horticultura brasileira

Research

ESCHEMBACK, V; KAWAKAMI, J; MELO, PE de. 2017. Performance of modern and old, European and Brazilian potato cultivars in different environments. *Horticultura Brasileira* 35: 377-384. DOI - http://dx.doi.org/10.1590/S0102-053620170310

Performance of modern and old, European and national potato cultivars in different environments

Vlandiney Eschemback[1]; Jackson Kawakami[1]; Paulo Eduardo de Melo[2]

[1]Universidade Estadual do Centro-Oeste (UNICENTRO), Guarapuava-PR, Brasil; vlandiney@hotmail.com; jkawakami@unicentro.br; [2]Embrapa Secretaria de Relações Internacionais, Brasília-DF, Brasil; paulo.melo@embrapa.br

ABSTRACT

Little information on the comparative yield of the main potato cultivars (*Solanum tuberosum* subsp. *tuberosum*) used in Brazil is available. The objective of this study was to evaluate the performance of modern and old, European and Brazilian potato cultivars in different environments. Two experiments were carried in the field in 2013, in Brazil: in Guarapuava, in the state of Paraná, from January to April; and in Brasília, the Federal District, from August to November. Treatments consisted of six cultivars (origin, year of release): Bintje (European, 1910), Monalisa (European, 1982) and Agata (European, 1990); Baronesa (Brazilian, 1955), Catucha (Brazilian, 1995) and BRS Clara (Brazilian, 2010), arranged in complete blocks at random, with four replications, in both areas. Growth cycle, total and commercial yield (number of tubers and mass), tuber average weight and tuber dry matter content were evaluated. We observed significant differences in yield among cultivars, both in Guarapuava and in Brasilia. We also observed that increases in yield in Brazil are possible, the modern cultivars having higher yield potential than old cultivars. No significant differences in yield were detected between European and Brazilian cultivars, in none of the growing zones. We suggest that the use of imported cultivars by Brazilian potato growers is related to factors not associated to yield.

Keywords: *Solanum tuberosum*, breeding, variety, yield potential.

RESUMO

Desempenho de cultivares de batata modernas e antigas, brasileiras e europeias em ambientes distintos

Há poucas informações sobre a produtividade comparativa das principais cultivares de batata (*Solanum tuberosum* subsp. *tuberosum*) utilizadas no Brasil. O objetivo deste trabalho foi avaliar o desempenho de cultivares de batata modernas e antigas, nacionais e europeias, em ambientes distintos. Foram conduzidos dois experimentos no campo em 2013: em Guarapuava-PR, de janeiro a abril, e em Brasília-DF, de agosto a novembro. Foram avaliadas seis cultivares (procedência, ano de lançamento): Bintje (europeia, 1910), Monalisa (europeia, 1982) e Agata (europeia, 1990) ; Baronesa (brasileira, 1955), Catucha (brasileira, 1995) e BRS Clara (brasileira, 2010), dispostas em blocos casualizados, com quatro repetições, em ambos locais. Foram avaliados o período de crescimento e a produtividade total e comercial de tubérculos, quantificando-se número e massa. Observou-se diferença na produtividade entre as cultivares, tanto em Guarapuava, quanto em Brasília. Os resultados deste estudo indicam que há espaço para aumento de produtividade, sendo que cultivares modernas apresentam maior potencial produtivo em comparação às cultivares antigas. Não houve diferenças significativas na produtividade entre cultivares brasileiras e europeias, mesmo em locais distintos. Especula-se que a predominância da utilização de cultivares importadas por produtores brasileiros está associada a fatores não ligados à produtividade.

Palavras-chave: *Solanum tuberosum*, melhoramento genético, potencial produtivo, cultivares.

Received on February 11, 2016; accepted on November 11, 2016

Potato (*Solanum tuberosum*) plays an important role as a food source for human populations in different regions. The crop has gone through major changes worldwide. Until the beginning of 1990, most of consumption and production took place mainly in Europe and North America. From 2004 onwards, the area dedicated to growing potatoes has been larger in developing countries (Walker *et al*., 2011). Even though, production remains higher in developed countries. According to the Food and Agriculture Organization (FAO), potato annual production in developing countries exceeds 150 million tons out of a total world production of 376 million tons (FAO, 2015). In Brazil, potato has expressive socioeconomic significance, with the national production reaching 3.5 million tons in 2013 (IBGE, 2015).

As years went by, there was a natural cycle of cultivar substitution, with modern cultivars replacing ancient ones. Although cultivar substitution is not a quick movement in potato worldwide, with some very old cultivars still having solid representativeness in many countries, it indeed takes place due mainly to traits such as resistance to pests and diseases and yield potential, which are enhanced in new cultivars. Gebhardt (2013) refers to the development of improved potato cultivars as one of the major research goals to increase agricultural productivity and to ensure food safety. Nevertheless, Carew *et al*. (2009) report that in Canada potato yield has been increasing more due to the combination of good fertilization and regional effects than to the use of improved cultivars.

