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SWEET POTATO: A “CLUSTER” APPROACH TO IMPROVE THE CROP SUSTAINABILITY IN TEMPERATE ZONES

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Abstract

Many cultures have the sweet potato how a staple food and that make it is the seventh of the most cultivated crops in the world. Its large capacity of adaptation is due to genetic and phenotypic diversity. The storage roots are the most consumption edible part but are possible to use the other parts of the plant too. Flesh can be orange, purple white, cream, or yellow, and the amount of vitamin and minerals can vary on the colour. In Europe, sweet potato is a niche crop mainly grown in the Mediterranean areas, with predominant white fleshed genotypes.

Generally, its associated with subsistence agriculture is very diffuse in developing countries and according to the FAO, in 2013, the consumption per capita per year is estimated to be 14.6 kg in Africa, 9.3 kg in Asia, 5.3 kg in Oceania, 2.9 kg in America and < 0.5 kg in Europe. Although in Europe its consumption is still small, it has grown exponentially, in the period from 2010 to 2014 the amount imported doubled.

These genotypes empirically cultivated are inherently inferior regarding nutritional quality, and nowadays, there is limited information about new genetics materials. The biochemical and nutraceutical characterisation of them is the first step to finding the accesses with interesting traits to temperate zones.

This Convolvulaceae has as a feature a wide phenotypic diversity due to its autohexaploidia (2n = 6x = 90), and to obtain genotypes with elevated levels of heterosis is necessary to select parents with high genetic variability. The morphological e biochemical characterisation is the less expensive methods to evaluated a dissimilarity among the genotypes.

The sweet potato is rich in vitamin C, Vitamin A, and antioxidants. The extracts from sweet potato exhibit strong radical scavenging and has anti-inflammatory, antimicrobial, and antihypertensive activities, and the pharmacological potential of the species is already described in the literature. And, we assign the intrinsic value of each genotype of the DAFNAE genetic bank then classify each one according to its aptitudes biochemical and nutritional. The results suggest that some genotypes have substantial amounts of starch, sucrose or glucose, may become a new source of these products. The elevated levels of vitamins and minerals indicate some accesses to be used for

biofortification of foods, such as cakes, soups or biscuits, to increase their nutritional aspects.

A characteristic of the horticulture is the intensification of the crop grow, and the sector has to need to reinvent each time to quick. So, to improve a tropical crop in temperate condition, so many factors need to be evaluated.

The sweet potato has high productive potential and can reach 40 t/ha. However, the European yield does not attain 20 ton/ha. The production of cuttings and the fertilisation are the first steps to advance the crop science of sweet potato because they have a straight influence on the homogeneity growth and yield.

In this context, this present research has the aim to hone the growth and competitiveness of the sweet potato in the temperate climate zone.

Introduction

1. Taxonomic and botanical aspects

The sweet potato is a plant of the *Convolvulaceae* family, the genus *Ipomoea*, and species *Ipomoea batatas* (L) Lam. It is a herbaceous plant of indeterminate habit; its growth can be the climber, creeping or erect. It has branches that vary from purple to green, of very variable length, some authors indicate five others up to 8 meters (Fig. 1) (Moreira, 2016). The internodes also have variable sizes and are susceptible to environmental variations (Fabri, 2009). Its leaves are simple, alternate and with spiral arrangement may or may not be pubescent. The number of lobes can vary from 1 to 9, with colours from yellowish green to purple, including the colours of the limbus and the ribs may differ in some accesses. The leaf limbus can be sagittal, cordiform, lobate, lanceolate, cracked or not. The petiole is long and may have colour green, purple or a mixture of the two (Huamàn, 1991).

Its storage roots form from the beginning of plant development, have a thin outer layer, approximately 1 to 4 mm. This peel may contain deformations such as veins and folds and be smooth or rough, even if it is a genetic factor, the presence of compacted areas or rocks may interfere with root development (Moulin, 2010). This genus has a perennial cycle with its tubers in continuous production, an aspect that makes the plant easy to grow. The shape of the roots can be round, oblong, elongated, elliptical or even variations of these. The pulp is mainly constituted by starch with various shades of purple, pink, orange, yellow and cream, depending on the amount of antioxidant and vitamins, or even being white (Huamàn, 1991).

The flowers, shaped like a funnel, have five joined petals, being white or a full shade of purple. They are complete and hermaphrodite, but self-incompatible. Arranged in bunches, they usually open in isolation. The chalice consists of 5 sepals, two outer and three lowers. The androecium had five stamens located around the pistil and adhered to the base of the corolla. The anthers are commonly white, yellow or slightly purple and varying in height relative to stigma. The pistil contains one or two supercilious ovaries with two loci, and the fruit is a dry, bilocular, glabrous or pubescent rounded capsule of varying colour according to each access, and when dry become brown. The fruits are

dried and plurilocular, with up to 4 seeds (Martin FW ; Jones, 1986). They are hard and have no dormancy, are deep brown or even black.

The commercial cultivation of sweet potatoes is carried out asexually using branches. The use of the apical parts of the stem gives a faster rooting and lower rates of contamination (Moulin, 2010). Commercial cultivation by seeds is not of interest since the level of segregation is high. Have been identified three phenological stages of the crop: the first is the development of the aerial part, absorbent roots, and tuberization; a second vegetative growth of the aerial part and the roots of tuberization; in the last stage is the deposition in the dry matter, mainly in the roots.

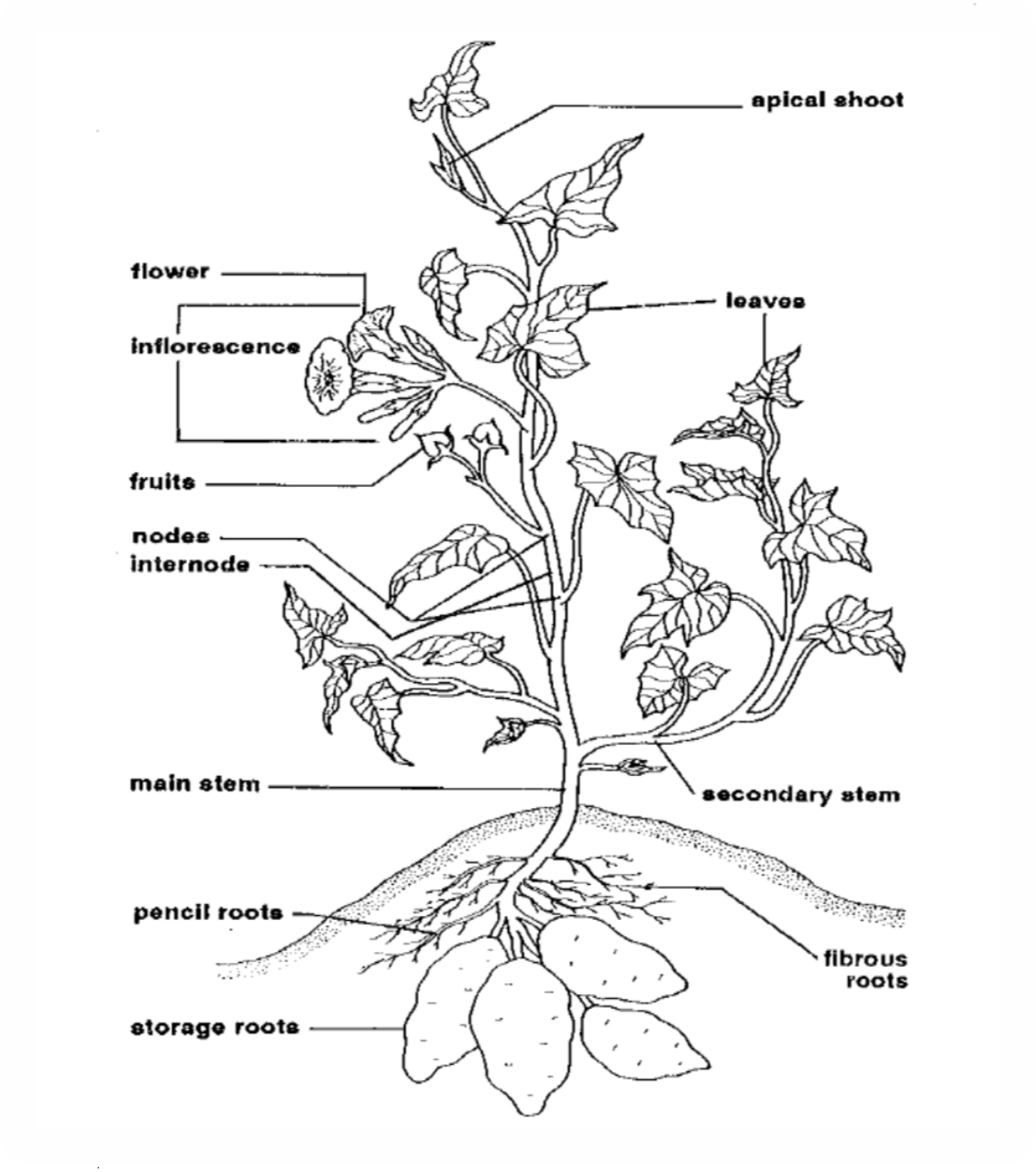

FIGURE 1 - MORPHOLOGY OF THE *IPOMOEA BATATAS* PLANT

2. Economic and social importance

Sweet potatoes are notably widespread and of vital importance in the diet of the population of African and Asian countries. In general, it is cultivated by small farmers and with little use of inputs and is the seventh most produced crop in the world (FAOSTAT, 2018). With a world production of 1.05 x 10^7 of tons in 2016, sweet potatoes are grown in 118 countries, with Asia accounting for 74% of world production and Africa 21% (Fig. 2). The largest producing countries are China, Nigeria, Tanzania and Ethiopia (FAOSTAT, 2018).

FIGURE 2 - A) GEOGRAPHIC DISTRIBUTION OF HARVESTED AREA OF THE SWEET POTATO IN WORLD - HA; B) GEOGRAPHIC DISTRIBUTION PRODUCTION OF SWEET POTATO IN WORLD - TON; C) YIELD OF THE SWEET POTATO WORLDWIDE - TON/HA. FONT: FAOSTAT, 2018

Europe is not yet a significant consumer of this vegetable. However, consumption has grown remarkably in recent years, as imports of sweet potatoes in the last five years have doubled (CBI Market Intelligence, 2015). Northern Europe has a strong demand for sweet potatoes, mainly UK and Holland, with its main suppliers being the USA, Egypt, and Honduras. Most of the imports are from sweet potatoes of orange pulp, supplied by the USA. England annually imports about 82,000 tons to supply its domestic market, while the Netherlands has a role as a European distributor of this product. The largest producers of sweet potatoes in Europe are Portugal -22 thousand tons, Spain with 13 thousand tons and Italy with 6 thousand tons. Sweet potatoes are considered an ethnic product. Thus, the immigration flow in Europe has created a market with much domestic demand, and of course, many opportunities. In Italy, the cities of Zero Branco, Anguillara and Stroppare, localised in the Veneto region, are those that commonly supply the market with white and cream flesh.

3. Origin

Convolvulaceae family is composed of approximately 50 genera, among them the *Ipomoea* genus, which includes 600 to 700 species (Huaman, 1999), whose *Ipomoea batatas* Lam. is the only one of economic interest (Woolfe, 1992). Initially described by Linneo in the mid-1700s, it was recategorised by Lamarck in 1791 based on morphological characters of stigma and pollen. It is a polyploid species (2n = 6x = 90 chromosomes), with central origin in Central and South America. Woolfe (1992) is related to archaeological studies carried out in Peru, as well as evidence of sweet potatoes in caves from 10,000 years earlier. Austin (1987) conducted a study where the base is a series of morphological characters and a sizeable phenotypic diversity, such as the Yucatan peninsula in Mexico and the Orinoco River in Venezuela as probable centres of origin.

The genetic origin of sweet potatoes is not yet fully understood. One possible explanation would be the natural hybridisation of I*. trifida* and *I. triloba* would have generated the ancestor of *I. batatas* (Austin, 1987). Nevertheless, studies suggest that the wild species *I. trifida*, after successive selections, with the intention of domestication, gave rise to I. potatoes (Huamàn, 1999). Currently, molecular techniques have been

used to identify the correlation between species, confirming the last hypothesis cited (Srisuwan et al., 2006).

In its exploratory voyages, Christopher Columbus began with a wide diffusion of tropical plants, and thus sweet potatoes were introduced into the old world around 1492. It was then brought to Asia and Africa in 1500 by the Portuguese and Spanish (Nicoletto, 2010). Particularly in Italy the sweet potato arrived in 1630 and was maintained as an ornamental plant until 1880 when it began its production for human consumption in the province of Rovigo.

4. Objectives and research questions

The European market for sweet potato is booming, due to increased consumer attention to health and the demand for ethnic food. However, 75% of imports are coming from the United States (CBI Market Intelligence, 2015). In Europe, are few countries that produce the crop, and among them, Italian production has been the only one that has grown in the last five years (FAOSTAT, 2018). Consumer demand for nutrient-rich and environmentally-friendly products is growing every day. In addition to the search for new flavours and products other than those commonly found, coloured pulp roots offer the opportunity to differentiate the market.

Sweet potatoes are a very efficient plant for converting energy; it can transform into solar energy into net energy and produce calories/ha in a short time with low costs (Barbosa, 2005). The culture has an amplitude of edaphoclimatic adaptation, but to obtain satisfactory yield is necessary to identify genotypes that have newsworthy characteristics for each climatic condition. Therefore, the research to identify potential ecotypes is extremely important to optimise production in temperate zones.

In horticulture, the nurseries techniques are a step of immense importance for the success of cultivation. Defective or uneven seedlings may compromise field development and yield. In Italy, the implantation of the crop is carried out with the use of non-rooted vegetative material, which causes heterogeneity and productivity losses. The technification and mechanisation of the sweet potato crop are still marginal, but it can improve the quality of the final product and lower costs. The development of technological knowledge and the use of rooted micro cuttings is an interesting alternative to minimise the post-transplant stress and the number of cutting, being another step to make the crop competitive in the temperate zones.

The current study was undertaken with the overall aim to hone the growth and competitiveness of the sweet potato in the temperate climate zone. The specific goals are: I) improve the nursery techniques; II) evaluate the effect of organic matter and fertilisation in the yield and global quality of the crop; III) identification of the ecotypes with market potential and adapted to the temperate zone.

Effect of cells number per tray on cuttings production and yield of sweet potato

Introduction

The production of cuttings is an important step of the growth, and it has a straight influence on the standard of crop and yield. The irrigation, substrate, trays, light, the density of plugs that alone or synergically can be affected the cuttings quality.

The commercial implantation of sweet potatoes is carried out vegetatively, in general, the farmers store part of the production to have cuttings in the next growing cycle. The sweet potato "seed" is buried in a mixture of manure and soil. The dung fermentation increases the temperature of the system, which is a significant help in countries with the temperate climate. When the stems are 30 cm long and 8 to 10 nodes, about 30 to 40 days, they are cut and placed in the field. The roots quantity required are variable but approximately are necessary 400 to 600 kg of sweet potatoes to produce cuttings to plant one hectare of the field.

The advantage of propagating through cuttings is to get much material in a brief time and genetically identical to the mother plant. The post-transplant stage of the crop is subject to considerable stress since it must concentrate all the energies for the development of its adventitious roots, this could limit the development of the aerial part and have an adverse effect regarding yield. Adventitious roots develop from underground nodes, and the plant uses most of the photosynthesis product to develop the initial root system from which the development of the storage roots.

The production of micro cuttings with few nodes can, in a brief time, generate a large number of cuttings, and there is no need to store a large number of the root matrices. Also, rooted cuttings reduce post-transplant stress and increase chances of the plant survival and growth uniformity. Another positive aspect is that the use of plugs creates the opportunity to mechanise the sweet potato crop and reduces the employed labour force.

According to Styer and Koranski (1997), the volume of cells to be used influences the good development of the seedlings, as well as their shape and colour. In a study of the Fisher and Benson (1984), the shape of the cells induced significant differences in

weight of dry matter of the cuttings and number of primary roots at asparagus. Reghin et al. (2004) verificated which the number of cells per tray influenced a quality of the seedling of the rocket directly.

Traditionally, the production of cuttings of the SP made by farmers does not employ much technology. By the way, this method presents disadvantages: the low genetic variability; the high quantities of the storage roots to be mother plant; a suitable place to the preparation of the bed; and the elevated risk of clones with diseases. In this context, the aim of this research is evaluate the effect of a number of cells using different trays on micro cutting of the several ecotypes of cultivation of SP.

The production of rooted micro cuttings allows to produced a many cuttings quickly and in a smaller space, besides guaranteeing a high percentage of rooting in the field. The production in greenhouse provides better control of diseases and pests, ensuring better sanity to the culture (Golla et al., 2010). The scope of this research was to verify the agronomic responses of seven accessions of sweet potato propagated into different trays to standardise a better practice of cutting propagation on quality of sweet potatoes

Materials and methods

- Plant material

The experiment was carried out at l'Azienda Agraria Sperimentale "L. Toniolo "dell'Università degli Studi di Padova in Legnaro, in the 2017 spring/summer growing cycles. For this paper was evaluated the effect of the tray size on the development of the sweet potato crop in the field. For this experiment, four types of trays were used: 77 (C1), 96 (C2), 150 (C3) and 200 (C4) cells and seven ecotypes of sweet potatoes were tested which belong to the germplasm bank of the Università of Padova (Tab. 1; Fig. 3).

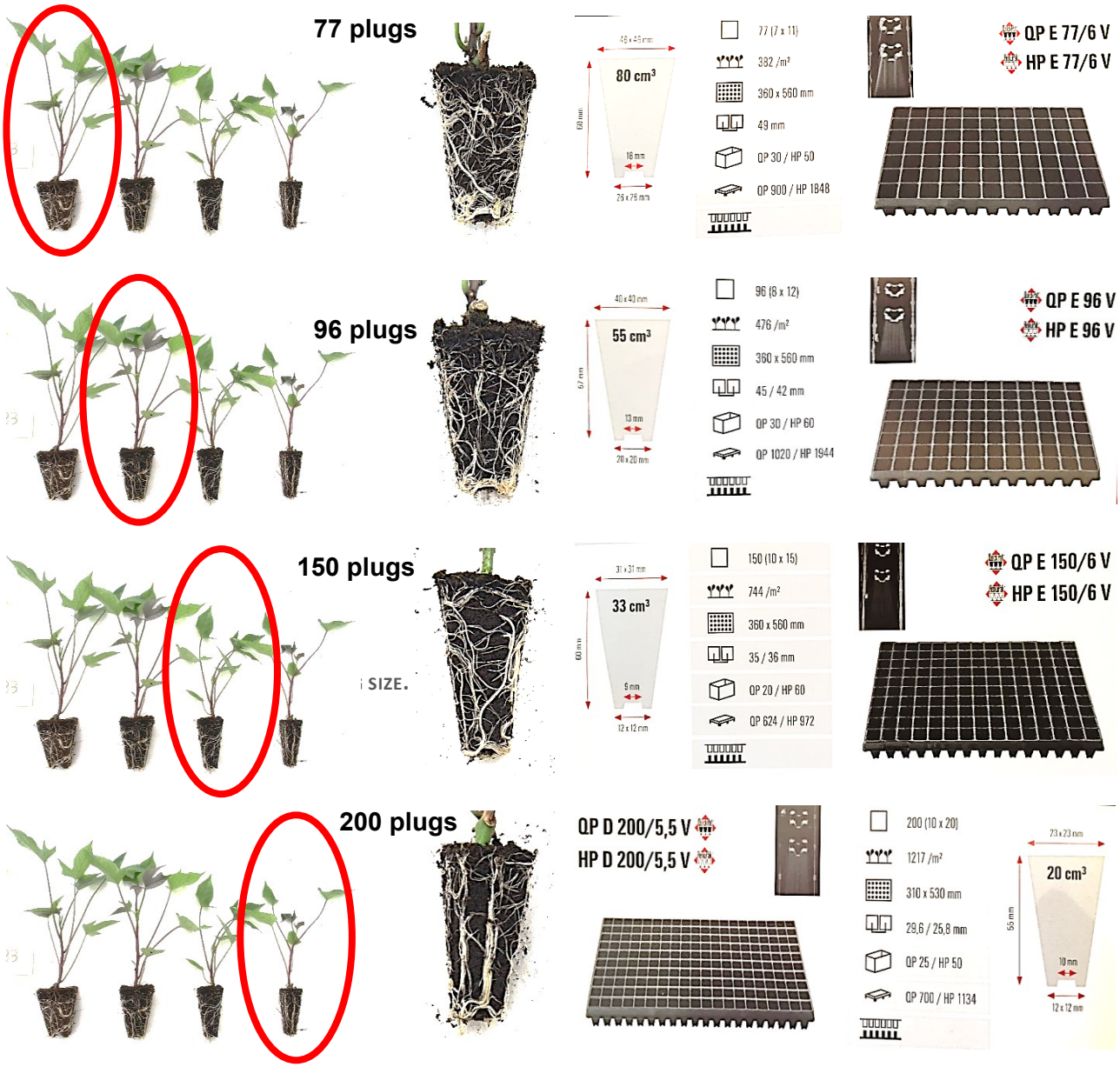

FIGURE 3 -TYPES OF TRAYS AND PLUG SIZE

TABLE 1 - LIST OF SWEET POTATO GENOTYPES USED

Genetic material	Origin
SP1	Brazil
SP3	Brazil
SP4	Brazil
SP5	USA
SP6	Brazil
SP7	Italia
SP8	Brazil

FIGURE 4 - SAMPLE PREPARATION

Sweet potato micro cuttings were produced by "seed" potatoes in the greenhouse with a temperature of 25 °C and 18 °C during the day and night, respectively. The micro-cutting was prepared with two nodes and no leaf on May 4, 2017, using intermediate and apical portions of sweet potato branches. At this point, the cuttings were planted on PVC plug tray, the peaty substrate used for pots filling was Klasmann Potgrond H integrated with 20% perlite, burying a single node and maintained in a glasshouse with a temperature of 20-25 ° C and relative humidity of 70% (Fig. 4).

