Journal American Pomological Society 57(3):121-127 2003

Performance of Six Asturian Apple (*Malus xdomestica*) Cultivars Growing on Two Rootstocks for Cider Production

B. DÌAZ-HERNÁNDEZ[1*], M. CIORDIA-ARA[2], M. COQUE-FUERTES[2], S. PEREIRA-LORENZO[1]

Abstract

Cider production is a traditional industry in Northern Spain and it needs specific cultivars to produce a high quality beverage. Six cultivars selected in Asturias (Spain) for cider production, 'Blanquina', 'Cristalina', 'Marialena', 'Reineta Encarnada', 'Raxao' and 'Teórica', have been tested to determine their performance during eleven years on two rootstocks, MM.106 and MM.111. Full bloom was quite late with all cultivars, from 28 April to 20 May, which could be of interest in areas with late frost. The harvest time of 'Marialena' was particularly early, and could be inconvenient for the cider industry. MM.106 and MM.111 showed similar vigor in our conditions, but MM.106 induced a higher productivity with some cultivars. With both rootstocks, 4 x 3.5 m was an insufficient planting distance for all cultivars except 'Cristalina' which could be planted closer. All cultivars began to fruit the fourth year except 'Blanquina' and 'Cristalina', which fruited the fifth and sixth year, respectively. The most productive cultivar during the first two years was 'Marialena'.

All cultivars exhibited biennial bearing except 'Cristalina'. Considering total production after ten years, two groups could be estabilished: i) cvs. Blanquina, Marialena and Raxao, with more than 200 kg/tree, and ii) cvs. Cristalina, Reineta Encarnada and Teórica, with less than 170 kg/tree. The most vigorous cultivars were 'Marialena' and 'Raxao'. 'Blanquina', 'Teórica' and 'Marialena' had high productivity and are recommended using MM.106 rootstock in our conditions. 'Raxao' is also quite interesting though it should be grafted on a dwarf rootstock such as M.9. 'Cristalina' should be rejected because it is non-precocious with low productivity, and likewise 'Reineta Encarnada' which was the least productive cultivar tested.

Introduction

In Northern Spain satisfactory production with high quality can be obtained with indigenous cultivars. The main problems of these cultivars have been the low precocity and excessive vigor but both these problems can be solved using modern rootstocks and appropriate cultivars adapted to local conditions.

The cider industry demands more acid and bitter apples than the dessert market and new plantations with appropriate cultivars are needed (1, 2, 4, 8, 17). Apple cultivars destined to make cider require heavy productivity, large fruit size, high soluble solids, a specific sugar acid ratio, yellow flesh color and non-browning flesh. Appearance is unimportant (11).

The cultivation of apples for cider began in Asturias (Northern Spain) during the 1960's with the studies of Alvarez et al. (1) and Alvarez (2) in the Estación Pomológica de Villaviciosa, Asturias, Servicio Regional de Investigación y Desarrollo Agroalimentario (S.E.R.I.D.A.). Coque-Fuertes et al. (3) continued that work with studies about the agronomic behavior of the most important apple cultivars for cider, which continues to the present.

[1]Universidad de Santiago de Compostela; Dpto. Producción Vegetal; Campus de Lugo; 27002 Lugo, Spain
[2]SERIDA (before Centro de Investigación Aplicada y Tecnologia Agroalimentaria, CIATA), Consejeria de Medio Rural y Pesca, Principado de Asturias, 33300 Villaviciosa, Asturias
*Corresponding author. Tel.: +34-982-252231; fax: +34-982-241835. E-mail address: belendh@lugo.usc.es (B. Diaz-Hernández).

This study was funded by the INIA, by means of the Project 6026 with the title "Stone and pome fruit trials for the Cantabrian area".