Evans (1998), comparing the yield potential of American potato cultivars

released from 1930 to 1990 observed that modern cultivars did not outyield old cultivars mainly because, in the USA, potato breeding programs focused other traits, like tuber commercial quality. In studies carried out by Love *et al.* (1998), 44 North American potato cultivars for industry, released from 1876 to 1998, were compared to evaluate the progress in breeding. This study states that potato breeders have been obtaining significant progress with new cultivars, but mainly in quality of tubers for industrial purpose. Gadum *et al.* (2003) reported that breeding programs have been focused not only on yield potential, but also on tuber quality and disease resistance. On the other hand, studies carried out by Bradshaw (2009) reported that increases in yield in new potato cultivars are quite possible, since potato yield potential is high.

In Brazil, the dependence on imported cultivars to meet the market demands for tubers, either for fresh consumption or processing, is still high. In the city of Guarapuava, where potato production is very traditional, 2025 ha are grown yearly with the crop (IBGE, 2015). Japanese immigrants started the potato production business in the 1950s, using predominantly the Dutch cultivar Bintje, which remained as the main potato cultivar in the region for many years. It was only in the beginning of the 1990s that cultivar Bintje was replaced by another Dutch cultivar, Monalisa, which, in its turn, lasted as the main cultivar until late 1990s. From then on, cultivar Monalisa was replaced by cultivar Agata, also Dutch. Cultivar Agata is still the main cultivar used in Guarapuava, as well as in the remaining of the main potato production zones in Brazil.

The great majority of foreign cultivars used in Brazil come from breeding programs set in countries with temperate climate, places with different weather, soil, pests, and diseases. As a rule, these cultivars are not expected to suit Brazilian growing conditions. For Fontes *et al*. (1995), the use of well-adapted potato cultivars, with desirable agronomic traits, such as upright growth habit, high stem number and density, high total and commercial potential yield and not susceptible to tuber physiological disorders, is fundamental to the success of a crop season.

In Southern Minas Gerais, a study was carried out in order to evaluate the market demands in relation to tuber appearance, quality, and yield of national and foreign potato cultivars (Carmo *et al*., 2009). In this study, authors observed that cultivars showed different agronomic performances depending on the growing environment. National cultivars showed higher yield and better adaptation to the local growing conditions than imported cultivars. According to Peixoto *et al.* (2002), the use of cultivars which are better adapted to the local environmental conditions can result in increases of regional production. Same authors state that the behavior of a cultivar in a specific environment is a result of genotypic and environmental effect and of the interaction of both, and add that trials to evaluate such interaction should be done prior to the use of national and foreign cultivars in a specific region, since the most traits are affected by environmental conditions.

In Brazil, studies on yield potential of the main potato cultivars used in the past and in the present, as well as studies comparing the yield potential of cultivars developed by national and foreign breeding programs, are scarce. Thus, this study aims to compare yield and yield components of the main modern and old, national and European potato cultivars used in Brazil, in two different environments.

MATERIAL AND METHODS

Two field experiments were carried out. The first experiment was carried out in the experimental area of Midwest Paraná State University (Unoeste), in the city of Guarapuava, from January to April 2013. The soil of the area was classified as Clayey Oxisol (FAO, 1994) and the local climate, according to Köppen weather classification, is temperate – Cfb (IAPAR, 2000). The soil chemical analysis, prior to the experiment, showed the following data for the 0-20 cm depth layer: pH ($CaCl_2$)= 5.3; P (Mehlich)= 1.9 mg/dm^3; K= 0.18 cmol$_c$/dm^3; Al= 0.0 cmol$_c$/dm^3; Ca= 5.2 cmol$_c$/dm^3; Mg= 2.9 cmol$_c$/dm^3; CEC= 12.74 cmol$_c$/dm^3; V= 64.99%.

The second experiment was carried out in the experimental area of Embrapa Hortaliças, in Brasilia, from August to November 2013. In this area, the soil is classified as Rhodic Ferralsol (FAO, 1994), with high contents of iron and aluminum (Embrapa, 2011). The local climate is type Aw, according to Köppen classification, tropical dry season. The soil chemical analysis for the 0-20 cm depth layer showed the following data: pH (H_2O)= 5.2; P(Mehlich)= 4.0 mg/dm^3; K= 0.24 cmol$_c$/dm^3; Al= 0.9 cmol$_c$/dm^3; Ca= 1.8 cmol$_c$/dm^3; Mg= 0.6 cmol$_c$/dm^3; CEC= 11.54 cmol$_c$/dm^3; V= 22.87%.

Planting was carried out when we reached adequate weather conditions (temperature, rain, luminosity, and photoperiod) for the crop in each region. In both areas, we began to prepare the soil one month before planting, subsoiling once and harrowing twice. During planting, a light harrowing followed by a grooving operation was carried out. Treatments consisted of six cultivars (origin and year of commercial release), namely Agata (European, 1990), Monalisa (European, 1982), Bintje (European, 1910), BRS Clara (Brazilian, 2010), Catucha (Brazilian, 1995) and Baronesa (Brazilian, 1955), and we used seed tubers of the same size (class type III, 30-40 mm). Seed tubers were kept in a chamber at 4°C to standardize sprouting about 15 days before planting. Seed tubers were planted manually, using 0.80 m spacing between lines in both areas and 0.25 m spacing between plants in Guarapuava and 0.30 m in Brasilia. In the Brasilia experiment, we used seed tubers grown in Guarapuava.