The plugs were manually transplanted in the field on June 4. Each plot was composed of 28 plants with eight m². There were previously ploughed and fertilized soil with 80-70-210 kg ha^{-1} respectively of N, P_2O_5 and K_2O (Perelli, et al. 2009)

Plugs were planted 0.10m deep on the built-up rows spacing the plants 0.30m apart in the row. During the cultivation cycle, three irrigations, providing 30mm for each irrigation, were performed. Harvesting occurred at 26 September 2017.

The total yield of fresh roots - TP (total mass of roots harvested) the results are expressed in grams; percentage of root dry matter (root samples of each plot crushed, and oven dried at 65 ° C until reaching constant mass) were measured for each observation plot. The aerial biomass was obtained by weighing the canopy of each plot. The dry mass content was obtained in samples of approximately 200 g by oven drying with forced air circulation at 65ºC until constant weight. Each root system was washed and weighed as a whole and, subsequently, the single root weighted to divide the storage roots yield into four weight groups (<99 g, 100–199 g, 200–399 g,>400 g). The first range refers to a scrap product, between 100 and 199 g reference is made to a product of the second choice, between 200 and 399 g is a product of the first choice and beyond 400 g is an extra-size product. (Tab.2). Once washed, each sample of the marketable fraction and the aerial biomass was cut and mixed in order to obtain a homogeneous sample for each plot. A sub-sample for each treatment and replication was weighed before and after oven drying (65°C for 48 h) and another sub-sample was frozen at −80°C and then freeze-dried for the qualitative analyses. For each sample, triplicate extractions and analyses were performed.

At 45 days after transplantation (DAT), the plots were submitted to a photographic analyse to compare coverage velocity of the queues. For this evaluation, a square of wood of 1 m² between two lines of planting was arranged, and all plots were photographed. The photographs were taken the same distance and analysed with ImageJ® software (Fig. 5).

FIGURE 5 - SEQUENCE OF THE GRAPHIC ELABORATION OF THE TEST AREAS FOR THE EVALUATION OF THE COVERAGE PERCENTAGE USING IMAGEJ ® SOFTWARE.

- Statistical analysis

The experiment compared split-plot design with four cell volumes, seven genotypes and three replicates (Fig. 6). The statistical evaluation of the obtained data was performed by ANOVA considering the trial years as variable factors and the fertilisation treatments as fixed factors. In the case of a significant F-value, the means were compared by Tukey's HSD test at the significance level of P≤0.05.

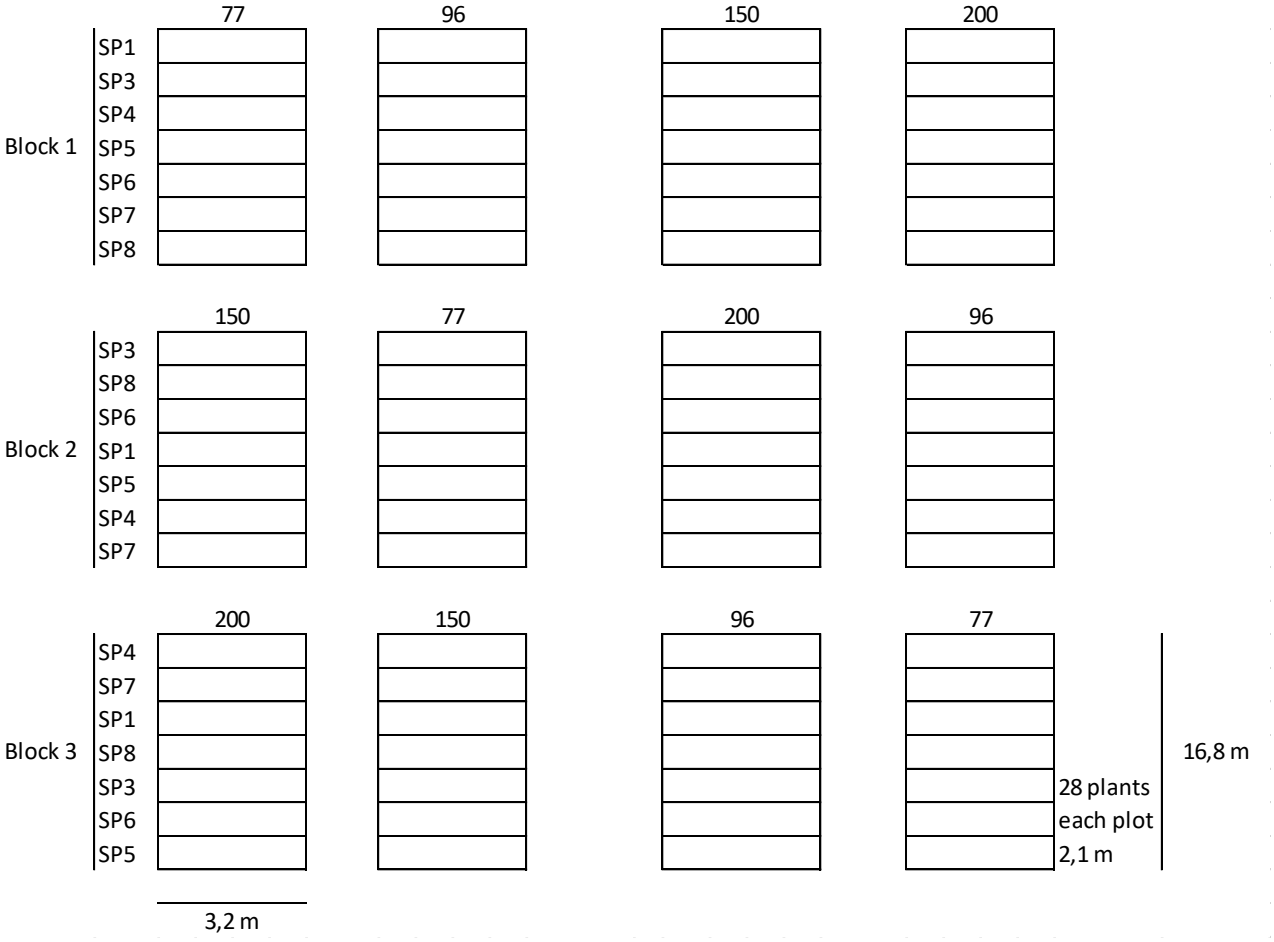

FIGURE 6 - EXPERIMENTAL SCHEME OF EXPERIMENT

- Meteorological data

As far as temperatures are concerned, lower than average values were seen during the first half of May; then, from the second half, the temperatures gradually increased, remaining above the average for the whole period at least until 10 September. In particular, June, July, and August were very hot with minimum temperatures between 15 ° C and 20 ° C, while the maximums were almost always higher than 30 ° C. Precipitation has been practically absent: only from 10 September and for ten days rains and low temperatures have followed, which led to a challenging harvest. The cumulative rainfall in the cultivation period totalled 243 millimetres. Most of it was found to fall in the weeks adjacent to the harvest, with rainy of high intensity (Fig. 7)

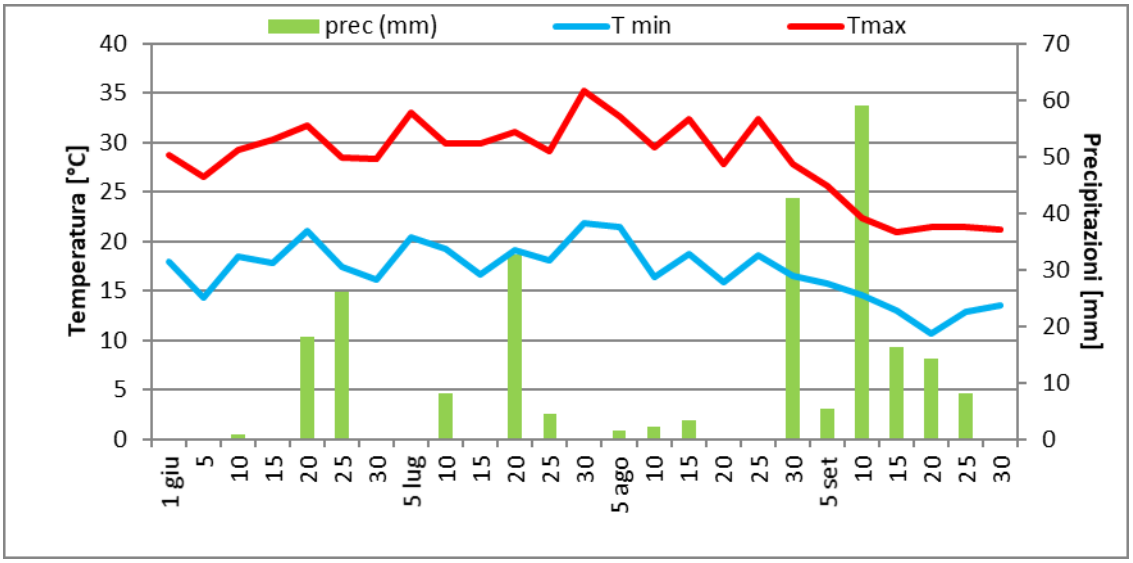

FIGURE 7 - HYDRO-CLIMATIC TREND IN LEGNARO (PD) DURING THE EXPERIMENTATION PERIOD (DATA SOURCE: ARPA-VENETO)

- Photographic analyse

The images were evaluated based on the total pixel/$m^{2,}$ and the green portion covered per pixel/m^2 and expressed as a percentage. The ANOVA test did not show the interaction between the parameters. The percentage of soil cover to the genotypes ranged from 36.5% to 22.7% (Fig. 8). The ecotypes that obtained the best results were SP4 (36.5%), SP8 (34%) and SP5 (33.7%). SP1 and SP6 covered the soil minimally, with 25.4% and 22.7%, respectively.

Surface coverage by aerial biomass decreased linearly with increasing amount of cells/tray (Fig .9). The tray with 77 cells had the most substantial coverage, with 36.8%. The tray with 200 cells with a minimum soil cover, 25,1%. With intermediate values, at 45 DAT (days after transplantation), trays with 96 and 150 cells covered 30.9% and 30.3% of the soil, respectively.

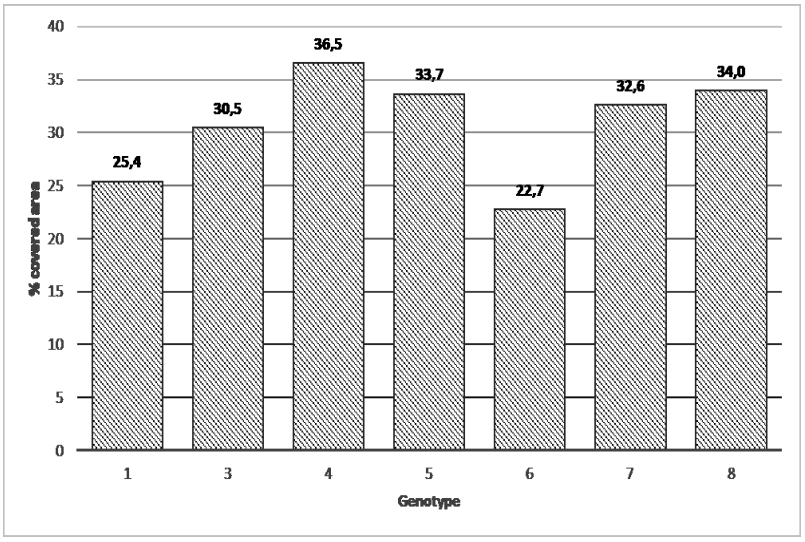

FIGURE 8- EFFECT OF GENOTYPE ON THE PERCENTAGE OF AREA COVERED BY THE SEVEN GENOTYPES AL 12/07/17

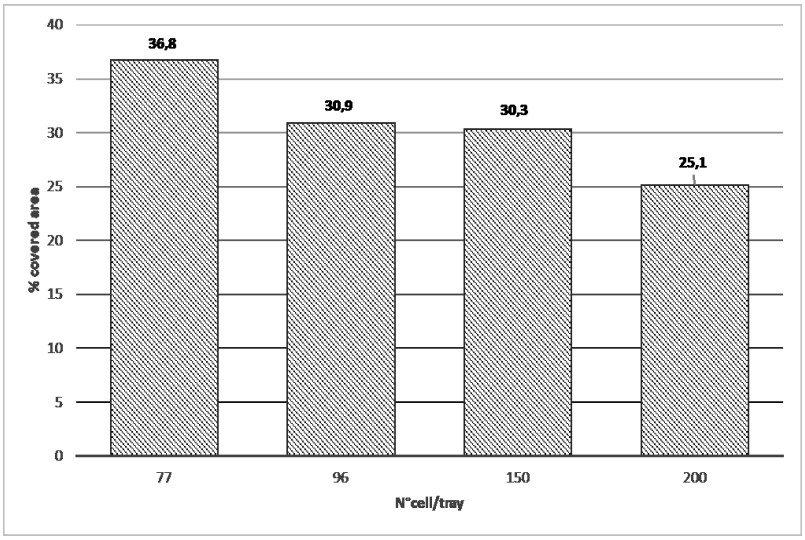

FIGURE 9 - EFFECT OF THE TRAY ON THE PERCENTAGE OF AREA COVERED BY THE CULTURE AL 12/07/17

- Production Yield

The total root productivity was statistically different to the function of the number of cells per tray. The Fig.10 shows that the 96 cells tray had the best performance followed by that of others trays. Indeed, the tray with 96 cells increases production by 41% compared to the tray of 200 cells. Regarding the root production within the different commercial classes, no significant differences were observed among the trays.

According to variance analysis, the genotype influenced the total root/plant productivity (Fig. 11). The SP8 produced a 637 g/pl, followed by SP7 and SP5, with 484 g and 445 g, respectively. SP3 and SP6 produced 2-fold, or 3-fold less compared to the others with values ranged from 279g to 195g, respectively.

The variance analysed was significant for the root production within the different commercialisation classes. Indeed, for roots out of the commercial standard (Fig.12), the SP6 was the one with the highest values, where 40.5% of the total production (TP) roots with more than 400g. The accessions with lower production of non-standard roots were SP1 and SP5, with 186.06g and 176.65g, respectively. The SP8, with 39.6% of TP, had the best performance of the production of class A roots the SP4, SP3, SP6, SP7, and SP1 obtained intermediate values ranged from 2920,7g to 1690g.

On the other hand, SP5 presented with inferior results, 2399,4g. The differences observed in the SP5 that had a 41.4% of the total production in class B. The lowest production in this class is given by SP6, 761,4g.

The other ecotypes had of the production of roots in class B a value ranged from 3189.5 to 1243g. The different accessions influenced the class D. SP1 produced most of the roots, 34.9%of TP. The SP6, SP3, and SP4 performed best with 8,6g, 11,9g, and 12,3g, respectively.

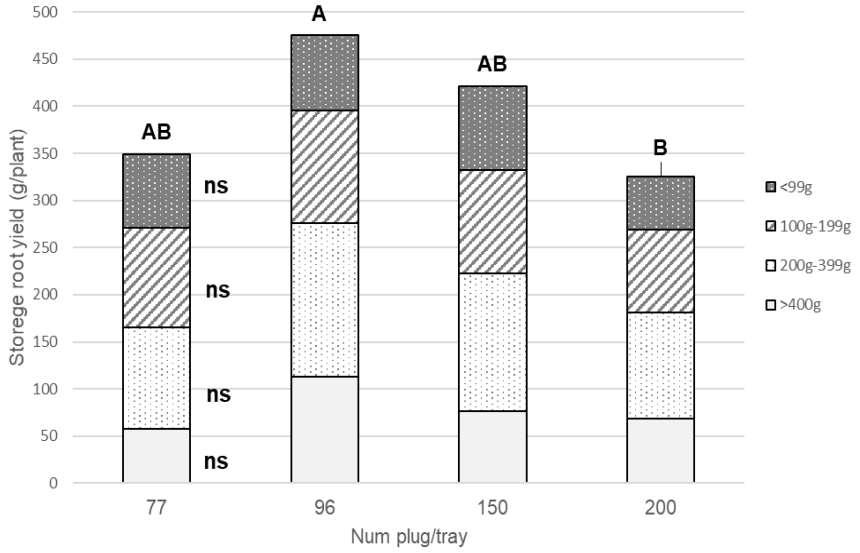

FIGURE 10 - EFFECT OF THE TYPE OF CONTAINER ON THE TOTAL PRODUCTION OF ROOTS PER PLANT AND STORAGE ROOT YIELD DIVIDED INTO WEIGHT GROUPS

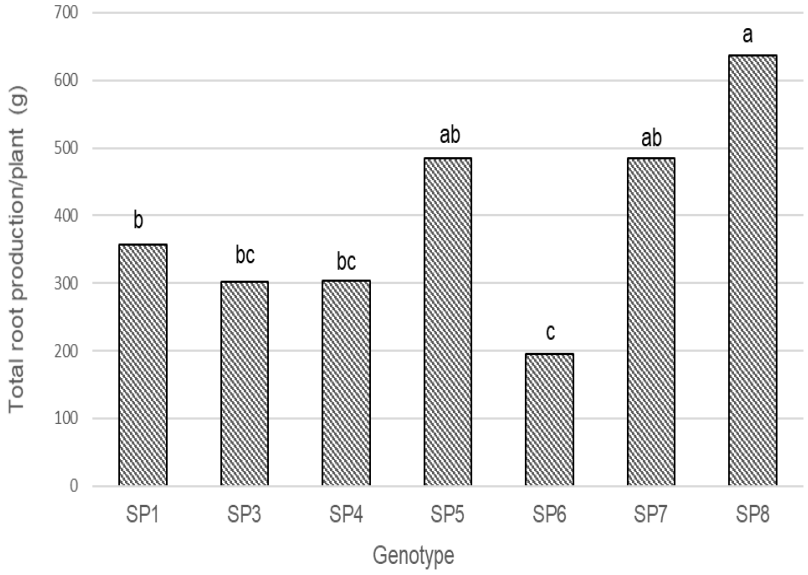

FIGURE 11 EFFECT OF THE GENOTYPE ON THE TOTAL PRODUCTION OF ROOTS PER PLANT

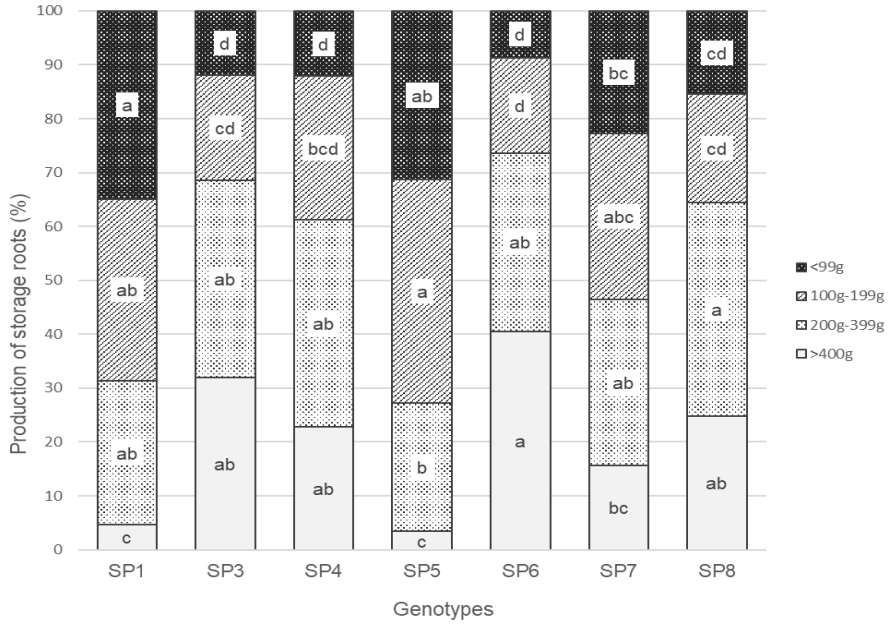

FIGURE 12 - EFFECT OF THE GENOTYPE ON STORAGE ROOT YIELD DIVIDED INTO WEIGHT GROUPS

- Shoot/root ratio

About root/shoot ratio, the seven genotypes studied presented significant statistical differences (Fig. 13) The SP6 had the superior production of aerial biomass. SP8, SP7, SP1, and SP5 produced a more considerable amount of root mass in proportion to leaves and branches, with values ranged from 3,2 to 1,7. This same index presents significant differences for the several trays with values fluctuated from 5.2 to 2.7 (Fig. 14). The containers with 200 and 150 cells had a superior production of the aerial biomass about the radical apparatus. The 96 cells had a lower index which benefited root production.