'Blanquina', 'Raxao', and 'Cristalina' were described as vigorous, less sensitive to diseases ('Cristalina' shows sensitivity to brown rot) with high production and alternate bearing (3). 'Raxao' was late in bearing. 'Blanquina' and 'Cristalina' bloom in the middle of May, and 'Raxao' does so after 15 May. They are harvested from the end of October to the middle of November. 'Marialena' was described as very vigorous, early in bearing, productive and not alternating, with high resistance to diseases. Its bloom period is from the end of April to the beginning of May, overlapping 'Teórica' and before 'Cristalina' and 'Blanquina', and they are harvested at the beginning of October. 'Teórica' has low vigor and high productivity, is early in bearing and very alternating, with moderate disease resistance. It blossoms at the end of April overlapping with 'Marialena' and 'Blanquina', and it is harvested at the beginning of November. Finally, 'Reineta Encarnada' was very vigorous, relatively precocious, very alternating, sensitive to nectria canker and less sensitive to scab. It blossoms in the middle of April and it is harvested in mid-late October.

In Spain the use of clonal rootstocks is quite recent, but they are necessary in new orchards to reduce the vigor and to achieve more regular tree size (5). MM.106 and MM.111 are especially interesting rootstocks since they can support high production without a trellis, which is very important for growing apples for cider production, since the low prices paid in the market do not allow high investments.

The objective of this study was to evaluate the behaviour of six main cider cultivars ('Blanquina', 'Cristalina', 'Marialena', 'Reineta Encarnada', 'Raxao' and 'Teórica') on two rootstocks (MM.106 and MM.111) in Villaviciosa, Asturias, Spain.

Materials and Methods.

Plant material and trial design. This study was developed at 5°26'W, 43°28'N, S.E.R.I.D.A. (Principado de Asturias) located in Villaviciosa (Asturias), at sea level. The weather in this area is warm and humid. The soil was sandy loam, deep, and with an appropriate structure and well drained. The land was not in trees previously.

Six apple cultivars selected in Asturias for cider production were compared: 'Blanquina', 'Cristalina', 'Marialena', 'Reineta Encarnada', 'Raxao' and 'Teórica'. The six cultivars were grafted on two rootstocks: MM.106 and MM.111. The trial was established in February 1984, grafting the rootstocks planted *in situ* by budding in the same year. Planting distance was 4 x 3.5 m. Ten replications of a combination of cultivar/rootstock were established at random where treatments were cultivar and rootstock. This trial was continued until 1995 when alternate rows were removed because the vigor became too strong to maintain all trees. In 1998 all trees were eliminated.

Orchard management. Before planting, 60 t/ha of cow manure, 100 kg/ha of N, 300 kg/ha of P_2O_5 and 300 kg/ha of K_2O were added. Soil was ripped with a deep chisel and then worked with a rotary hoe. After planting, in spring 1984 the trees were fertilized with 140 g/tree of calcium ammonium nitrate. In 1985 and the following years, ammonium nitrate was added at a rate of between 100 g/tree and 300 g/tree. In 1987 150 g/tree of magnesium sulfate, was also added. After 1991, ammonium nitrate was replaced with 300 g/tree of 8-24-12 and 190 g/tree of potassium sulfate was added in 1993. Trees were trained to a central leader. Winter pruning was done in January or February and was supplemented by summer pruning. Irrigation water was supplied in July and August with a trickle system controlled by tensiometers. Pest and diseases were controlled as necessary according to local practices. Ground was covered by permanent sod and herbicides were used to eliminate weeds and other vegetation along the tree rows after two years of tillage.

Studied traits and statistical analyses. Trees were checked every two days to study phenology according to the Fleckinger (6) system. The beginning of bloom was considered when 5% of flowers were open, full bloom when 50 to 95% were open and finished when over 95% had opened. Vigor was estimated by measuring trunk circumference at 10-20 cm above the graft in February each year. Fruits collected from the ground were weighed. Harvest time was determined according to the color of the skin (red, yellow or green depending on the cultivar) and the natural fall of the fruits for each cultivar. Healthy fruits were collected from the tree or from the ground excluding those that fell before normal maturity time (3). Yield efficiency was estimated by dividing accumulated production by the trunk cross-sectional area.

