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Some Environmental Factors and Yield Variabilities of Avocado Trees in a Spanish Commercial Orchard

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Abstract

The yields of individual trees in a typical hillside, multi-terraced commercial avocado orchard with weathered-slate soils near Velez-Málaga, southern Spain, were studied for three years. The 24 terraces were divided into different-sized sectors determined by soil factors, orientation, exposure to wind, and tree density. Separate analyses of the tree yields of each terrace and each sector revealed that the decreased yields (50% in extreme cases) were associated with various deleterious factors: soil quality (stoniness, soil compaction, high salt content, and soil depth), and orientation and exposure to easterly winds. The mean yield under "acceptable" cultivation conditions was 9.2 MT/ha (3 years and a cultivation area of 11.6 ha). The average tree age at the end of the three-year experimental period was 13.1 years. The statistical variability of the yield, expressed as kg/tree, was 74%. These drastic and cumulative effects on yield, of the several limiting factors identified in this work, may be found frequently in other farms in this area.

INTRODUCTION

Because the avocado has a high index of heterozygosis, the use of seed rootstocks in avocado cultivation causes large differences between the yield of different trees even when the climatic and soil conditions are homogenous. In this way, cultivations of trees of similar appearance can present differences in yield as high as 100% of the mean (Farré, unpublished data). The variability due to the rootstock behavior pattern or the different sources of the graft (for a given cultivar) is described by Ben-Ya'acov (1976), who demonstrates clear differences not only between different rootstocks, but also with the same rootstock cultivar. Ben-Ya'acov demonstrates that the graft source can give rise to variations of yield in cv. Fuerte, but not in Hass. LaRue (1974) reports that in avocado cultivations in the San Joaquin Valley, differences between trees are considerable, and the mean yields are around 8 MT/ha. On the other hand, in the subtropical regions of Spain, the only data available refer to experimental plots (Farré, 1987); it is difficult to find data about commercial yields. Galán (1990) suggests yields between 8 and 12 MT/ha for cultivations in southern Spain and opines that if all the production factors could be optimized, yields of up to 25 MT/ha would be possible.

In this present work, the yields of individual trees in a typical hillside, multi-terraced commercial avocado orchard with weathered-slate soils near Vélez-Málaga, southern Spain, were studied for three years with the following objectives:

1. to identify and eliminate those trees with low yields;
2. to quantify the range of yields per tree;
3. to identify and establish the effects on individual yields of other factors, such as soil conditions, orientation of the plot, and exposure to winds.

MATERIAL AND METHODS

Description of the Orchard

The orchard is located some 4 km north of the Mediterranean sea coast on the hills which form the right side (east and southeast facing) of the valley of the south-flowing Vélez River in Málaga Province. The climate is characteristic of this area. Elias (1977) reports that the thermal pattern is subtropical to semi-hot within the Mediterranean subtropical climatic category. The different orientations and altitudes of each terrace gave rise to relatively different microclimates.

The terraces and the irrigation system were constructed in the years 1969-1970. The soils are formed from weathered-slates, and are very heterogeneous; they vary in depth, and some are very stony. Drainage, on the whole, is very good because the sub-soil consists of the weathered-slate rock or of stony soil produced by the leveling operations to make the terraces; however, there are isolated areas with bad drainage because of hard rock or compacted soil. The area selected for the experiment (11.65 ha) is the part of the orchard given entirely to Mass cv. cultivation. Irrigation is by drippers, and the original tree spacings were 4 x 4 or 5 x 4 m, but these were thinned later. The thinning and the removal of poor trees gave rise to large variations in spacing densities. Management of the orchard follows the usual practice of not tilling the soil between trees. The applications of N, P_2O_5, and K_2O were 75, 0, and 100 kg/ha, respectively. There were leaf applications of zinc sulphate twice-yearly. Flower clusters were pruned if flowering was excessive. The average water supply was 9,000 m^3/ha/year. The drip system has 2,000 drippers/ha and a flow of 20 1/h/tree. During the month of maximum water consumption, the mean supply was about 50 m^3/ha/day.

Methodology

The selected area was divided into 24 terraces whose areas ranged between 0.08 and 1.17 ha. The trees on each terrace were correlatively numbered; total tree population was 4,975. Each tree was plotted on 1:500-scale plans of the orchard. The weights were recorded at the moment of harvesting, and fallen fruits were not included. (In 1989, fallen fruit represented some 25% of the total yield recorded.)

Each terrace was divided into "sectors" that took into account soil factors (stoniness, soil compaction, salt content, and soil depth), the orientation of the sector, the exposure to wind, and the tree density. Some terraces differed in the ages of their trees.

Qualitative field observations were made of the sector characteristics; and in some cases, these included soil analyses.

The number of trees in each sector was counted, and the total area cultivated was estimated from the plans. We calculated the statistical parameters (mean and standard deviation) for each sector and terrace from these data and the mean yield in kg/tree/year, and carried out an analysis of variance with three sources of variation: terraces, sectors within terraces, and variability within sectors between individual trees. The first two sources represent the variations due to environmental and management factors, and the last to differences between individual trees due to genotypic differences.

