

Early greenhouse production of male genotypes of green asparagus (*Asparagus officinalis* var. *altilis*) in their seventh year since planting in Buenos Aires, Argentina

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Abstract

Asparagus is an interesting productive option with growing global demand and an opportunity for seasonal early production, as well as the elaboration of greenhouse produce. In order to evaluate the behavior in their seventh production year of the Italian cultivars 'Italo', 'Zeno', 'Eros', 'Ercole', 'H-668', 'Marte' and 'Giove' versus the North American 'UC-157' as control, a trial was initiated on 15/11/2006 by means of seedlings transplanted at 1×0.3 m. For the current study, 35 harvests were performed between 21/08/2013 and 16/10/2013. The following traits were evaluated: total and commercial fresh productivity (TFP and CFP), total and commercial spear number (TSN and CSN) and calibre distribution (CD) (Jumbo (J), Extra-Large (XL), Large (L), Medium (M), Small (S) and Asparagin (A)). Analysis of variance (ANOVA) was carried out, with means compared by LSD ($P \leq 0.05$). For TFP ($t\ ha^{-1}$), the ranking was 'Italo': 24.8^a; 'Zeno': 15.9 and 'Giove': 12.4^b; 'UC-157': 7.4, 'Ercole': 7.0 and 'Eros': 6.8^c; 'H-668': 5.1^{cd}; and 'Marte': 3.1^d; and for CFP ($t\ ha^{-1}$), the ranking was: 'Italo': 13.4^a; 'Zeno': 7.2 and 'Giove': 6.4^b; 'UC-157': 4.0, 'Ercole': 3.1 and 'Eros': 3.3^{cd}; and 'H-668': 1.9 and 'Marte': 1.7^d. For TSN (number ha^{-1}), the results were: 'Italo': 1155000^a; 'Zeno': 557515^b; 'Giove': 542500^{bc}; 'H-668': 457485 and 'Eros': 447510^{bcd}; 'Ercole': 402500^{cd}; and 'UC-157': 347515 and 'Marte': 194985^e; and for CSN (number ha^{-1}), the following was obtained: 'Italo': 822500^a; 'Giove': 367500 and 'Zeno': 325010^b; 'UC-157': 227500^c; 'Eros': 207515 and 'H-668': 172515^{cd}; and 'Marte': 120015^d. For CD, 'Italo'^a stood out for J, L, M and S; whereas in XL and A there was homogeneous calibre production. It can be concluded that 'Italo' was the best productive option available among the cultivars studied for the productive stage evaluated.

Keywords: asparagus, cultivars, spears, calibres, quality, productivity

INTRODUCTION

Asparagus is an interesting productive option due to growing global demand. In parallel, there is an unsatisfied demand in the domestic market of some countries, such as Argentina, which comprises an opportunity for seasonal production, as well as early greenhouse spears, where the covered protected crop allows positioning in the market one month before the conventional start of the season, representing commercial advantage associated with the extended period of supply.

Cultivated asparagus (*Asparagus officinalis* L.) is a perennial vegetable that has been cultivated as a food and medicinal plant for at least 2000 years (Moreno et al., 2012). It belongs to the family *Liliaceae* and the genus *Asparagus* comprising approximately 300 species; however, the one that most interest producers, because of its economic importance, is *officinalis* (Güvenç and Koyuncu, 2002).

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At the global level, the area devoted to asparagus cultivation is quite small, occupying an area of approximately 250,000 ha, with average marketable yields estimated at 3 to 4 t ha⁻¹ (Laemers, 2008; Caffarena et al., 2014). This results in a rather restricted supply of a product that is widely accepted by the consuming public, meaning that asparagus is considered a high-priced luxury product in international markets (Krarup and Krarup, 2002).

The trend of world trade has been growing for two decades, with the main producing countries being China, Peru, Germany, Mexico, the United States, Spain, Japan and Italy, in order of importance (FAO, 2011; Santos, 2011). Traditionally in Argentina between 2,000 and 4,000 ha have been cultivated (Castagnino, 2004; Castagnino et al., 2006a, b).

This crop currently represents a productive alternative with very good potential, since it is a crop that can reach high yields of up to 10 t ha⁻¹ for at least 8 years, from the third year after planting (Castagnino et al., 2012a, b). It has two main stages: productive and postharvest. With regard to the life-cycle of green asparagus plants, this can be divided into four phases: early growth, i.e., the first two years from planting characterized by strong vegetative development; of increasing productivity (3rd-4th year) corresponding to the first two years of harvest; of stable productivity (4th-10th year); and finally of decreasing productivity (10th year onwards). Of these, the phase corresponding to the planting of the crop is the most critical (Falavigna, 2004).

