interannual variations in production correspond to higher standard deviations), these values could also be normalized.

Elite trees (ET) are considered as those with normalized corrected production (NCP) within the range 2.9-6. These trees were compared with adjacent trees with NCP=0, *e.g.,* trees showing average behaviour within the orchard. For these trees, we have ten years production data tree by tree, and we had calculated the average production per tree, and the average production per terrace. So we could correct the environmental factors (soil, orientation, *etc.)* associated to each terrace, and to determinate the average corrected production per tree (CP). Twenty one pairs were studied, and the following parameters were evaluated:

- corrected production
- position within the orchard.
- trunk area (below graft union), measuring in each case the corresponding perimeter.
- horizontal projection of tree canopy (measured as two perpendicular diameters, as $\mu d_1 d_2/4$).
- estimation of green canopy surface of the tree[1]
- planting[2] distance (available surface per tree).
- possible differences in vigour, foliage colour, soil, *etc.*

Results and Discussion

Productions.

In relation to production, the differences, year to year, of elite minus average trees have been obtained (Table 1). These differences are not stable throughout the whole period; in fact, there seems to be negative differences (1-4 times) according to the trees. The analysis of the standard deviations, among trees (figure 1) or among years for a given tree (figure 2) shows values which are superior to the averages (up to 2x). This suggests an irregular, unpredictable behaviour, probably caused by uncontrolled factors (climate factors or the tree biennial-bearing itself).

These elite trees show a great production capacity, and considering the whole period, are really superior trees, but this is not true on a yearly basis. For instance, a tree pair on terrace n 1 8 (55/54) shows regular alternation of positive and negative differences, although when they are positive, they are really higher in absolute values. In contrast, a tree pair of terrace n 1 6 (25/23) always give positive differences. This could probably simply be due to synchronization or lack of it in the biennial-bearing. However, it is clear that in any case, elite trees show higher production capacity within the years of this study.

Production as related to tree size (productivity).

Table 2 shows results in which elite trees are grouped to their correspondent average trees. They include corrected production (CP) in kg, trunk area (TA) in dm^2, horizontal projection of canopy (HPC) in m^2, available area per tree (AA) in m^2, tree height (H) in m, estimation of green area of canopy (GA) in m^2. The corrected productions (CP) were referred to:

- trunk area (CP/TA) kg dm^{-2}

- horizontal projection of canopy (CP/HPC), kg m^{-2}
- available surface per tree(CP/AA), kg m^{-2}
- green area, (CP/GA) kg m^{-2}

Examination of these data shows that most productive trees in absolute values could not be the more interesting ones from a physiological or commercial point of view. There is a clear relationship between absolute production and available surface, in such a way that, higher surface available corresponds to a greater tree size and thus, higher production; *e.g.,* correlation obtained with available surface is 0.76 (highest observed value) while in the case of trunk area is 0.51 (lowest observed value). However, from a commercial point of view, other values of productivity are more interesting, *e.g.*, CP/AA which could be equivalent to production per hectare. If Table 5 was ordered in accordance to this index, other trees appear (2-109, 15-160, 19-77, 6-25, 12-126) as the most interesting ones. Some average trees are better than other elite trees when this CP/AA index is used.

The appearance of average trees with good productivities seems to suggest that when trying to maximize production per hectare, we should also look at trees with lower absolute production values. We have also looked, through the GA index, for possible differences in the efficiency of photosynthetic assimilation, but after contrasting data of CP/GA and CP/AA, only a great dispersion of values obtained can be observed (Figure 3).

Average values for both groups of trees (elite and average) are shown in Table 3. It can be observed that while differences in production increments are about 156%, there is a 52% increment in TA, 48% increment in HPC, 3% in height, 58% increment of AA, and 69% increment for GA. As a whole, elite trees present superior productivities, except for the productivity referred to GA.

