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Organic production of leek *(Allium porrum* L.) seeds in the northeast of the Province of Buenos Aires. II. Phenology, yield and quality

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Abstract

The aim of this work was to determine whether the local agroecological conditions of the northeast of the Province of Buenos Aires (33º 41' S, 59º 41' W) permit the organic production of leek (cv. Monstruoso de Carentan) seeds. In the 2000/01, 2001/02 and 2002/03 growth seasons, percentage flowering and seed yield (g m^{-2}) and quality were recorded, the latter by determining the thousand grain weight and germination capacity. In the 2001/02 and 2002/3 seasons, the phenological stages of the crop were also determined, as well as the number of hours of cold temperatures experienced and the number of degree days. Significant differences between years were found in the number of days from 50% fruit setting to harvest, probably because three harvests were collected during the first season whereas only one was collected during the second and third. A total of 1,116 and 1,019 hours of cold temperatures and 925 and 1,127 degree days were recorded for 2001/2 and 2002/3 respectively. There were no significant differences between years for yield, percentage flowering or thousand seed weight (average values 78.53 g m^{-2}, 93.36% and 3.55 g respectively). Differences in germination capacity were recorded, but Argentine legislative requirements were always surpassed. Seed yield and quality were comparable to figures cited in the literature. In conclusion, the agroecological conditions of the northeast of the Province of Buenos Aires allow the normal, organic cultivation of this leek cultivar for seed.

Key words: agroecological conditions, hours of cold temperatures, degree days, Argentina.

Resumen

Producción orgánica de semillas de puerro *(Allium porrum* L.) en el nordeste de Buenos Aires. II. Fenología, rendimiento y calidad

El objetivo de este estudio fue determinar si las condiciones agroecológicas locales (33º41' L.S.; 59º 41' L.O.) permiten satisfacer los requerimientos fisiológicos de la producción de semillas de puerro, cultivado según las normas de la agricultura orgánica. Durante las campañas 2000/01, 2001/02 y 2002/03 se determinaron los porcentajes de floración; los rendimientos de semillas en g m^{-2} y la calidad, a través del peso de mil semillas y la germinación. En las campañas 2001/02 y 2002/03 se determinaron las etapas fenológicas, las horas de frío y los días grado. No se registraron diferencias estadísticas significativas ($\alpha = 0,05$) entre años en la mayoría de las etapas fenológicas evaluadas. Existieron diferencias entre el 50% de cuaje y la cosecha, probablemente porque durante el primer año se realizaron tres cosechas, mientras que durante el segundo año se efectuó una sola. Se registraron 1.016 y 1.019 horas de frío y 925 y 1.127 días grado, durante las campañas 2001/02 y 2002/03, respectivamente. Los rendimientos (78,53 g m^{-2}), porcentajes de floración (93,36%) y peso de semillas (3,55 g), no arrojaron diferencias estadísticas en tres años de medición. El poder germinativo tuvo diferencias entre años, aunque siempre superando los requerimientos de la legislación argentina. El rendimiento y la calidad de la semilla obtenidos son comparables a los citados en la bibliografía disponible. Las condiciones agroecológicas del noreste de Buenos Aires permiten el desarrollo normal del cultivo de puerro (cv. Monstruoso de Carentan) para la producción de semillas, cultivado según las normas de la agricultura orgánica.

Palabras clave: condiciones agroecológicas, horas de frío, días grado, Argentina.

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Introduction

The introduction of organic production systems to new regions demands the phenological response of candidate species and cultivars be evaluated under the reigning agroecological conditions. It has been shown that the production system employed influences the yield of vegetables (Brumfield *et al.*, 2000). Until this study, the phenological response —in terms of seed production— of the leek cultivar Monstruoso de Carentan to organic cultivation under the agroecological conditions of the northeast of the Province of Buenos Aires was not known. Although, the evaluation of some aspects of yield components and quality showed that this region could be adequate for organic seed production of leek (Paunero *et al.*, 2003).