We limited our range to six cultivars due to the historical concentration of the Brazilian market in few materials. The foreign cultivars used here are the leading ones in Guarapuava region for the last 65 years and represent about 80% of what has been planted by farmers during this period: cultivar Bintje from 1950 onwards, cultivar Monalisa, mainly in the 1990s, and

cultivar Agata, from the beginning of the last decade to today. The Brazilian cultivars were selected following the same criteria of market relevance and time of release.

Each experimental plot consisted of 6 lines of 18 plants, arranged in complete blocks at random, with four replications, in both areas. Fertilizers were supplied in pre-planting, homogeneously distributed within the furrow. In Guarapuava, as liming was not necessary, fertilization consisted of 4 t/ha NPK, 04-14-08, supplying 160 kg/ha of N, 560 kg/ha of P_2O_5 and 320 kg/ha of K_2O, a practice used by producers in the region and, as checked by Queiroz *et al.* (2013), very close to the dose for maximum technical efficiency for cultivar Agata in the region. In Brasilia, according to the soil analysis and for yield expectations above 30 t/ha, liming was carried out using 2.5 t/ha of dolomitic limestone and fertilizers were applied to supply 40 kg/ha of N (urea), 600 kg/ha of P_2O_5 (super triple phosphate), 90 kg/ha of K_2O (potassium chloride), 2 kg/ha of B (borax) and 4 kg/ha of Zn (zinc sulfate). Cultural practices (control of weeds, pests, and diseases) followed the standards adopted in each region. The experiment carried out in Brasilia received irrigation according to the traditional management used at Embrapa Hortaliças for potatoes: bi-weekly shifts, with 26-mm water depth. Ridges were hilled up in both areas 15 days after emergence.

To assess plant emergence, we counted the number of plants/plot in 2-3-day intervals until reaching 75% emergence. Senescence was registered when leaves in at least 75% of the plants in the plot became yellowish. To assess yield, we took 12 plants per plot from the four central lines, after physiological maturation. Tubers were harvested and split into two categories: non-commercial (tuber transversal diameter below 45 mm) and commercial (tuber transversal diameter above 45 mm), counting and weighting tubers in each category. Commercial tubers were divided into three classes: up to 100 g, 100 to 200 g and heavier than 200 g. The number of tubers, as well as fresh (FM) and dry mass (DM) were recorded. Later, DM percentage was calculated.

Data were submitted to analysis of variance and to the Tukey test at 5% probability, for differentiation of means. Comparison between European and Brazilian cultivars was evaluated by t-test ($P<0.05$). For growth period, tuber DM percentage, number of total and commercial tubers, total and commercial yield, we used the relative average percentage in the regression analysis, based on the year of release of each cultivar as the independent variable, using SPSS statistical package (v. 20.0).

RESULTS AND DISCUSSION

In Guarapuava, cultivar Agata was the earliest, with a 99- and 77-day cycles counting from planting and from emergence, respectively (Table 1). In Brasilia, cultivars Agata (91-; 76-day cycles) and BRS Clara (94-; 79-day cycles) were the earliest. Cultivar Catucha, both in Guarapuava and Brasilia, showed the longest cycle from planting and from emergence to senescence, being about three weeks longer than the earliest cultivars. The other cultivars showed intermediate cycle. In general, cultivars showed a cycle longer cycles in Guarapuava than in Brasilia, probably due to the lowest temperatures in Guarapuava. From January to April 2013, monthly average temperatures ranged from 17.3 to 20.8°C in Guarapuava, while in Brasilia, average temperatures ranged from 24.6 to 29.2°C between August and November, in the same year. In studies carried out by Silva *et al.* (2013), observing the cycle of potatoes, authors report cultivar BRS Clara as having a slightly longer cycle than cultivar Agata. Filgueira (2008), on his turn, reports cultivar Monalisa as presenting in average 110-day cycle from planting to senescence. Our results corroborate both reports. Menezes *et al.* (1999) state high temperatures decrease plant life cycle, which agrees with our observations when we confront plant cycles observed in Brasilia and Guarapuava for the different cultivars (Table 1).

Cultivars BRS Clara and Bintje in Guarapuava showed the highest number of tubers, scoring around 78 tubers/m^2. In Brasilia, cultivar Agata produced the highest number of tubers, 48 tubers/m^2, along with cultivars Bintje, Catucha and Baronesa, which did not differ significantly from cultivar Agata. When it comes to number of commercial tubers, cultivar BRS Clara was the top scoring in Guarapuava, 42 commercial tubers/m^2, statistically similar to what was observed for cultivars Agata and Bintje. In Brasília, cultivar Agata produced more commercial tubers, 38 tubers/m^2, without differing significantly from cultivar BRS Clara.