An analysis of variance (ANOVA) was conducted to determine the effects of the cultivar (C) and the rootstock (R). The procedure PROC GLM of SAS for unbalanced data (1988) was used to analyze data from each year (from 1986 to 1995) for the following quantitative variables: vigor, production, accumulated production and yield efficiency according to the following model: $X_{ijk} = \mu + Ci + R_j + (CR)_{ij} + \varepsilon_{ijk}$ where X_{ijk} is the observation of the cultivar i (i= 1 to 6) over the rootstock j (j=1 and 2) and the sample k (k= 1 to 10); μ = the mean of all the observations; C_i, R_j, $(CR)_{ij}$, and ε_{ijk} are the effects of the cultivar i, the rootstock j, the interaction of cultivar x rootstock ij, and the error associated with sample k in the observation ijk, respectively. All effects are assumed to be fixed. Then, the error is the term for testing the significance of the mean squares for cultivars, rootstocks, and cultivar x rootstock interaction. Student-Newman-Keuls multiple range test was used to indicate significant differences between means at the 5% level.

Results and Discussion

Phenology. The period of flowering during the trial varied from 28 April to 20 May (Table 1). The earliest flowering cultivar was 'Reineta Encarnada' and the latest was 'Raxao', with 23 days difference in the start of flowering and 17 in the finish. However, cross-pollination was assured since at least two cultivars were producing pollen nearly at the same time (Table 1). The influence of the rootstock on phenology was small, since deviations were more than one day only in 'Marialena', in which first flowering was earlier and last flowering was later with MM.111 than with MM.106 (Table 1). The main period of flowering was from 28th April to 20th May and it corresponded with other local cultivars from North Spain (14). Our results showed that 'Reineta Encarnada' flowered later than reported by Coque-Fuertes (3), and it can be used with 'Teórica' as a pollinator. 'Blanquina', 'Cristalina' and 'Marialena' should be cultivated together according to the pollination periods and 'Raxao', being the latest, needs to be combined with 'Marialena' or 'Cristalina' for good fruit set.

In this study flowering periods were quite similar among years except 1990, when the period was late and protracted (data not shown). This was likely due to a warm winter with less chilling. Comparing the average of all years, the duration of flowering varied between 12 days for 'Cristalina' to 25 days for 'Teórica'. These cultivars, as others with late flowering, showed quite high chilling requirements ('Marialena', 'Raxao' and 'Reineta Encarnada') or high ('Blanquina', 'Cristalina' and 'Teórica') to break dormancy (data not shown). Years with more chilling corresponded with shorter flowering periods (1989, 1991 and 1992), 1989 being the shortest.

Harvest began on 22 September with 'Marialena' and finished on 23 October with 'Blanquina' (on MM.111), 'Cristalina', 'Raxao' and 'Reineta Encarnada' (Table 1). Early maturity of 'Marialena', some days before that described by Coque-Fuertes et al. (3), can be inconvenient, especially in warm years, because at that time the cider industry has not begun to process apples. 'Cristalina', 'Raxao', 'Reineta Encarnada' and 'Teórica' also ripened earlier than reported by Coque-Fuertes et al. (3). 'Marialena' showed the shortest period between full bloom and harvest, 137 days, in comparison to the other cultivars with over 156 days (Table 1).

Table 1. Flowering time (average 1986-95), harvest and days between flowering and harvest for six apple cultivars on two rootstocks.

