horticultura brasileira

Research

VIRMOND, EP; KAWAKAMI, J; SOUZA-DIAS, JAC. 2017. Seed-potato production through sprouts and field multiplication and cultivar performance in organic system. *Horticultura Brasileira* 35: 335-342. DOI - http://dx.doi.org/10.1590/S0102-053620170304

Seed-potato production through sprouts and field multiplication and cultivar performance in organic system

Eduardo P Virmond[1]; Jackson Kawakami[1]; José AC Souza-Dias[2]

[1]Universidade Estadual do Centro Oeste (UNICENTRO), Guarapuava-PR, Brasil; prigolvirmond@hotmail.com; jkawakami@unicentro.br; [2]Instituto Agronômico de Campinas (IAC), Campinas-SP, Brasil; jcaram@iac.sp.gov.br

ABSTRACT

Organic farming requires the production or use of certified seeds from the same cultivation system and, the information of potato cultivars adapted to organic production system is important. The objective of this work was to study the feasibility of utilizing sprouts of different potato cultivars, seed multiplication and yield potential in field conditions without using agrochemicals. Three experiments were conducted: the first experiment using sprouts as seed under protected cultivation in Guarapuava, Paraná State, Brazil, from November 2011 to February 2012; the second experiment was field conducted in Candói, Paraná State, from May to September 2012 and the third experiment was field conducted in Guarapuava, Paraná State, from February to May 2013. The experimental design was a randomized block design with 3 replications in all 3 experiments. In the 2 first experiments the following cultivars were evaluated: BRS Ana, BRS Clara, BRS Eliza, Crystal and Catucha, and in the last experiment Agata, Bintje, Baronesa and BRSIPR Bel were included. The traits analyzed were length of main stem, number of stems, number of leaves, fresh weight and number of tubers, percentage of infection by viruses and in the second experiment the incidence of late blight on leaves. In the third experiment, leaf area index (LAI), tuber, leaves and stem dry weights and late blight severity were also analyzed. In the first experiment, the cultivars showed differences in plant height and minituber production, the highest value was observed in cultivars BRS Clara and BRS Ana for plant height and cultivar BRS Clara for minituber production. In the second experiment, there was difference only in plant height, the tallest cultivars were BRS Ana and BRS Clara. There was low spread of viruses and, it did not directly reflect in tuber yield. In the third experiment the cultivars with lower disease severity were those recommended to organic farming, especially BRS Clara and Catucha; this second cultivar had the higher LAI and tuber yield, as well as resistance to late blight, factors that might have contributed to the recorded highest total tuber yield (13.8 t/ha).

Keywords: *Solanum tuberosum*, *Phytophthora infestans*, minituber, production, yield.

RESUMO

Produção de batata-semente por brotos, multiplicação e desempenho a campo de cultivares para sistema orgânico

O cultivo orgânico demanda a produção ou aquisição de sementes ou mudas certificadas a partir do mesmo sistema de cultivo, sendo imprescindível o estudo de cultivares de batata adaptadas ao sistema orgânico de produção. O objetivo deste trabalho foi estudar a viabilidade do aproveitamento de brotos de cultivares de batata, a multiplicação de sementes no campo e a produção comercial sem utilização de agroquímicos. Conduziu-se três experimentos, o primeiro sob cultivo protegido em Guarapuava-PR, de novembro de 2011 a fevereiro de 2012, o segundo em campo em Candói-PR, de maio a setembro de 2012, e o último em campo em Guarapuava-PR, de fevereiro a maio de 2013. O delineamento experimental foi de blocos casualizados com 3 repetições nos 3 experimentos. Avaliou-se nos 2 primeiros experimentos as cultivares: BRS Ana, BRS Clara, BRS Eliza, Cristal e Catucha e no último foram adicionados Agata, Bintje, Baronesa e BRSIPR Bel. As características analisadas foram: comprimento de haste principal, número de hastes, número de folhas, massa fresca e número de tubérculos, porcentagem de infecção por viroses, além de incidência de requeima nas folhas no segundo experimento, e no terceiro experimento ainda foi analisado, índice de área foliar (IAF), massa seca de tubérculos, folhas e hastes e severidade de requeima. No primeiro experimento as cultivares demonstraram diferença na altura de plantas e produção de minitubérculos, sendo a maior média observada nas cultivares BRS Ana e BRS Clara em altura de planta, e na cultivar BRS Clara na produção de minitubérculos. No segundo experimento houve diferença apenas na altura de plantas, com maior média final observada nas cultivares BRS Ana e BRS Clara. Observou-se baixa disseminação de viroses e isto não refletiu diretamente na produtividade. No terceiro experimento as cultivares com menor severidade de doença foram as indicadas para cultivo orgânico, em especial a BRS Clara e a Catucha; esta segunda se destacou em IAF e produtividade, e demonstrou alta resistência à requeima, principal motivo que levou esta cultivar a atingir 13,8 t/ha de produtividade total.

Palavras-chave: *Solanum tuberosum*, *Phytophthora infestans,* minitubérculos, produtividade, rendimento.

Received on November 12, 2016; accepted on March 12, 2017

Potato (*Solanum tuberosum*) ranks fourth among the major food sources in the world. China is the country with largest production, followed by India and Russian Federation. Brazil ranks 21st in production area, with 3.69 million tons in a total of 132 thousand hectares, with an average yield of 27.9 t/ha (FAO, 2016).

Over the past decade, the awareness of more sustainable agriculture increased the demand for organic and sustainable food production, mainly among vegetable crops, which are those usually associated with intensive application

of agrochemical and fertilizers. It is well known that a major constrain on organic potato production is disease with great destructive potential, such as late blight (*Phytophthora infestans*). Therefore, the correct use of late blight resistant cultivars is fundamental for satisfactory yields on organic cropping system (Möller & Reents, 2007).