Considering total yield in Guarapuava, cultivar BRS Clara, with a productivity corresponding to 57 t/ha (5.7 kg/m^2, table 1), and cultivars Monalisa, Agata and Baronesa were statistically the most productive, with cultivar BRS Clara significantly differing from cultivars Bintje and Catucha (Table 1). In Brasilia, there were no significant differences among cultivars and total yield ranged from the equivalent of 39 t/ha (3.9 kg/m^2, cultivar Agata) to 23 t/ha (2.3 kg/m^2, cultivar Monalisa). Turning to commercial yield (tubers above 45 mm in diameter), in Guarapuava, cultivars Monalisa and BRS Clara showed the highest figures, corresponding to about 48 t/ha, differing significantly only from cultivar Bintje, whose yield in tubers/m^2 corresponded to 26 t/ha (Table 1). In Brasilia, cultivars Agata and Baronesa had significantly the highest commercial yield, corresponding to about 32 t/ha, whereas cultivar Bintje had the lowest yield (corresponding to 18 t/ha), significantly below all other cultivars.

In studies carried out by Pereira *et al.* (2013), in the Southern Brazilian Region (Canoinhas, state of Santa Catarina, and Pelotas, state of Rio Grande do Sul), cultivar BRS Clara, in five experiments in a period of three years, showed averages to total and commercial yield of 18.9 and 11.0 t/ha, respectively. Cultivar Agata, in the same set of experiments, averaged 13.3 and 7.4 t/ha as total and commercial yield respectively. Data similar to ours for total and commercial yield and number of tubers were obtained by Queiroz

et al. (2013) with cultivar Agata in Guarapuava, where authors observed 45 and 39 t/ha as total and commercial yield respectively, with 36 commercial tubers/m^2. In our experiments, cultivar Monalisa yielded the equivalent to 21 t/ha of commercial tubers in Brasília, far below the observed in Guarapuava (equivalent to 49 t/ha). According to Filgueira (2008), cultivar Monalisa is sensitive to high temperatures, which may be the reason for the low yield observed in Brasilia, where average temperatures were high during the growth cycle.

The t-test did not detect significant differences between European and Brazilian cultivars, nor in Guarapuava (p= 0.651), neither in Brasília (p= 0.858). In Guarapuava, European cultivars (Agata, Monalisa, and Bintje) showed average total yield corresponding to 43.3 t/ha, while the average total yield of Brazilian cultivars (BRS Clara, Catucha, and Baronesa) pointed to 45.6 t/ha. In Brasilia, European and Brazilian cultivars showed average total

Table 1. Growth cycle from planting and emergence to senescence of plants, number and fresh mass (FM) of total and commercial tubers, percentage of dry mass (DM) and average weight of commercial tubers (TW) of modern and old cultivars of potato. Guarapuava/Brasilia, Unicentro/Embrapa Hortaliças, 2013.

Cultivar/local	Days to senescence		Tubers	
	Planting (days)	Emergence (days)	Nº (m^2)	Yield (kg/m^2)
Guarapuava				
Ágata	99c	77c	51b	4.4ab
Monalisa	119a	92b	38bc	5.1ab
Bintje	112b	89b	78a	3.5b
BRS Clara	112b	86b	79a	5.7a
Catucha	119a	100a	32c	3.9b
Baronesa	112b	91b	39bc	4.1ab
CV (%)	7	5	10	16
Brasília				
Ágata	91c	76c	48a	3.9a
Monalisa	112a	85b	26b	2.3a
Bintje	105b	83b	27ab	2.5a
BRS Clara	94c	79c	39b	2.6a
Catucha	112a	90[a]	31ab	2.7a
Baronesa	107b	83b	27ab	3.2a
CV (%)	9	7	27	23
Cultivar/local	**Commercial tubers**			
	Nº (m^2)	Yield (kg/m^2)	Tuber dry matter (%)	Tuber mean weight (g)
Guarapuava				
Ágata	34ab	4.0ab	15.2c	118b
Monalisa	30b	4.9a	19.7b	163a
Bintje	34ab	2.6b	19.6b	76c
BRS Clara	4a	4.6a	19.5b	110b
Catucha	24b	3.6ab	22.3a	150ab
Baronesa	24b	3.6ab	18.8b	150ab
CV (%)	15	20	5	12
Brasília				
Ágata	38a	3.5a	15.9c	92b
Monalisa	23b	2.1b	16.2c	91b
Bintje	15b	1.8c	19.1b	120a
BRS Clara	33ab	2.3b	20.2a	70c
Catucha	22b	2.4b	19.0b	109ab
Baronesa	25b	2.8a	19.3b	112ab
CV (%)	18	23	4	10

Means followed by same letters in the columns, for each area, do not significantly differ from each other, Tukey test ($p<0.05$).

yields estimated in 29.0 and 31.7 t/ha, respectively. Yields in Guarapuava were higher than in Brasilia, probably due to environmental effects, mainly climatic conditions, as observed in the studies carried out by Carew *et al*. (2009). The yield similarity we observed between Brazilian and European cultivars in the same growth area differs from the data obtained by Carmo *et al.* (2009) who, studying 22 national and imported potato cultivars in the Southern region of Minas Gerais, reported higher yields with Brazilian cultivars.

