

Impact of orientation and height on grain quality in pistachio cultivation: A multivariate analysis.



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Introduction

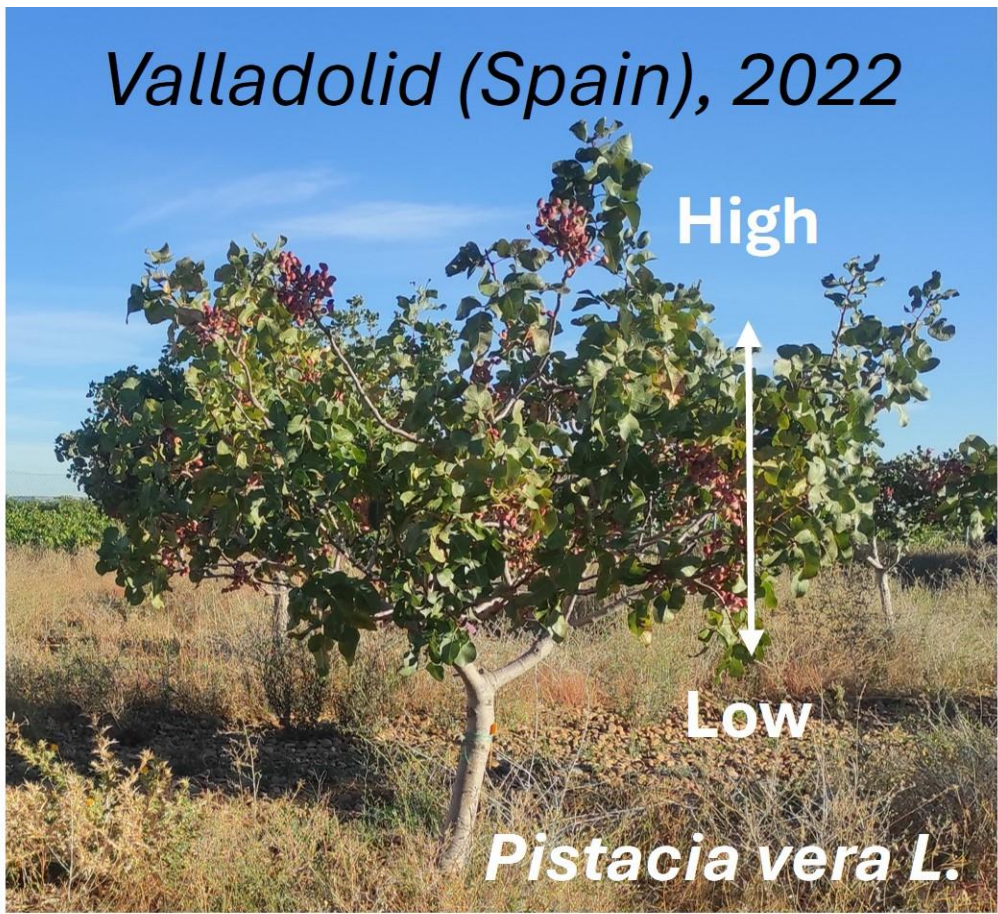


Pistachios are a crop significant to the world economy and nutrition, and their demand is rising in several foreign markets. Pistachios are one of the nuts with the **highest nutritional content** in the world; they have a considerable quantity of dietary fibre, protein, vitamins, and important minerals, among other nutrients, indicating their potential health advantages. Owing to these advantageous characteristics, pistachios show promise as a component for the food industry in creating several novel products. Agronomically speaking, hedgerow orientation can be expected to modify nut composition because of differences in temperature and irradiation patterns.

Material and Methods

In 2022, experiments were performed in two pistachio orchards located in **Valladolid, Castilla y León, Spain**. These orchards were situated in "Moraleja de las Panaderas" (M) and "La Seca" (S), areas in the southern part of the province.

In an extensive analysis of pistachio nuts, this work investigates **a spectrum of nutritional and biochemical parameters**, inclusive of **macroelements** and **microelements**, and their **lipid profile**. Key constituents including **fats**, **carbohydrates** and **proteins** were also meticulously quantified. The study specifically explored how variables such as orientation and height influence the nutritional makeup of the pistachio crop, including the use of Hyperspectral imaging to infer the localisation of these nuts in the tree.