Summary

Twenty one elite trees, from 2603 in which the production was recorded during 10 years, have been selected in which normalized production (NP) is above 2.9 (in a case it reaches 6). Adjacent trees in which NP was near 0 were also selected and comparisons in relation to size and different productivity values have been made. The trees with the highest absolute production values are not the more interesting ones from a commercial point of view, since higher productivities were obtained with other trees.

Higher absolute production values are generally associated to greater tree size. In the analysis pair to pair, it can be observed that the response model is not the same. There are tree pairs in which the superiority of elite trees is constant while in others an alternative behaviour is observed, although higher differences are obtained when the elite tree is on its year on. This observation seems to suggest that fruit set is not associated to quality of elite tree; but it is probably associated with uncontrolled environmental conditions; however, the capability to sustain a higher number of fruits to maturity, seems to be a trait of elite trees.

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References

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Notes

[1] The green canopy surface of the tree was established from a geometric model. The tree was considered as a semisphere, with an extension in cylindrical form, towards the basal part. The total height of the tree, the length of two perpendicular diameters as well as the distance between soil and base of canopy were estimated. With these data, the geometric shape was defined. This shape was divided into 4 parts (N, S, E, W) and a percentage, estimated visually, was assigned to each part; this assignment was much in proportion to the fraction covered by the foliage. Arpaia *et al.* 1993 suggests a similar geometrical approximation, but only for the size of the tree. We believe that the total green area, an approximation to total leaf area would be more exact when the adjacent trees have their respective canopies in contact.

[2] The real planting distance was calculated as a function of the distance among adjacent trees, sharing the available distance between the two canopies. If the tree was planted near a slope between terraces, or if the adjacent tree was far away, the planting distance was limited to 2 m away from canopy border.

Table 1 Production differences between elite and control trees

		Years											
Terrace	Paired tree	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Average	S.D.
2	37-57	-58	-72	-38	215	-30	255	1	175	131	350	93	151
2	89-118	92	-29	125	-15	80	35	180	205	168	30	87	82
2	109-140	24	29	-73	130	30	100	-26	275	-152	215	55	129
2	258-263	84	0	180	-30	40	36	68	225	21	120	74	80
2	472-434	80	-44	185	90	130	135	25	255	2	305	116	110
2	474-487	40	-5	163	20	60	-88	105	0	133	260	69	99
5	37-47	-23	35	-23	99	238	143	5	98	91	125	79	82
6	21-19	76	55	45	189	-10	44	51	205	3	35	69	72
6	25-23	50	20	130	140	168	85	38	140	21	140	93	57
8	55-54	-38	90	-4	152	-96	213	-4	60	0	180	55	101
9	21-123	-52	116	-73	216	-20	290	-22	240	12	230	94	140
9	96-97	105	150	47	75	-50	0	182	55	105	-105	56	88
9	120-121	92	40	-132	64	-8	185	77	-10	60	270	64	109
9	194-196	64	-40	-17	63	150	68	40	20	-52	322	62	109
9	240-234	15	13	-17	32	79	165	-17	55	32	177	53	69
12	117-121	-32	35	-76	83	77	254	-2	373	38	0	75	137
12	133-126	-33	27	20	130	-95	160	60	186	0	248	70	108
15	160-165	-6	64	142	-23	173	-90	148	100	0	170	68	93
15	319-343	68	35	157	-90	232	-62	-9	-15	70	230	62	114
17	5-4	0	10	3	181	-78	203	-4	49	-2	325	69	125
19	77-83	19	-18	132	60	110	90	35	237	19	250	93	91
	Average	27	24	42	85	56	106	44	139	33	185	74	54
	S.D.	53	53	98	84	102	111	63	109	70	119	17	101

Figure 1.Average and standard desviations for elite and control trees production diferences