These results suggest that the wide use of imported potato cultivars by Brazilian producers should not be attributed to differences in yield potential between the Brazilian and foreign cultivars. We postulate that the Brazilian potato cultivars are not more widely spread due to other issues, such as low seed availability, producers' lack of knowledge about cultivars and their crop management or even due to lower acceptance of national tubers in the market. Although the Brazilian cultivars did not outyield the European material in our work, we believe that a more general use of cultivars bred and selected under Brazilian weather and soil conditions, more resistant to pests and diseases, may result in the reduction in the use of agrochemicals and fertilizes in potato production in Brazil.

Concerning tuber MS content, in Guarapuava cultivar Catucha, whose cycle was the longest, scored the highest percentage (22.3%), while cultivar Agata, the earliest cultivar, had the lowest value (15.2%). In Brasilia, cultivars Agata and Monalisa showed the lowest tuber MS percentage (about 16%), while cultivar BRS Clara had the highest (20.2%) with the other cultivars showing intermediate values, around 19%. Kooman *et al.* (1996) and Love *et al.* (1998) reported that cultivars with long cycles tend to have higher tuber MS percentage, corroborating what we observed in Guarapuava, where weather conditions during the potato growing season are similar to those in the Netherlands and Idaho, during their

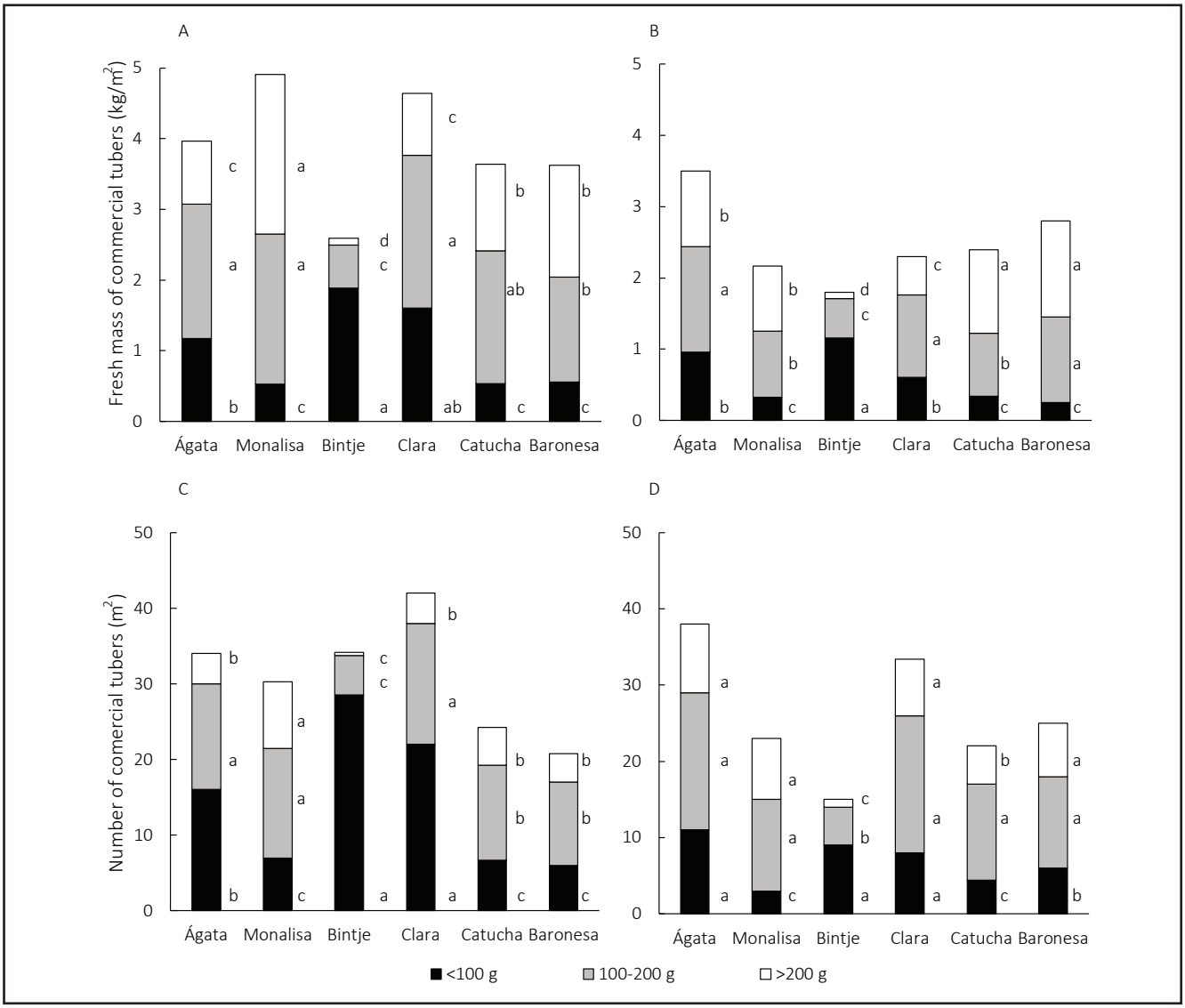

Figure 1. Fresh mass (kg/m^2, A and B) and number (m^2, C and D) of commercial tubers per class of size of modern and old potato cultivars. Guarapuava (figures A and C), and Brasilia (figures B and D). Guarapuava/Brasilia, Unicentro/Embrapa Hortaliças, 2013. Means followed by same letters, for each class of tuber size, do not differ significantly from each other, Tukey test ($p<0.05$).

growing seasons, average temperatures from 15 to 21°C, respectively), which is definitely not the case in Brasilia. Thus, it is very likely that, under milder growing conditions, tuber MS content is directly related to the cultivar vegetative cycle.

Cultivar Monalisa produced tubers with the largest average weight in Guarapuava, not differing significantly from cultivars Catucha and Baronesa, and significantly overcoming cultivar Bintje, which had the lowest average. On the other hand, in Brasilia, cultivar Bintje had the tubers with the largest average weight, significantly heavier than tubers from cultivars Agata, Monalisa, and BRS Clara, the last recording the lowest average. When tuber commercial (or marketable) production is studied in function of tuber classes (Figure 2, A and B), in Guarapuava cultivar Monalisa had the highest yield of medium and big tubers (>100 g), whereas cultivar