The market for organic vegetables is growing both in Argentina (Bazzigalupi, 1997; Puppi and Ramírez, 2002) and internationally (Thompson, 2000; Kortbech-Olesen, 2002), and the demand for seed by producers is not being met. For organic production, crops must be introduced by using seed produced under organic conditions (Boletín Oficial, 1999). Leek seeds, however, are currently not produced organically in Argentina, and none are imported either since the use of non-organically produced seeds is still accepted (Paunero, 2003). However, this is likely to change shortly and there will be serious difficulties in supplying sufficient seed.

In Argentina, the total area given over to organic animal and vegetal production has grown significantly, reaching 3,192,158 ha in 2001 (a slight decrease was recorded in 2003). Of the 45,700 ha crop harvested, 11% are used to produce vegetables and pulses: Salta, Buenos Aires and Mendoza are the major producing provinces (SENASA, 2004). This important growth in organic production, and the shortcoming in seed supplies, raises the question of whether adequate seed can be produced in new agroecological environments.

In the seed-seed production of leek seed, a certain number of physiological requirements must be met, such as accumulating a determined number of hours of cold temperatures before the scapes begin to emerge (George, 1989; Brewster, 1994). The range of cold temperatures is between 0 and 18ºC, with an optimum of 5ºC (Wiebe, 1994). To be receptive to cold stimulus, the plantlets must have more than five visible leaves (Wiebe, 1994), although there are differences between varieties (Van der Meer and Hanelt, 1990). When the scapes emerge (the reproductive phase), the production of new leaves (the vegetative growth phase) ends (Brewster, 1994). To obtain high seed yields it is estimated that 950 degree days must occur in the range of 6-27ºC between 50% flowering and harvest (Gray and Steckel, 1991). If cultivation is rain-fed, the water needs of the plants must be met mainly by precipitation (George, 1989).

Given this relationship between environment and production, the agroecological conditions of every potential cultivation site must be evaluated in terms of their interaction with the physiological requirements of each species and cultivar.

The aim of this work was to determine whether the agroecological conditions of the northeast of the Province of Buenos Aires satisfy the requirements of organic leek seed production.

Material and Methods

The present growth trial was performed at the *Estación Experimental Agropecuaria (EEA) San Pedro* belonging to the *Instituto Nacional de Tecnología Agropecuaria (INTA),* in the northeast of the Province of Buenos Aires (33º 41' S, 59º 41' W).

Seed production was undertaken using the seed-seed method (George, 1989; Brewster, 1994). The plants were grown in experimental plots (3 m long), with five repetitions, containing three plant beds each. Two rows of leeks cv. Monstruoso de Carentan were planted per bed. The separation between the beds was 0.8 m. The sampling unit was the central bed in each plot. Plant density at transplant was 25 plants m^{-2}. Phenological observations were made of every plant in the sample bed every 3-10 days, according to the development of the crop. Seed yield (g m^{-2}) was determined by harvesting 1 m^2 of the centre of the sample bed, threshing the flower umbels and cleaning the seeds with riddles.

The results were examined by ANOVA and the Duncan test ($\alpha = 0.05$) and the interaction between years and each variable determined using SAS software (1988).

In the 2000/01, 2001/02 and 2002/03 growth seasons, percentage flowering and seed yield (g m^{-2}) and quality were recorded, the latter by determining the thousand grain weight and germination capacity according to ISTA rules (ISTA, 1999).

Seeds were sown in cloches in previously solarized soil in 2000/1 and 2002/3, but with no treatment in 2001/2. The cultivar used is widespread, adapted to the area, and raised for consumption. Transplanting (bare root) was performed at the 3-4 true leaf stage.