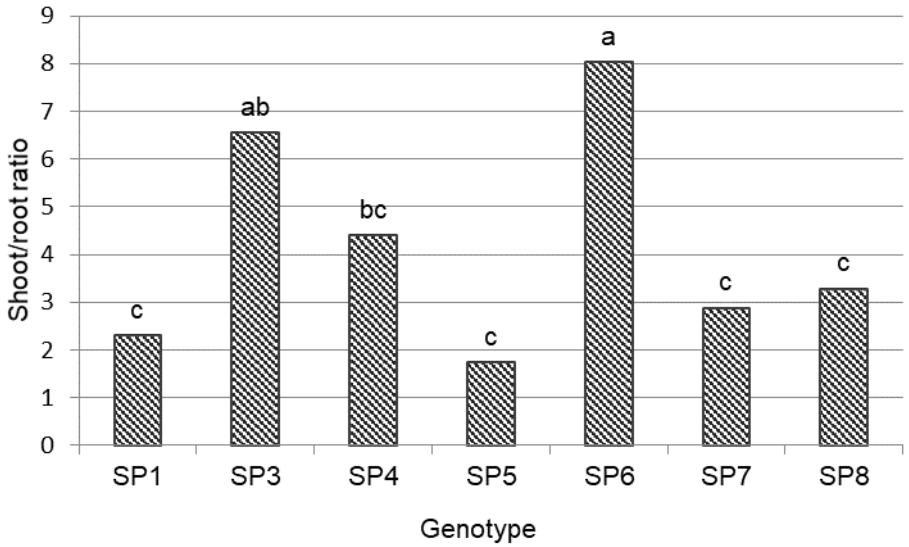

FIGURE 13 - EFFECT OF THE GENOTYPE ON THE BIOMASS-TO-ROOT BIOMASS RATIO OF THE DIFFERENT GENOTYPES

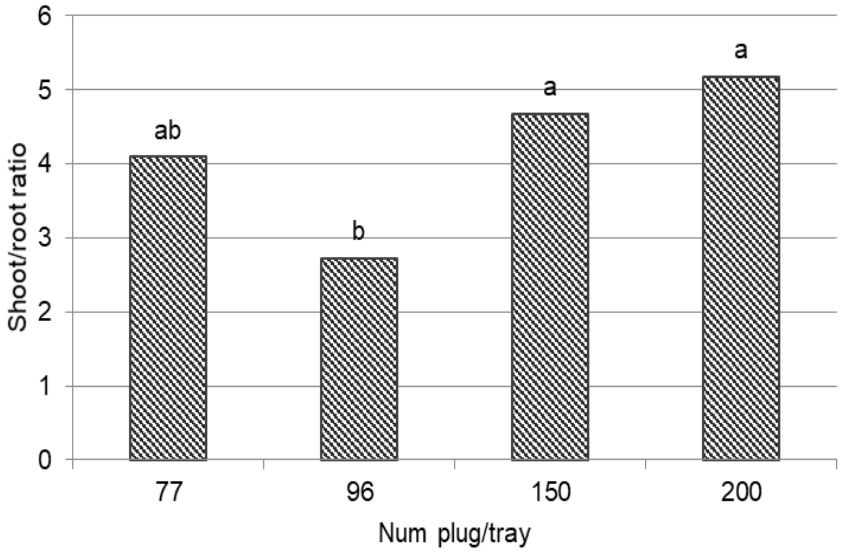

FIGURE 14 - EFFECT OF THE CONTAINER ON THE AIR BIOMASS RATIO ON ROOT BIOMASS

Discussion

The canopy has as the primary functions the protection of the ground against erosion and assists in the handling of spontaneous plants. The experimental results contained in this paper, allow verifying that some innovative sweet potato materials had a growth that enabled them to cover the soil quickly. Moreover, the production of biomass depends on how many leaves the plant can produce in the firsts stages of development, so the more extensive the canopy, the higher the interception of light and the more considerable increase of biomass. The SP4, SP5, SP7 and SP8 supply a superficial cover around 32% at 45 DAT. The shorter the soil coverage time, the lower the costs of handling, so the ecotypes with a swift production of the leaves and branches can be evidence the easiness of adaptation of this crop and the possibility of reducing costs during the cultivation cycle. The trays with a higher volume of the substrate, supply that the plants would develop with more quickly, most probably because the these provided the cuttings better conditions of development of the roots and consequently of the canopy. These results were corroborated by Reghin et al. (2003) who detected that in trials with rocket salad, which cutting with lower quality affected shoot development.

The number of cells in the tray influences the quality of the cutting directly. The use of trays with 77, 150 and 200 cells showed the lowest root/plant yield (g). These results were probably due to the insufficient quantity of nutrients, moisture, and light for the excellent development of cutting. In the same way, Reghin et al. (2007) in a study about the effect of the different trays in chicory yield, observed that seedling from trays with a lower number of cells (128 cells) had the highest values of fresh mass when grown an open field.

The trays of 200 cells, with their reduced volume of the substrate, did not favour budding of primary roots, thus reducing the production of thickened roots. It is likely that the 77 cell be plants developed many capillary roots, and when in the field the plants were not able to turn all of them into thickened roots. Park and Jeong (2010) in a study with the cutting of rose found that the larger the size of the cell the higher the percentage of rooting of the cuttings. Malformed cutting, when transplanted, have difficulty compensating for evapotranspiration, thus affecting crop productivity significantly (Wien, 1997).

The number of cells per tray did not affect root production in the various commercialisation categories. However, that the two containers with the highest number of cells (150 and 200) had similar behaviour. That is, they gave rise to roots considered outside the market standard, presumably with the small space available in the plug the cutting produced a small number of adventitious roots, this limitation represents a stress for the plant and therefore the cutting has difficulty to development after the transplant (Echer et al., 2007).

Both trays with the highest volume of the substrate (77 and 96 cells) had root production in the primary marketing classes around 61%. It is likely that the volume of the substrate being higher yielded better conditions for the seedling to develop. This fact has been reported in other studies with vegetables, where trays with smaller numbers of cells gave rise to higher quality cuttings or seedlings, consequently in the later, fresh mass of the cultivated plants (Echer et al., 2007; Reghin et al., 2007, 2004).

According to FAOSTAT (2018), the yield in Italy is 21,5 ton/ha. Among the several genetic materials studied in this paper, we observed that all had production below this average. The low precipitation in the initial period of cultivation had the dominant influence on the general development of the culture. Similarly, with the seasons defined, the grown window is restricted to a few months in the year, which indicates that the delayed transplant had an adverse effect on the final production. In the same way, the genetic load of each access contributed significantly to the differences found. Golla (2010), testing micro seedling of two sweet potato varieties on two tray types (72 and 128 cells) did not find significant differences for commercial root productivity.

Even though the transplant did not occur at the most favourable time, the SP7 and SP8 had an excellent productive response. As for commercial production, SP8 obtained the best productive means in the most appreciated categories of consumers. However, proportionally the "foreign" materials SP1, SP4, and SP5 had excellent conversions of marketable roots, which emphasises the productive capacity of these materials.

The shoot/root ratio is a correlation expressing the equilibrium of plant development (Wilson, 1988). This index when it has high values evidences a detriment of the root system, whereas the smaller values indicate the increase of the roots about the shoots. In herbaceous plants, usually, the shoot/root ratio is altered during the cultural cycle and is influenced by genetic characteristics as well as the environment (Atwell et al., 1999). Statistical differences were significant among accessions to the shoot/root ratio. During the harvest, some materials had a deep root system, which makes us think that, in

addition to the genetic characteristics, water stress and soil density may have contributed to such disparities (Nejad, 2011). The smaller number of cells raised the shoot/root ratio between the distinct types of trays. The 96 cell trays stimulated the increment of the root mass. The higher volume of substrate stimulates the production of capillary roots surrendering the cutting more resilient to stress. These cuttings, in turn, will have fewer adaptation difficulties, and consequently higher yield.

In this perspective, although there are higher expenses with the substrate, the nurseries handling and proper formation of the cuttings are an essential step for crop success. The trays with 96 cells are a better option for the eradication of sweet potato micro cuttings. The ecotype has presented the worthy performance of the SP8, independent of the trays utilised. Moreover, the SP5 and SP7 had the attractive characteristics considering the results of the commercial production, class A, and B, of the roots.

Distillery anaerobic digestion residues: a new opportunity for sweet potato fertilisation

Introduction

Sweet potatoes have elevated energy conversion potential, related to rice or corn, and have much more effective use of solar energy (Camargo, 2013). Moreover, their roots have high efficiency in colonising the whole profile of the soil, achieving considerable yields even with low inputs. This ability to overcome the low availability of nutrients and other inputs makes the crop highly resilient. Therefore, the low dedicated investment restricts the crop to express all its productive potential.

The culture has a proper development in several edaphoclimatic, being able to be cultivated on the level of the sea up to 2000 meters of altitude. The optimum pH of the crop is between 5.5 and 6.5, because at pH above 7, soil nutrient uptake by the roots decreases, harming the production. Sweet potato is a "rustic" crop because it has a remarkably branched root apparatus with an excellent capacity for the soil exploration. However, the responsive action of the crop depends on the fertility of the soil. In soils with medium-high fertility, the response to fertilisation is limited, however, in the infertile soils, the use of fertilisers can increase the yield (Nasser et al., 2017).

According to Echer et al. (2009), the order in which the sweet potato extracts nutrients from the soil is N-K-Ca-Mg-P-S-Mn-B-Zn-F-Cu. Although nitrogen is an essential nutrient for the crop, it needs attention; its excess accelerated the growth of the aerial part to the detriment of the radical apparatus. However, its deficiency causes the senescence of the leaves (Nasser et al., 2017). Potassium, the second element most absorbed by the roots, is a crucial element for culture since it regulates the translocation of carbohydrates and water use efficiency. Sweet potatoes are very skilled in the absorption of phosphorus, nevertheless, has a response very well to the supply of this nutrient since phosphorus participates in root development, formation and accumulation of starch (De Oliveira et al., 2005).

The pH of the soil influence profoundly the absorption of the microelements. Boron participates in carbohydrate translocation and regulation of metabolism. The synthesis of chlorophyll, consequently photosynthesis, is associated with iron and manganese. In

the sandy soil or with alkaline pH the availability of these elements is reduced and may restrict the crop growth.

According to Oliveira et al. (2005), urea in high doses had an unfavourable effect on several productive variables of sweet potato. Starch contents decreased linearly with increasing urea dose. However, the glucose content increased until the dose 187kg ha^{-1}. Likewise, the higher fertiliser doses have negatively affected the commercial root production.

Alves et al. (2009), show that ammonium sulfate was more efficient than urea in the yield of marketable roots, noting that the faster a nutrient is available to the plants, the higher the probability of leaching losses.

Foloni et al. (2013) emphasise that fertilisation covered with N and K does not interfere in the number of tradable roots. Even though sweet potatoes had a favourable response to the application of combined N and K, steady doses of these nutrients provided the best results.

The organic matter (OM) provides alterations in soil particle arrangement, reducing soil compaction and permeability, increasing root penetration and facilitating nutrient uptake. Oliveira et al. (2013) evaluated the productivity, and qualitative characteristics of sweet potato fertilised with various sources of OM and found that goat manure provided the most significant productivity increase. Likewise, the starch content increased linearly with the application of goat and bovine manure.

Ramos (2004) evaluated several systems of sweet potato production and found which systems used as composted fertilisation obtained higher root production and better levels of starch. The gradual decomposition of OM slowly delivers the nutrients and functions as a long-term stock, thus stimulating the balance of elements that provide the highest productivity.

The reduced supply of organic matter and the intensification of agro-ecosystems have led to several issues, among which one of the most important is the loss of soil carbon (Shrestha et al., 2015) with the increase of greenhouse gas emission and adverse effect on global warming. In this context, the fertilisation with organic materials such as digestate, the residue of anaerobic digestion, represents an alternative for sustainable agriculture (Vaneeckhaute et al., 2013). Traditional amendments such as manures, composts and sewage sludge have been studied extensively in the past (Gallardo-Lara and Nogales, 1978; Edmeades, 2003; Diacono and Montemurro, 2010; Liang et al.,

2012) whereas applications of anaerobic digestion residues (ADRs) and their impacts on the environment and human health are still partially unexplored (Nkoa, 2014). The production of ADRs in Europe and Italy is increasing by the growing presence of digesters for biogas production (Carrosio, 2013). The bulk of research on anaerobic digestates has been mainly focused on the evaluation of their stabilities with the objective to reduce their pathogenicity, foul odours and putrescibility (Kirchmann and Bernal, 1997; Gómez et al., 2005, 2007; Sanchez et al., 2008; Drennan and Distefano, 2010). There has been limited research on the chemical, biochemical and biological properties that would underline digestate agricultural functions (Tambone et al., 2009, 2010; Teglia et al. 2011). Only a few studies reported information about ADRs use in horticulture underlining the good fertilising properties of ADRs that appear to be effective in supporting vegetable yield (Montemurro et al., 2010; Alburquerque et al., 2012; Nicoletto et al., 2012, 2014; Maucieri et al., 2017). Thus, many question marks pertaining to digestate agronomic functions remain unanswered. Furthermore, most of the studies that have employed digestates in the agronomic field have used animal matrices, while digested products of plant origin have not yet been extensively studied.

As part of fertilisation techniques, only few information are present in the literature on the use of ADRs in the management of this crop (Li et al., 2013). This study is part of a long-term project, where several vegetable crop cycles were tested, aimed to improve sustainable techniques of open-field horticulture. Notably, the aim of this study was to evaluate the productive potential derived from ADRs used to partially or entirely replace the mineral fertilisation of sweet potato, an innovative species in the European continent, potentially strategic for the market in the coming years.

Material and methods

- Experiment setting up

The experiment was carried out at the Experimental farm “L. Toniolo” of Padova University (45°21’ N; 11°58’ E; 8 m a.s.l.) in 2014 and 2015 spring/summer growing cycles. Information about the soil where the trial was performed is reported in Table 2. Three fertilisation treatments were tested using ADRs to partially or wholly substitute mineral N crop requirements: one with 50% N through ADRs and 50% N through mineral fertiliser (T50), one with75% N through ADRs and 25% N through mineral

fertiliser (T75) and one with 100% N through ADRs (T100). Two controls treatments were also predisposed one unfertilised (T0), and one with only mineral fertilisation (TMIN). The P and K content in the ADRs were taken into consideration to calculate the amount of P and K minerals to supply in the different treatments the same quantity of these macronutrients. ADRs used in this trial derived from an anaerobic digestion process of fruits and distillery by-products used to produce biogas. ADRs chemical properties and the amount of macronutrients provided with each fertilisation treatment are reported in Tables 2 and 3. N, P and K rates from mineral fertilisers were supplied according to standard recommendations in the area for sweet potato crop (Perelli et al., 2009): 80, 70, 210 kg ha^{-1} respectively for N, P2O5 and K2O using urea (46%), triple superphosphate (46%) and potassium sulfate (50%). Both mineral and organic fertilisation were supplied on May 20 and May 18 respectively in 2014 and 2015 and immediately incorporated by rotavator. After fertilisation the experimental area was set up with built up rows 0.80 m spaced on which to transplant. A randomized block experimental design with three replications was used, and plots were 60 m^2 wide (15 m × 4 m).

- Plant material

The propagation material used in the experiment was obtained from local sweet potato genotypes characterized by white flesh and grey skin. Sweet potato transplants were produced by bedding “seed” potatoes in the greenhouse with a temperature of 25°C and 18°C during the day and night, respectively. In the first decade of March potatoes, about 40 mm to 80 mm in diameter, were used for bedding to produce transplants. 80-100 roots/m2 were set in the bed side by side and covered with about 30 mm of the peaty substrate (Klasmann® n°4). Six to eight weeks from bedding, sprouts were suitable for transplanting (0.30 – 0.35 m tall). Plants were cut from the bed about 50 mm above the soil in order to prevent the possible transfer of diseases from the plant bed to the field. The transplant was manually realized on May 22nd and May 20th respectively in 2014 and 2015. Cuttings were planted 0.10 m deep on the built-up rows spacing the plants 0.35 m apart in the row. After transplanting, about 100 mL of water was provided for each cutting. Concerning irrigation during the growing cycle, no irrigation was required in 2014, whereas in 2015 sweet potato crop was irrigated twice (July 22nd and August 12th) providing about 30 mm for each irrigation.

Harvest took place on September 15th and September 11th respectively for 2014 and 2015. Sampling procedure included the identification of a sampling area for each plot of about 10 m^2 (30 plants). In each sampling area, the number of plants was counted, and the weight of the total aerial biomass was measured. Then storage roots were harvested using a modified plough. Each root system was washed and weighed as a whole and, subsequently, the individual root weight was recorded in order to divide the storage roots yield into 4 weight groups (<99 g, 100-199 g, 200-399 g, > 400 g). The first one refers to a waste product, between 100 and 199 g reference is made to a product of 2° choice, between 200 and 399 g is a product of 1st choice and beyond 400 g is an extra product that, however, it is not always appreciated by the consumer because of the big size and cooking time consuming.

Once washed, each sample of the marketable fraction and the aerial biomass was cut and mixed in order to obtain a homogeneous sample for each plot. A sub-sample for each treatment and replication was weighed before and after oven drying (65°C for 48 h) and another sub-sample was frozen at −80°C and then freeze-dried for the qualitative analyses. For each sample, triplicate extractions and analyses were performed.

- Quantitative determination of sugars by HPLC

Sweet potato root freeze-dried sample (0.2 g) were homogenized in demineralized water (20 mL) with an Ultra Turrax T25 until uniform consistency at 13500 rpm. Samples were filtered in sequence through filter paper (589 Schleicher), and the extracts were further filtered through cellulose acetate syringe filters (0.45 mm) and analyzed by HPLC. The liquid chromatography apparatus utilized in this analysis was a Jasco X.LC system consisting of a model PU-2080 pump, a model RI-2031 refractive index detector, a model AS-2055 autosampler and a model CO-2060 column. ChromNAV Chromatography Data System was used as software. The separation of sugars was achieved on a Hyper-Rez XP Carbohydrate Pb++ analytical column (7.7mm × 300mm, ThermoScientific), operating at 80°C. Isocratic elution was effected using water at a flow rate of 0.6 mL min-1. D-(+)-glucose, D-(-)-fructose and sucrose were quantified following a calibration method. All standards utilized in the experiments were accurately weighed, dissolved in water and the calibration curves were generated with concentrations ranging from 100 mg L^{-1} to 1000 mg L^{-1} of standards.

- Quantitative determination of ions by IC and organic nitrogen

For the estimation of anions and cations freeze-dried sample (200 mg), was extracted in water (50 mL) and shaken at 150 rpm for 20 min. Samples were filtered in sequence through filter paper (589 Schleicher), and the extracts were further filtered through cellulose acetate syringe filters (0.20 mm) before analysis by ion chromatography (IC).

The IC was performed using an ICS-900 Ion Chromatography system (Dionex Corporation) equipped with a dual piston pump, a model AS-DV autosampler, an isocratic column at room temperature, a DS5 conductivity detector and an AMMS 300 suppressor (4 mm) for anions and CMMS 300 suppressor (4 mm) for cations. Chromeleon 6.5 Chromatography Management Software was used for system control and data processing. A Dionex Ion-Pac AS23 analytical column (4 mm×250 mm) and a guard column (4 mm×50 mm) were used for anion separations, whereas a Dionex IonPac CS12A analytical column (4 mm×250 mm) and a guard column (4 mm×50 mm) were used for cation separations. The eluent consisted of 4.5 mM sodium carbonate and 0.8 mM sodium bicarbonate at a flow rate of 1 mL/min for anions and of 20 mM metansolfonic acid for cations at the same flow rate. Anions and cations were quantified following a calibration method. Dionex solutions containing seven anions at different concentrations and five cations were taken as standards, and the calibration curves were generated with concentrations ranging from 0.4 mg L-1 to 20 mg L-1 and from 0.5 mg L-1 to 50 mg L-1 of standards respectively. The Kjeldahl method (ISO1656) was used for organic nitrogen determination.