In 2013 the Brazilian legislation for organic cropping systems imposed that seed or propagating material, should be originated from organic systems, for all organic crops (MAPA, 2008). Therefore, research for suitable and feasible organic seed-potato production systems has been demanded. Potato seed production under organic system is complex due to the high incidence of pathogens causing seed-potato degeneration, particularly viruses, like *Potato Virus Y* (PVY) and *Potato Leafroll Virus* (PLRV). Like most potato viruses, these two are seed-tuber borne, resulting in expressive yield reduction and table-quality depreciation (Rahman *et al.*, 2010).

Searching for alternative organic-certified seed-potato production systems, the sprout/seed-potato technology has been considered as a sustainable, low cost system for large scale production of seed-potato stocks (Silva *et al.*, 2006; Souza-Dias *et al.*, 2011). However, the sprout/seed-potato technology has not yet been tested in Brazil for organic seed-potato production, nor, either for field multiplication of seed-potato cultivars on organic production system.

The present work was carried out aiming to evaluate: 1) the multiplication potential and sanitary status of seed-potato stocks from different potato cultivars, produced from sprouts as original propagating material, without use of agrochemicals in protected and in field cultivation systems; and 2) its successive growth and yield of the different potato cultivars originated from the organically produced seed-potato stocks.

MATERIAL AND METHODS

The experimental work was split in three phases:

1. Summer sprout cultivation under insect-proof greenhouse

The experiments were carried out inside an insect-proof greenhouse at Feroz Farm, located in the region of Guarapuava (25°26 S, 51°34 W, altitude 1016 m), from November, 2011 through January, 2012.

Seed-potato tuber lots from five different potato cultivars classified as basic were supplied by Embrapa-Canoinhas Products and Marketing, whith indication as most fitted for organic cropping: BRS Ana, BRS Clara, BRS Eliza, Catucha and Cristal. All cultivar's seed-potato tuber lots were certified with zero percentage of *Potato Leafroll Virus* (PLRV) as well as *Potato Virus Y* (PVY). The experimental design was random blocks of 12 pots with 3 replications of each cultivar, totalizing 180 plastic pots containing 1.5 L of a commercial soil substrate, composed of processed pine and coconut fibers, plus expanded vermiculite and turf.

On November 13th 2011, apical single sprouts measuring 5-10 cm high were detached from the tubers, placed in zipped plastic bags, stored in a refrigerator overnight and planted, one per pot. Sprouts were vertically inserted at 2 primordial bud nodes deep in previously wetted substrate and at least one bud node was left outside.

At 25 and 45 days after planting (DAP), number of emerged stems, formed leaves and plant height were recorded in 6 plots per treatment. Despite of the maturity stage, using a razor blade the stems of each plant were cut at base in order to standardize the harvesting, which took place at 73 DAP, when records were taken on the diameter, fresh weight and amount of tuber (minituber) produced per sprout. Immunoassays (DAS-ELISA) test on the sprout of 15 minitubers, representing one plant each, were performed in order to evaluate the presence of PLRV and PVY in each cultivar.

2. Winter field planting

The second experiment, using as seed-potato the minitubers produced on the previous experiment, took place at Itaguaçu Farm, in the region of Candói (25°44 S, 52°13 W; altitude 559 m), during the months from May through September, 2012.

The soil chemical analysis revealed, at 0-20 cm depth, the following composition: organic matter: 42.3 g/kg; pH (H_2O)= 5.1; P (Mehlich)= 1.1 mg/dm^3; K= 0.2 cmol$_c$/dm^3; Ca= 4.1 cmol$_c$/dm^3; Mg= 1.7 cmol$_c$/dm^3; H= 5.0 cmol$_c$/dm^3, Al= 0.1 cmol$_c$/dm^3; CTC= 11.1 cmol$_c$/dm^3 and V= 54.1%.

Each field experimental plot was represented by 36 plants distributed in 4 rows, 2.25 m long, 0.75 m between rows and 0.25 m between plants. The plots were randomly distributed with 3 replicates of the 5 same cultivars planted in the first experiment. On the 5th May, 2012, minitubers were planted by hand without any chemical treatment, throughout the experiment.

Prior to potato, the experimental area was planted with corn, also cultivated without chemical fertilizer nor any chemical treatment. Field soil preparation took place 25 days before planting with a single subsoiler and rotary tillage procedures. For soil fertilization, we applied at once 1000 kg/ha high calcium (calcitic) lime (CaO: 50% and MgO: 2%, PRNT= 90%) and 1000 kg/ha of reactive natural phosphate (P_2O_5: 29%).

The emergence was evaluated at 15 and 25 DAP, when at least 70% of the plants started breaking up above the soil. At 45 and 65 DAP the number of emerged stems, expanded leaves and plant height were measured from the 6 plants at the central rows. The incidence of late blight natural infection was recorded on foliage at 65 DAP. Harvesting took place when plants reached natural senesce or physiological maturity stage, being recorded tuber diameter, fresh weight, quantity and total yield of 10 plants in the two central rows, excluding the 2 plants at the beginning and at the end of each row.

To determine the occurrence of virus spread and the incidence of the two major seed-potato viruses (PLRV and PVY), one tuber per plant/cultivar was taken and sprout/DAS-ELISA tested.

3. Summer field cultivation

The third experiment was performed

from February through May, 2013, at Instituto Agronômico do Paraná Experimental Farm, located in Guarapuava (25°23 S, 51°32 W, 1048 m altitude).