RESULTS AND DISCUSSION

Table 1 displays a summary of the results. The analyses of variance (ANOVA) revealed significant overall differences between the means of the terraces and sectors. A partial ANOVA for each terrace was made that revealed several cases in which the differences between the sector means were significant. The overall mean was 21.5 (kg/tree), and the standard error (when the terrace and sector effects were separated) was 15.9. These figures illustrate the high variability of the population studied. Individual annual tree yields recorded during the three years of the study ranged from zero to 123 kg. Comparing terraces, it can be seen that those with the largest yields were in areas sheltered from the east wind; that is to say, facing south or west. High planting densities are not detrimental if they are in stepped and relatively narrow terraces with good illumination. The terraces with easterly orientation had poor yields, probably due to the exposure to the easterly winds (these winds flow from the sea and sometimes may be salty.) In this present work, the poorest yields appear to be associated with young trees (1, 23, 24), exposure to wind (4, 12, 13, 19), and perhaps poor soils or poor illumination.

Table 2 shows that for those terraces which have significant differences between sectors, some poor sector means are associated with limiting factors that reflect poor quality soil and exposure to east wind. Those values shown as prejudicial are associated with yield losses of around 50 %.

Table 3 groups the results of several analyses of soil limiting factors. The figures are mean values for all the soil volumes explored by the roots. At this point, it should be borne in mind that drip irrigation produces spatial distortions close to the dripper of the several soil characteristics analyzed.

For example, it is usual to find high concentrations of salt at the periphery of the wet bulb; these generally do not affect the tree because they are outside the volume explored by the roots. Furthermore, the volume occupied by a dense proliferation of the root system close to the emitter distorts the results of soil density analyses (soil dry weight by unit volume of soil sampled).

Table 1. Summary of yields, planting densities, and other associated factors, for each terrace.

Terr. No.	Age Yrs.	Surface area (ha)	No. of sect.	Yields Kg/tree Mean	Yields Kg/tree SD(1)	Yields MT/ha Mean	Yields MT/ha SD(1)	Planting density (No. trees by ha)	Orientation	Soil	Wind
1	6	0.78	10	123	1.9	5.8	0.8	469	SE	n	vs
2	18	1.34	11	37.1(4)	6.0	13.6	1.6	366	SE	n,c-iss	as
3	18	0.53	2	29.0	0.4	10.7	0.2	368	S	n	n
4	15	0.08	1	22.6	—	6.3	—	280	ESW	sd	ve
5	15	0.17	1	38.7	—	9.6	—	248	ESW	sd-iss	ve
6	15	0.14	1	22.7	—	7.4	—	326	W	n	s
7	16	0.37	2	18.1(4)	5.0	5.9	0.3	328	SE	n	vs
8(3)	15	0.39	2	36.7	4.4	14.1	2.5	384	S	n	s
9(3)	15	0.27	2	25.4	0.4	11.4	2.6	451	S	n	s
10(3)	15	0.44	3	37.6(4)	6.8	11.7	6.6	311	S	n,s-iss	s
11(3)	15	0.19	2	32.2(4)	13.7	14.0	4.5	435	S	n,s-iss	ve-iss
12	14	1.17	4	32.5	2.7	7.6	5.2	235	All	n	ve
13	14	0.81	4	16.6	5.5	7.1	2.6	426	E	n,s-iss	e
14	14	0.15	2	32.2(4)	5.5	15.8	2.8	492	ESW	n,s-iss	e-iss
15	10	0.21	2	8.8	1.1	5.5	0.3	626	N-W	n	e
16	10	0.24	3	6.3(4)	3.4	5.4	2.8	860	ESW	n,s-iss	e
17	14	0.30	4	20.0(4)	3.1	11.5	2.6	576	ESW	—	s,e-iss
18	14	0.29	3	14.4	2.4	11.9	1.2	829	SE	g	vs
19	16	0.70	5	16.3	1.1	6.5	0.2	399	E	g	e
20	16	0.48	5	25.1(4)	7.6	9.7	3.4	387	ESW	g,sd-iss	s,e-iss
21	16	0.57	4	20.0(4)	9.3	7.1	3.3	375	ESW	g,sd-iss	s,e-iss
22	15	0.73	6	20.1(4)	6.6	9.2	2.9	457	ESW	g,sd-iss	ve
23	9	0.96	24	15.6(4)	4.0	7.8	2.0	500	E-W	g,cd-iss	ve
24	9	0.56	10	13.5(4)	3.0	8.0	2.1	593	E-W	g,s-iss	ve
Means				21.5	3.1(2)	9.2		427			
Totals		11.65	113								

Keys: Soil: n, normal; s, stony; vs, very stony; c, clay; bd, bad drainage; sd, shallow depth; cd, compacted; g, good; iss, in some sectors.
Wind exposure: ws, well-sheltered; s, sheltered; n, normal; e, exposed; ve, very exposed; iss, in some sectors. (1) Standard deviation for sector means. (2) L.S.D. (5%) between terrace means. (3) Terraces with more illumination than usual on south-facing slopes. (4) Significantly different sector means within terraces.