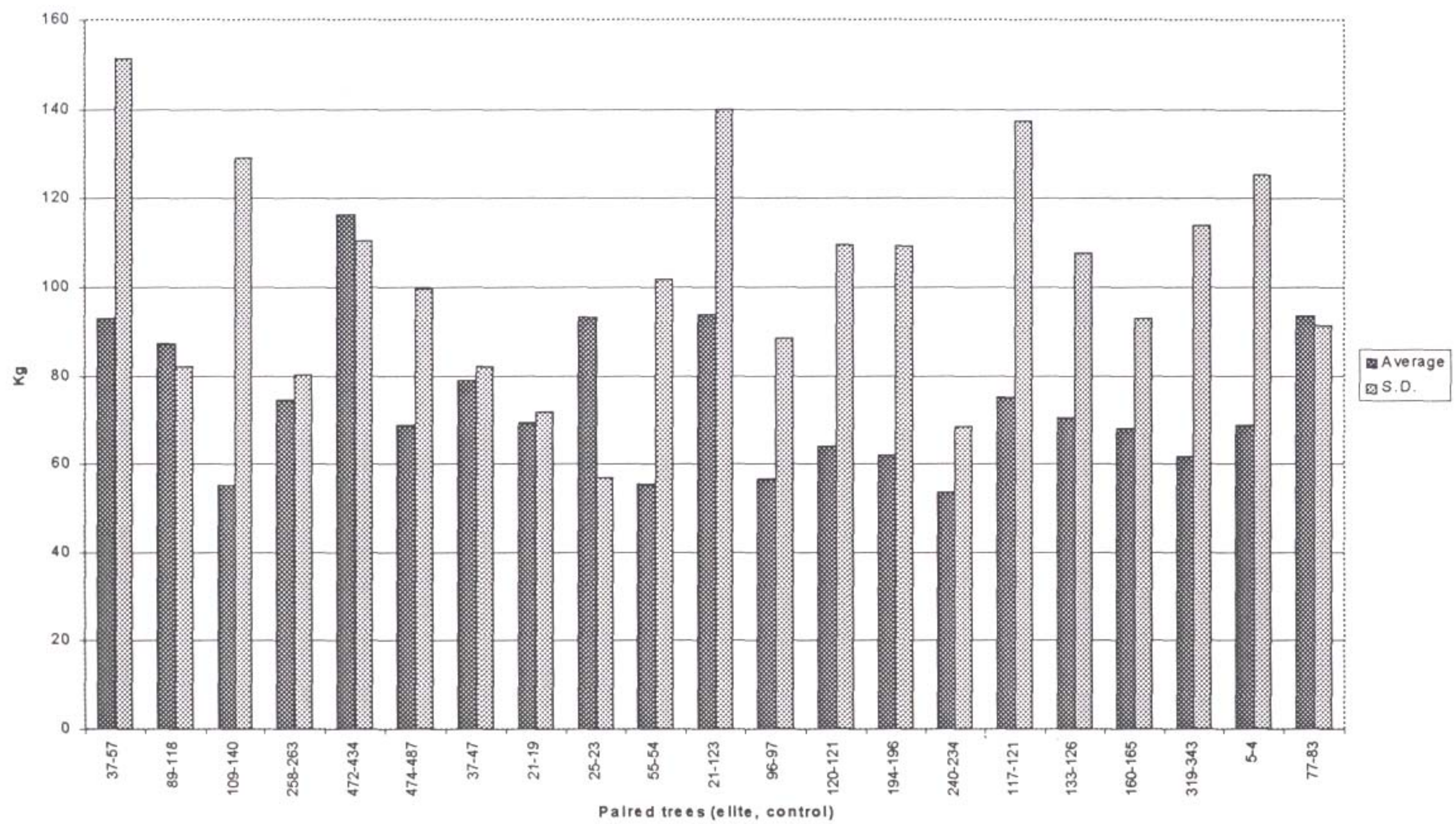

Figure 2.Yearly differences average and s.d. between 20 elite and control trees