Any errors can affect the production and the quality of the harvested shoots throughout its productive life; it is thus essential to carry out adequate crop planning, including the choice of the hybrid to be cultivated, the starting system, plant spacing, etc. The postharvest stage is also very important, since it influences the possibility to provide the product to the consumer in optimal condition (Falavigna, 2004).

Among the innovative techniques applicable to this perennial crop are the so-called defenses such as the use of mulching (of greater application in white asparagus) and the management of crops in the greenhouse in order to advance the market entry date and hence contribute to the optimisation of positioning (Castagnino et al., 2009).

Asparagus is one of the few dioecious horticultural species. Female plants are less productive, but produce thicker shoots, while male plants are more productive and produce finer shoots (Cattivello, 2002; Caffarena et al., 2014). Currently there are super-hybrids on the market whose production is more uniform than traditional dioecious hybrids (such as 'UC-157' of North American origin), which, given the presence of genotype×environment interaction, do not always maintain production over time (Castagnino et al., 2006a, b; Caffarena et al., 2014).

Asparagus, unlike other horticultural species, has a small number of commercial cultivars that, based on a very restricted genetic and historical basis, have been improved and selected with different objectives (Knaflewski, 1996), with yield potential and characteristics quite different for different countries or productive regions (Benson, 2002).

According to several studies (Franken, 1970; Moon, 1976; Falloon and Nikoloff, 1986), male plants produce higher numbers of spears than female plants, whereas the latter give spears with larger diameters. The cultivation of all-male hybrids, with their potential in appropriate environments for calibre uniformity, high yield and superior plant health, has become widespread (Castagnino et al., 2011). The yield and quality of any crop is determined by genetic and environmental components (Holliday, 1960) and each component needs to be quantified for successful cultivation. Over more than two decades the cultivar 'UC-157' and its derivatives have been used as a benchmark for the evaluation of new cultivars (Krarup et al., 1997), i.e., the genetic component; this has helped to overcome the hitherto relative lack of objective evaluation in the crop and the difficulties presented by it being a perennial species. 'UC-157', which is a conventional hybrid with equal numbers of female and male plants, has been shown to be high yielding and widely adapted (Krarup and Krarup, 2002), and hence suitable as a control cultivar.

The normal period of production of green asparagus in Argentina is from mid-September to mid-November, according to the agro-climatic characteristics of the year of production (Pascualetti et al., 2013), with the possibility of anticipating it for one month through the use of greenhouses (Risso et al., 2012). Semi-furrowing in the greenhouse also

allows the following advantages to be achieved: to keep the crop protected from climatic inclemency during harvesting, to increase production per unit of surface and to save labor costs during harvesting, as well as to improve spear quality compared to that obtained from early harvesting in open air cultivation and to open up new markets for asparagus production that are later harvested in field cultivation (Serrano Cermeño, 2003). This system, in which harvesting begins in winter, results in increases in production compared to open air cultivation of between 20 and 40%, depending upon cultivar, crop type and soil fertility (Serrano Cermeño, 2003).

The most widely grown cultivar in Latin American countries is 'UC-157'; hence there is a need to evaluate new cultivars, not only in their early stages, but also in their adult stages, due to the marked genotype-environment interaction observed in this species.

The aim of the current study was to evaluate the productivity of different cultivars of all-male green asparagus genotypes in their seventh year, versus the American dioecious hybrid traditionally cultivated in Argentina and Latin American countries.

MATERIALS AND METHODS

The current work reports the evaluation under greenhouse conditions of the 7th production year of the following seven Italian all-male hybrid cultivars: 'Italo', 'Zeno', 'Eros', 'Ercole', 'H-668', 'Mars' and 'Giove'; the North American conventional hybrid cultivar 'UC-157' was included as standard. The climate in the region of the greenhouse trial is characterized as being temperate and humid (commonly called pampas), with a mean temperature of 16.6°C and mean relative humidity of 71.4%. Annual rainfall is 1000 mm, of greater incidence in summer and markedly influenced by the region's proximity to the Rio de la Plata (River Plate). Daily thermal range is generally moderate and thermal variation well-differentiated between seasons. The use of the greenhouse allowed for an inside daily mean temperature of 12°C compared to an outside mean of 5.5°C, accelerating production in the first month of harvest during winter.