Table 2. Some yield-limiting factors of avocado trees.

Terrace	Sector	Kg/tree	MT/ha	Trees/ha	Soil(1)	Wind(1)
2	8	31.7	13.4	424	c	—
	11	40.2	17.5	435	n	—
7(2)	2	15.1	6.1	381	—	—
	1	22.2	5.8	276	—	—
8	2	40.0	16.1	370	—	s
	1	33.8	12.5	402	—	e
10(2)	3	43.3	20.1	464	—	—
	2	40	8.6	215	—	—
11	1	21.4	10.2	477	sd	e
	2	40.8	16.6	407	n	s
14	1	36.3	17.9	493	n	s
	2	28.5	14.0	490	s	e
16	2	9.8	8.5	867	n	e
	3	3.2	4.2	1326	vs	e
	1	5.5	3.2	573	n	e
17	1-2	18.1	13.7	735	—	e
	3-4	22.5	9.4	422	—	s
20	4	10.9	4.0	371	—	ve
	2	27.3	12.3	449	—	s
21	4	6	1.9	318	sd	ve
	3	18.4	8.6	468	n	s
22	4	13.5	6.6	488	sd	—
	2	32	14.7	459	n	—
23	5	9.1	4.6	500	s	—
	9	12.6	6.3	500	cd	—
	4	25.1	12.6	500	n	—
24	10	8	4.3	540	s	—
	4	17.7	11.1	625	n	—

(1) Abreviations as in Table 1.
(2) Differences between sectors attributed to planting densities.

Table 3. Some soil characteristics considered to be limiting factors.

	Type of soil			
Characteristic	Normal	Stony	Compacted	High Salinity
Fraction >2 mm (%)	38	62		
Bulk Density	1.35		1.70	
E.G. (1:5) unhos	219			470

Except for those variations in yield due to rootstock variability (Ben-Ya'acov, 1976; LaRue, 1974), we have not found any references to measurements of the effects of poor soils or wind on yields; but, qualitatively, Rodriguez (1982), Alvarez de la Peña (1975), and Fersini (1975) all mention wind as a prejudicial factor, particularly during flowering and fruit and fruit set, and the cause of broken branches. Heavy soils are shown to be prejudicial because of poor drainage and aeration, but there appears to be no mention of the negative effect of soil compaction on medium soils. In the works cited, salinity levels similar to those termed dangerous in this present work (2 mmhos on soil-water saturation extract) are given.

CONCLUSION

The cultivation conditions in the 11.6 ha avocado orchard during the three-year period of this present work were acceptable. The mean yield was 9.2 MT/ha. The mean tree age at the end of the study period was 13.1 years. In the 23.6% of total surface cultivated, the trees were younger than the age of maximum yield, and this suggests that future yields will be better. The variability in yield between individual trees when management and environmental effects were separated was 74%.

The great influence of the two limiting factors of poor soil and exposure to east wind was clearly demonstrated. In the more extreme cases studied, the two factors reduced mean yield by nearly 50%. The critical soil factors identified were stoniness, soil compaction, high salt concentration, and soil depth.

On the other hand, when the environmental and soil factors were optimized, mean yield increased by 72%.

These findings suggest that the planning of new avocado orchards should include a preparatory survey of all the potential limiting factors that could adversely affect production and profitability. A combination of poor soils and exposure to wind would be economically disastrous. Of course, it would be possible sometimes to correct the factors, but the costs of these corrections must be set against the expected improvement of yields and considered in the light of the price trends in the avocado markets.

LITERATURE CITED

Alvarez de la Peña, F. J. 1975. El Aguacate. Ministerio de Agricultura, Madrid. Ben-Ya'acov, A. 1976. Avocado rootstock-scion relationships: a long-term large-scale field research project. V. Final report on some orchards planted during the years 1960-64. Cal. Avoc. Soc. Yearbook 1975-76, 122-133.

Elias, F., y L. Ruiz. 1977. Agroclimatología de España. Cuaderno I.N.I.A. No. 7.

Farre, J. M., J. M. Hermoso, and F. Pliego. 1987. Effects of pre-bloom pruning on leaf nutrient status, growth, and cropping of the avocado cv. Hass. South Afr. Avoc. Gro. Assoc. Yearbook, 10 (I Avocado World Congress), 71-72.

Fersini, A. 1975. El cultivo del aguacate. Diana, México.

Galán, V. 1990. Los frutales tropicales en los subtrópicos. Mundi-Prensa, Madrid.
LaRue, J. H., and R. D. Copeland. 1974. Avocado yields in the San Joaquin Valley. Cal. Avoc. Soc. Yearbook 1973-74, 72-74.
Rodriguez, F. 1982. El aguacate. AGT Editor SA, México.