The experiments were arranged in a randomized block design, with 9 treatments and 3 replications. Each block consisted of 64 seed-potato tubers distributed in 8 rows spacing 0.8 m wide between furrows and 0.25 m between tubers. The treatments consisted of the following potato cultivars: Agata, Baronesa, Bintje, BRS Ana, BRS Clara, BRS Eliza, BRSIPR Bel, Catucha and Cristal, obtained from local seed-potato producers or Embrapa Canoinhas Products and Market.

Based on soil analysis measurements taken from 0-20 cm depth the experimental field plots contained the following amounts of major elements: organic matter = 46.1 g/kg; pH (H_2O)= 5.6; P (Mehlich)= 1.3 mg/dm^3; K= 0.2 cmol$_c$/dm^3; Ca= 4.3 cmol$_c$/dm^3; Mg= 1.9 cmol$_c$/dm^3; H= 4.9 cmol$_c$/dm^3; Al= 0.0 cmol$_c$/dm^3; CTC= 11.3 cmol$_c$/dm^3 and V= 56.6%.

Following a deep moldboard plow and conventional potato soil tillage, involving a disc plowing, raised seed beds were prepared. At planting time, furrows fertilization (mixed with the soil) was applied with 10 m³/ha of sheep manure; 10 m³/ha of poultry manure and 1000 kg/ha of natural reactive phosphate. On February 5th, 2013, hand-planting (0.10 m deep) was carried out while counting of above ground (emerged) plants took place at 26 DAP. Ridges were mechanically made at 38 DAP and at the 40th DAP a 1% (v/v) Bordo mix was sprayed at 200 L/ha of solution.

Natural occurrence, disease progress and symptoms severity of late blight were evaluated 4 times, from the 55th until the 76th DAP, on a 7 days interval. According to James (1971), records were made, for each cultivar, on the basis of total percentage of foliar area damaged, where a rate of 100% damage was recorded for completely plant death, due to the disease; while 0% was recorded for none visual symptoms on total foliar area of a plot. Following records taken to late blight severity, we calculated the area under disease progress curve (AUDPC) over the same period considered (55-76 DAP).

Plant height and leaf number of 6 plants per plot were evaluated at 45 and 72 DAP. At 72 DAP, on a destructive harvest of 4 plants per plot, the following evaluations were performed: leaf area index (LAI); total accumulated dry weight distributed among leaves, stems and tubers; as well as fresh weight and tuber numbers. To determine dry weight, the samples were placed into a forced air circulating chamber at 70°C until constant weight was reached. The LAI was estimated by means of quantification of specific foliar area, for each plant, with digital photos taken from leaf sub-samples and compared against standard area of 5x5 cm, using the ImageJ 1.41 software (Abramoff *et al.*, 2004).

On May 23rd, of 2013, at 107 DAP, final harvesting was performed for 10 plants per plot, considering only the 6 central rows, not considering the first plants of each row. The total yield was estimated from the number of tubers and their total fresh weight, while the commercial yield was estimated on the basis of yield of tubers sizing over 45 mm of diameter. In this experiment, viruses incidence was not evaluated.

All data were submitted to analysis of variance and the means were separated by Tukey test at 5%, using the software package Assistat version 7.6 beta (2012).

RESULTS AND DISCUSSION

1. Summer protective cultivation of sprouts

Under protective cultivation, the development of the primary leaflets was similar among all different potato cultivars, as recorded at 3 DAP. This performance could be explained for the fact that sprouts, as propagating material, are naturally capable of fast leaf differentiation (Daniels-Lake & Prange, 2007). In addition, this differentiation could have been facilitated by the fact that each sprout was planted with at least one axial node above soil. No difference among number of shoots (stem) was observed among cultivars, while an average 1.17 stems per sprout was recorded from 25 until 45 DAP. Kawakami *et al.* (2003) also observed only one stem grown from propagating material of small size, such as microtubers weighting 1.0 g. These results suggest that small size propagating material, such as sprouts or microtubers, will generally emerge a single-stem plant.

No significant differences were recorded on developed leaves among cultivars; an experimental average of 7.0 leaves were recorded at 25 DAP, while 8.7 leaves at 45 DAP (Table 1). A difference on plant height among cultivars was recorded: BRS Ana and BRS Clara showed the highest plants on both first and second evaluations; while cultivar Cristal revealed shortest plants at both evaluations. Virmond *et al*. (2011) observed average of 9.5 cm tall, at 20 DAP, for cultivar Agata plants originated from sprouts, using same type of soil substrate, with mineral fertilizer. These results corroborate with those from the present study.

The plants from the different cultivars originated from sprouts produced similar tuber size and quantity, however with differences on fresh weight, what result in differences per pot production. The average diameter of tubers was 3.7 cm, a result close but lightly superior from those from Factor *et al*. (2007): 3.0 cm, recorded for sprouts planted in a hydroponic system. On the present work, an average of 3.0 tubers were produced per plant, an amount inferior of that observed by Silva *et al*. (2006): 4.4 tubers per plant grown on different substrate soil mix under protected cultivation system. Virmond *et al*. (2011) reported, also under protected environment, an average of 4.0 tubers per plant from sprout on a single substrate soil, although fertilized with granulated NPK before planting. Queiroz *et al*. (2013) observed that the increase on tuber number/area, is a function directly associated with increase on fertilization, which would explain, in part, the smaller number of tubers observed in the present work as compared to those observed from Silva *et al*. (2006) and Virmond *et al*. (2011), as no mineral fertilizer was

Table 1. Potato production per pot and yield of tubers grown in greenhouse and in field under organic system: number of leaves, plant height at 25, 45 and 65 days after planting (DAP) and tuber diameter, fresh weight and number per pot and per plant. Guarapuava and Candói, UNICENTRO, 2011/12.