La Seca $\uparrow 4,660 \text{ m}^3 \text{ ha}^{-1}$ $\downarrow 2,750 \text{ m}^3 \text{ ha}^{-1}$

Moraleja $\uparrow 1,161 \text{ m}^3 \text{ ha}^{-1}$ $\downarrow 844 \text{ m}^3 \text{ ha}^{-1}$

Samples:
- Two heights (H, L)
- Four orientations (N,S,E,W)

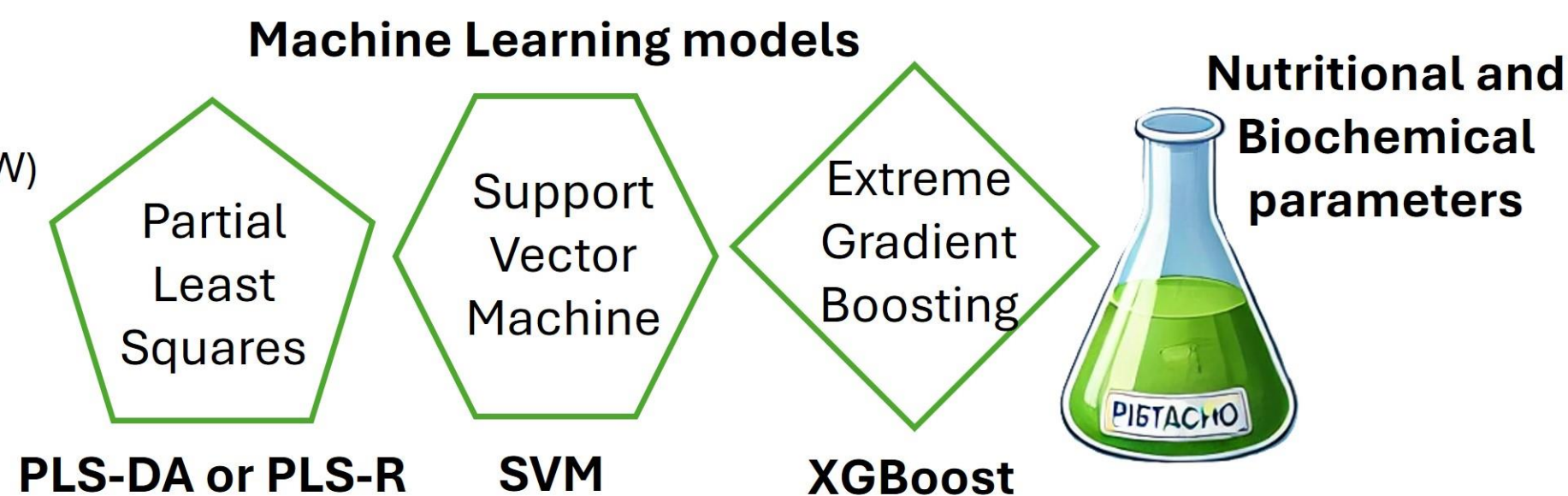
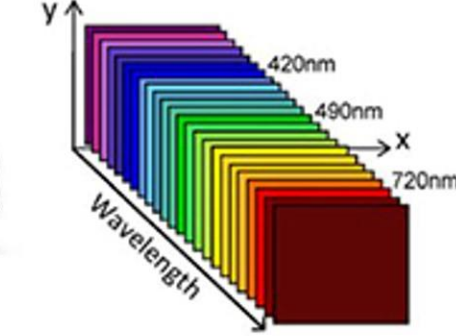


Figure 1. Graphical scheme of the methodology followed in the study.

Results

Findings reveal significant disparities in some parameters based on the orientation and height of growth. For instance, **fat content showed notable variation concerning tree orientation**, while some fatty acids analysed were affected by the crop's height. These results underscore the substantial impact of environmental factors on the nutrient profile of pistachios, suggesting that the directional planting and elevation of the land are critical considerations in cultivating pistachios.

In addition, the **three different Machine Learning models** showed that predicting the tree height and orientation was challenging, obtaining low F1 scores for tree orientation (0.35 (SVM) and 0.36 (PLS and XGBoost)), but better results for height location (F1 scores: 0.61 (PLS) and 0.59 (XGBoost and SVM)).