Cultivar	Rootstock	First flowering	Full bloom	Last flowering	Harvest time	Days from full bloom to harvest
Blanquina	MM.106	3-May	9-May	19-May	21-October	165
	MM.111	4-May	9-May	18-May	23-October	167
Cristalina	MM.106	9-May	13-May	21-May	23-October	163
	MM.111	10-May	13-May	22-May	23-October	163
Marialena	MM.106	30-April	5-May	15-May	22-September	140
	MM.111	26-April	11-May	20-May	22-September	134
Raxao	MM.106	14-May	20-May	31-May	23-October	156
	MM.111	14-May	20-May	31-May	23-October	156
Reineta Encarnada	MM.106	21-April	29-April	14-May	23-October	178
	MM.111	22-April	28-April	14-May	23-October	179
Teórica	MM.106	24-April	12-May	18-May	22-October	164
	MM.111	24-April	12-May	20-May	22-October	164

Vigor. No significant differences in trunk circumference were found between rootstocks but cultivars had a significant effect every year (Table 2). The cultivar x rootstock interaction showed low significance in 1990 and 1992, meaning that the behaviour of all cultivars over the two rootstock was generally similar. Normally, MM.111 is more vigorous than MM.106 (13), but this was not found in our study.

'Marialena' and 'Raxao' were the most vigorous cultivars by the 10th year (1995), which showed a strong relationship with early growth (grafted by budding in August 1984 and measured in February 1986), since they were at that time also the most vigorous. 'Blanquina' and 'Reineta Encarnada', followed by 'Cristalina', formed an intermediate group. As it was described earlier by Coque-Fuertes et al. (3), 'Marialena' showed the highest vigor, but not 'Raxao', which was considered previously as vigorous as 'Blanquina' and 'Cristalina'. Finally, 'Teórica' was the least vigorous starting in the first year of growth and this corresponded with a previous study (3). Planting distance between trees was not enough for both rootstocks

Table 2. Trunk circumference (mm) of six apple cultivars on two rootstocks.

Cultivar	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Blanquina	52 bc[z]	97 b	155 b	219 abc	282 b	323 b	368 a	397 ab	424 a	452 ab
Cristalina	54 bc	89 bc	142 b	194 bc	245 c	283 c	321 b	372 b	399 b	427 b
Marialena	59 ab	116 a	188 a	249 ab	323 a	367 a	396 a	438 a	465 a	493 a
Raxao	62 a	110 a	180 a	271 a	304 ab	341 b	391 a	431 a	456 a	482 a
Reineta Encarnada	49 cd	91 bc	150 b	211 bc	281 b	326 b	371 a	407 ab	429 ab	451ab
Teórica	42 d	83 c	120 c	177 c	225 c	270 c	289 c	336 c	352 c	367 c
Significance										
Cultivar	****	****	****	****	****	****	****	****	****	****
Rootstock	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV * RS	ns	ns	ns	ns	*	ns	•	ns	ns	ns

[z]For eacn column, means without a letter in common are significantly different (P=0.05) according to Student-Newman-Keuls multiple range test . ns, *, ****. non-significant, significant, at P≤ 0.05 and P≤0.01, respectively.

with every cultivar, except 'Teórica' in which it could be reduced. As every cultivar showed high vigor, in winter 1995-96 trees of alternate rows were removed to increase the penetration of the light in the lower parts of the canopy.

Growth development and precocity in bearing. None of the cultivars studied had a spur type growth habit. Cultivars Reineta Encarnada, Blanquina, Marialena and Teórica fruited as Type 3 (type Golden) defined by Lespinasse (12). Fruits were borne on two or three year old wood and on spurs. These cultivars showed a main axis with lateral shoots inserted at wide angles, which flowered and debilitated soon. 'Reineta Encarnada' showed acute angles and too much vigor in the upper part of the tree. Renovation by eliminating strong shoots is suggested to maintain fruiting in the older wood.

'Cristalina' corresponded to the Type 4 (type Granny Smith). It flowered mainly on spurs on two or three year old wood. It showed a great tendency to transfer its vigor to the upper part of the canopy, debilitating the lower part. Branches formed acute angles the first years, spreading when they began to bear. Until the tree began bearing, it was necessary to summer prune, cutting back the new shoots and eliminating the strong shoots in the upper part of the tree. Pruning should be light, reducing spurs in the end. Renovation was done by eliminating four or five year old branches, when spurs begun to be scarce. In general, it was a more difficult cultivar to manage.