- ADRs analysis

The pH and electrical conductivity (EC) of ADRs were determined according to EN13037 and EN13038 respectively. Dry matter was calculated following EN13040 and organic matter (OM) using EN13039. Total Kjeldahl-N (%) was measured according to ISO1656; total organic carbon (TOC) was calculated according to Nelson and Sommers (1996), C/N and ash content from the above parameters. Total contents of P, K, Ca, Mg, Al, Mn, Cd, Cr, Cu, Ni, Pb, Zn, Co, Fe and Na were determined using inductively coupled plasma atomic-emission spectrometry (ICP-AES) SPECTRO Ciros (Spectrum Italy Srl, Italy). In addition, to fully characterize ADRs, Hg, As, B, Li, Mo, S, Sb, Se, Sn, Sr, Ti and V were also determined. These ICP analyses were conducted on ADRs ash (Zancan et al., 2006) and in water extracts (1:6, v/v) (ADAS, 1988) in order to check the soluble amount of macro and micro-nutrients.

- Meteorological data

The meteorological data were recorded by the weather station that was close to the experimental site. The two experiment years were characterized by considerably different weather conditions as reported in Figure 15.

2014 was generally characterized by maximum temperatures lower than the average values of the period (1996-2016 average data) except for the first ten days of June, where the maximum temperature reached 32.5 °C. Rainfall phenomena were quite frequent and intense especially in the central part of the crop cycle with peaks of 70 mm. During the crop cycle, 444 mm of rainfall were measured against the 293 mm customarily expected. 2015 was significantly warmer than 2014 with maximum and minimum temperatures that are well above the average for the period, especially during the month of July and August. Differing from 2014, rainfall in 2015 was lower (232 mm) during the crop cycle, about -47% than 2014.

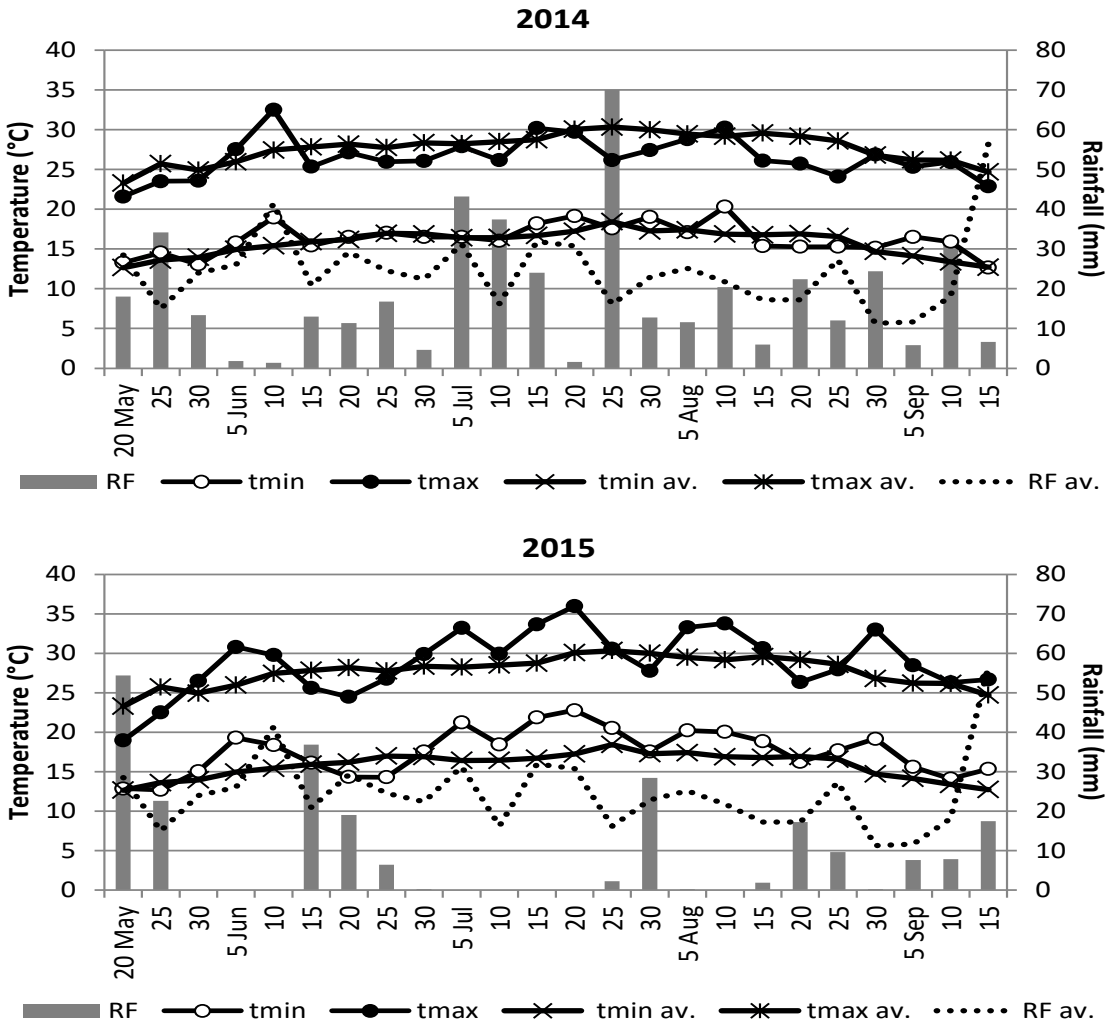

FIGURE 15 - HYDRO-CLIMATIC TREND IN LEGNARO (PD) DURING THE EXPERIMENTATION PERIOD (DATA SOURCE: ARPA-VENETO). FIVE-DAY AVERAGES FOR MAXIMUM (TMAX) AND MINIMUM (TMIN) TEMPERATURES AND FIVE- DAY CUMULATIVE RAINFALL (RF)

- *Nitrogen use efficiency*

N harvest index was calculated using the following equations:

N harvest index (NHI) = N uptake in marketable dry biomass/N uptake in total dry biomass

N use efficiency (NUE) was evaluated using the approach suggested by Fageria et al. (2010) calculating: Agronomic efficiency (AE), Physiological efficiency (PE), Agrophysiological efficiency (APE), Apparent recovery efficiency (ARE), Utilization efficiency (EU).

Nitrogen indexes were calculated using the following equations:

AE (mg mg−1) = Gf–Gu/Na

PE (mg mg−1) = BYf–BYu/Nf–Nu

APE (mg mg−1) = Gf–Gu/Nf–Nu

ARE (%) = (Nf–Nu/Na) × 100

EU (mg mg−1) = PE × ARE

where Gf is the marketable yield of the DSF fertilised plots (mg), Gu is the marketable yield of the mineral fertilised plots (mg), and Na is the quantity of nitrogen applied (mg), BYf is the biological yield (total biomass) of the DSF fertilised plots (mg), BYu is the biological yield of the unfertilised plots (mg), Nf is the nitrogen uptake (total biomass) of the DSF fertilised plots, and Nu is the nitrogen uptake (total biomass) of the unfertilised plots (mg).

- Statistical analysis

The experiment compared ten treatments derived from 5 fertilisation treatments x 2 years factorially combined in an experimental randomised block design with three replications. The statistical evaluation of the obtained data was performed by ANOVA considering the trial years as variable factors and the fertilisation treatments as fixed factors. In the case of a significant F-value, the means were compared by Tukey's HSD test at the significance level of $P \leq 0.05$.

TABLE 2 - CHEMICAL PROPERTIES OF SOIL USED FOR THE EXPERIMENT AT THE DIFFERENT DEEP ON DRY MATTER BASIS.

Parameters		Soil deep	
		0-0.20 m	0.20-0.40 m
pH		7.35	7.30
EC	$\mu S\ cm^{-1}$	250	250
NO_3^-	$mg\ kg^{-1}$	101	87
K	$mg\ kg^{-1}$	94	61
PO_4^{3-}	$mg\ kg^{-1}$	100	213
Na	$mg\ kg^{-1}$	2921	2283
NH_4^{+-}	$mg\ kg^{-1}$	49	24
Cl^-	$mg\ kg^{-1}$	187	228

EC: electrical conductivity

TABLE 3 - CHEMICAL PROPERTIES OF ANAEROBIC DIGESTATES RESIDUES (ADRS) USED FOR THE EXPERIMENT ON DRY MATTER BASIS

Parameters		ADRs	
		Water extract	Ash content
pH		7.68	
EC	µS cm^{-1}	1.462	
Total organic matter	%	49.94	
Organic carbon	%	28.97	
Total N	%	3.48	
C/N		8.32	
Ash	%	50.06	
Dry matter	%	30.21	
P	mg kg^{-1}	42.6	5824
K	mg kg^{-1}	1942	3044
Ca	mg kg^{-1}	134	19189
Mg	mg kg^{-1}	14.7	941
Mn	mg kg^{-1}	0.038	63.7
Al	mg kg^{-1}	0.363	3125
Fe	mg kg^{-1}	0.238	1659
Na	mg kg^{-1}	126	2039
Co	mg kg^{-1}	0.006	0.42
Cd	mg kg^{-1}	nd	nd
Cr	mg kg^{-1}	0.006	6.72
Cu	mg kg^{-1}	0.371	488
Pb	mg kg^{-1}	nd	1.81
Ni	mg kg^{-1}	0.054	3.96
Zn	mg kg^{-1}	0.904	56.8
As	mg kg^{-1}	0.038	0.75
B	mg kg^{-1}	4.11	64.6
Li	mg kg^{-1}	0.665	6.79
Mo	mg kg^{-1}	0.018	0.60
S	mg kg^{-1}	72.3	1509
Sb	mg kg^{-1}	0.031	0.25
Se	mg kg^{-1}	0.031	0.25
Sn	mg kg^{-1}	0.018	1.73
Sr	mg kg^{-1}	0.542	56.4
Ti	mg kg^{-1}	0.006	23.3
V	mg kg^{-1}	0.012	3.97

TABLE 4 - ANAEROBIC DIGESTATES RESIDUES (ADRS) AND MINERAL FERTILISER SUPPLY FOR DIFFERENT FERTILISATION TREATMENTS ON SWEET POTATO

Treatments	ADRs (kg ha^{-1})	Nutrients supply					
		N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
		From ADRs	From mineral fertiliser	From ADRs	From mineral fertiliser	From ADRs	From mineral fertiliser
T0	0	0	0	0	0	0	0
TMIN	0	0	80	0	70	0	210
T50	3809	40	40	7.6	62.4	3.8	206.2
T75	5714	60	20	11.4	58.6	5.7	204.3
T100	7619	80	0	15.2	54.8	7.6	202.4

Results and discussion

- *Sweet potato production*

The effects of ADRs application on sweet potato aboveground and belowground yield in the two years and for each fertilisation treatment are reported in Table 5. Considering the dry matter percentage in leaves and storage roots, values are significantly higher (+12.8% and +33.8%, respectively) in 2015 than 2014. In general, the high dry matter percentage of storage roots allow defining the used genotype as a dry cultivar (Walter et al., 2000). Contrary to what recorded in the two cultivation years, the fertilisation treatments did not significantly influence these parameters. Instead, the whole aerial biomass production was significantly influenced by both studied treatments. Considering the years, at the end of 2014 cropping season was measured a higher (+32.2%) aboveground biomass production than 2015. Among fertilisation treatments, T75 showed the highest aerial biomass yield with over 57 t ha^{-1}, significantly higher than T0, T50 and T100 which were not statistically different among them. It was also found that the fertilisation treatments expressed different answers in the two-year trial (Fig. 16A). In particular, the most significant differences were registered about the intensity of response, especially in T75. The latter presented results well above the others in 2014, in contrast with 2015 where it is substantially aligned with the other treatments. Even the marketable yield was profoundly affected by the cultivation year: in 2015 were found the highest values with almost 16 t ha^{-1}. The genotypes were commonly grown in Italy generally have low production when compared to those of other varieties that can reach more than 50 t ha^{-1} (Ankumah et al., 2003). The fertilisation treatments with the highest yield were T100 and T75, significantly higher than the treatments with the highest percentage of mineral N and the unfertilised control. Regarding the fertiliser properties

of anaerobic digestates, researches have shown that their efficacies lie between those of livestock manures and mineral fertilisers, with many instances where digestates equalled mineral fertilisers (Nkoa, 2014). Our higher yield in the treatments with ADRs (T75 and T100) than mineral treatment indicates a positive effect on a crop that cannot be traced only at the direct nutritional aspects but also at the positive effects exerted on soil biological properties (Alburquerque et al., 2012). The effect of digestates use for crops fertilisation, with in several cases positive results, has also been tested for other crop species like maize (Bachmann et al., 2014; Maucieri et al., 2016), grass (Andruschkewitsch et al., 2013), lettuce (Nicoletto et al., 2014), watermelon and cauliflower (Alburquerque et al., 2012), winter wheat (Šimon et al., 2015), kohlrabi (Lošák et al., 2016), green bean, savoy cabbage, cabbage and cauliflower (Maucieri et al., 2017). Considering cultivation year it had a significant influence on crop performances in term of marketable yield (Fig. 16B). T50 and T75 were the only treatments not to be influenced about the overall storage roots production. T0, TMIN and T100, instead, provided significantly different findings in the two years in favour of 2015. The marketable roots yield was affected by excessive rainfall in 2014. As reported by Thompson et al. (1992), excessive irrigation or water amount can significantly reduce the commercial production. With excessive irrigation, volumes were observed a decrease of up to over 60% for the Pontotoc cultivars (Centennial) and over 30% for the cultivar Tifton (Jewel). About harvest index Hartemink et al. (2000) reported a harvest index of 25% for optimal nitrogen fertilisation; increasing the N proportion, HI is reduced to 6%. In this experiment, values were between 20.5% and 26.9% respectively for TMIN and T100. The complete replacement of mineral N with the organic one tends to increase the HI of the crop. Finally, considering the ratio between storage roots and aerial biomass, higher values were registered in 2015; under the fertilisation point of view, TMIN presented a ratio clearly shifted in favour of the aerial biomass contrary to what occurred for treatments with increasing organic N percentages. The results of the ratio between storage roots and aerial biomass suggest that this species in the presence of good nutritional and water condition use photosynthesis products to increase the aerial biomass. This is possible because when N is readily available to sweet potato plants, lignification of the cells in the roots is promoted at the time of tuber differentiation, tuber root enlargement is impaired, and consequently, aerial growth is promoted (Tsuno, 1974). This problem can be partially overcome by the addition of K (Marti and Mills, 2002). Also for this parameter, a significant interaction year x

fertilisation was observed; in particular T0 has provided the most different results between years (Fig. 16C).

The marketable yield of the storage roots weight groups showed different responses in relation to the cultivation year and the fertilisation mode (Fig. 17). For the first aspect, a high amount of waste roots (weight <99 g) in 2014 was observed (Fig. 17A). This result is linked to the high rainfall amount that affected the test, resulting in extended periods of water stagnation and reduced thermal values that have limited the growth and development of roots as also suggested by Thompson et al. (1992). The product of second choice (100-199 g) was not differentiated in the two years, while the production of big size roots (200-399 g) increased by 44% in 2015 exceeding 5 t ha^{-1}. The production of storage roots more massive than 400 g did not statistically change in the two years due to the high variability. However, given the large gap between the two years (+126% in 2015), some considerations can be done about the extra product. Considering the climatic conditions experienced, it is reasonable to assume that the high thermal values of 2015 encouraged and stimulated the storage roots development contrary to what observed during the previous year. In the average of the two studied years, the fertilisation treatments did not significantly affect the roots weight classes although they influence the total storage roots production with significantly higher values in T75 and T100 than other treatments (Fig. 17B).

TABLE 5 - TWO YEARS SUCCESSION AND FERTILISATION TREATMENTS EFFECTS ON DRY MATTER CONTENT, YIELD TRAITS AND HARVEST INDEX IN SWEET POTATO

	Leaves dry matter	Storage roots dry matter	Storage root/aerial biomass ratio	Storage root yield	Aerial biomass	HI
	(%)	(%)		t ha^{-1}	t ha^{-1}	(%)
Year (Y)						
2014	11.5b ± 0.28	28.4b ± 0.25	0.248b ± 0.013	13.9b ± 0.6	57.5a ± 3.2	19.8b ± 0.9
2015	12.8a ± 0.39	33.8a ± 0.47	0.443a ± 0.025	15.9a ± 0.9	39.0b ± 1.6	27.8a ± 1.4
Fertilisation treatments (FT)						
T0	12.2 ± 0.95	32.0 ± 1.53	0.406a ± 0.070	14.0b ± 1.3	43.0b ± 4.5	24.9 ± 3.1
TMIN	11.8 ± 0.46	30.6 ± 1.50	0.276c ± 0.023	14.1b ± 1.2	51.4ab ± 2.3	20.5 ± 2.1
T50	13.0 ± 0.61	30.6 ± 1.41	0.357b ± 0.043	14.6b ± 1.1	47.4b ± 4.8	23.7 ± 2.1
T75	11.5 ± 0.42	31.1 ± 1.06	0.326b ± 0.064	15.9a ± 0.9	57.2a ± 9.5	22.9 ± 3.2
T100	12.1 ± 0.36	31.3 ± 1.05	0.363b ± 0.042	16.0a ± 1.9	42.2b ± 2.5	26.9 ± 1.4
Y	*	***	***	***	***	***
FT	ns	ns	***	***	***	ns
Y × FT	ns	ns	***	***	***	ns

n.s.. not significant; * significant at P ≤ 0.05; *** significant at P ≤ 0.001
Within years and fertilisation treatments column values with no letter in common differ significantly at P≤0.05 (Tukey HSD test).

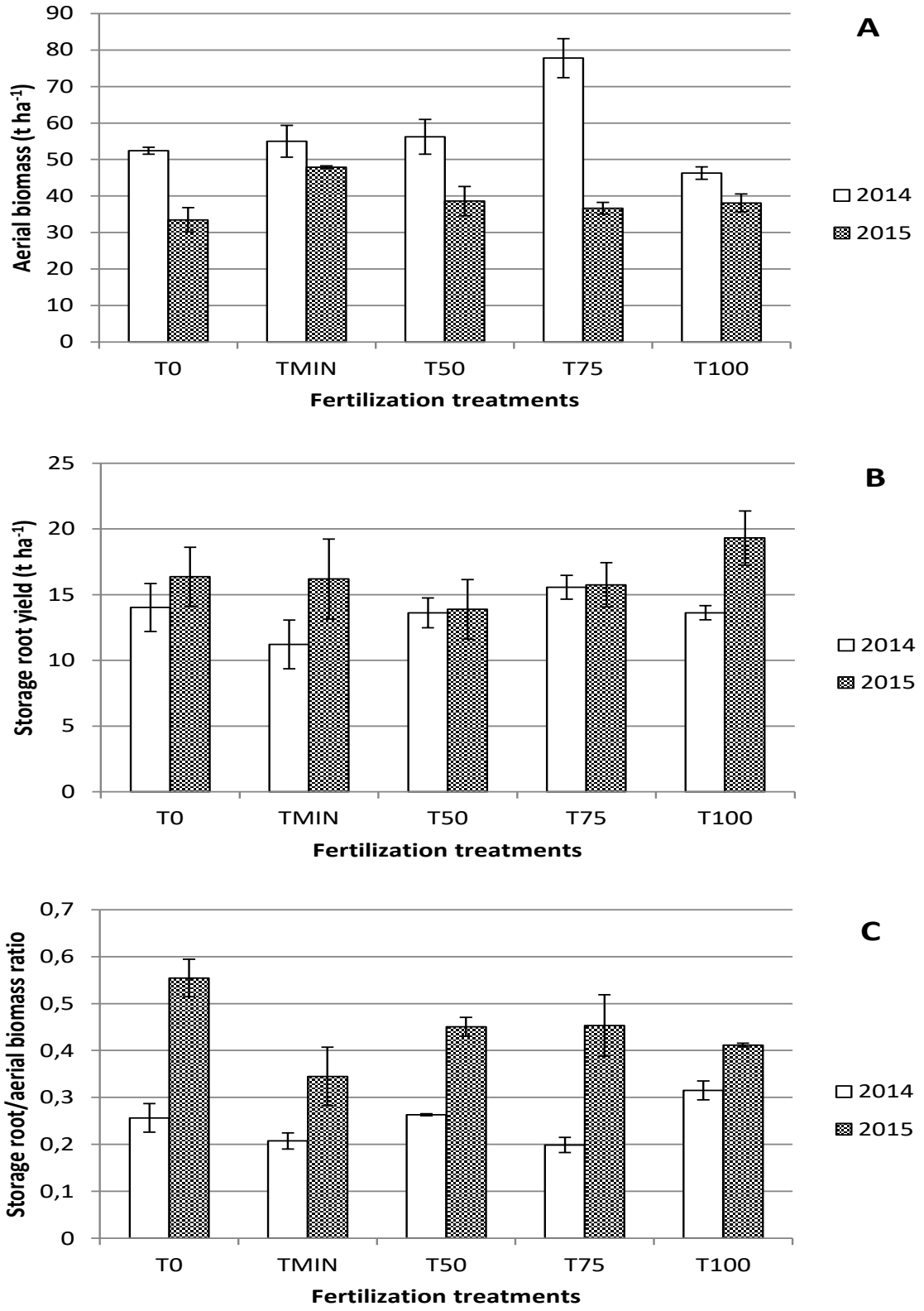

FIGURE 16 - THE DIFFERENT EFFECT OF FERTILISATION TREATMENTS ON AERIAL BIOMASS, STORAGE ROOT YIELD AND THEIR RATIO IN TWO YEARS SWEET POTATO SUCCESSION.