Cultivar	Number of leaves (plant)		Plant height (cm)		Tubers/final harvest			
	25 DAP	45 DAP	25 DAP	45 DAP	Diameter (cm)	Mass (g/tuber)	Number (pot)	Production (g/pot)
Greenhouse/summer								
BRS Ana	6.1^{ns}	7.8^{ns}	9.1a[1]	11.5a	4.04^{ns}	18.3a	2.4^{ns}	40.7ab
BRS Clara	7.9	9.4	9.2a	12.2a	3.56	14.6ab	4.0	53.0a
BRS Eliza	7.7	9.5	5.8ab	8.9ab	3.56	12.81b	3.3	40.4ab
Catucha	6.9	8.6	4.4b	8.6ab	3.86	12.9b	3.0	32.1ab
Cristal	6.5	8.2	3.4b	6.5b	3.35	9.6b	2.4	21.2b
Field/winter	**45 DAP**	**65 DAP**	**45 DAP**	**65 DAP**	**Diameter (cm)**	**Mass (g/tuber)**	**Number (plant)**	**Yield (t/ha)**
BRS Ana	6.8^{ns}	9.5^{ns}	10.0a	11.8a	3.74^{ns}	20.1^{ns}	2.3^{ns}	4.02^{ns}
BRS Clara	6.0	9.2	10.0a	11.2a	3.87	23.4	2.6	4.88
BRS Eliza	6.2	9.1	9.3a	9.8ab	4.29	27.6	2.2	3.94
Catucha	6.0	7.4	6.9ab	7.3b	4.46	27.2	2.2	4.46
Cristal	5.2	8.3	5.0b	6.4b	4.16	16.6	2.3	3.15

^{ns} = not significant; [1]Averages followed by same letter in columns, do not differ according to Tukey test, 5%.

Table 2. Field grown potato plants at summer, under organic production system: fresh weight, number of tubers, leaf area index (LAI) at 72 days after planting (DAP) and tuber yield for total and commercial number of tubers. Guarapuava, IAPAR, 2013.

Cultivar	72 DAP			Harvest			
	Tubers/plant		LAI	Tuber number (plant)		Tuber yield (t/ha)	
	(g)	(n°)		total	commercial	total	commercial
Agata	31.2c[1]	3.3^{ns}	--	8.5ab	0d	1.79c	0.00c
Baronesa	27.2c	2.4	0.20cd	7.3ab	0d	3.06c	0.00c
Bintje	42.1bc	3.5	0.14d	9.7ab	0d	2.26c	0.00c
BRS Ana	20.4c	2.2	0.48bcd	7.3ab	0.5cd	3.34c	0.48c
BRS Clara	110.3a	4.2	0.76bc	11.8ab	1.3b	9.27ab	3.19b
BRS Eliza	77.9abc	2.7	0.66bcd	8.9ab	1.5b	6.10bc	2.87b
BRSIPR Bel	36.1bc	5.0	0.33cd	13.1a	0.2cd	4.09c	0.33c
Catucha	92.7ab	3.9	1.47a	9.6ab	2.8a	13.8a	7.08a
Cristal	74.2abc	2.9	0.93ab	6.6b	0.7c	5.85bc	1.27c

^{ns} = not significant; [1]Averages followed by same letter in columns, do not differ according to Tukey test, 5%; -- = plants without leaf area due to late blight (*P. infestans*) infestation.

applied in the present studies. Plants of cultivar BRS Ana produced minitubers containing higher fresh weight (18.3 g) than plants of cultivars BRS Eliza, Catucha and Cristal (average of 11.8 g). The average fresh weight of these minitubers were higher than those reported for cultivar Agata, by Silva *et al.* (2006) and Virmond *et al.* (2011): 4.5 and 4.0 g, respectively. It is possible that the more minitubers produced by theses authors were inversely related to the less fresh weight as reported in their experiments.

Only one tuber of cultivar BRS Eliza was infected with PVY, representing 6.67% of the total analyzed tubers. This result sustains previous observations that using sprouts as propagating material under protected cultivation can result in high grade, low virus incidence (near virus-free) minitubers/seed-potato stocks.

2. Winter field cultivation

For all cultivars, over 70% of plants had emerged at 25 DAP and, in average 85% of plants at 45 DAP, from the total tubers planted. Kawakami *et al.* (2003) also recorded a high percentage (97%) of plant emergence from microtubers weighing 1.0 to 3.0 g, revealing that even small tubers can result in near

100% emergence.

Plant height from tubers of different cultivars varied, although maintaining similar foliage number (Table 1). Readings taken at 45 and 65 DAP showed cultivars BRS Ana and BRS Clara with plants higher than cultivar Cristal. The measurements recorded in the present studies were lower than those recorded by Queiroz *et al*. (2013), whose records for cultivar Agata at 41 days after emergence in field cultivation on summer season were 46.0 cm in average, without addition of fertilizer. This difference probably may be explained because the present study was carried out in winter season with average temperatures lower than those recorded by Queiroz *et al*. (2013) in summer season. In addition, the higher size of pot plants experiments, as recorded for cultivars BRS Ana and BRS Clara, would agree with the field experiments, corroborating with evidences that these two cultivars are characterized by high plants. The average number of foliage for each cultivar at 45 and 65 DAP was 6.0 and 8.7, respectively. These values are below the 18 leaves recorded in same season experiments by Bisognin *et al*. (2008), working with different potato clones, cultivated under conventional system, including mineral fertilization.