'Raxao' belonged to Type 2 (Type Reineta). It flowered mainly on two or three year old wood and older. It is a vigorous cultivar which naturally forms a leader, with lateral branches with wide angles, stronger closer to the trunk. Few branches were formed during the early years, which must be considered in order to avoid blind wood. It was not necessary to renovate frequently as in previous cultivars, because it produced fruit with more quality on older wood. Also new shoots appeared naturally in the basal area, facilitating the formation and maintenance of the trees. Renovation was necessary when branches were curved by the weight of the fruit, which in the fourth or fifth year produced small sized fruit.

'Marialena' produced significantly more apples the first (1988) and the second cropping year (1989) (Table 3), 10.9 and 35.1 kg/tree, respectively. That means that this cultivar began to produce after four years

Table 3. Annual production by six apple cultivars on two rootstocks (kg/tree).

Cultivar	Production (kg) 1988	1989	1990	1991	1992	1993	1994	Accumulated
Blanquina	5.8b[z]	4.1c	26.0a	7.0c	47.8a	3.5c	159.9a	277.6a
Cristalina	1.5c	7.5bc	6.3b	20.5c	15.5b	34.9b	74.2c	160.4b
Marialena	10.9a	23.2a	23.4a	68.8a	17.9b	80.0a	46.0c	270.2a
Raxao	2.7bc	15.8ab	27.4a	9.8c	51.6a	1.8c	129.0b	238.3a
Reineta Encarnada	1.0c	12.9b	24.1a	14.8c	43.7a	6.4c	62.8c	165.7b
Teórica	3.4bc	15.8ab	6.0b	44.9b	7.5b	68.5a	13.9d	160.0b
Significance								
Cultivar	*	*	*	*	*	*	*	****
Rootstock	ns	ns	ns	ns	ns	ns	ns	ns
Cultivar* Rootstock	ns	ns	ns	ns	ns	ns	ns	ns

[z]For each column, means without a letter in common are significantly different (p=0.05) according to Student-Newman-Keuls multiple range test. ns, *, ****. non-significant and significant at P≤0.05, or 0.001, respectively.

of growth. The second most precocious cultivar was 'Raxao' followed by 'Teórica' and 'Reineta Encarnada'. There was no difference in precocity or yield due to rootstock (Table 3). 'Blanquina' did not show significant production until 1990 and 'Cristalina' 1991, five and six years after grafting, respectively.

Total and marketable production. As occurred for vigor, no significant differences were found between rootstocks in annual and accumulated production (Table 3), but important differences were found among cultivars. These results do not agree with other work showing differences in precocity and production between MM.106 and MM.111 (9).

All cultivars except 'Cristalina' showed some alternate bearing, with 'Marialena' and 'Teórica' being the most alternating cultivars (Table 3). 'Marialena' and 'Teórica' had on-years in the even years, while the opposite was true for 'Blanquina', 'Raxao' and 'Reineta.' Alternate bearing is a disadvantage for orchard production, and normally is reduced by thinning or pruning (10, 15).

Table 4. Yield efficiency (YE) of six apple cultivars on two rootstocks.

Cultivar	YE (kg/cm²)	YE (kg/cm²)	YE (kg/cm²)
		MM106	MM111
Blanquina	1.75a[Z]	1.76A	1.75A
Cristalina	1.15bc	1.18A	1.12A
Marialena	1.44abc	1.45A	1.43A
Raxao	1.29bc	1.35A	1.23A
Reineta Encarnada	1.04c	1.25A	0.84B
Teórica	1.55ab	1.74A	1.05B
Significance			
Cultivar	***		
Rootstock	*		
Cv * Rs	ns		

[Z]For each column in small letters and for lines in capital, means without a letter in common are significantly different (P=0.05) according to Student-Newman-Keuls multiple range test. ns, *, ***: non-significnat and significant at $P \leq 0.05$, or 0.001, respectively

In terms of cumulative production after 10 years, two different groups of cultivars were apparent, i) 'Blanquina', 'Marialena' and ii) 'Raxao', with more than 200 kg/tree, and 'Cristalina', 'Reineta Encarnada' and 'Teórica', with less than 170 kg/tree.