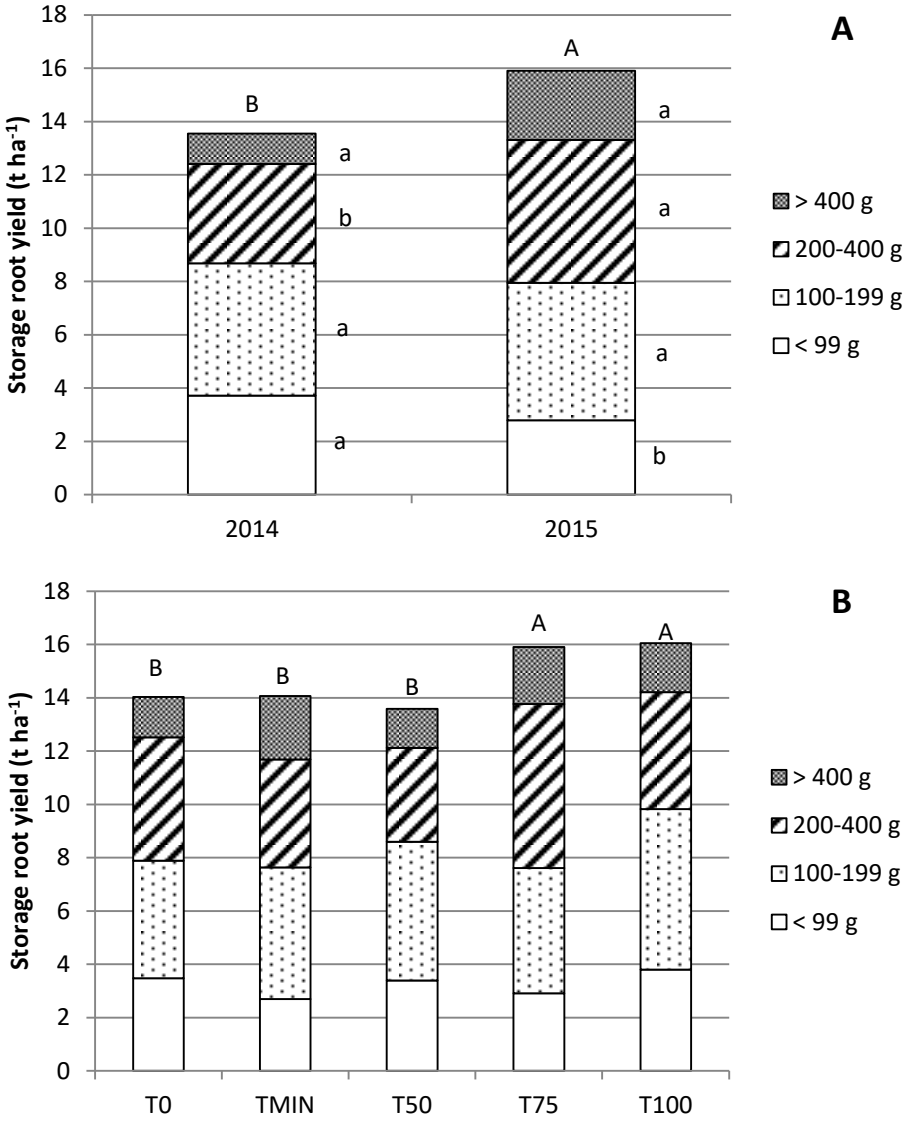

FIGURE 17 - EFFECT OF CULTIVATION YEAR (A) AND FERTILISATION TREATMENTS (B) STORAGE ROOT YIELD DIVIDED INTO WEIGHT GROUPS. WITHIN YEARS AND FERTILISATION TREATMENTS COLUMN VALUES WITH NO LETTER IN COMMON DIFFER SIGNIFICANTLY AT P≤0.05 (TUKEY HSD TEST)

- *Sweet potato quality*

The plant ionic composition highlighted the significant effects of the cultivation year and how the crop nitrogen requirement was supplied (Tab. 6). This result completes what assessed by Ukom et al. (2009) adding that the plant mineral composition can also be affected by the N form supplied and not only by the effect of N dose increase. In the upper part of the table, dedicated to the composition of the aerial part of the plant, the year effect influenced most of the components analysed except sulphates. Mainly, plants are grown in the less wet and warmer year (2015) were characterised by significantly higher chlorine, nitrates, ammonium, potassium and magnesium concentration than plants grown in 2014 which were instead richer in sodium and calcium. About the N compounds, the higher concentration of nitrates in the aerial biomass of the plants grown in 2015 is linked to the lower nitrogen runoff due to rainfall. Examining calcium and magnesium in the two years, the concentrations of these nutrients showed opposite responses. This is related to real phenomena of antagonism between the two ions as found in other works (Malvi, 2011; Krochmal-Marczak et al., 2014). The fertilisation treatments effects on the ion concentration in the aerial part of the plant were generally irrelevant. Only the content of nitrate and ammonium was affected. The highest content of nitrates was detected in combination with the N organic treatments because this last was less easily washed out, whereas ammonium was higher in TMIN. The latter result is probably due to the reduced availability of nitric N for the plant, which tends to absorb even higher amounts of ammonium N to satisfy its needs.

Similarly to what reported for the aerial part, the concentration of ions in the storage roots was mainly influenced by the cultivation year; in this context, only the sodium content did not significantly change. As part of anions content, the higher amount was recorded for phosphate, but it did not statistically differ. The sulphates and chlorides were affected by fertilisation presenting the highest values in TMIN and T100 in the first case and T100 and T0 in the second one. As part of the cations, as expected, the potassium is the most abundant element with values generally greater than 14 g kg^{-1} dw. These values are significantly higher than those detected by Laurie et al. (2012), probably due to the high presence of K typical of the soil in which the test was performed.

Concerning sugar content (Tab. 7) the obtained data showed the double effect of fertilisation and year of cultivation on their concentration. Except for sucrose, the storage roots harvested in 2014 presented a higher concentration of glucose (+19.7%) and fructose (+29.4%) than that harvested in 2015. The application of nitrogen through ADRs was effecting in influencing the sucrose concentration (T100). The concentration of glucose and fructose increased with the amount of nitrogen supplied with ADRs. About the type of the organic matrix used, Antonious et al. (2011) showed the different effect of municipal sewage sludge and green compost on sweet potato sugar content. In both cases, the sugar content increased if compared to the unfertilised and mineral control. The more significant quantity of simple sugars presented in 2014 is probably connected to the lower chance that had the crop of completing a full root system development. The high rainfall and low thermal values that have characterised much of the crop cycle may have reduced the regular activity of amylase by reducing the conversion of most of the simple sugars into starch (La Bonte et al., 2000). This, similarly to what happens for the common potato is also applicable to the effect of fertilisation mode (Kumar, 2004). In this case, the increasing presence of simple sugars occurred for treatments with high organic N intake, which significantly lengthened the growing cycle of the crop by postponing the complete maturation of the roots and shifting the roots/aerial biomass ratio in favour of the latter.

- *Nitrogen use efficiency*

In relation to the nitrogen use efficiency, the indexes showed significant differences between the factors involved in the experiment (Tab. 8). AE was considerably lower (-59.1%) in 2014 as a result of the high rainfall amount compared to 2015. The amount of nitrogen supplied in all treatments with a single application was probably washed out, especially in the treatment managed with only mineral N, with significant consequences for the crop. However, under normal weather conditions, the single N application seems to present high productive results as also reported by Ankumah et al. (2003). The remaining indices were not affected by the cultivation year. The fertilisation treatments affected AE, ARE and EU. The first parameter (AE) is related to the higher or lower availability of nitrogen supplied to the culture. The increasing percentage of organic N supplied to crops increased AE. TMIN showed negative values of AE index, mainly due to nitrogen leaching. The highest ARE percentage was obtained in T75 that did not statistically differed from T50 and TMIN. The lower values were registered in T100. The latter result, as other parameters, is linked to the ADRs mineralisation rate (Möller and

Müller, 2012) which was undoubtedly influenced by the reduced thermal values and high rainfall of 2014. This assumption is partially supported by what appears in figure 18A, which show the interaction year x fertilisation of ARE. In 2014 the environmental conditions were not optimal for the mineralisation of organic matter resulting in low nitrogen release in T100. The increasing contribution of mineral N improved the N availability for the crop as demonstrated by T75 and T50. TMIN highlighted the low ARE values during the rainy year contrary to what recorded in 2015. EU was significantly influenced by fertilisation mode, and the higher results were registered in T75. Also for this parameter the interaction year x fertilisation (Fig. 18B) clarifies the EU dynamics. In 2014 the EU decreased with increasing organic nitrogen percentage. In the second cropping season (2015) responses were completely different, all treatments showed positive values, and TMIN significantly increased EU.

The ADRs application in the cultivation of sweet potato can support the crop production with a yield comparable with that obtained using the classical mineral fertilisation. T75 and T100 were the best solutions in the fertilisation management of the crop under the productive point of view. T75 treatment presented the highest N apparent recovery efficiency and utilisation efficiency. Under the qualitative point of view also the sugar quantity was affected by fertilisation with a concentration of glucose and fructose increase with the increase of the N amount supplied with ADRs. The application of N through ADRs leads to an economic saving of about 75% in the respect urea fertilisation costs (€ 1 unit N-1). The obtained results indicate sweet potato as a promising crop in the North-Est Italy area offering in the same time potentially useful data for producers order to demonstrate the usability of ADRs as an alternative to traditional mineral fertilisation in sweet potato cultivation.

Table 6 - Two years succession and fertilisation treatments effects on ions concentration in sweet potato leaves and storage roots.

	Cl^-	NO^{3-}	PO_4^{3-}	SO_4^{2-}	Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}
					g kg^{-1} dw ± SE				
Leaves									
Year (Y)									
2014	1.29 b ± 0.02	0.10b ± 0.02	5.21b ± 0.11	3.07 ± 0.11	0.44a ± 0.02	0.32b ± 0.04	40.2b ± 0.69	1.82b ± 0.05	5.33a ± 0.12
2015	2.99 a ± 0.11	4.67a ± 0.59	12.9a ± 0.46	3.05 ± 0.24	0.23b ± 0.02	1.24a ± 0.10	44.9a ± 2.18	4.87a ± 0.21	2.07b ± 0.13
Fertilisation treatments (FT)									
T0	2.01 ± 0.33	3.21a ± 1.41	9.32 ± 1.95	3.26 ± 0.17	0.40 ± 0.03	0.65bc ± 0.17	39.4 ± 2.85	3.44 ± 0.79	3.84 ± 0.70
TMIN	2.10 ± 0.42	1.54ab ± 0.85	9.04 ± 1.52	2.76 ± 0.44	0.30 ± 0.05	0.99a ± 0.37	43.3 ± 2.12	3.39 ± 0.79	3.96 ± 0.65
T50	2.22 ± 0.43	1.04b ± 0.46	9.37 ± 2.14	2.96 ± 0.27	0.31 ± 0.06	0.71abc ± 0.21	44.9 ± 4.37	3.13 ± 0.67	3.30 ± 0.83
T75	2.29 ± 0.44	2.92a ± 1.23	8.44 ± 1.57	3.06 ± 0.29	0.34 ± 0.06	0.96ab ± 0.18	41.7 ± 1.41	3.51 ± 0.68	3.79 ± 0.75
T100	2.09 ± 0.38	3.22a ± 1.56	9.00 ± 1.72	3.29 ± 0.25	0.31 ± 0.05	0.59c ± 0.17	43.6 ± 2.23	3.28 ± 0.69	3.61 ± 0.82
Y	***	***	***	ns	***	***	*	***	***
FT	ns	**	ns	ns	ns	**	ns	ns	ns
Y × FT	ns	**	ns	ns	ns	**	ns	ns	ns
Storage roots									
Year (Y)									
2014	0.99a ± 0.061	0.047b ± 0.003	3.14a ± 0.159	0.74b ± 0.042	1.02 ± 0.107	0.045b ± 0.007	16.3a ± 0.68	1.17b ± 0.042	4.56a ± 0.120
2015	0.88b ± 0.055	0.279a ± 0.111	1.52b ± 0.073	1.56a ± 0.235	1.11 ± 0.160	0.627a ± 0.186	14.1b ± 0.75	2.81a ± 0.119	1.29b ± 0.074
Fertilisation treatments (FT)									
T0	0.95a b ± 0.038	0.206 ± 0.077	2.22 ± 0.285	1.48a ± 0.325	1.43a ± 0.096	0.178b ± 0.065	14.1 ± 0.52	2.10 ± 0.410	2.94 ± 0.665
TMIN	0.80a ± 0.028	0.024 ± 0.011	2.29 ± 0.419	0.85b ± 0.108	0.98ab ± 0.124	0.720a ± 0.313	16.0 ± 0.68	1.81 ± 0.303	2.83 ± 0.783
T50	0.96a b ± 0.048	0.180 ± 0.140	2.33 ± 0.432	0.93b ± 0.107	0.98ab ± 0.163	0.339b ± 0.143	15.5 ± 1.04	2.01 ± 0.384	2.97 ± 0.767
T75	0.92a b ± 0.048	0.251 ± 0.105	2.35 ± 0.413	1.09ab ± 0.181	1.07ab ± 0.099	0.283b ± 0.112	14.3 ± 0.99	2.06 ± 0.405	2.90 ± 0.745
T100	1.04a ± 0.096	0.152 ± 0.072	2.43 ± 0.347	1.41a ± 0.317	0.88b ± 0.091	0.160b ± 0.075	16.2 ± 0.72	2.00 ± 0.368	2.99 ± 0.728
Y	**	**	***	***	ns	***	**	***	***
FT	*	ns	ns	***	*	***	ns	ns	ns
Y × FT	*	ns	ns	**	ns	***	ns	ns	ns

n.s.. not significant; * significant at P ≤ 0.05; ** significant at P ≤ 0.01; *** significant at P ≤ 0.001
Within years and fertilisation treatments column values with no letter in common differ significantly at P≤0.05 (Tukey HSD test).

TABLE 7 - TWO YEARS SUCCESSION AND FERTILISATION TREATMENTS EFFECTS ON SUGAR CONTENT IN SWEET POTATO.

	Sucrose (mg kg^{-1} dw)	Glucose (mg kg^{-1} dw)	Fructose (mg kg^{-1} dw)
Year (Y)			
2014	124145a ± 34857	6711a ± 1076	13452 a ± 1580
2015	118307a ± 845	5384b ± 541	9498 b ± 633
Fertilisation treatments (FT)			
T0	102906b ± 10599	4831b ± 793	7193b ± 148
TMIN	104525b ± 11012	4701b ± 999	9151b ± 568
T50	102333b ± 13119	6122a ± 652	8288a ± 387
T75	105286b ± 12147	7566a ± 508	10159a ± 605
T100	191078a ± 38449	7018a ± 1037	12808a ± 1645
Y	*	*	*
FT	**	*	*
Y × FT	*	*	*

n.s.. not significant; * significant at P ≤ 0.05; ** significant at P ≤ 0.01
Within years and fertilisation treatments. column values with no letter in common differ significantly at P ≤ 0.05 (Tukey HSD test).

TABLE 8 - TWO YEARS SUCCESSION AND FERTILISATION TREATMENTS EFFECTS ON NITROGEN USE EFFICIENCY IN SWEET

	AE kg kg^{-1}	PE kg kg^{-1}	APE kg kg^{-1}	ARE %	EU kg kg^{-1}
Year (Y)					
2014	7.02b ± 3.61	0.371 ± 0.091	0.027 ± 0.029	19.0 ± 9.75	8.72 ± 4.82
2015	17.2a ± 4.15	0.336 ± 0.153	0.075 ± 0.024	24.0 ± 6.11	10.2 ± 2.05
Fertilisation treatments (FT)					
TMIN	-2.71b ± 4.61	0.423 ± 0.099	0.053 ± 0.063	25.2ab ± 11.4	10.3ab ± 5.70
T50	8.69b ± 3.13	0.316 ± 0.140	0.064 ± 0.029	17.5ab ±14.5	6.44ab ± 7.12
T75	20.0a ± 3.10	0.286 ± 0.352	0.051 ± 0.037	39.9a ± 10.1	19.8a ± 3.93
T100	22.4a ± 5.04	0.388 ± 0.137	0.036 ± 0.045	3.53b ± 12.3	1.31b ± 3.95
Y	*	ns	ns	ns	ns
FT	*	ns	ns	*	*
Y × FT	ns	ns	ns	***	**

AE: agronomic efficiency; PE: physiological efficiency; APE: agrophysiological efficiency; ARE: apparent recovery efficiency; EU: utilisation efficiency.
n.s.. not significant; * significant at P ≤ 0.05; ** significant at P ≤ 0.01; *** significant at P ≤ 0.001
Within years and fertilisation treatments column values with no letter in common differ significantly at P ≤ 0.05 (Tukey HSD test).

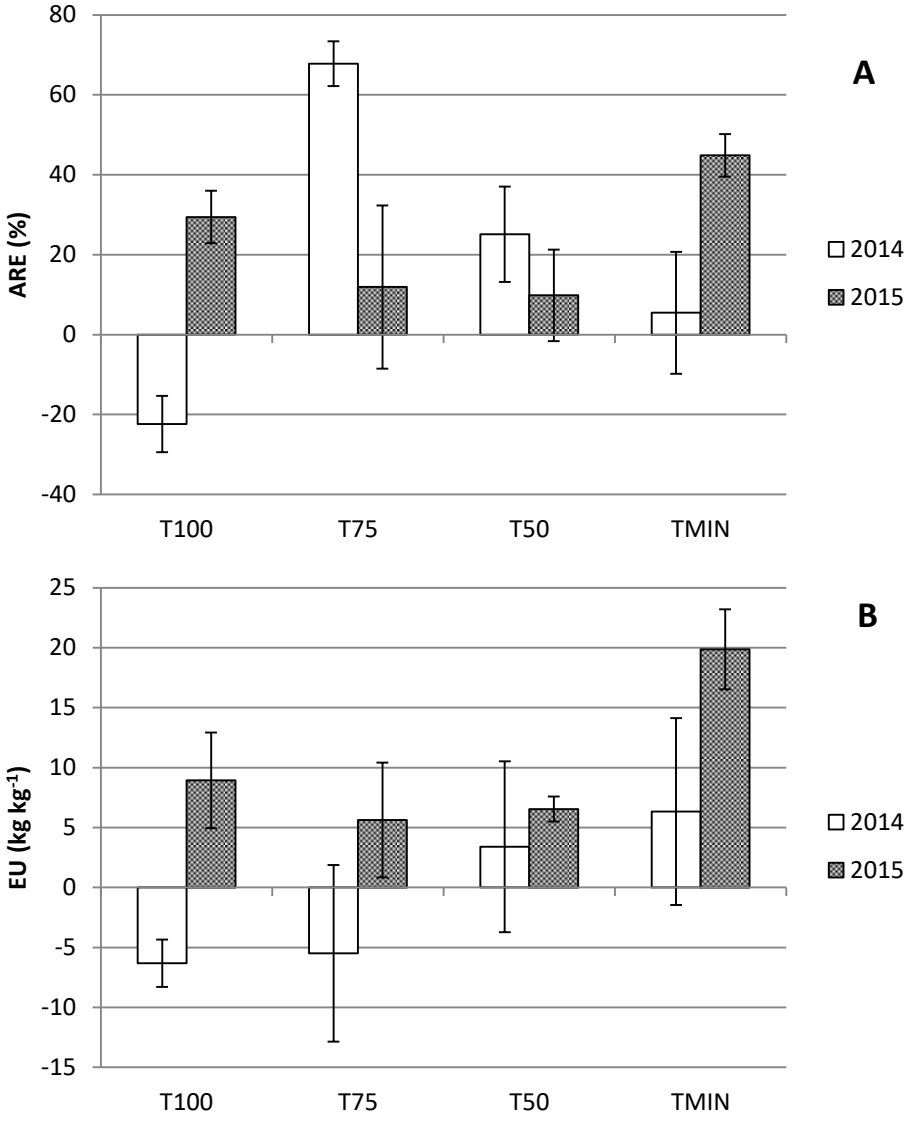

FIGURE 18 - THE DIFFERENT EFFECT OF FERTILISATION TREATMENTS ON NITROGEN APPARENT RECOVERY EFFICIENCY (A) AND UTILISATION EFFICIENCY (B) IN TWO YEARS SWEET POTATO SUCCESSION.