Phenological studies were performed in the 2001/02 and 2002/03 seasons according to the method of Paunero (1999) with some modifications. The following variables were recorded in these growing seasons: the date of sowing, transplanting and harvest, the date of the beginning of scape emergence (until 10% of scapes were > 1 cm long), the date of 50% scape emergence, the start of flowering (until 10% of flowers were open per umbela), the date of 50% flowering, the start of fruit setting (until 10% of fruit set per umbela), the date of 50% fruit setting, and finally the harvest date. In 2001/02, harvesting was performed on three occasions as the fruits matured; the aim was to corroborate that seed maturation takes place over a relatively long period, as reported by Gray and Steckel (1986a and 1991). In 2000/01 and 2002/03, however, all harvesting was performed at the same time when all the seeds were mature, as performed by commercial growers (George, 1989). The number of days of each phenological stage were then calculated. The percentage of plants at the different stages was determined using the following formula:

$$\text{Phenological stage (\%)} = N * TN^{-1} * 100$$

where N = No. of plants at the stage in question, and TN = total number of plants in the sampling plot.

The amount of rainfall since transplanting was also recorded. Vegetative growth was monitored by counting the number of leaves until the emergence of the scapes (the reproductive phase).

The number of hours of cold temperatures accumulated until the emergence of the scapes was determined using the program of Sands *et al*. (1979) and the temperature range proposed by Wiebe (1994). Also calculated were the number of degree days between 50% flowering and seed harvest, using the temperature range proposed by Gray and Steckel (1991), and employing the method of Huber (University of California, 2002). Maximum and minimum temperatures were used in both calculations.

Given the reigning high temperatures and humidity, two treatments with 5 g L^{-1} copper oxychlorate (84% wettable powder) and 10 g L^{-1} sulphur (wettable powder 80%) were applied each season to prevent fungal disease. Insecticide treatments were not provided. Weeding was performed manually. Approximately 50 mm of complementary water were provided each year by aspersion.

The soil at the experimental site, a Vertic Argiudoll (Ramallo series) (INTA, 1973), was typical of the region. In the first two years, a lot fertilised with earthworm compost and green manure was used, according to previous work (Paunero *et al.,* 2003). A rotation was made in the 2002/03 season, using a different lot to reduce the incidence of diseases and infestations (Greer and Kuepper, 1999). Soil from a depth of 0-20 cm in this second lot was analysed (Table 1). Thirty days after planting it was fertilized with 29.5 Mg ha^{-1} of organic compost, a dose commonly used for the cultivation of Alliaceas (Greer and Kuepper, 1999). The analysis of the soil and organic compost was performed using the methodology of Chapman and Pratt (1973) [pH: in water (1:2.5); organic matter (OM): Walkley-Black wet combustion; total nitrogen (N tot): Kjeldahl method; assimilatable P: Bray and Kurtz No.1 method; and the determination of interchangeable K, Ca and Mg]. For the organic compost the methods were: pH: in water (1:5); OM: by ignition at 550ºC; N tot: Kjeldahl method; total P, K, Ca and Mg: acid digestion (nitric/perchloric) (Table 1).

Results

In 2001/02 and 2002/03 the cloches were sown on the same day. In 2001/2002 transplanting was 21 days later than in 2002/2003 because the plants grew more slowly. After transplanting, the differences between these seasons in the date of the start of scape emergence, flowering, fruit setting and harvest were 8, 14, 17 and 8 days respectively (Table 2).

Both sowing and transplanting were performed in one operation; there is therefore no deviation from the mean (Table 3). No significant differences were seen

Table 1. Analysis of soil and organic compost used in the trial (2002/03)

Analysis	pH	OM	N tot	P	K	Ca	Mg
Soil	6.66	4.08%	0.21%	75 ppm	2.97 meq(100 g)$^{-1}$	13.12 meq(100 g)$^{-1}$	2.54 meq(100 g)$^{-1}$
Organic compost	7.48	23%	0.66%	0.45%	0.6%	1.35%	0.20%

OM: organic matter. N tot: total nitrogen.