Productivity. Highest yield efficiency was obtained with cv. Blanquina with 1.75 kg/cm^2 (Table 4), followed by 'Teórica' and 'Marialena'; 'Blanquina' and 'Marialena' had high accumulated production due to large tree size, while 'Teórica' corresponded to its low accumulated production and vigor. 'Cristalina' and 'Raxao' presented a similar low level of yield efficiency, due to the high production and high vigor on both cultivars. 'Reineta Encarnada' showed the lowest yield efficiency due to a high vigor and low accumulated production.

As reported previously (9, 13), MM.106 showed less vigor though not significantly different and induced a significant higher productivity than MM.111 (Table 4) for 'Reineta Encarnada' and 'Teórica'.

Literature Cited

1. Alvarez, S., E. Dìaz, M.M. Palacios. 1982. La manzana y la sidra en Asturias. Bankunión, Spain. 125p.
2. Alvarez, S., 1983. El Manzano. M.A.P.A., Madrid, Spain. 431 p.
3. Coque-Fuertes, M., M.B. Dìaz-Hernández, J.C. Garcia-Rubio. 1996. El cultivo del manzano en Asturias. Servicio Central de Publicaciones del Principado de Asturias, Oviedo, Spain. 223 pp.
4. De Groof, J., 1987. Qualite des fruits pour la fabrication de jus, de vins et de cidre. Le Fruit Belge. 418: 101-104.
5. Felipe, A.J., 1990. Situación de los patrones frutales en España. XII JORNADAS DE AIDA, ITEA, Vol. 9:13-39.
6. Fleckinger, J., 1964. Phénologie et arboriculture fruitiére. In: Le bon jardinier. (Grisvard, P. and Chaudun, V.C., Eds.). La Maison Rustique, Tome I, 2éme partie, Paris, France, pp. 362-372.
8. González, E., 1991. Una historia reciente de la sidra. El libro de la sidra, Pentalfa, Asturias. pp 149-158.
9. Iglesias, I., 1994. Patrones de manzano. Fruticultura Profesional. 65: 5-26.
10. Jackson, D., 1999. Flowers and fruit. In: Temperate and subtropical fruit production (Jackson, D.I. and N.E. Looney, Eds.). CABI Publishing, UK, 33-44.
11. Janick, J., J.N. Cummins, S.K. Brown, M. Hemmat., 1996. Apples. In: Fruit Breeding, Vol. I: Tree and Tropical Fruits. (Janick, J. and J.N. Moore, Eds.). Wiley & Sons, Inc., New York, USA, pp. 1-77.
12. Lespinasse, J., 1988. La conduite du pommier. Les types de fructification. INRA-CTIFL, Paris. 76 p.
13. Masseron, A., 1989. Les porte-greffe pommier, poirier et nashi. CTIFL, Paris, France. 300p.
14. Pereira-Lorenzo, S. J. Ascasibar-Errasti, A.M. Ramos-Cabrer, J. Piñeiro-Andión. 2001. Colección de cultivares autóctonos gallegos de manzano (*Malus xdomestica*) del Banco de Germoplasma de Mabegondo. Monografía INIA-Serie Agricultura (In press).
15. Ryugo, K. 1988. Fruit culture: its science and art. John Wiley & Sons, Inc. New York, USA.
16. SAS Institute Inc.. 1988. SAS/STAT TM guide for personal computers. SAS, Inst. Inc. Cary, N.C. USA.
17. Suárez-Valles, B. and A. Picinelli-Lobo. 2001. Research and development in the cider area in Asturias. Background and perspectives. Recent Res. Devel. Agric. & Food Chem. 5: 1-17.