The ADRs application in the cultivation of sweet potato is able to support the crop production with a yield comparable with that obtained using the classical mineral fertilization. T75 and T100 were the best solution in the fertilization management of the crop under the productive point of view. T75 treatment presented the highest N apparent recovery efficiency and utilization efficiency. Under the qualitative point of view also the sugar quantity was affected by fertilization with a concentration of glucose and fructose increase with the increase of the N amount supplied with ADRs. The application of N through ADRs leads to an economic saving of about 75% in the respect urea fertilization costs (€ 1unitN^{-1}). The obtained results indicate sweet potato as a promising crop in the North-Est Italy area offering in the same time potentially useful

data for producers order to demonstrate the usability of ADRs as an alternative to traditional mineral fertilization in sweet potato cultivation.

Multivariate evaluation of the phenotypic and quality components dissimilarity among sweet potato (*Ipomoea batatas* (L.) Lam) genotypes

Introduction

Polyploidy gives *I.batatas* a high level of genetic variability. According to Silva et al. (2012), the vast genetic diversity is due to sexual and asexual segregation due to the exchange and introduction of plants in a particular region. To mitigate the genetic divergence of a population, we can use morphological, agronomic, molecular characters, among others (Cruz et al., 2012)

According to Silva Ritschel and Huamán (2002), the morphological characterisation is an indirect measure of the genetic diversity of a population. Morphological markers for sweet potatoes are accessible and easy to use, making the technique one of the most used to characterise a population. Huamàn (1991) described with a scale of notes, 21 morphological parameters for the aerial part and root of sweet potato.

Elameen et al. (2011) conducted a study in Tanzania to characterise sweet potato's 105 accesses based on morphological and molecular parameter settings. Twenty-seven morphological characters were used to verify the broad phenotypic variability, where each access had a character that differentiated it from the others. Three descriptors presented a significant coefficient of variation: storage root defects, secondary skin colour, and secondary flesh colour, that demonstrated great phenotypic malleability of the species.

Camargo (2013), with the objective of characterising the accesses of the UNICENTRO gene bank, Parana Brazil evaluated the morphological diversity of 40 ecotypes indicating the high phenotypic diversity among the clones. The shape of the lobe, lobe type and the colour of the roots form were the descriptors that contributed the most to the discrimination of groups. J Mbithe and Steven (2016) used 18 morphological descriptors to analyse 11 F1 hybrids of sweet potatoes generated by polycrossing in Uganda and found that even though the climatic factors may have influenced some

parents, the elevated level of polyploidy in the species is the principal factor that influences the wide phenotypic variation.

The agronomic characterisation evaluates traits that meet the market demand and can bring benefits to farmers, for instance: production of roots ton/ha, type of root insertion, ease of harvesting, the speed of soil cover adaptation to the climate, among others.

Fabri (2009) examined 135 accessions of sweet potatoes concerning agronomic characters and showed that even small anatomical differences might influence the final yield. Thus, for each purpose and cropping system, the parameters of interest need to change.

Tairo et al. (2008) evaluated 136 sweet potato genotypes from various parts of Tanzania and demonstrated that the geographic area could influence the variation of root numbers and mean root weigh. Moreover, he concluded that the choice of regionally adapted accesses is paramount for promising fruitful results. Therefore, morpho-agronomic characterisation helps to increase genetic variability within a population.

In this context, this present research has the aim to catalogue the collection of the sweet potato of the UNIPD and evaluate the divergence among the ecotypes through the characteristics agronomic, biochemical and phenotypes.

Material and Method

- Plant material

The experiment was carried out at the Experimental farm “L. Toniolo” of Padova University (45°21′ N; 11°58′ E; 8 m a.s.l.) in 2016 spring/summer growing cycle. The propagation material used in the experiment was obtained from the genetic bank of the Padova University (Tab 9). In January 2016, sweet potato cuttings were produced by pot in the greenhouse with a temperature of 25 °C and 18 °C during the day and night, respectively (Fig. 19). Roots about 40 mm to 80 mm in diameter, were used to produce cuttings, the peaty substrate used for pots filling was Klasmann Potgrond H integrated with 20% perlite. In May, the cuttings were suitable for transplanting (0.30–0.35m tall) and the that was manually realised. Cuttings were planted 0.10m deep on the built-up rows spacing the plants 0.35m apart in the row. After transplanting, about 100 mL of

water was provided for each cutting. There were previously ploughed and fertilized soil with 80-70-210 kg ha-1 respectively of N, P_2O_5 and K_2O (Perelli et al., 2009). Concerning irrigation during the growing cycle, sweet potato crop was irrigated three times providing about 30mm for each irrigation. Sweet potatoes were harvested at 29 September 2016.

Sampling procedure included the identification of a sampling area for each block of about 7 m^2. In each block area, the number of plants was counted, and the weight of the total aerial biomass was measured. The total yield of fresh roots - TP (total mass of roots harvested) the results are expressed in grams; percentage of root dry matter (root samples of each plot crushed, and oven dried at 65°C until reaching constant mass) were measured for each observation plot. The aerial biomass was obtained by weighing the canopy of each plot. The dry mass content was obtained in samples of approximately 200 g by oven drying with forced air circulation at 65ºC until constant weight. Samples of approximately 100g were lyophilized and kept in a freezer until the chemical analysis.

FIGURE 19 - PREPARATION OF THE CUTTINGS

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TABLE 9 - LIST OF SWEET POTATO GENOTYPES USED FOR CHARACTERISATION

Genetic material	Plant type	Country of origin	Flesh colour	Skin colour	Form
Bra1	Extremely spreading	Brazil	Purple	Dark purple	Elliptic
Bra11	Spreading	Brazil	Cream	Pink	Round elliptic
Bra13	Extremely spreading	Brazil	White	Cream	Elliptic
Bra25	Semi-erect	Brazil	Purple	Cream	Long oblong
Bra32	Semi-erect	Brazil	Pale orange	Pink	Oblong
Bra33	Semi-erect	Brazil	Purple	Cream	Oblong
Bra51	Extremely spreading	Brazil	White	Cream	Long elliptic
Bra54	Extremely spreading	Brazil	Intermediate orange	Yellow	Elliptic
Bra78	Semi-erect	Brazil	Cream	Pink	Long irregular
Bra79	Spreading	Brazil	Purple	Pink	Obovate
IT41	Semi-erect	Italy	Cream	Cream	Long irregular
IT42	Spreading	Italy	Cream	Pink	Round
IT43	Spreading	Italy	Pale yellow	Pink	Obovate
IT44	Semi-erect	Italy	White	Cream	Elliptic
IT46	Spreading	Italy	Cream	Pink	Obovate
IT48	Erect	Italy	Cream	Cream	Round elliptic
IT49	Semi-erect	Italy	Pale yellow	Pink	Round elliptic
IT81	Erect	Italy	Cream	Cream	Obovate
IT82	Erect	Italy	Cream	Cream	Round elliptic
IT83	Semi-erect	Italy	Cream	Cream	Obovate
USA45	Semi-erect	USA	Purple	Dark purple	Long oblong

- Photographic analyses

At 45 and 60 days after transplantation (DAT), the plots were submitted to a photographic analyse to compare coverage velocity of the queues. For this evaluation, a square of wood of 1 m2 between two lines of planting was arranged, and all plots were photographed. The photographs were taken the same distance and analysed with ImageJ® software.

- Extraction of phenols for analysis

Freeze-dried samples (1 g) were extracted in methanol (20 mL) with an Ultra Turrax T25 (IKA-Labortechnik, Staufen, Germany) at 1018 g until a uniform consistency was achieved. Samples were filtered (589 filter paper; Whatman, Germany) and appropriate aliquots of extracts were assayed by Folin–Ciocalteau (FC) reagent for total phenolic (TP) content and by the ferric reducing antioxidant power (FRAP method) for antioxidant

activity. For HPLC analyses, extracts were further filtered by cellulose acetate syringe filters (0.45 µm porosity).

- Determination of TP content by the FC assay

The content of TP was determined by the FC assay with gallic acid as a calibration standard, using a UV-1800 spectrophotometer (Shimadzu, Columbia, MD, USA). The FC assay was carried out by pipetting 200 µL of sweet potato extract into a 10-mL test tube, followed by the addition of FC reagent (1mL). The mixture was vortexed for 20–30 s and 800 µL of filtered 20% sodium carbonate solution was added within 1–8 min after the FC reagent addition. The mixture was then vortexed for 20–30 s (time 0). After two h at room temperature, the absorbance of the coloured reaction product was measured at 765 nm. The TP content in extracts was calculated from a standard calibration curve obtained with different concentrations of gallic acid, ranging from 0 to 600 µg mL^{-1} (correlation coefficient: r^2 =0.9992). The results are expressed as mg gallic acid equivalent (GAE) kg^{-1} dry weight.

- Determination of total antioxidant activity by FRAP

Freshly prepared FRAP reagent contained 1 mmol L^{-1} 2,4,6-tripyridyl-2-triazine and 2 mmol L^{-1} ferric chloride in 0.25mol L^{-1} sodium acetate (pH 3.6). A methanol extract aliquot (100 µL) was added to FRAP reagent (1900 µL) and accurately mixed. After leaving the mixture at 20 ∘C for 4min, absorbance was determined at 593 nm. The calibration was performed with a standard curve (0–1200 µgmL^{-1} ferrous ion) (correlation coefficient: r^2 =0.9985), obtained by the addition of freshly prepared ammonium ferrous sulfate. FRAP values were calculated as µgmL^{-1} ferrous ion (ferric reducing power) from three determinations and reported as mg kg^{-1} of Fe2+ (ferrous ion equivalent) of dry matter.

- Quantitative determination of ions by IC and organic nitrogen

For the estimation of anions and cations freeze-dried sample (200 mg), was extracted in water (50 mL) and shaken at 150 rpm for 20 min. Samples were filtered in sequence through filter paper (589 Schleicher), and the extracts were further filtered through cellulose acetate syringe filters (0.20 mm) before analysis by ion chromatography (IC).

The IC was performed using an ICS-900 Ion Chromatography system (Dionex Corporation) equipped with a dual piston pump, a model AS-DV autosampler, an isocratic column at room temperature, a DS5 conductivity detector and an AMMS 300 suppressor (4 mm) for anions and CMMS 300 suppressor (4 mm) for cations. Chromeleon 6.5 Chromatography Management Software was used for system control and data processing. A Dionex Ion-Pac AS23 analytical column (4 mm×250 mm) and a guard column (4 mm×50 mm) were used for anion separations, whereas a Dionex IonPac CS12A analytical column (4 mm×250 mm) and a guard column (4 mm×50 mm) were used for cation separations. The eluent consisted of 4.5 mM sodium carbonate and 0.8 mM sodium bicarbonate at a flow rate of 1 mL/min for anions and 20 mM metansolfonic acid for cations at the same flow rate. Anions and cations were quantified following a calibration method. Dionex solutions containing seven anions at different concentrations and five cations were taken as standards, and the calibration curves were generated with concentrations ranging from 0.4 mg L^{-1} to 20 mg L^{-1} and from 0.5 mg L^{-1} to 50 mg L^{-1} of standards respectively. The Kjeldahl method (ISO1656) was used for organic nitrogen.

- Chemical analyses

The pH and electrical conductivity values were recorded on the defrosting liquid by means of a portable pH meter/conductivity meter, model HI 255 Hanna Instruments; the titratable acidity was evaluated according to the ISO 750: 1998 method and the results obtained were expressed in mg of citric acid on fresh weight. About 0.5 ml of defrosting liquid of the product were used for the determination of the °Brix carried out by Hanna Instruments HI 96801 portable digital refractometer.

- Morphologic analyses

The morphological characterisation was realised in August 2016. The descriptors analysed are 30. The description of each item used is available in Huamàn (1991) (tab. 10).

FIGURE 20- OVERVIEW OF THE ROOT SYSTEMS OF SOME GENOTYPES CONSIDERED IN THE TEST.

TABLE 10 - MORPHOLOGICAL DESCRIPTORS OF STORAGE ROOT:

Storage root shape	1 - Round 2 - Round elliptic 3 - Elliptic 4 - Ovate 5 - Obovate 6 - Oblong 7- Long oblong 8 - Long elliptic 9 - Long irregular or curve
Storage root predominant skin colour	1 - White 2 - Cream 3 - Yellow 4 - Orange 5 - Brownish orange 6 - Pink 7 - Red 8 - Purple-red 9 - Dark Purple
Storage root predominant flesh colour	1 - White 2 - Cream 3 - Dark cream 4 - Pale yellow 5 - Dark yellow 6 - Pale orange 7 -Intermediate orange 8 - Dark orange 9 - Strongly pigmented with anthocyanins

- Statistical analysis

The complete set of data (morphological, related to yield, ionic concentrations and biochemical) for each variety was used for random combinations using the Bootstrap method (Efron, 1979). For each variety, a set of 1000 combination was produced, and the data were analysed using the PCA procedure using the software Statgraphics XVII. The varieties were separates using the minimum Euclidean distance.

- Photographic analyse

The images were evaluated based on the total pixel/$m^{2,}$ and green portion covered per pixel/m^2 and expressed as a percentage (Fig. 21). In the first sampling, some of the evaluated ecotypes by the rapid soil cover: IT49, BRA51, USA45, and BRA11 with 71.9%, 65.7%, 52.9% and 50.5% of leaf cover. In 45 DAT, the BRA54 and IT43 had results with less than 10% of the soil covered. In the sampling at 60 DAT, the ecotype BRA54 showed a coverage rate higher than 70%. IT49 remained with the highest coverage rate among genetic materials, above 90%. BRA1 in the second sampling exceeded 80% of the leaf cover, even though at 45DAT there was little coverage, less than 50%. Two other ecotypes that in the first sampling had indices less than 50% and at 60 DAT exceeded 90% were IT81 and IT46. BRA54 and IT81 were the ones that had the most significant variation among the samples, whereas BRA11, USA45, and BRA51 had slight variation.

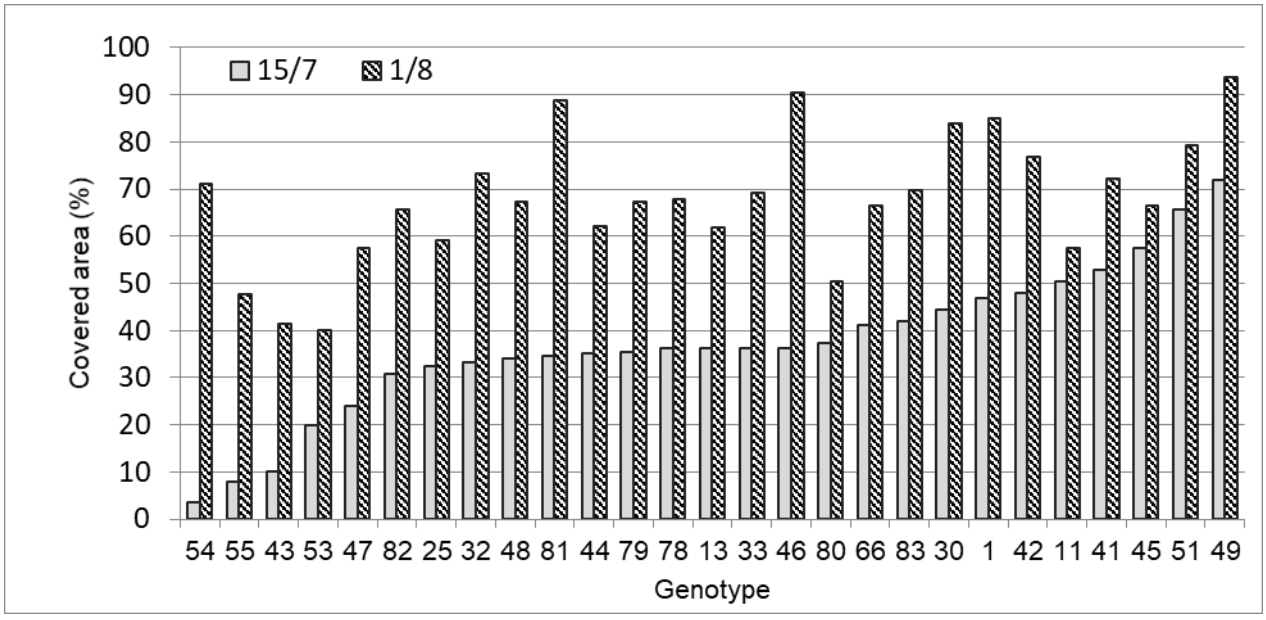

FIGURE 21 - PERCENTAGE OF LAND COVER BY THE CROP AFTER 45 (15 JULY) AND 60 (1 AUGUST) DAYS FROM TRANSPLANTATION.

- Morphological descriptors of roots

Three descriptors were used to determine the diversity among the 21 accessions (Huaman, 1991): skin colour, flesh colour, and root shape (Tab. 9). We can notice a high variability between the characters. As for the shape of the roots, 8 variations were

found for this factor (Tab. 11) Obovate (24%), Elliptic (19%), Round elliptic (19%), Oblong (10%), Long oblong (9%), Long irregular (9%), Long elliptic (5%), Round (5%). For skin colour, the roots were classified in Cream (48%) and Pink (38%). Other less prevalent colourations were Dark purple (9%) and Yellow (5%).

Regarding the flesh colour, 43% of the ecotypes showed Cream, 24% Purple, 14% White, 9% Pale yellow, 5% Pale orange, 5% Intermediate Orange.

- Production Yield

To produce commercial roots ton/ha higher results were found by BRA11, BRA79, and BRA51. With values lower than the accesses IT82 and BRA1 (fig 22).

The marketable classes verified a high variability of results among the ecotypes (Fig. 23). BRA78 produced 60% of its roots in commercialisation class A, followed by IT43 with the 53%. The ecotypes that had the lowest production levels in this category were BRA33, IT44, BRA1, IT46, and BRA25. The IT46, IT42, IT49 and BRA78 accessions produced about 10% of the roots in class B. The ecotypes IT44, BRA32, IT41, produced about 45% of the roots weighing between 100 and 199 grams. IT46 had almost 70% of the roots inside the category considered out of the commercial standard, class C. Instead, with percentages around 10% were IT44, BRA32, IT82, IT4. The produce roots in class D found that accessions BRA78, IT41 and IT44 produce about 35% of roots weighing less than 99 grams. The accesses that had a low percentage, less than 5%, of roots considered non-commercialize (class D) were BRA1, BRA33, and BRA46.

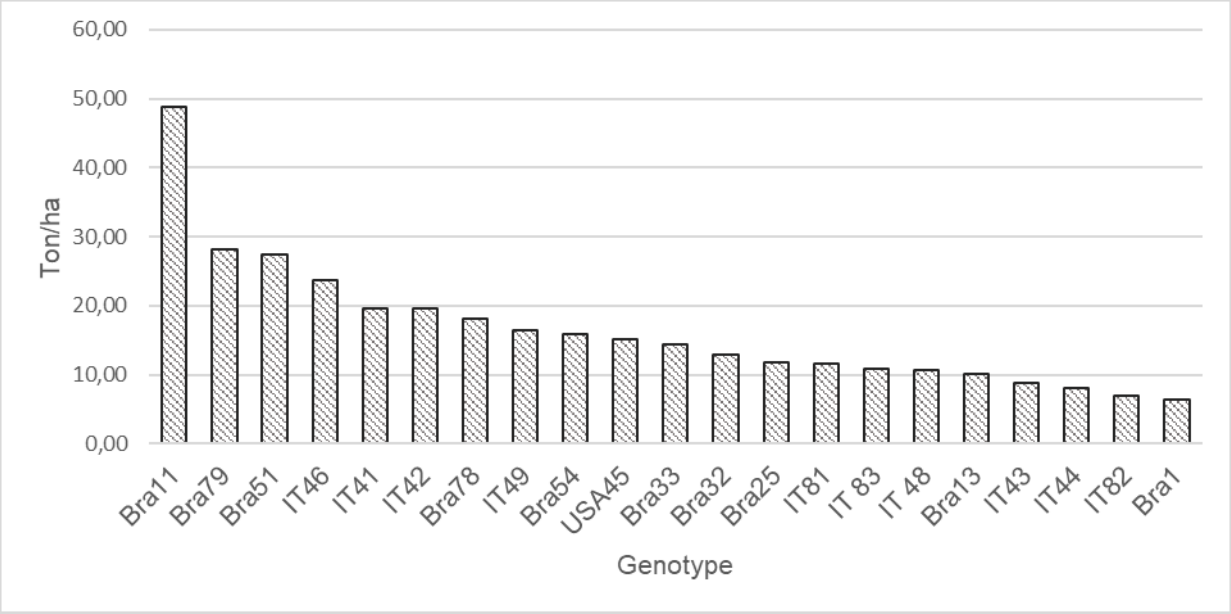

FIGURE 22- PRODUCTION OF SWEET POTATO ECOTYPES (TON/HA).