Evaluations at 65 DAP showed a significant difference on natural occurrence of late blight among all potato cultivars. An incidence of 36% for plants of cultivar BRS Ana, 22% for cultivar BRS Clara, 5% for cultivar BRS Eliza and 2% for cultivars Catucha and Cristal were observed, showing differences on initial infection resistance among the cultivars. Möller & Reents (2007), in Germany, also observed variable resistance level in 8 potato cultivars grown on eight years of evaluation under organic cultivation system.

The cultivar BRS Ana, due to a severe damage caused by late blight, was harvested at 90 DAP, while the other cultivars were harvested when the cycle (natural senescence) was completed: cultivar Cristal, at 110 DAP, the others at 140 DAP. No significant difference was recorded among treatments in none of the cultivars analyzed. The tuber

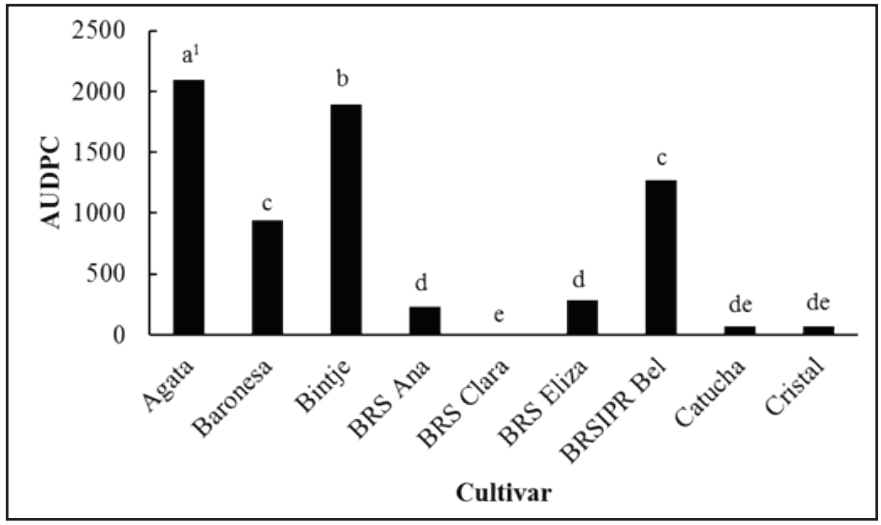

Figure 1. Area under disease progress curve (AUDPC) of potato cultivars affected by late blight (*Phytophthora infestans*) under organic cultivation at summer field; ([1]averages followed by the same letter do not differ according to Tukey test, 5%). Guarapuava, IAPAR, 2013.

diameter recorded in these experiments averaged 4.1 cm which would be fitting at class type II on the certified tuber/seed-potato classification. Regarding tuber diameter as a function of yield, Queiroz *et al*. (2013) observed that 4.1 cm seed-potato size did not differ in comparison with seed-potato of larger size. Since tuber/seed-potato lots are commercialized on the basis of fresh weight, this results could turn out to be a good point as economical option to growers.

The tubers produced in the present work showed an average size of 23.0 g. Based on Kawakami *et al*. (2003) and Kawakami & Iwana (2012), as long as cultivation is carried out in ideal conditions, this average tuber fresh weight can be considered as satisfactory as these authors demonstrated that tuber/seed-potato weighing less than 1.0 g, i.e., 20 fold lighter in weight than tubers produced in the present work, did not reveal major differences in yield, when compared with plants originated from conventional tuber seed weighting around 50 g.

The average number of tubers per plant was 2.3, which is considered low if compared with the average of 7.0 tubers, as observed by Kawakami & Iwana (2012), using microtubers/seed-potato of an average of shorter size than the tubers used in this system, however, using mineral fertilization and cultivars of longer cycle. The low number of tubers can be explained by the fact that a drought season, lasting 42 days was recorded, with a water deficiency that is known to cause potato plants to produce less tuber number as well as fresh weight (Hassanpanah, 2010).

Giusto (2006) observed an average potato tuber production of 13.9 t/ha under conventional field cultivation in Alfenas, Minas Gerais State (Southeast of Brazil), using minituber/seed-potato originated from sprouts, on a controlled environment cultivation during fall season in Campinas, São Paulo State. In the present studies, the average yield of 4.1 t/ha could be due to the fact that cultivation seasons and geographic locations were very different: winter in the south of Brazil, when generally the solar radiation and temperatures are lower, as well as precipitation. Also, in the present studies, a hail precipitation was observed on June 7th, 2012, at 33 DAP. Temperature recorded 0.8°C for minimum, a fact that could also had been contributed to reduced tuber number and yield. Indeed, Zarzynska & Pietraszko (2015) concluded that potato cultivated on organic systems is more severely impacted by climatic variations than potato cultivated under conventional systems.

Concerning viruses infection, the same percent occurrence of virus infection by PVY in tubers of cultivar