The trial was initiated by planting 100-day-old nursery-grown seedlings, which had been grown in a mixture of 70% peat and 30% perlite capped with vermiculite, on November 15, 2006, at the greenhouse facility of the Faculty of Agrarian Sciences of the Pontifical Catholic University of Argentina (UCA) located in the city of Buenos Aires. Plants were spaced at 1×0.3 m (equivalent to a density of 33,333 plants ha⁻¹), planting depth was 25 cm, plot size 5 m² and 13 plants were evaluated per plot.

At the time of planting, base fertilization with ammonium phosphate at the rate of 200 kg ha⁻¹ was carried out. Chemical control of pre-emergence weeds was carried out with Linuron (C₉H₁₀Cl₂N₂O₂), complemented with rotavator application between rows and manual within-row weeding during the vegetative period. Later weed control consisted of a combination of mechanical, manual and chemical work using mixtures of Metribuzin (C₈H₁₄N₄O₅) and Pendimethalin (C₁₃H₁₉N₃O₄). The irrigation system used was initially by furrow and in the year of evaluation by drip-feed.

For the current study, 35 harvests were performed between 21/08/2013 and 16/10/2013. The harvested spears were classified according to the results indicated in the Green Asparagus Quality Protocol (SAGPyA. Secretaría de Agricultura, Ganadería, Pesca y Alimentos, 2007) and the following traits were evaluated: total and commercial fresh productivity (TFP and CFP); total and commercial number of spears ha⁻¹ (TSN and CSN); mean commercial weight per spear (MCWS); calibre distribution (CD): Jumbo (J), Extra-Large (XL), Large (L), Medium (M), Small (S) and Asparagin (A); and defective spears in the following categories: sprouted spears, short spears, diseased spears and spears with other defects.

Analysis of variance (ANOVA) was carried out (P≤0.05) and means were compared by LSD.

RESULTS AND DISCUSSION

Productivity traits

By far the best cultivar for both total and commercial fresh productivity was 'Italo' (TFP

and CFP, respectively; Table 1). Its productivity was considerably, significantly better than that of the following placed cultivars, 'Zeno' and 'Giove', which in turn were significantly better than the remaining cultivars, including the standard UC-157. 'Italo' gave a commercial productivity equivalent to 9011 top quality trays of 350 g each.

Table 1. Total and commercial productivity of green asparagus under greenhouse cultivation in their seventh production year. TFP: total fresh productivity; CFP: commercial fresh productivity; TSN: total spear number plant⁻¹; CSN: commercial spear number plant⁻¹; MCWS: mean commercial weight per spear. TFP and CFP are given in both t ha⁻¹ and, in brackets, g plant⁻¹. TSN and CSN are given in both numbers ha⁻¹ and, in brackets, numbers plant⁻¹. The cultivars are ordered according to their ranking for TFP, from highest to lowest.

Cultivar	TFP t ha ⁻¹ (g plant ⁻¹)	CFP t ha ⁻¹ (g plant ⁻¹)	TSN ha ⁻¹ (plant ⁻¹)	CSN ha ⁻¹ (plant ⁻¹)	MCWS (g spear ⁻¹)
Italo	24.8 ^a (826 ^a)	13.4 ^a (447 ^a)	1155000 ^a (39 ^a)	822500 ^a (27 ^a)	16
Zeno	15.9 ^b (529 ^b)	7.2 ^b (240 ^b)	557515 ^b (19 ^b)	325010 ^b (11 ^b)	22
Giove	12.4 ^b (413 ^b)	6.4 ^b (213 ^b)	542500 ^{bc} (18 ^{bc})	367500 ^b (12 ^b)	17
UC-157	7.4 ^c (246 ^c)	4.0 ^{cd} (134 ^c)	347515 ^e (12 ^d)	227500 ^c (8 ^c)	18
Ercole	7.0 ^c (233 ^c)	3.1 ^{cd} (105 ^{cd})	402500 ^{cd} (13 ^{cd})	240000 (8 ^c)	14
Eros	6.8 ^c (227 ^c)	3.3 ^{cd} (111 ^{cd})	447510 ^{bcd} (15 ^{bcd})	207515 ^{cd} (7 ^{cd})	16
H668	5.1 ^{cd} (170 ^{cd})	1.9 ^d (64 ^d)	457485 ^{bcd} (15 ^{bcd})	172515 ^{cd} (6 ^{cd})	11
Marte	3.1 ^d (102 ^d)	1.7 ^d (56 ^d)	194985 ^e (6 ^e)	120015 ^d (4 ^d)	14
Mean	10.3 (343)	5.1 (171)	513126 (17)	310319 (10)	16

Different letters (a-e) denote statistically significant differences among cultivars by LSD ($\alpha=0.05$).