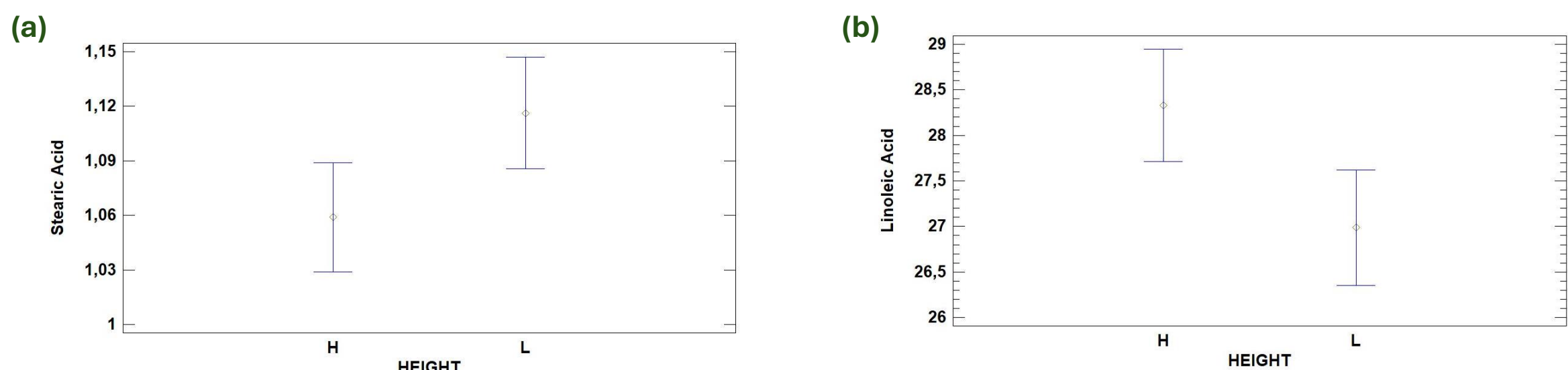


Figure 2. Plots of means obtained after analysis of variance and Tukey's Honest Significant Difference test (<0.05) for (a) Stearic acid and (b) Linoleic acid, according to the variations observed in the different heights.