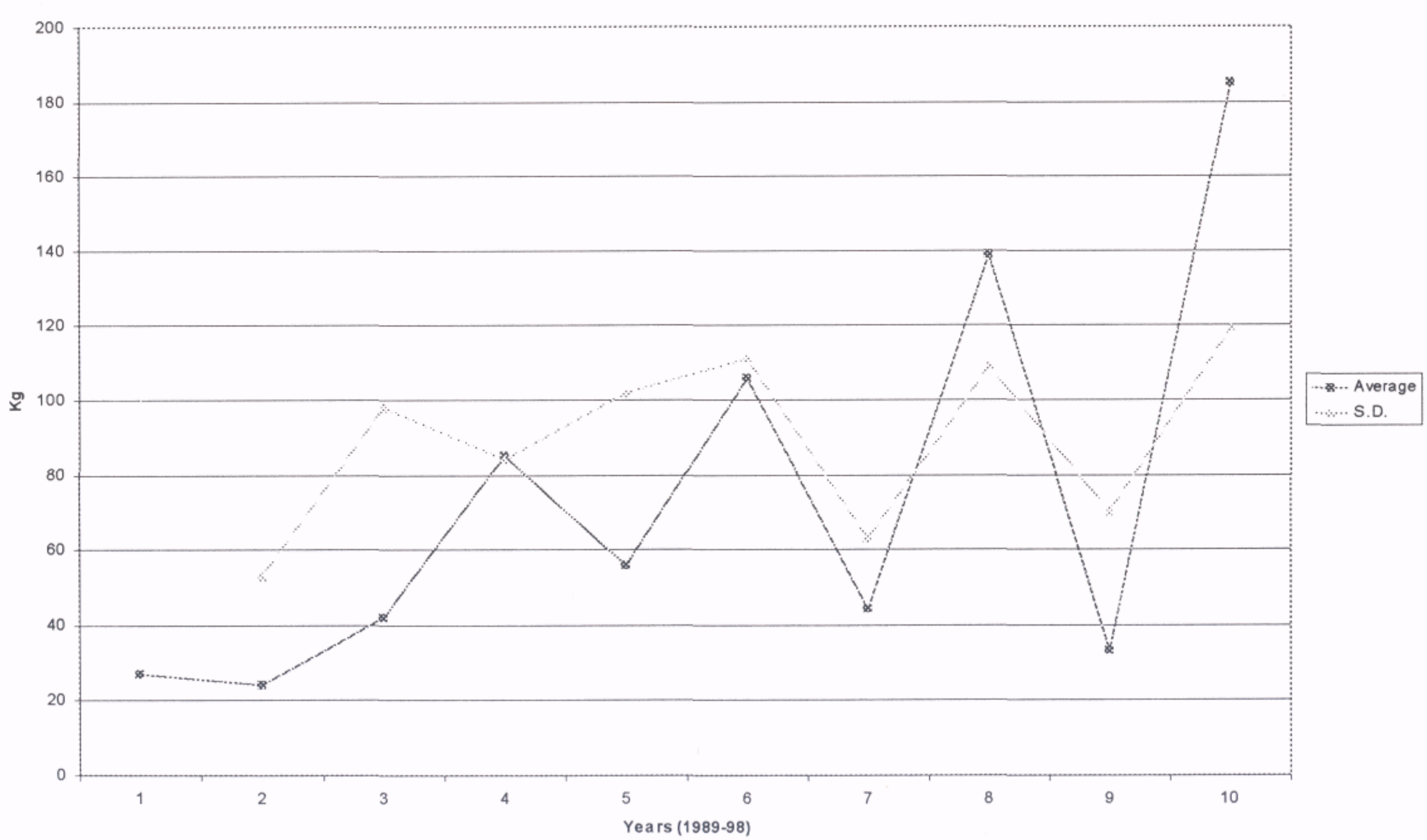

Table 2. Some data about corrected production and tree size for elite and associated control tree.