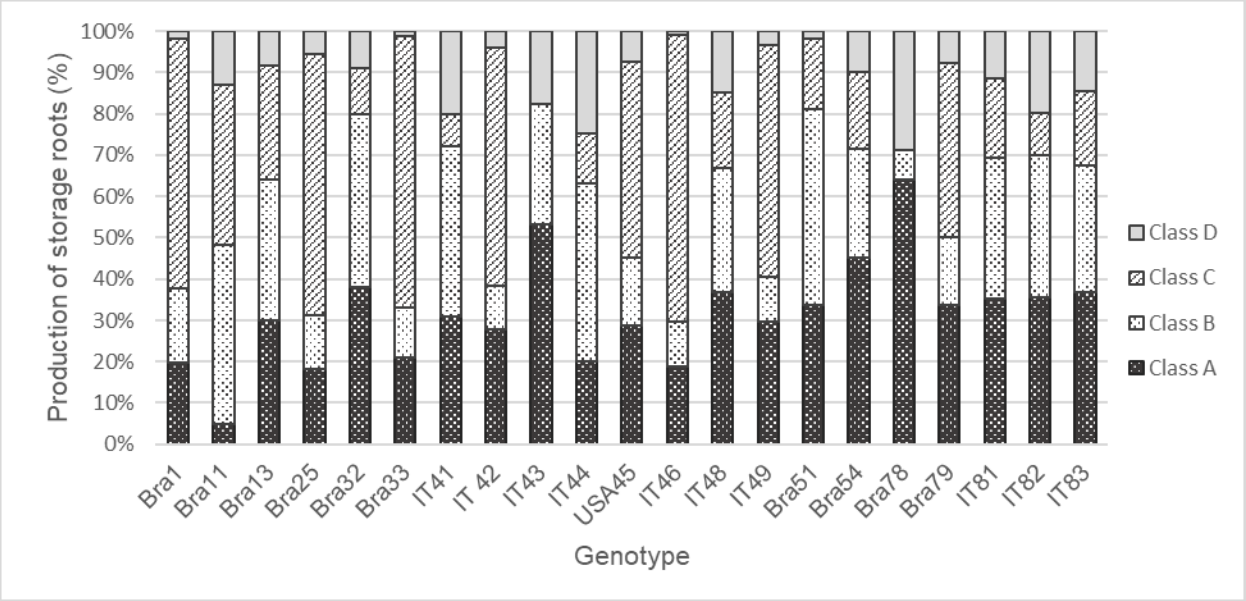

FIGURE 23 - PERCENTAGE SUBDIVISION OF TOTAL ROOT PRODUCTION BASED ON MARKETABLE CLASS.

- Multivariate analyses

The analysed factors were significant since they allowed the discrimination of ecotypes in distinct groups. We can verify that the measures of dissimilarity between the genetic materials estimated from Euclidean distance indicate a wide genetic variability. The figure 24 shows the dendrogram expressing the genetic divergence among the 21 sweet potato ecotypes, and it was possible to distinguish four groups. Three groups are formed by only one ecotype each (BRA1, BRA11, and USA45), the other 18 accessions

are grouped into one group. The genotypes USA45 - BRA11, and BRA1 - BRA13 had the most substantial dissimilarity. The closest genetic materials were IT82 and IT83.

The two principal components together account for 33.6% (Tab 11). The PC1 explains 20.2% (eigenvalue 4.24) of the variation among the ecotypes, while the second component (PC2) accounts for 13.4% (eigenvalue 2.82) of the variation. For the first component (PC1), the most important descriptors were: sodium content (0.345796), length of the main vine (0.34373), vine internode length (0.32) and EC (-0.352058). For the PC2 the discriminants were: vine internode diameter (-0.44223), soluble solids content-BRIX (-0.38226), Yield (0.345762) and calcium content (-0.33708). In PC3 the characters that be noteworthy were: mature leaf size (0.436774), production single plant (0.39439), sulfate content (0.379745) and petiole length (0.349849). And in PC4: phosphor content (0.473051), total antioxidant activity (0.450036), total phenols (0.442134) and sulfate content (0.328698) (Tab 12).

TABLE 11 - VARIANCE ESTIMATES (EIGENVALUES) OF PRINCIPAL COMPONENTS AND CUMULATIVE PERCENT OF VARIANCE EXPLAINED BY THE COMPONENTS.

Components	Eigenvalues	Variation of each component (%)	Accumulated variation (%)
1	4,2432	20,206	20,206
2	2,82084	13,433	33,638
3	2,7382	13,039	46,677
4	2,04612	9,743	56,421
5	2,01395	9,590	66,011
6	1,6556	7,884	73,895
7	1,25566	5,979	79,874
8	0,939447	4,474	84,348
9	0,828205	3,944	88,291
10	0,633471	3,017	91,308
11	0,418453	1,993	93,301
12	0,395216	1,882	95,183
13	0,286573	1,365	96,547
14	0,226616	1,079	97,626
15	0,132969	0,633	98,260
16	0,122487	0,583	98,843
17	0,10375	0,494	99,337
18	0,0602731	0,287	99,624
19	0,0435151	0,207	99,831
20	0,0243859	0,116	99,947
21	0,0110804	0,053	100,000

TABLE 12- CANONICAL DISCRIMINANT COEFFICIENT OF FOUR PRINCIPAL COMPONENTS AND TRAITS OF THE GENOTYPES

Traits	PC 1	PC 2	PC 3	PC 4
Length of the main vine	0,34373	-0,111857	-0,056153	0,0371711
Vine internode length	0,324218	-0,0670168	-0,0606827	-0,0280429
Vine internode diameter	-0,00194048	-0,442227	0,149581	-0,215943
Mature leaf size	0,160236	-0,200341	0,436774	-0,0656079
Petiole length	0,26535	-0,0630476	0,349849	-0,197669
Yield (g/plant)	0,230429	0,345762	0,195862	-0,000527954
Production single plant (g)	0,195621	0,0131318	0,39439	-0,0692467
Phosphate (mg/kg dw)	0,0652159	-0,10453	0,108888	0,473051
Sulphate (mg/kg dw)	0,0444271	0,121874	0,379745	0,328698
Sodium (mg/kg dw)	0,345796	0,00910068	-0,131294	-0,138958
Ammonium (mg/kg dw)	-0,168152	0,293863	-0,0598554	0,162325
Potassium (mg/kg dw)	-0,228121	0,0809646	0,255987	0,00327894
Magnesium (mg/kg dw)	-0,194107	-0,0507916	0,151122	0,142752
Calcium (mg/kg dw)	-0,0682905	-0,337083	-0,124767	0,0123579
Titratable acidity %	0,101632	0,034128	-0,109336	-0,120082
Brix	-0,272068	-0,38226	-0,0887648	-0,123563
pH	0,177005	-0,319529	0,0242118	-0,0790024
EC (mS)	-0,352058	-0,190978	0,18455	-0,0233749
Total phenols dw	0,175791	-0,244201	-0,099611	0,442134
Total antioxidant activity dw	0,192663	-0,180458	-0,209349	0,450036
Vit C mg/kg dw	0,182131	0,10277	-0,273265	-0,265552

From the graphical analysis of the vectors (fig . 25 and 26), it was possible to designate four groups. Group I is composed of the IT81, IT82, IT83, IT41, IT44 and IT48 ecotypes and are characterised by the high content of potassium and ammonium. Group II is formed by accessions IT43 and BRA78 and is grouped by calcium and magnesium content, soluble solids and EC. The third group consisted of the ecotypes BRA1, BRA11, BRA13, BRA 32, IT49, USA45, BRA54 and BRA78, being aggregated by the morphological characteristics analysed, the high content of antioxidants and total phenols and pH. Group IV was clustered by the high content of Vit C, higher productivity and yield per plant, titratable acidity, and sulfate content, in this group are allocated BRA25, BRA33, IT42, IT46, and BRA51.

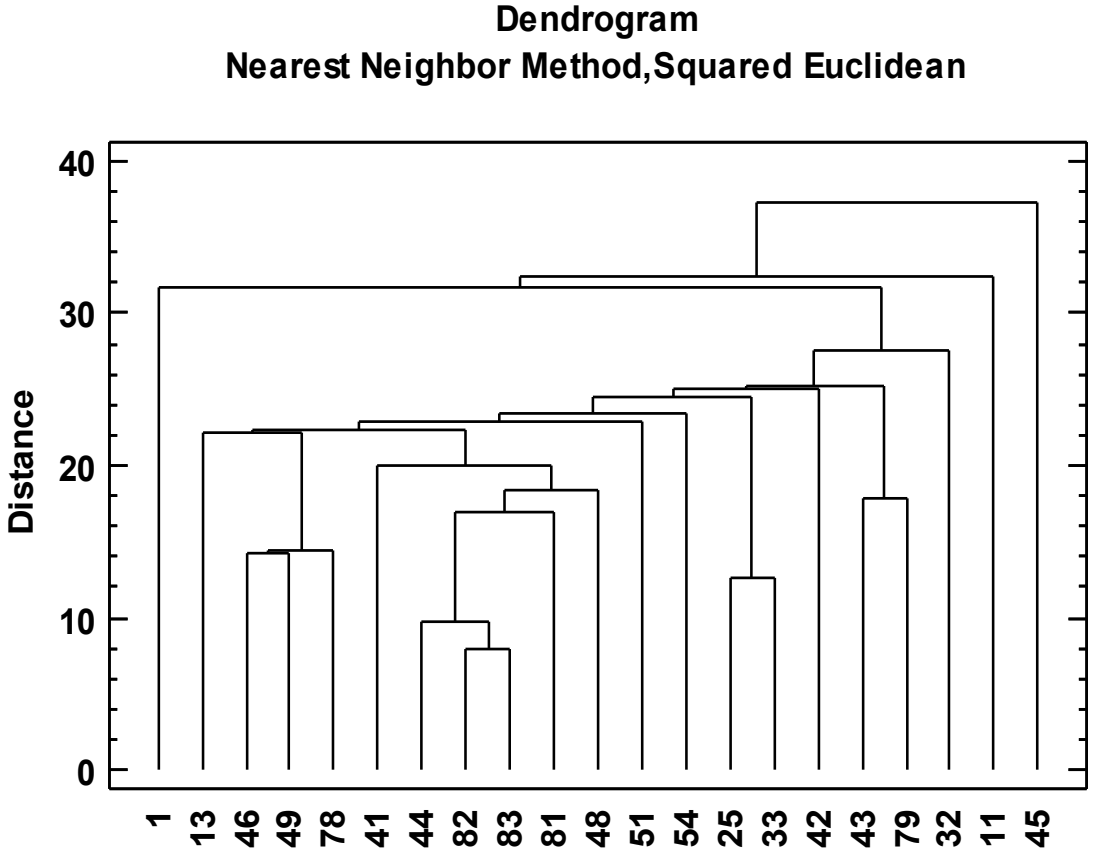

FIGURE 24- DENDROGRAM BASED ON UPGMA ANALYSIS GENERATED USING THE SQUARED EUCLIDEAN COEFFICIENT AMONG THE 21 SWEET POTATO ECOTYPES.

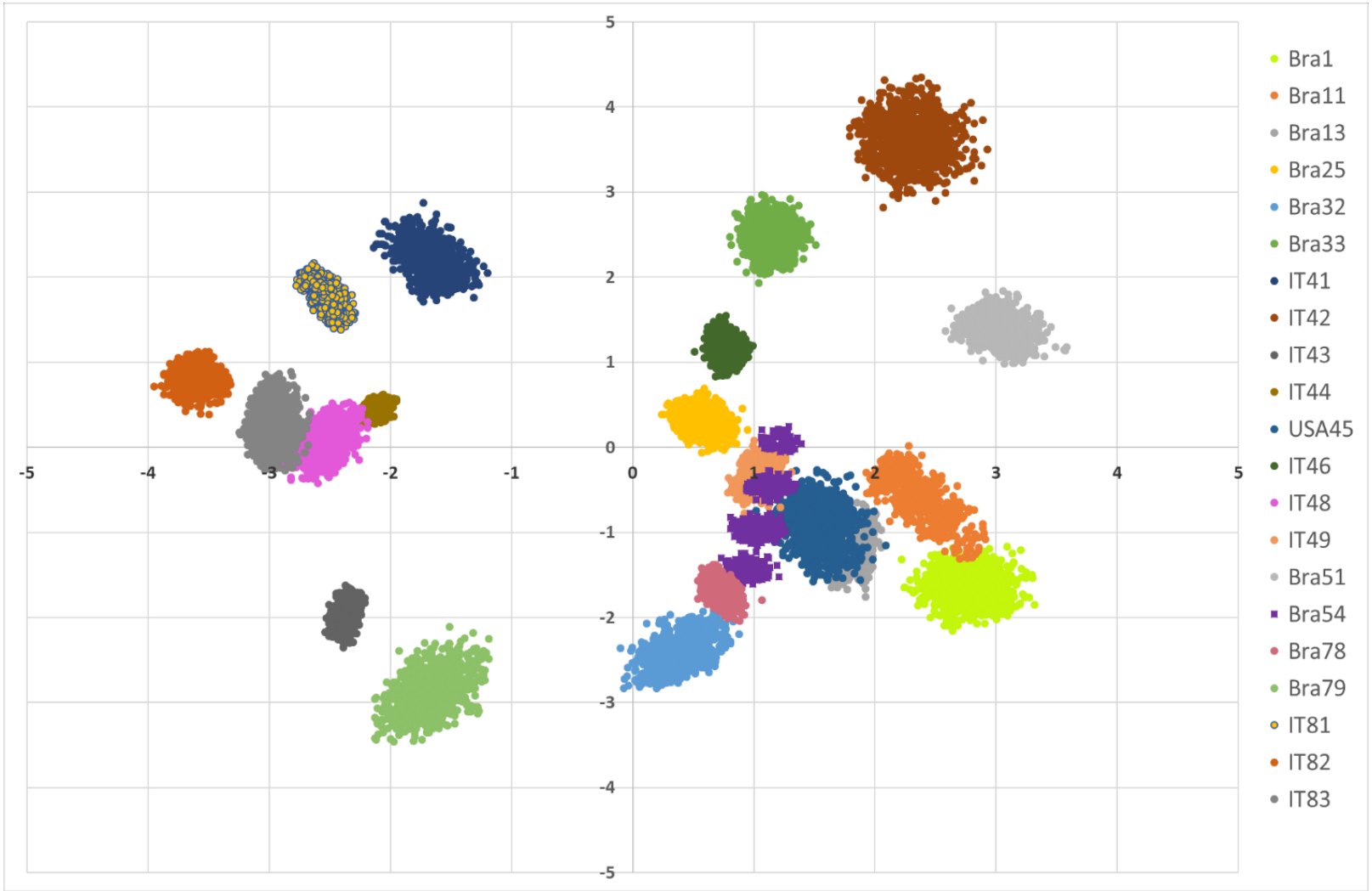

Figure 25. Principal component analysis (PCA) score plot of 21 sweet potato ecotypes

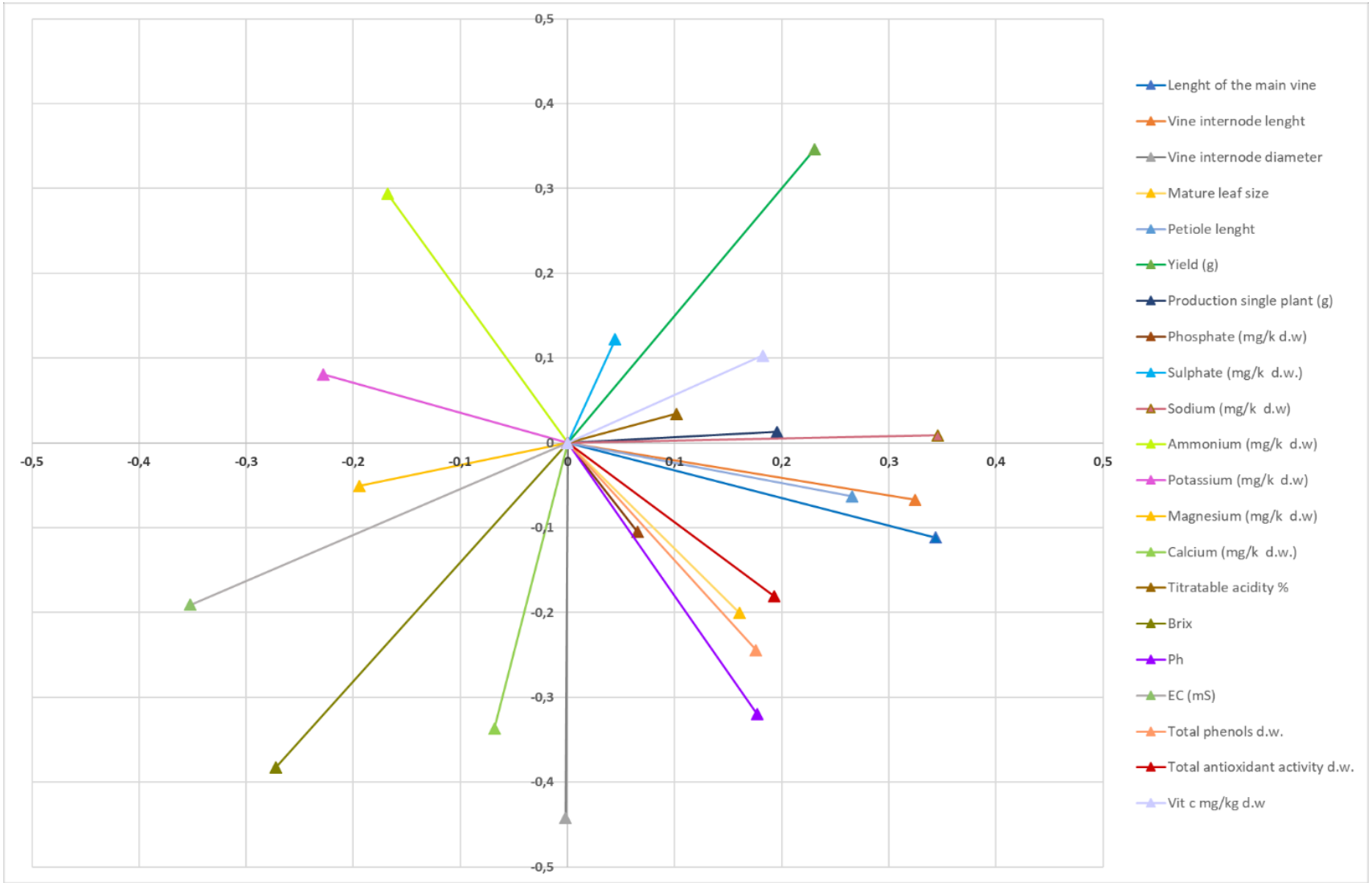

Figure 26. Principal component vectors

Discussion

To evaluate the agronomic and biochemical morphological characteristics of sweet potatoes provide a panorama that allows us to evaluate the best alternatives of cultivation for the needs of the Veneto region.

- Photographic analyse

The rate of soil cover by the aerial biomass is a crucial factor to evaluate since it interferes directly with the periodicity of the cultural treatments carried out in the crop. The faster the plant growth rate, the lower will be the costs of spontaneous plant management. Another advantage is that soil protection against the impact of raindrops and consequent erosion, in addition to maintaining moisture and evapotranspiration losses. Since all ecotypes were grown under the same conditions, the variations found are due to the intrinsic genetic differences of each material. This demonstrates that each has its thermal requirement and some as BRA51 and USA45 have adapted well to the temperate conditions of the region.

- Morphological descriptors

In the evaluation of the morphological descriptors, the shape of the roots was very variable, correlated with the data obtained by Camargo (2013) that found long elliptic roots (25%), oblong (22.5%) and long irregular roots (20%). However, Moulin et al. (2012) also found a high variability: round (8.7%), round elliptical (2.2%), oval (4.3%), long oblong (2.2%), long elliptic (6.5%) and long irregular (56.5%). The shape of the roots even being a character intrinsic to the genotype is conditioned to the growth conditions. When the soil is very dense and has a low permeability along with periods of high rainfall, the storage roots can be affected negatively.