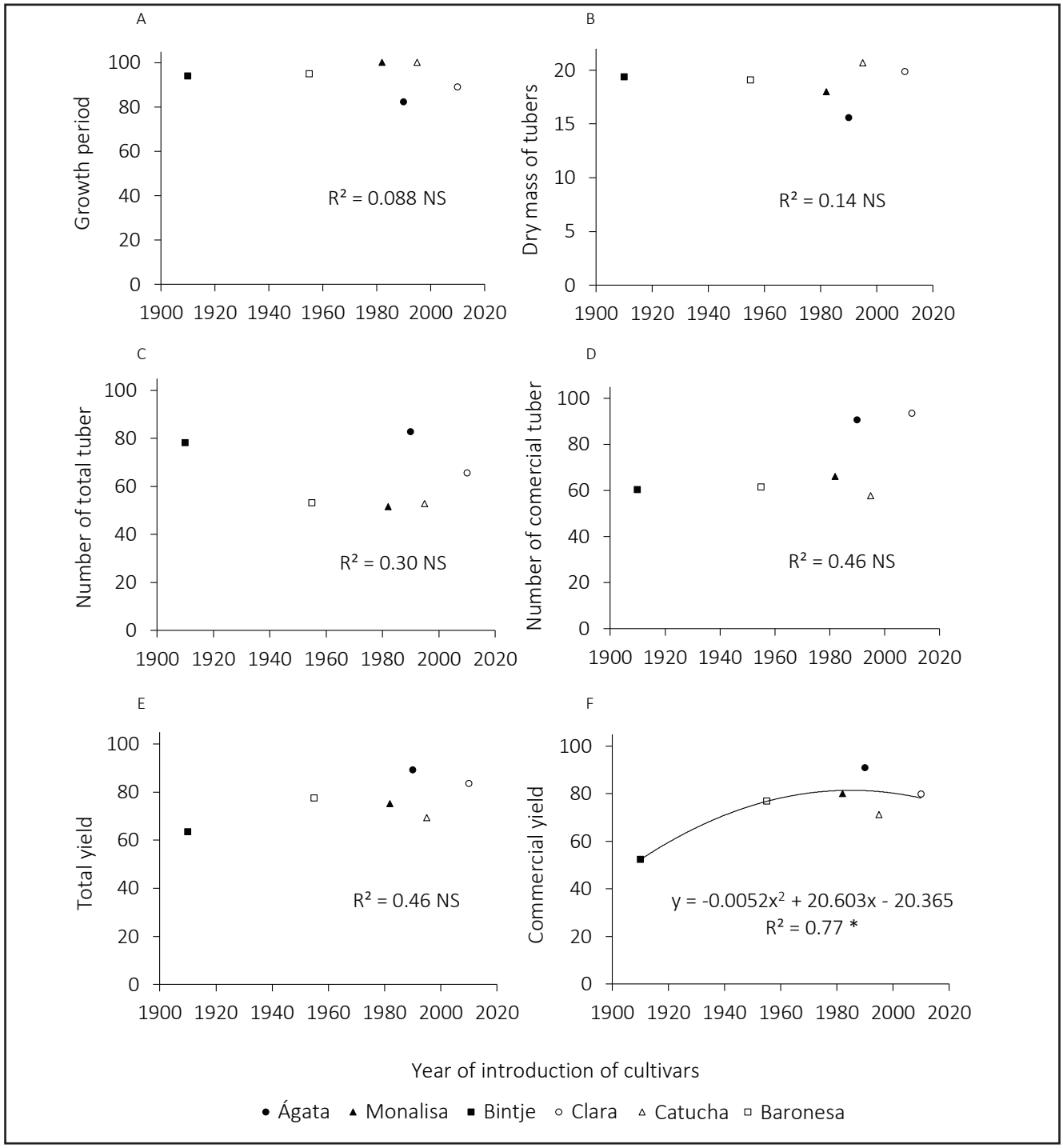

Figure 2. Relative average (%) for growth period (A), percentage of tuber dry mass (B), number of total tubers (C), number of commercial tubers (D), total (E) and commercial yield (F) of modern and old potato cultivars, for plants grown in Guarapuava and Brasilia. Guarapuava/Brasilia, Unicentro/Embrapa Hortaliças, 2013. *significant at 5% and NS: not significant. N=12.

Bintje had the lowest. However, and as expected, cultivar Bintje outyielded the others in small tubers (<100 g) (Figure 1A). In Brasilia, cultivars Catucha and Baronesa had the highest yield of large tubers (>200 g), cultivars Agata, BRS Clara and again Baronesa outyielded the others concerning medium tubers (>100g) and cultivar Bintje, as it happened in Guarapuava, had the highest yield of small tubers (<100 g) (Figure 1B).

The number of commercial tubers, in Guarapuava, had a trend similar to tuber production: cultivars Monalisa and Bintje produced the highest number of large and small tubers, respectively (Figure 1C). In Brasilia, cultivar Bintje produced few large and medium tubers and cultivars Monalisa and Catucha, on their turn, produced few small tubers (Figure 1D).

When cultivars were clustered by year of release, in general, no relation was noticed between cultivar "age" and growth cycle (Figure 2A), tuber MS content (Figure 2B), total number of tubers (Figure 2C), number of commercial tubers (Figure 2D), and total yield (Figure 2E).

The lack of relationship between growth cycle and year of cultivar release might have imposed by the crop management system used in Brazil. The difficulties of growing potatoes in tropical conditions led farmers to prefer, since old days, cultivars with rather short cycles, especially if it is compared to the potato cycle in cooler countries in Europe or North America. Thus, a decrease in the potato growth period in Brazil would have been a surprise.

Considering the results obtained by Love *et al.* (1998), which showed that in the USA from 1876 to 1998 an increase of tuber dry mass content was observed, the absence of a relation between the year of cultivar release and tuber DM content in our study was unexpected. The discrepancy might have to do with the fact that Love *et al.