Tree	CP	TA	HPC	AA	H	GA	PTA	PHPC	PAA	PGA
2-472	152	20.4	109	201	8.9	156	74.5	1.40	0.75	0.98
2-434	42	8.4	75	123	10.2	58	50.3	0.57	0.34	0.73
9-21	129	20.4	107	176	11.3	211	63.1	1.21	0.73	0.61
9-123	32	13.4	69	99	8.5	82	23.4	0.45	0.32	0.38
6-25	126	14.5	77	127	8.1	105	86.7	1.64	0.99	1.19
6-23	41	6.3	40	67	7.4	53	64.4	1.03	0.60	0.76
19-77	115	14.9	66	106	9.2	107	77.1	1.75	1.08	1.07
19-83	28	6.0	31	63	5.4	30	46.7	0.90	0.45	0.95
2-474	115	21.1	80	135	9.2	131	54.4	1.44	0.85	0.88
2-487	57	12.8	37	68	9.6	148	44.4	1.54	0.84	0.39
2-37	135	18.4	101	197	11.3	204	73.4	1.34	0.69	0.66
2-57	54	11.1	72	92	11.7	43	49.1	0.76	0.59	1.28
2-89	110	13.0	71	137	13.3	159	84.6	1.55	0.80	0.70
2-118	38	9.8	75	120	10.9	93	38.4	0.50	0.31	0.41
2-258	94	20.9	98	124	10.7	107	45.0	0.96	0.76	0.88
2-263	28	10.9	67	85	10.1	144	25.8	0.42	0.33	0.20
2-109	99	13.4	59	83	10.8	76	73.9	1.69	1.19	1.31
2-140	50	14.9	51	73	11.5	100	33.4	0.98	0.68	0.50
12-133	111	7.0	63	140	7.1	97	157.5	1.76	0.79	1.14
12-126	45	6.9	29	47	9.7	34	65.8	1.58	0.95	1.32
6-21	108	13.4	104	166	9.5	175	80.1	1.04	0.65	0.62
6-19	54	13.4	74	121	7.3	97	40.0	0.73	0.44	0.55
17-5	116	10.7	78	137	8.1	146	108.3	1.50	0.85	0.80
17-4	54	8.8	48	86	8.3	72	61.8	1.12	0.63	0.75
15-160	104	8.3	62	94	8	109	125.3	1.66	1.10	0.95
15-165	41	7.0	32	53	8.9	27	57.7	1.26	0.77	1.49
9-120	104	14.9	68	117	7.25	40	69.9	1.54	0.89	2.62
9-121	39	10.4	39	70	9	23	37.7	1.02	0.57	1.73
9-194	83	16.0	74	112	8.3	43	51.8	1.12	0.74	1.90
9-196	32	4.8	35	56	7.4	40	66.5	0.93	0.57	0.81
9-96	103	8.3	62	111	8.1	74	124.8	1.66	0.93	1.40
9-97	47	9.8	71	133	7.49	42	47.7	0.66	0.35	1.12
9-240	87	12.0	51	103	6.2	101	72.4	1.72	0.85	0.86
9-234	43	11.4	42	59	7.32	72	37.8	1.03	0.73	0.59
8-55	111	18.5	63	124	7.8	99	59.7	1.75	0.89	1.12
8-54	58	8.4	54	100	7.5	109	68.6	1.08	0.58	0.53

Measured data

CP, corrected production, Kg/tree
TA, trunk transversal section area, below the scion, dm^2
HPC, horizontal projection of canopy, m^2
AA, tree available area, m^2
H, tree height, m
GA, green area of canopy, m^2

Calculated data

PTA=CP/TA, productivity per trunk area, g/cm^2
PHPC= CP/HPC, productivity per horizontal projection of canopy
PAA=CP/AA, productivity per tree available area, Kg/m^2
PGA=CP/GA, Kg/m^2

Table 3. Average values of corrected production , tree size, and productivity for elite and associated average tree.

Tree	CP	TA	HPC	AA	H	GA	PTA	PHPC	PTAA	PGA
Elite										
Average	111	14.8	77	133	9.1	119	82.4	1.48	0.86	1.09
s.d.	17	4.5	18	33	1.8	49	29.2	0.26	0.15	0.50
Control										
Average	43	9.7	52	84	8.8	70	47.8	0.92	0.56	0.81
s.d.	10	2.9	17	27	1.7	39	14.0	0.34	0.19	0.43
% Elite vs. Control	156	52	48	58	3	69	72	62	54	36