Table 2. Dates of the beginning of phenological stages: 2001/02 and 2002/03

Dates	2001/02	2002/03
Sowing	12 March	12 March
Transplanting	18 July	27 June
Scape emergence	29 October	21 October
Start of flowering	9 December	22 November
Start of fruit setting	22 December	8 December
Harvest	14 February	6 February
Days since transplant	211.2	223.75

between years with respect to the duration of the phenological stages, except for the period between 50% fruit setting and harvest and the total duration of the growth seasons (the sum of the duration of the different phenological stages) (Table 3).

Table 4 shows the climatic variables recorded in 2001/02 and 2002/03. The rainfall in 2002/03 was more abundant, especially during October-December. Seed quality was, however, not affected (Table 5).

The number of hours of cold temperatures until the emergence of the scapes was similar in 2001/02 and 2002/03, the requirements of vernalization were therefore met. The number of degree days in 2002/2003 was 18% greater than in 2001/02, but neither flowering nor seed yield were affected (Tables 4 and 5). No differences were seen between years with respect to percentage flowering, seed yield nor seed weight. The germination capacity in 2001/02 was lower than in the other two years (Table 5).

Figure 1 shows the progress of vegetative growth (number of leaves). No differences were seen between years with respect to the number of leaves at any of the dates on which data were recorded. Neither was any difference seen between years in terms of the number of leaves at the beginning of scape emergence (7.7 ± 0.56; $Pr > F = 0.29$).

Discussion

The number of days between sowing and harvest was within the normal range for the seed-seed method (George, 1989; Brewster, 1994). The difference in the duration of the last phenological stage (50% fruit setting to harvest) was due to the fact that three harvests were performed in 2001/2 and the mean date used, whereas in 2000/01 and 2002/03 only one harvest was performed when all seeds were mature. The lack of any difference in seed yield between the years in which only one harvest was performed (2000/01 and 2002/03) and the mean for the year in which there were three harvests, indicates the stability of yields obtained in the area. Gray and Steckel (1986b, 1991) also report a lack of any important differences in the quality of seeds harvested at different dates within a range similar to those used in the present study.

In the 2001/02 and 2002/03 seasons, water had to be supplied during transplanting due to a temporary drought. However, the rain that did fall, plus the extra irrigation provided, covered the needs of the plants. In

Table 3. Duration of phenological stages: 2001/02 and 2002/03

Stage	Season	Mean	Standard deviation	Pr > F (between years)
Sowing - transplant (1)	2001/02	128	—	—
	2002/03	107	—	—
Transplanting - 50% scape emergence (2)	2001/02	128 a	2.74	0.089
	2002/03	123.80 a	2.17	
50% scape emergence - 50% flowering (2)	2001/02	30 a	1.87	0.11
	2002/03	33.50 a	1.73	
50% flowering - 50% fruit setting (2)	2001/02	20.20 a	5.12	0.23
	2002/03	17 a	1.41	
50% fruit setting - harvest (2)	2001/02	33 b	5.79	0.003
	2002/03	50.25 a	1.71	
Season (transplanting - harvest) (2)	2001/02	211.20 b	0.45	0.001
	2002/03	223.75 a	0.50	

(1): only one sowing and transplanting. (2): mean of each year indicated. Same letters for a variable within the same column indicate no significant differences according to the Duncan test ($\alpha = 0.05$). Pr: probability.

Table 4. Climatic factors: 2001/02 and 2002/03

Climatic factor	2001/02	2002/2003
Precipitation (mm)	790.7	956.2
Hours of cold temperatures until scape emergence	1,016	1,019
Degree days between 50% flowering and harvest	925	1,127

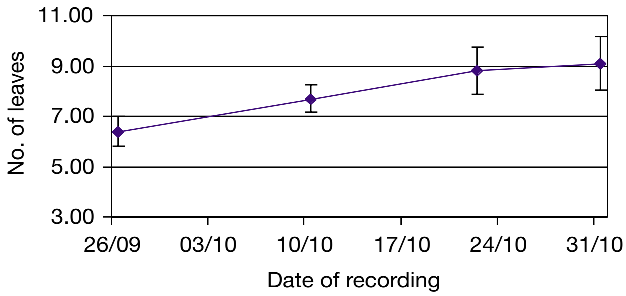

Figure 1. Change in number of leaves: means and variation range for 2001/02 and 2002/03.