* (1998) studied industrial cultivars, while ours are mainly for table consumption. In addition, although consumers became more demanding towards quality along the years, tuber DM content is not yet a trait consumers pay that much of attention to in Brazil. In addition, the consumption of processed potato in Brazil is still low in comparison to other countries and imports, mainly pre-fried French fries, play an important role in the supplying chain. Nevertheless, some studies have been reporting increases in the *per capita* consumption of industrialized processed potato, as average income in the country also increases. In fact, this trend opened room for the release of national cultivars bred for industrial purposes, like cultivars BRS Ana and BRSIPR Bel (Pereira *et al*., 2010, 2015).

Despite the lack of significant relationship between year of cultivar release and total yield (Figure 2E), it was noticed that the modern cultivars used in Brazil evaluated in this study increased their commercial yield potential until the 80s (Figure 2F). From this year on, yield stabilized, corroborating the data observed by Bradshaw (2009), who relates that increases in the yield of new potato cultivars in Europe are not expected, since the crop harvest index is already high. Our data are also in agreement with Gadum *et al.* (2003), which reported that breeding programs have been focused not only on yield potential of new cultivars, but also on tuber quality and resistance to the main diseases. It is not known if the higher commercial yield of modern cultivars we observed is due to greater photoassimilate production or to greater photoassimilate partitioning directed to tuber formation.

When compared to the yield potential of the oldest cultivar used in this study (cultivar Bintje), we observed about 30% of commercial yield increase in the modern cultivars. Taking this into consideration, we may say that cultivar Catucha has low yield potential in relation to its year of release. On the other hand, cultivar Agata shows high yield potential, explaining why Brazilian producers increasingly adopt it. There were no significant differences in yield between European and Brazilian cultivars when comparison was carried out grouping cultivars by origin. On the other hand, when the two growth areas were compared, Guarapuava showed the highest yield. Considering it all, we may say that potato yield in Brazil has increased in the latest years by the combination of the use of good crop management practices and cultivars with high yield potential.

REFERENCES

BRADSHAW, JE. 2009. Potato breeding at the Scottish Plant Breeding Station and the Scottish Crop Research Institute: 1920-2008. *Potato Research* 52: 141-172.