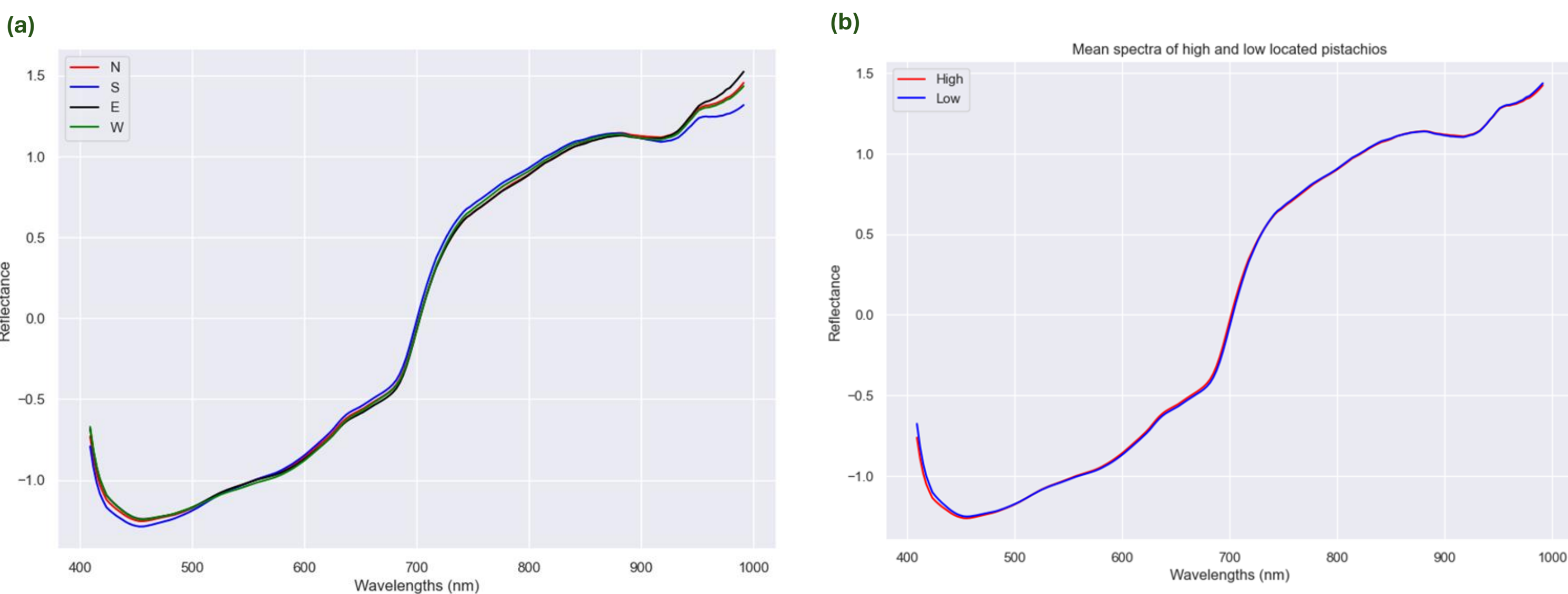


Figure 3. (a) Mean spectra after SNV treatment of each fruit orientation in the three: North (N), South (S), East (E) and West (W). (b) Mean spectra after SNV treatment of each fruit height location in the tree (high and low).

Table 1. (a) Prediction results of the models for pistachio orientation in the tree classification. (b) Prediction results of the models for pistachio height in the tree classification.

(a)															
Fruit orientation in the tree															
PLS				XGBoost				SVM							
F1 = 0.36				F1 = 0.36				F1 = 0.35							
Class	Predicted			Class	Predicted			Class	Predicted						
	N	S	E		W	N	S		E	W	N	S	E	W	
Real	N	72	48	29	46	N	72	34	34	55	N	70	32	38	55
	S	17	53	36	17	S	46	69	49	49	S	50	50	68	45
	E	16	61	61	81	E	43	46	78	52	E	41	26	94	58
	W	20	51	33	115	W	42	39	56	82	W	46	39	56	78
Fruit orientation in the tree Moraleja															
PLS				XGBoost				SVM							
F1 = 0.36				F1 = 0.36				F1 = 0.37							
Class	Predicted			Class	Predicted			Class	Predicted						
	N	S	E		W	N	S		E	W	N	S	E	W	
Real	N	74	19	34	0	N	60	19	18	30	N	53	25	19	30
	S	58	31	31	0	S	29	20	35	36	S	30	28	37	25
	E	26	25	56	0	E	18	14	47	28	E	20	17	47	23
	W	29	20	39	0	W	23	11	23	31	W	20	12	19	37
Fruit orientation in the tree La Seca															
PLS				XGBoost				SVM							
F1 = 0.37				F1 = 0.36				F1 = 0.37							
Class	Predicted			Class	Predicted			Class	Predicted						
	N	S	E		W	N	S		E	W	N	S	E	W	
Real	N	14	38	0	32	N	18	20	21	25	N	35	12	14	23
	S	11	54	0	48	S	15	52	23	23	S	25	44	25	19
	E	0	33	0	59	E	7	27	30	28	E	22	20	29	21
	W	0	36	0	80	W	15	28	27	46	W	36	18	20	42
Fruit orientation in the tree Moraleja control															
PLS				XGBoost				SVM							
F1 = 0.38				F1 = 0.36				F1 = 0.37							
Class	Predicted			Class	Predicted			Class	Predicted						
	N	S	E		W	N	S		E	W	N	S	E	W	
Real	N	41	31	10	0	N	41	7	12	22	N	60	14	8	0
	S	21	47	20	0	S	15	19	35	19	S	36	28	21	3
	E	7	35	36	0	E	10	15	30	23	E	23	24	28	3
	W	15	31	29	0	W	18	8	22	27	W	31	20	21	3
Fruit orientation in the tree Moraleja high															
PLS				XGBoost				SVM							
F1 = 0.38				F1 = 0.50				F1 0.43							
Class	Predicted			Class	Predicted			Class	Predicted						
	N	S	E		W	N	S		E	W	N	S	E	W	
Real	N	30	0	9	0	N	22	5	9	3	N	22	5	6	6
	S	26	0	6	0	S	10	11	7	4	S	11	9	6	6
	E	12	0	15	0	E	3	2	20	2	E	3	4	16	4
	W	13	0	8	0	W	5	2	8	6	W	11	2	4	4
Fruit orientation in the tree La Seca high															
PLS				XGBoost				SVM							
F1 = 0.36				F1 = 0.45				F1 = 0.43							
Class	Predicted			Class	Predicted			Class	Predicted						
	N	S	E		W	N	S		E	W	N	S	E	W	
Real	N	0	12	0	15	N	2	2	1	22	N	17	0	1	9
	S	0	35	0	33	S	2	33	16	17	S	11	23	20	7
	E	0	18	0	22	E	2	11	17	10	E	12	1	20	7
	W	0	22	0	35	W	7	1	15	34	W	30	0	4	23
Fruit orientation in the tree La Seca control															
PLS				XGBoost				SVM							
F1 = 0.39				F1 = 0.38				F1 = 0.37							
Class	Predicted			Class	Predicted			Class	Predicted						
	N	S	E		W	N	S		E	W	N	S	E	W	
Real	N	17	35	0	4	N	18	11	13	14	N	23	1	19	13
	S	12	53	0	1	S	17	25	13	15	S	16	13	24	17
	E	4	30	0	1	E	5	11	19	4	E	6	1	27	1
	W	2	32	0	14	W	9	14	7	18	W	10	9	13	16