In the case of 'Italo', its high relative productivity was due to its high relative spear number (27 commercial spears plant⁻¹, compared to the mean value of 10), rather than higher weight per spear, which was confirmed by the observation that for mean commercial weight per spear (MCWS), it was no better than the remaining cultivars (Table 1). In contrast, 'Zeno' achieved its relatively high productivity by a combination of high commercial spear number (CNS) and high mean commercial weight per spear. Different cultivars clearly achieve their productivity values via different routes, and it is striking how much variation there is between these cultivars for mean commercial spear weight (MCWS), where there is a two-fold difference between the highest value ('Zeno') and the lowest ('H668').

During the previous year, i.e., the sixth season, Kirschenbilder et al. (2014) (who expressed productivity in g plant⁻¹) found that total fresh productivity per plant (TFP) averaged 300 g with a range of 409 g plant⁻¹ ('Giove') to 221 g plant⁻¹ ('UC-157'), compared to 343 g in the current season and a range of 826 ('Italo') to 102 ('Marte') (Table 1). Hence in the current year, the overall mean had slightly increased, whereas the range had increased markedly and the highest and lowest yielders in the respective years were different cultivars.

The standard, widely-grown cultivar 'UC-157' provides another example of interesting evolution in performance over the seasons of evaluation. In the first evaluation year (2008), it was highest yielder (TFP) of all the cultivars, with 251 g plant⁻¹, whereas it was the lowest yielder in the sixth season (previous paragraph) and toward the lower end of performance in the current year (Table 1). 'UC-157' was also the only cultivar that actually reduced yield between the first year and the sixth (for 12%) (Kirschenbilder et al., 2014). This implies that it ought to be taken into account that this cultivar under greenhouse conditions may present a relatively short period in full production, where its productivity might decline after only a few years, both in absolute terms and relative to other cultivars.

The results also demonstrate the need to evaluate cultivars over a number of seasons: it would appear that the results from early years are not good predictors of relative cultivar performance during later years.

Calibre distribution

Regarding calibre distribution (CD) and considering the cultivars as a whole, the Medium (M) and Large (L) categories (29 and 27%) were the most common, followed by Small (S) 19%; Extra-large (XL): 13%, Asp (A): 8% and Jumbo (J): 4%. The cultivar 'Italo' departed from this scheme by giving a relatively high proportion of Jumbo spears in its production.

In an evaluation by Kirschenbilder et al. (2014) of the previous production year, the percentage corresponding to shoots of the major calibres (J, XL and L) was 58%, whereas the percentage in the current evaluation was 43%, which would indicate the incidence of intraspecific competition in the calibres obtained. However, during the current year, the cultivar 'Giove' gave a higher percentage than the remaining cultivars, as it had done the previous year.

Defective spears

Concerning defective spears, 61% corresponded to sprouted spears, 24% to short spears, 2% to diseased spears and 12% to spears with other defects. The predominance of the ear sprouting defect was probably due to the higher temperature inside the greenhouse, compared to that found for a crop grown outside, and to the harvesting frequency: although 35 harvests were carried out within just under two-months, this does not appear to have been sufficient to contain this defect to more acceptable values.

CONCLUSIONS

It may be concluded that the hybrid 'Italo' showed superior behavior for the production of first spears.

The mean productivity obtained was promising; however, adjustments, tending to minimize differences between total and commercial productivity, must be carried out.

The greater productivity obtained in the seventh year since plantation with the cultivar 'Italo' shows the convenience of growing them for first spears in a greenhouse in the Province of Buenos Aires.

For plantations whose objective is spears of greater calibre it would be advisable to grow the cultivar 'Zeno'.

It can be said that asparagus is an alternative for productive diversification for first spears that gives entrepreneurs the possibility of placing a high-quality product earlier in the market provided the choice of hybrid is appropriate.

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