CAREW, R; KHAKBAZAN, M; MOHR, R. 2009. Cultivar development, fertilizer inputs, environmental conditions and yield determination for potatoes in Manitoba. *American Journal of Potato Research* 86: 442-455.

CARMO, EL; PÁDUA, JG; DIAS, JPT; DUARTE, HSS; DUARTE FILHO, J; LEONEL, M; ZAMBOLIM, L. 2009. Desempenho de cultivares nacionais e estrangeiras de batata em duas condições ambientais do Sul do Estado de Minas Gerais. *Revista Trópica* 3: 18-24.

EMBRAPA. 2011. *O novo mapa de solos do Brasil, legenda atualizada*. Rio de Janeiro: Embrapa Solos. 67p.

EVANS, LT. 1998. Steps towards feeding the ten billion: A crop physiologists view. *Proceeding of International Symposium: "Word Food Security"*, Kyoto. 1: 1-7.

FAO. 1994. *World reference base for soil resources: draft.* Paris: UNESCO. 161p.

FAO: FAOSTAT. 2015. *Crop productions*: Potatoes. 2015, 27 de maio. Disponível em: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor

FILGUEIRA, FAR. 2008. *Novo manual de olericultura*: agrotecnologia moderna na produção e comercialização de hortaliças. Viçosa: UFV. 412p.

FONTES, PCR; MASCARENHAS, MHT; FINGER, FL. 1995. Densidade de plantio em batata em função do preço dos tubérculos e da cultivar. *Horticultura Brasileira* 13: 184-187.

GADUM, J; PINTO, CABP; RIOS, MCD. 2003. Desempenho agronômico e reação de clones de batata (*Solanum tuberosum* L.) ao PVY. *Ciência e Agrotecnologia* 27: 1484-1492.

GEBHARDT, C. 2013. Bridging the gap between genome analysis and precision breeding in potato. *Trends in Genetics* 29: 248-256.

IAPAR. 2000. Instituto Agronômico do Paraná. *Cartas Climáticas do Paraná*. Londrina: SOB (CD-ROM).

IBGE - Sistema IBGE de recuperação automática SIDRA. 2015, 16 de março. Disponível em: http://www.sidra.ibge.gov.br/bda/tabela/listabl.asp?z=t&c=1612

KOOMAN, PL; FAHEN, M; TEGERA, P; HAVECOTT, AJ. 1996. Effects of climate on different potato genotypes. 2. Dry matter allocation and duration of the growth cycle. *European Journal of Agronomy* 5: 207-217.

LOVE, SL; PAVEK, JJ; THOMPSON-JOHNS, A; BOHJ, W. 1998. Breeding progress for

potato ship quality in North America cultivars. *American Journal of Potato Research* 75: 27-36.

MENEZES, CB; PINTO, CABP; NURMBERG, PL; LAMBERT, ES. 1999. Avaliação de genótipos de batata (Solanum tuberosum L.) nas safras "das águas" e de inverno no sul de Minas Gerais. *Ciência e Agrotecnologia* 23: 776-783.

PEIXOTO, N; FILGUEIRA, FAR; MELO, PE; BUSO, JA; MONTEIRO, JD; BRAZ, LT; PURQUERIO, LFV; HAMASAKI, RI. 2002. Seleção de clones de batata para microclimas de altitude no Planalto Central. *Horticultura Brasileira* 20: 438-441.

PEREIRA, AS; BERTONCINI, O; CASTRO, CM; MELO, PE; MEDEIROS, CAB; HIRANO, E; GOMES, CB; TREPTOW, RO; LOPES, CA; NAZARENO, NXR; MACHADO, CMM; BUSO, JA; OLIVEIRA, RP; UENO, B. 2010. BRS Ana: cultivar de batata de duplo propósito. *Horticultura Brasileira* 28: 500-505.

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; REISSER JUNIOR, C. 2013. BRS Clara: cultivar de batata para mercado fresco, com resistência a requeima. *Horticultura Brasileira* 31: 664-668.

PEREIRA, AS; NAZARENO, NRX; SILVA, GO; BERTONCINI, O; CASTRO, CM; HIRANO, E; BORTOLETTO, AC; TREPTOW, RO; DUTRA, LF; LIMA, MF; GOMES, CB; KROLOW, ACR; MEDEIROS, CAB; CASTRO, LAS; SUINAGA, FA; LOPES, CA; MELO, PE. 2015. BRSIPR Bel: Cultivar de batata para *chips* com tubérculos de boa aparência. *Horticultura Brasileira* 33: 135-139.

QUEIROZ, LRM; KAWAKAMI, J; MÜLLER, 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.

SILVA, GO; PEREIRA, AS; SUINAGA, FA; PONIJALEKI, R. 2013. Qualidade de pele e produtividade da cultivar de batata BRS Clara. *Horticultura Brasileira* 31: 613-617.

WALKER, T; THIELE, G; SUAREZ, V; CRISSMAN, C. 2011. *Hindsight and foresight about potato production and consumption*. Lima: CIP, 43p. (Social Sciences. Working Paper 2011-5).