(b)											
Fruit height in the tree											
PLS				XGBoost				SVM			
F1 = 0.61				F1 = 0.59				F1 = 0.59			
Class	Predicted			Class	Predicted			Class	Predicted		
	High	Low			High	Low			High	Low	
Real	High	306	140	Real	High	281	165	Real	High	272	174
	Low	191	209	Real	Low	178	222	Real	Low	170	230
	Fruit orientation in the tree Moraleja										
PLS				XGBoost				SVM			
F1 = 0.62				F1 = 0.52				F1 = 0.53			
Class	Predicted			Class	Predicted			Class	Predicted		
	High	Low			High	Low			High	Low	
Real	High	107	98	Real	High	107	96	Real	High	93	112
	Low	68	169	Real	Low	114	123	Real	Low	96	142
	Fruit orientation in the tree La Seca										
PLS				XGBoost				SVM			
F1 = 0.69				F1 = 0.62				F1 = 0.57			
Class	Predicted			Class	Predicted			Class	Predicted		
	High	Low			High	Low			High	Low	
Real	High	210	36	Real	High	164	82	Real	High	110	136
	Low	89	70	Real	Low	73	86	Real	Low	37	122
	Fruit orientation in the tree Moraleja control										
PLS				XGBoost				SVM			
F1 = 0.55				F1 = 0.54				F1 = 0.60			
Class	Predicted			Class	Predicted			Class	Predicted		
	High	Low			High	Low			High	Low	
Real	High	86	66	Real	High	87	64	Real	High	81	70
	Low	79	93	Real	Low	84	88	Real	Low	60	112
	Fruit orientation in the tree Moraleja high										
PLS				XGBoost				SVM			
F1 = 0.71				F1 = 0.50				F1 0.58			
Class	Predicted			Class	Predicted			Class	Predicted		
	High	Low			High	Low			High	Low	
Real	High	34	22	Real	High	22	34	Real	High	20	36
	Low	13	50	Real	Low	26	37	Real	Low	13	50
	Fruit orientation in the tree La Seca high										
PLS				XGBoost				SVM			
F1 = 0.75				F1 = 0.69				F1 = 0.65			
Class	Predicted			Class	Predicted			Class	Predicted		
	High	Low			High	Low			High	Low	
Real	High	97	13	Real	High	89	21	Real	High	76	34
	Low	35	47	Real	Low	37	45	Real	Low	33	49
	Fruit orientation in the tree La Seca control										
PLS				XGBoost				SVM			
F1 = 0.64				F1 = 0.58				F1 = 0.58			
Class	Predicted			Class	Predicted			Class	Predicted		
	High	Low			High	Low			High	Low	
Real	High	81	36	Real	High	61	56	Real	High	35	82
	Low	41	56	Real	Low	32	64	Real	Low	8	89