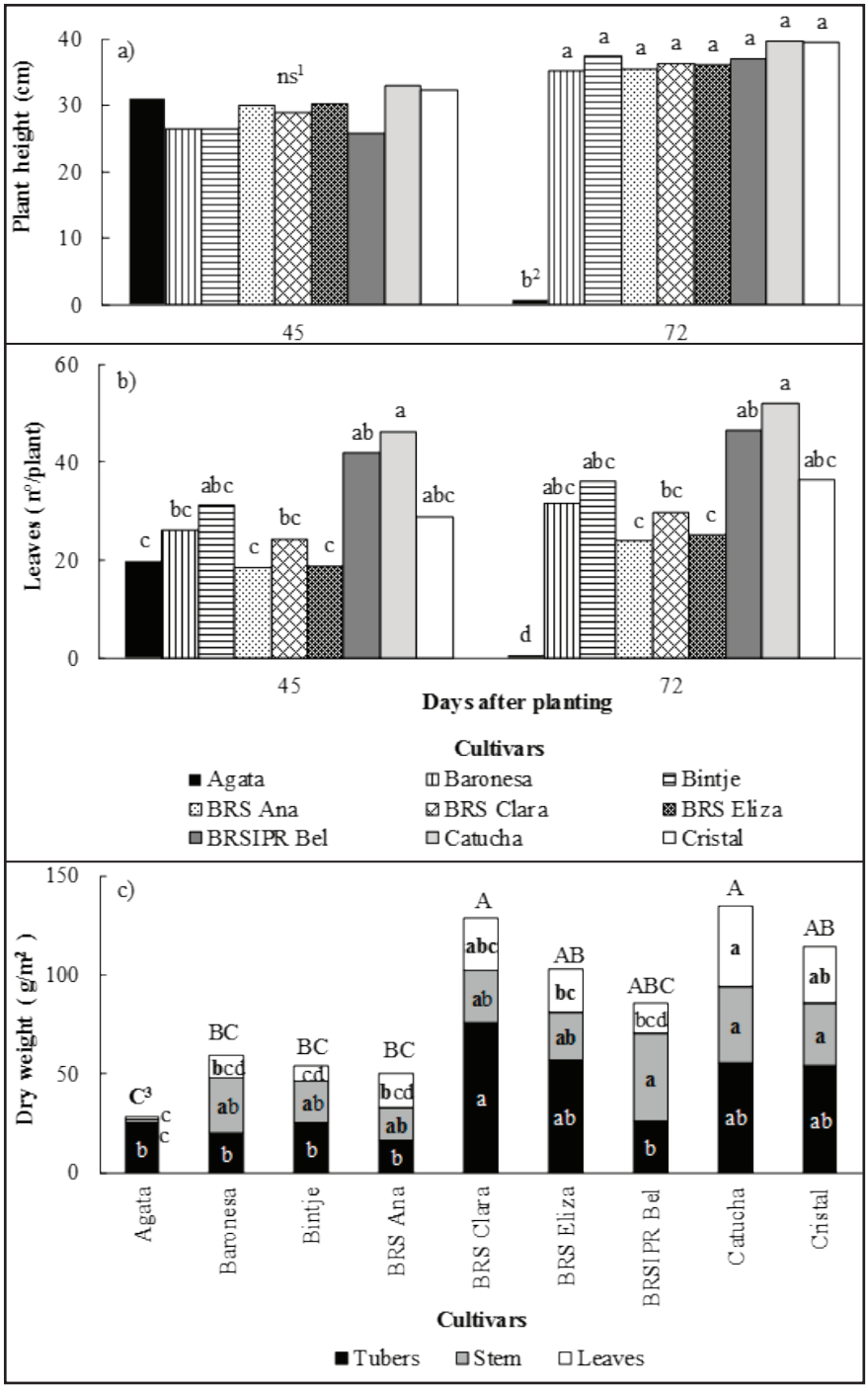

Figure 2. Potato cultivars grown under organic system at summer field crop: plant height and number of leaves per plant at 45 and 72 days after planting; tuber, stem, leaf and total dry weight at 72 days after planting. Guarapuava, IAPAR, 2013.
ns[1]: not significant difference (p>0.05); [2]averages followed by same lowercase letter do not differ according to Tukey test, 5%; [3]averages followed by same uppercase letter do not differ according to Tukey test, 5%.

BRS Eliza (6.7%) in the first experiment, was also recorded in one plant of cultivar Catucha, probably due to aphid transmission within the experiment.

3. Summer field cultivation

The plant emergence, at 26 DAP, was similar among the treatments, showing an average of 86%.

Considering late blight severity evaluations, cultivars BRS Clara, Catucha and Cristal showed the highest resistance at 76 DAP, when last records were taken. Such result was observed associated to a low AUDPC as shown by these cultivars (Figure 1). Cultivar BRS Clara was the most tolerant as none disease symptoms were recorded until the last evaluation. These results sustain Pereira *et al.* (2013) whose records for late blight concluded that BRS Clara possess foliar resistance against late blight. On the other hand, cultivar Agata showed a high susceptibility to late blight, as a high AUDPC record was recorded on this cultivar: at the 55 DAP, plants of cultivar Agata showed no effective photosynthetic leaf area due to severe disease incidence. For cultivar Bintje, the total loss of photosynthetic leaf area was recorded at 69 DAP, standing as a second most susceptible cultivar, with high AUDPC. This results corroborate Töfoli *et al.* (2013) on their observations that cultivars Agata and Bintje were susceptible to late blight. In addition, it is known that potato cultivars with short cycle are more susceptible to late blight than long cycle ones (Brune *et al.*, 1994), a result that was also observed in this study on cultivars Agata and Bintje, the two most short cycle cultivars. The high late blight severity as recorded in the susceptible cultivars could have been a response to the climatic records: 17°C, with distributed precipitations maintaining foliage wet for an ideal disease progress during the whole cycle (Töfoli *et al*., 2013).

On the first evaluation, taken at 45 DAP, there were no significant differences in plant height among the studied cultivars (Figure 2). On the second evaluation (72 DAP) a difference among cultivars was recorded due to a complete late blight destruction of photosynthetic leaf area on plants of cultivar Agata. The recorded values were lower than those from Queiroz *et al*. (2013) whose records showed an average of 46 cm on cultivar Agata, at 57 days after emergence, without applying mineral fertilizers.