rain-fed areas the needs of the crops have to be satisfied mainly by the rain (George, 1989). The rainfall registered during these two seasons was slightly greater than the historical mean for the area: 783 mm for the period 1985-2000, recorded by the *EEA San Pedro* meteorological station (INTA EEA San Pedro, 2003).

The number of hours of cold temperatures met the vernalization requirements of the plants for adequate flowering (> 90%). The degree days recorded between flowering and harvest were similar to figures estimated of Gray and Steckel (1991) for high yields. The maximum and minimum temperatures (data not shown) used in the calculation of the number of hours of cold temperatures and degree days, as well as the precipitation values, were comparable to the historical values of 1985-2000 recorded by the *EEA San Pedro* meteorological station (INTA EEA San Pedro, 2003).

The sowing date used allowed the plants to get through the juvenile 5-visible-leaves stage with time to become receptive to the cold stimulus proposed by Wiebe (1994). The 7.7 visible leaves recorded at the beginning of scape emergence is within the 7-13 range reported by Van der Meer and Hanelt (1990). After the beginning of scape emergence, the vegetative growth of the plants became markedly reduced in favour of reproductive growth (Fig. 1). This agrees with that reported by Brewster (1994).

The duration of flowering was slightly longer than that reported by Gray and Steckel (1986a); seed maturation was extended, in agreement with that reported by the same authors (Gray and Steckel, 1986a and 1991). This confirms that the seed maturation period of leeks is longer than that of other Alliaceas such as the onion (Brewster, 1994). Given the good flowering rate obtained, clean seed yield was above the 50 g m^{-2} mean reported by Jones and Man (1963) and the 50-60 g m^{-2} reported by George (1989) (both in field crops).

The thousand grain weight recorded, 3.55 g, was slightly lower than that reported by George (1989), and slightly higher than that reported by Gray and Steckel (1986b). Although there were differen-

Table 5. Percentage flowering, yields and seed quality: 2000/01, 2001/02 and 2002/03

	Season	Mean; standard deviation	Pr > F
Percentage flowering	2000/01	94 a; 8.94	0.40
	2001/02	88.06 a; 12.21	
	2002/03	99.17 a; 1.65	
Seed yield (g m^{-2})	2000/01	84.11 a; 9.27	0.63
	2001/02	72.68 a; 6.72	
	2002/03	78.79 a; 11.30	
Thousand grain weight (g)	2000/01	3.49 a; 0.12	0.44
	2001/02	3.62 a; 0.23	
	2002/03	3.53 a; 0.05	
Germination capacity (%)	2000/01	90.5 a; 0.71	0.008
	2001/02	83.8 b; 5.07	
	2002/03	89.25 a; 3.09	

Same letters for a variable within the same column indicate no significant differences according to the Duncan test ($\alpha = 0.05$). Pr: probability.

ces between years, the germination capacity (83.8 ± 5.07% in the worst season) amply surpassed the requirements of current Argentine legislation (which establishes a minimum of 70%) (Boletín Oficial, 1997).

The management of the soil maintained fertility, as required by Argentine organic production laws (Boletín Oficial, 1999). The levels of disease and infestations were not restrictive.

The number of days of cold temperatures required in order for adequate flowering were sufficient, as were the number of degree days required to satisfy the requirements of a high yielding crop (more than 72.68 ± 6.72 g m^{-2}). The precipitation was also sufficient for the normal development of the plants. Seed yields and quality were comparable to figures in the literature. In conclusion, the agroecological conditions of the northeast of the Province of Buenos Aires allow the normal development of leek «Monstruoso de Carentan» crops for the organic production of seed.

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