Regarding the number of developed leaves, records taken at 45 and 72 DAP showed distinct groups, with one of them striking for its most foliage counting: cultivars Catucha and BRSIPR Bel; and the other group formed by cultivars Agata, BRS Ana and BRS Eliza, showing the least foliage counting. The remaining cultivars showed an

intermediated foliage number, standing between these two most distinctive groups.

In terms of stem and leaf dry weight, cultivar Agata was the one with the lowest record due to the early death caused by late blight. Records on tuber dry weight at 72 DAP revealed cultivar BRS Clara standing for the highest; a similar result as observed on tuber fresh weight evaluations. The total dry weights for cultivars Catucha and BRS Clara were superior than those recorded on cultivars Agata, Baronesa, Bintje and BRS Ana, while the remaining cultivars stood on intermediate levels.

Differences on tuber fresh weight were observed as a function of treatments on evaluations taken at 72 DAP: cultivars BRS Clara and Catucha stood highest with production of 90 g/plant (Table 2). On the other hand, cultivars Agata, Baronesa and BRS Ana produced less than 32 g/plant. For number of tubers at 72 DAP, there was no difference among the treatments, with an average of 3.3 tubers per plant.

Cultivars Catucha and Cristal formed a higher LAI than cultivars Agata, Baronesa, Bintje and BRSIPR Bel. A possible explanation for this result could be the intensive damage caused by late blight, which reduced foliar area of cultivars with low resistance to this disease, despite of the fact that cultivar Catucha since the first records registered the highest number of leaves, contributing to the highest LAI of cultivar Catucha. For cultivar Catucha, the observed LAI was similar to that recorded by Queiroz *et al*. (2013) on cultivar Agata without utilization of mineral fertilizer at 57 days after emergence, which revealed a good vegetative growth of cultivar Catucha.

Considering final number of tubers, cultivar BRSIPR Bel was the best, showing 13.1 tubers per plant. However, despite of this result its final yield was low, most likely due to late blight disease severity as recorded at 72 DAP, which affected tuber development. The cultivar Cristal showed the lowest number of tubers: 50% lower than BRSIPR Bel. The other cultivars showed similar results, with an average of 9.0 tubers per plant. Silva *et al*. (2013) observed similar tuber number for cultivars BRS Ana and BRS Clara: 8.37 and 10.7 per plant, respectively; but a higher total tuber number for cultivar Agata (13.9 tubers/plant) in a experiment under conventional cultivation system, using synthetic fertilizers and agrochemical pest management.

Cultivar Catucha showed the highest total yield (13.8 t/ha), this figure was seconded by BRS Clara, with 9.27 t/ha. Regarding commercial yield, cultivar Catucha streaked from the others with 7.08 t/ha; a result most likely due to vegetative growth: high foliage number, plant height, LAI and low late blight severity. Rossi *et al*. (2011) reported a total yield lower for cultivar Catucha (9.68 t/ha); however, higher for cultivar Agata (8.37 t/ha) under organic cultivation system, in Monte Alegre do Sul, São Paulo State, Brazil.

Palmer *et al*. (2013), in Europe, carried out a 6-year study on conventional and organic fertilization and phytosanitary managements. The authors concluded that the main constrain to organic production of potato is related to fertilization, pointing out a deficiency on high nitrogen supply sources. Ceretta & Fioreze (2006) observed in their studies the need of mineral nutrients to be added as a complement to organic fertilization. The authors showed that simple use of 10 t/ha of chicken bed resulted in 13% lower yield as compared to a system using 5 t/ha of chicken bed plus 1 t/ha of NPK 7-11-9 as mineral fertilizer.

The average yield recorded on winter cultivation was 4.1 t/ha, with no difference among the tested cultivars (Tabela 1). On the other hand, the average yield at summer cultivation was 5.5 t/ha; however, with an observed difference in yield among studied cultivars (Table 2). These results allow to conclude that: in winter cultivation, factors other than genetic potential affected yield, while in summer cultivations, a clear observation is possible on the potential that each cultivar has on tuber yield under organic management.

Considering the observed results of tuber multiplication rate and sanitary aspects of propagating material (seed), it is possible to conclude that under the conditions that present work was carried out, potato sprouts, detached from tuber/seed-potato are viable for minituber productions of the studied cultivars, under organic cultivation systems. The use of minitubers for seed-potato production revealed suitable and feasible, with production of tuber size adequate to commercial use. The results reported in this work revealed that organic potato production in Guarapuava region can achieve around 14 t/ha for cultivar Catucha, while the choice of a correct cultivar is fundamental for commercial success, mainly for summer cultivation.

ACKNOWLEGMENTS

The authors express their gratitude to Embrapa for the supply of seed-potato and to Fundação Araucária de Apoio ao Desenvolvimento Científico e Tecnológico do Estado do Paraná to financial support under agreement No. 185/2012. To Iapar for the area used in the 3rd experiment.

REFERENCES

ABRAMOFF, MD; MAGELHAES, PJ; RAM, SJ. 2004. Image processing with ImageJ. *Biophotonics International* 11: 36-42.

BISOGNIN, DA; MÜLLER, DR; STRECK, NA; ANDRIOLO, JL; SAUSEN, D. 2008. Desenvolvimento e rendimento de clones de batata na primavera e no outono. *Pesquisa Agropecuária Brasileira* 43: 699-705.

BRUNE, S; MELO, PE; LIMA, MF. 1994. Resistência a *Alternaria solani*, características agronômicas e qualidade de fritura em clones de batata imunes a PVX e PVY. *Horticultura Brasileira* 12: 125-130.

CERETTA, C; FIOREZE, CA. 2006. Fontes orgânicas de nutrientes em sistemas de produção de batata. *Ciência Rural* 36: 1788-1793.

DANIELS-LAKE, BJ; PRANGE, RK. 2007. The canon of potato science: 41. Sprouting. *Potato Research* 50: 379-382.

FACTOR, TL; KAWAKAMI, FP; IUNCK, V. 2007. Produção de minitubérculos básicos de batata em três sistemas hidropônicos. *Horticultura Brasileira* 25: 82-87.

FAO - Food and Agriculture Organization. 2016. *FAOSTAT: Production: Crops*. 2016. Available at http://faostat3.fao.org/download/Q/QC/E. Accessed Jun. 24th

GIUSTO, AB. 2006. *Tecnologia do broto como propágulo na produção de minitubérculos de batata-semente: Avaliação do ELIZA na detecção de quatro vírus regulamentados*. Campinas: IAC. 160p (Tese mestrado).

HASSANPANAH, D. 2010. Evaluation of potato cultivars for resistance against water deficit stress under in vivo conditions. *Potato Research* 53: 383-392.

JAMES, WC. 1971. An illustrated series of assessment keys for plant diseases, their preparation and usage. *Canadian Plant Disease Survey* 51: 39-65.

KAWAKAMI, J; IWANA, K. 2012. Effect of potato microtuber size on the growth and yield performance of field grown plants. *Plant Production Science* 15: 144-148.

KAWAKAMI, J; IWAMA, K; HASEGAWA, T; JITSUYAMA, Y. 2003. Growth and yield of potato grown from microtubers in fields. *American Journal of Potato Research* 80: 371-378.

MAPA. Ministério da Agricultura. *Instrução Normativa nº 64*, de 18 de dezembro de 2008. Available at http://extranet.agricultura.gov.br/sislegis-consulta. Accessed Jun. 24th 2016.

MÖLLER, K; REENTS, HJ. 2007. Impact of agronomic strategies (seed tuber pre-sprouting, cultivar choice) to control late blight (*Phytophthora infestans*) on tuber growth and yield in organic potato (*Solanum tuberosum* L.) crops. *Potato Research* 50: 15-29.

PALMER, MW; COOPER, J; TÉTARD-JONES, C; SREDNICKA-TOBER, D; BARANANSKI, M; EYRE, M; SHOTTON, PN; VOLAKAKIS, N; CAKMAK, I; OZTURK, L; LEIFERT, C. 2013. The influence of organic and conventional fertilization and crop protection practices, preceding crop, harvest year and weather conditions on yield and quality of potato *Solanum tuberosum* in a long-term management trial. *European Journal of Agronomy* 49: 83-92.

PEREIRA, AS; BERTONCINI, O; SILVA, GO; CASTRO, CM; GOMES, CB; HIRANO, E; BORTOLETTO, AC; MELO, PE; MEDEIROS, CAB; TREPTOW, RO; DUTRA, LF; LOPES, CA; NAZARENO, NRX; LIMA, MF; CASTRO, LAS; KROLOW, ACR; SUINAGA, FA; REISEER, JR, C. 2013. BRS Clara: cultivar de batata para mercado fresco, com resistência à requeima. *Horticultura Brasileira* 31: 664-668.

QUEIROZ, LRM; KAWAKAMI, J; MULLER, MML; OLIARI, ICR; UMBURANAS, RC; ESCHEMBACK, V. 2013. Adubação NPK e tamanho da batata-semente no crescimento, produtividade e rentabilidade de plantas de batata. *Horticultura Brasileira* 31: 119-127.

RAHMAN, MS; AKANDA, AM; MIAN, IH; BHUIAN, MKA; KARIM, MR. 2010. Growth and yield performance of different generations of seed potato as affected by PVY and PLRV. *Bangladesh Journal of Agricultural Research* 35: 37-50.

ROSSI, F; MELO, PCT; AZEVEDO FILHO, JA; AMBROSANO, EJ; GUIRADO, N; SCHAMMASS, EA; CAMARGO, LF. 2011. Cultivares de batata para sistemas orgânicos de produção. *Horticultura Brasileira* 29: 372-376.

SILVA, EC; GIUSTO, AB; SOUZA-DIAS, JAC. 2006. Produção de minitubérculos a partir de brotos de cultivares de batata em diferentes combinações de substratos. *Horticultura Brasileira* 24: 241-244.

SILVA, GO; STOKER, G; PONIJALEKI, R; PEREIRA, AS. 2013. Rendimento de tubérculos de três cultivares de batata sob condições de estiagem. *Horticultura Brasileira* 31: 216-219.

SOUZA-DIAS, JAC; LINDNER, K; RAMOS, VJ; COSTA, AA; QINQFEN, X; WEI, W; MARTINHO, C; CHOUGOUROU, D. 2011. *The Sprout/Seed-Potato (S/S-P) Technology: An update on attempts to transfer this affordable minituber production system to developing nations*. Abstracts of the 18th Triennial Conference of the European Association for Potato Research; EAPR.

TÖFOLI, JG; MELO, PCT; DOMINGUES, RJ; FERRARI, JT. 2013. Requeima e pinta preta na cultura da batata: importância, características e manejo sustentável. *Biológico* 75: 33-40.

VIRMOND, EP; KAWAKAMI, J; SOUZA-DIAS, JAC. 2011. *Produção de minitubérculos de batata semente através do aproveitamento de brotos*. In: Congresso Brasileiro de Olericultura, 51, 2011, Viçosa-MG. Hortaliças: da origem aos desafios da saúde e sustentabilidade. Viçosa: ABH. 29: 2819-2825.

ZARZYNSKA, K; PIETRASZKO, M. 2015. Influence of climatic conditions on development and yield of potato plants growing under organic and conventional systems in Poland. *American Journal of Potato Research* 92: 511-517.