The skin colour of sweet potato roots was slightly variable. Moulin et al. (2012) in a study with local genotypes from Rio de Janeiro, BR, also found little divergence for this descriptor: pink (84.4%), cream (19.8%), brownish orange (2.2%) and dark purple (2.2%). Nonetheless, Silva Ritschel and Huamán (2002) the white colour was predominant (41.22%), and other stains evaluated were pink (28.57%), red (20%), cream (7.76%) and red-purple (2.04%). The content of phenolic compounds and antioxidants influence the colour of flesh roots (Wu et al., 2015). The colour variations identified in the UNIPD genebank are five. Norman et al. (2014) evaluated eight

different phenotypes in the collection of Njala Agricultural Research centre in Sierra Leone: 29.4% white, 11.8% cream, 11.8% orange intermediate, 23.5% pale orange, 5.8% pale yellow, 5.9% dark orange, 5.9% purple and 5.9% dark yellow. In Camargo (2013), the predominant colour of the roots was light cream (35.5%) and white (27.5%)

- Production Yield

According to Vargas et al. (2017), the productivity of sweet potato can be influenced by several environmental factors as well as by the genetic load. The ecotypes coming from Brazil had an adequate development in the Veneto region. The BRA11 accesses had productive performance twice the commercial genotype IT41. These values are around 328% higher than the world average of productivity (FAOSTAT, 2018) demonstrating the high possibility of adaptation of foreign genetic materials to the Mediterranean climate and their propensity to use a genetic improvement program.

For the commercialisation of roots for the consumption in nature, the classes of more significant interest are the A and B. Some landraces had inferior performance to IT41, however much of the foreign ecotypes and with flesh colour show superior to this factor. However, the climatic conditions can significantly influence crop performance, as stated by Nicoletto et al. (2017), who studying the sweet potato in the Veneto region observed substantial differences in the response of the crop to climatic intemperate. Also, we can point out the differences in production cycles between ecotypes, denoting precocity of some ecotypes.

- Multivariate analyses

According to the clustering analysis for the analysed descriptors, the accesses are not grouped by origin or by colour. We can verify that even materials from very distant geographical regions can have many similarities between them. The high phenotypic variability of the accessions was also confirmed by Norman et al. (2014). However, Tairo et al. (2008) found dissonant data for a Tanzania germplasm collection, and they separated into only two groups the 127 accessions analysed. According to the dendrogram, it was possible to detect only two possible duplicates, IT82 and IT83. Also, Silva Ritschel and Huamán (2002), analysing 324 accessions of sweet potatoes from the Embrapa germplasm bank collected in all regions of Brazil, found a low incidence of duplicates within the collection. Possibly, due to the self-incompatibility of the species

that leads to cross-fertilisation, a condition that generates high heterosis in the species (Silva, 2010).

The analysis of the first two principal coordinates explained only 32.7% of the dissimilarities, which according to Silva Ritschel and Huamán (2002) indicates the progressive distribution of variability, where the formation of groups close to each other occurs.

It was possible to observe the formation of the same number of groups by the different analyses, but there was differentiation of clusters. The differences between the multivariate analyses were observed in several other works (Augustin et al., 2000; Camargo, 2013; Faria et al., 2012; Norman et al., 2014; Veasey et al., 2008) since the techniques use different criteria of grouping. However, some ecotypes had the same behavior (clustering) in the two analyzes, such as IT43 and BRA79, that with high soluble solids content (11.4 and 11.6, respectively), these values corroborate with the data found by Wassu Mohammed (2015) and Moulin (2010) but are higher than those found by Suarez et al. (2016) e George et al. (2002), which denotes the wide variability of this character and is therefore an intrinsic characteristic of each genotype and low contribution to genetic divergence, as demonstrated by Gonçalves Neto et al. (2012) and Oliveira et al. (2000). The BRA25 and BRA33 accesses are having similar biochemical characteristics, and are morphological neighbours, differing by the shape of the roots. The ecotypes IT41, IT44, IT82, IT83, IT81, and IT48 belong to the agro-climatic zones nearby, probably the narrowing of genetic variability is due to the exchange of cuttings among the farmers or asexual propagation of the species.

For genetic improvement of the species, the choice of parents with high genetic divergence produces the maximum segregation of the characters. In general, the breeding is associated with human consumption; however, sweet potatoes have multiple uses, such as animal feed or the production of biofuel (Camargo, 2013; Neto et al., 2011). In general, the descriptors that most influence the determination of the selection of parents are flesh colour and yield, but the percentage of starch and aerial biomass production can affect the decision. We can note the dual aptitude of some access such as IT46, BRA11, and BRA51 (Camargo, 2013).

Insufficient vitamin A intake may lead to partial or total blindness, especially in pre-school children and many studies have already demonstrated the efficiency of sweet potatoes in combating malnutrition and prevent of the blindness in areas of extreme poverty (Islam et al., 2016; Laurie et al., 2015; Mohanraj and Sivasankar, 2014;

Tumwegamire, 2011). Wu et al. (2015) related in your work the antitumoral property about the purple sweet potato. In our observations, we detected some ecotypes enabled to the improve the contents of this substances, as BRA1, BRA25, BRA32, BRA33, BRA54, BRA79 and USA45.

Each genotype has its growth requirement, and for example, BRA51 and USA45 have superior performance in the temperate conditions of the region. It is possible to state that the plant is the ability to close the inter-row fast is higher in the Brazilian genotypes than those traditionally used. This means that there are genotypes able to counteract the growth of weeds, excluding competition to the resource.

We do not observe a correlation between geographic regions and genetic distances. The morphological, agronomic and biochemical analyses provided with the necessary tools for clustering the ecotypes. The genotypes BRA1, BRA11, and USA45, are suggesting breeding with other accesses.

Nutrient content and daily recommendation intake of several accessions of Ipomoea batatas (L.) for improving sweet potatoes European market.

Sweet potatoes are potentially a reliable source of energy. The roots contain about 30% dry matter, of which 80-90% are carbohydrates (Tab. 13). However, the total composition varies between cultivars, harvest season, cultivation system and storage (Woolfe, 1992). A study by Foloni et al. (2013) showed that doses of combined N and K increase crop productivity. Tang et al. (2015) show that potassium deficiency significantly interferes with root productivity. Queiroga et al. (2007) evaluated a considerable influence of the harvest season on sweet potato yield.

TABLE 13 - COMPOSITION OF 100 G OF FRESH SWEET POTATO.

Component	Unit	Sweet potato
Moisture	%	70
Total Carbohydrates	g	26,1
Protein	g	1,5
Lipids	g	0,3
Calcium	mg	32
Phosphorus	mg	39
Iron	mg	0,7
Digestible Fibers	g	3,9
Energy	kcal	111

font: Woolfe, 1992

Another preponderant aspect is the high contents of phenolic compounds and antioxidants. They function as a cell cleanser and make detoxification of the free radicals. Although they are present in all genotypes, countless studies report the high amount of anthocyanins in the purple pulp varieties (Ji et al., 2015; Padda and Picha, 2007; Teow et al., 2007). Anthocyanins present in vegetables, flowers, and fruits, are a group of pigments with the blue, purple and red colour. Many foods and plants can be

used to extract these pigments. However, Hwang et al. (2011) report that anthocyanins extracted from sweet potatoes have high stability conferring to this food a source of these compounds. A large part of the anthocyanins is connected to protection against colon tumors (Hagiwara et al., 2002); decreased risk of neurological diseases (Ye et al., 2010) protective hepatic effect (Sun et al., 2014), inhibition of cell tumors and regulator of glucose levels (Salawu et al., 2015; Zhao et al., 2013).

Insufficient intake of nutrients is a primary concern of countries in Africa and Asia. Vitamin A deficiency affects 190 million school-aged children and an additional 19 million pregnant women, and is, therefore, essential for public health in countries with scarce resources (WHO, 2012). The lack of this vitamin can affect the retina and lead to irreversible blindness, in addition to reducing the growth and prejudice in the development of the immune system, increasing the risk to infections, and consequently of mortality (Kurabachew, 2015). The nutritional status of pregnant and breastfeeding women directly affects the development of the fetus and neonates (Islam et al., 2016), seropositive mothers with vitamin A deficiency are more likely to transmit HIV from mother to child (Semba et al., 1994). Carotenoids are pigments present in plants that give them orange, yellow or red colour. Among them is β carotene that has a significant conversion factor in vitamin A (Burri, 2011). Sweet potato genotypes with orange pulp are rich in β carotene and may set an option for the supplementation of this vitamin.

Biofortification consists of strategies to increase nutrient content in plants. The selection of genetic materials with high nutritional indexes is an easily accessible technique in countries with scarce resources. The sweet potato is a crop of high elasticity and resilience because it adapts readily to diverse edaphoclimatic conditions and crop systems with low technology. Alling that and to great productive capacity, this culture seemed to have conquered the world, like a staple food.

Thus, the present study aimed to evaluate the content of nutrients and nutraceuticals compounds inside twenty-nine accessions of sweet potatoes, to evaluate either production and quality about colour, and introduce new accessions in Europe. So, to identify valuable compounds present in these plants is necessary for the food and breeding industries.

Materials and methods

- Plant material

Twenty-nine sweet potato accessions were used in this study. The field trials were planted at l'Azienda Agraria Sperimentale "L. Toniolo " of Università degli Studi di Padova in Legnaro, in 2016. The propagation material used in the experiment was obtained from genetic bank of the Padova University. In January 2016, sweet potato cuttings were produced by pot in the greenhouse with a temperature of 25 °C and 18 °C during the day and night, respectively. Roots about 40 mm to 80 mm in diameter, were used to produce cuttings, the substrate used for the bedding is (Klasmann® n°4). In May, the cuttings were suitable for transplanting (0.30–0.35m tall) and the that was manually realised. Cuttings were planted 0.10m deep on the built-up rows spacing the plants 0.35m apart in the row. After transplanting, about 100 mL of water was provided for each cutting. Concerning irrigation during the growing cycle, sweet potato crop was irrigated three times providing about 30mm for each irrigation. Sweet potatoes were harvested commercial size at September 29-2016.

- Extraction of phenols for analysis

Freeze-dried samples (1 g) were extracted in methanol (20 mL) with an Ultra Turrax T25 (IKA-Labortechnik, Staufen, Germany) at 1018 g until a uniform consistency was achieved. Samples were filtered (589 filter paper; Whatman, Germany) and appropriate aliquots of extracts were assayed by Folin–Ciocalteau (FC) reagent for total phenolic (TP) content and by the ferric reducing antioxidant power (FRAP method) for antioxidant activity.28 For HPLC analyses, extracts were further filtered by cellulose acetate syringe filters (0.45 μm porosity).

- Determination of TP content by the FC assay

The content of TP was determined by the FC assay29 with gallic acid as a calibration standard, using a UV-1800 spectrophotometer (Shimadzu, Columbia, MD, USA). The FC assay was carried out by pipetting 200 μL of sweet potato extract into a 10-mL test tube, followed by the addition of FC reagent (1mL). The mixture was vortexed for 20–30 s and 800 μL of filtered 20% sodium carbonate solution was added within 1–8 min after

the FC reagent addition. The mixture was then vortexed for 20–30 s (time 0). After 2 h at room temperature, the absorbance of the coloured reaction product was measured at 765 nm. The TP content in extracts was calculated from a standard calibration curve obtained with different concentrations of gallic acid, ranging from 0 to 600 µg mL–1 (correlation coefficient: r2 =0.9992). The results are expressed as mg gallic acid equivalent (GAE) kg–1 dry weight.

- Determination of total antioxidant activity by FRAP

Freshly prepared FRAP reagent contained 1 mmol L–1 2,4,6-tripyridyl-2-triazine and 2 mmol L^{-1} ferric chloride in 0.25mol L–1 sodium acetate (pH 3.6). A methanol extract aliquot (100 µL) was added to FRAP reagent (1900 µL) and accurately mixed. After leaving the mixture at 20 ◦C for 4min, absorbance was determined at 593 nm. The calibration was performed with a standard curve (0–1200 µgmL–1 ferrous ion) (correlation coefficient: r2 =0.9985), obtained by the addition of freshly prepared ammonium ferrous sulfate. FRAP values were calculated as µgmL–1 ferrous ion (ferric reducing power) from three determinations and reported as mg kg–1 of Fe2+ (ferrous ion equivalent) of dry matter.

- Extraction and determination of ascorbic acid

Ascorbic acid was determined in accordance with a standard method (ISO 6557/2, 1984). Sweet potato freeze-dried samples (1 g) were homogenized until a uniform consistency was achieved with an Ultra Turrax in 20mL of meta-phosphoric acid and acetic acid solution. As a colourant reagent, a solution of 2,6-dichlorophenolindophenol was employed. After adding xylene and 3min of centrifugation at 2236 g, samples were measured with a UV-1800 spectrophotometer (Shimadzu) at a wavelength of 500 nm.

- Quantitative determination of sugars by HPLC

Sweet potato root freeze-dried sample (0.2 g) were homogenised in demineralised water (20 mL) with an Ultra Turrax T25 until a uniform consistency was achieved at 1018 g. Samples were filtered in sequence through filter paper (589; Schleicher), and the extracts were further filtered through cellulose acetate syringe filters (0.45 mm) and analysed by HPLC. The liquid chromatography apparatus utilised in this analysis was a

Jasco X.LC system consisting of a model PU-2080 pump, model RI-2031 refractive index detector, a model AS-2055 autosampler and a model CO-2060 column. ChromNAV Chromatography Data System software was used for the analysis of the results. The separation of sugars was achieved on a Hyper-Rez XP Carbohydrate Pb++ analytical column (7.7 × 300 mm; Thermo Scientific, Waltham, MA, USA), operating at 80 ∘C. Isocratic elution was effected using water at a flow rate of 0.6mL min–1. D-(+)-glucose, D-(–)-fructose and maltose were quantified by a calibration method. All standards utilised in the experiments were accurately weighed, dissolved in water and the calibration curves were generated with concentrations ranging from 100 to 1000mg L–1 of standards.

- Quantitative determination of ions by IC and organic nitrogen

For the estimation of anions and cations freeze-dried sample (200 mg), was extracted in water (50 mL) and shaken at 150 rpm for 20 min. Samples were filtered in sequence through filter paper (589 Schleicher), and the extracts were further filtered through cellulose acetate syringe filters (0.20 mm) before analysis by ion chromatography (IC).

The IC was performed using an ICS-900 Ion Chromatography system (Dionex Corporation) equipped with a dual piston pump, a model AS-DV autosample, an isocratic column at room temperature, a DS5 conductivity detector and an AMMS 300 suppressor (4 mm) for anions and CMMS 300 suppressor (4 mm) for cations. Chromeleon 6.5 Chromatography Management Software was used for system control and data processing. A Dionex Ion-Pac AS23 analytical column (4 mm×250 mm) and a guard column (4 mm×50 mm) were used for anion separations, whereas a Dionex IonPac CS12A analytical column (4 mm×250 mm) and a guard column (4 mm×50 mm) were used for cation separations. The eluent consisted of 4.5 mM sodium carbonate and 0.8 mM sodium bicarbonate at a flow rate of 1 mL/min for anions and of 20 mM metansolfonic acid for cations at the same flow rate. Anions and cations were quantified following a calibration method. Dionex solutions containing seven anions at different concentrations and five cations were taken as standards, and the calibration curves were generated with concentrations ranging from 0.4 mg L^{-1} to 20 mg L^{-1} and from 0.5 mg L^{-1} to 50 mg L^{-1} of standards respectively. The Kjeldahl method (ISO1656) was used for organic nitrogen.

- Pigment determination

Chlorophyll a, b and xanthophylls + carotenoids were determined with the method reported by Welburn and Lichtenthaler (1984) and the following formulas where A is the absorbance: Chla = (13.95×A665)−(6.88×A649); Chlb = (24.96×A649)−(7.32×A665); Xan + Car = [(1000×A470)−(2.05×Chla)−(114.8×Chlb)]/245. Results are expressed in _g g−1 fw.

- Starch

OAC Official Method 996.11 Starch (total) in cereal products. AOAC Official Method 979.10 Starch in Cereals. University of Florida, IFAS, Bulletin 339-2000 “Starch Gelatinization & Hydrolysis Method” Boehringer Mannheim, Starch determination, cat. N ° 207748. A method adapted for chromatographic analysis.

- Sweet potato contribution to Daily Value

The contribution of sweet potato to the DV for Vitamin A, Vitamin C, potassium, phosphorus, calcium, and magnesium was calculated by assuming an intake of 100 g fresh sweet potato storage root per day. The values of requirement diary intake (RDI) are: 400 µg retinol (coefficient factor: 12 beta-carotene:1 retinol (USDC, 2010), vitamin C 80 mg, potassium 2000 mg, phosphorus 700 mg, calcium 800 mg and magnesium 375 mg (DIR.CE 2008/100). For each data value, the corresponding percent DVSP was calculated by the following formula: Sweet potato contribution to Daily Value = nutrient content in 100 g (fw)*100/RDI.

Results and discussion

Roots of sweet potatoes are generally stored before the commercialisation to increase their sweetness index, so the content of the main metabolic sugars such as glucose, sucrose, and fructose can be influenced either by post-harvest condition or by the specific physiology of every accessions. Indeed, sugar composition is specific to every accession however sucrose and starch play a central role in considering the post-harvest behaviour and the taste of the produce. Moreover, sugar composition can be further modified by the cooking procedure (Van den et al., 1986).

Glucose content in storage roots ranged from 4.40 to 46.73 g kg^{-1} dw (Fig. 27). The higher values were found in BRA51, BRA30 and HON86 with values 10-fold higher than the lower one (IT44). Our results of row produce showed that BRA66 had 4-fold higher content of sucrose (149.53 g kg^{-1} dw) compare to the lowest one USA45 (36.43 g kg^{-1} dw)(Fig.28). BRA51 showed the higher values of fructose, followed by HON86 and IT42. Accessions with the lowest content of fructose were found for the CFSP, and WFSP such as IT81, IT44 and IT84 with values ranged from 3.67, 3.76 and 4.42 g kg^{-1} dw, respectively (Fig.29).

As reported by Bovel in 2016 there is a strong correlation between monosaccharides and coloured fleshed of sweet potatoes. *Indeed,* four breeding lines, and five commercial varieties of SPs, analysed by Lewthwaite et al. (1997), showed that orange flesh SPs had the higher content of glucose and fructose compared to the others. Alike, Nabubuya (2012) detected a decreasing trend of the content of sucrose linked to the colours: the white fleshed SP (WFSP) ensued to OFSP, and yellow fleshed sweet potato (YFSP). Furthermore, an opposite trend was detected for the glucose and fructose content, as well. Moreover, sucrose content is a physiological signal for the formation of storage roots because this is a trigger of several genes involved in tissue differentiation. Besides, sucrose is loaded inside storage cells, and it is converted to hexoses inside amyloplasts and stored as starch (Ravi et al., 2009). Cervantes-Flores et al. (2011) claim that varieties of sweet potatoes with orange fleshed have lower concentrations of starch. According to them, the concentration of starch and the amount of β-carotene are inversely proportional, most likely because these two substances compete for the synthesising sites in the plastids. As reported in table 14, the starch percentage of sweet potato ecotypes ranging from 91.3% to 52.3%. The data of this study agree with Cervantes-Flores et al., and the lower starch value was recorded for an orange accession HON86.

Low content of soluble sugars makes the retrogradation of starch slow, improving the texture after cooking Kohyama and Nishinari (1991). The genotypes with lower total sugars content were BRA33, USA45, and IT48 thus, these accessions could be used by food processing industry, because the low content of soluble sugars increases the shelf life as reported by Chang and Liu, 1991 and Germani et al., 1983. Moreover, the high amount of sugar can affect the final colour and the texture of food. Indeed, high levels of simple sugars can interfere with the starch hydration due to the competition with the starch for free water in the flour-water system. Free sugars during cooking at high

temperature interact with proteins and confer brown colouration during the process of caramelisation. Furthermore, the dehydration of the carbohydrates at high temperatures provides characteristic colour and flavour. Therefore, thanks to the ration among sugars: BRA51, HON86, BRA32 and IT43 could be suitable for fried production.

Therefore for the food industry is vital to consider the ratio among sugars and the content of starch because it changes the chemical-physics properties of the food. The varieties with high starch content, low total sugar and high dry matter content are suitable to fry, roasted or baked (Nabubuya, 2012). So, could say that USA45 and BRA33 have the interesting characteristics to fresh consumption.

Moreover, cooking methods influenced nutrient retention of raw SPs such as phenolic compounds, vitamin C or carotenoids, therefore this aspect should be considered for the estimation Sweet potato contribution to Daily Value, indeed several studies demonstrated that high retention of total carotenoids is reached by using an oven drying with a range of losses from 10 to 4 % compared to the raw materials, followed by boiling and frying with loss of carotenoids from 15% to 10% and 23% to 15%, respectively (Vimala et al., 2011).

The phenolic compounds are connected to protective effects against the mutagenic activity and free radicals (Rumbaoa et al., 2009; Yamada and Tomita, 1996). Indeed, regular consumption of food reach of phenols fruits and vegetables can be enough to prevent a several of diseases, like cardiac pathology, cancer, and infections.

The heating can affect the content of the phenolics compounds and antioxidant because during the thermal process the temperature affects the cells structure that releases pigments from the cell wall (Huang et al.27). In fact, Nicoletto et al. (2018) measured the effect of the cooking process on the traits quality of SP and them proved an increase of the total phenol and antioxidant capacity content after the cooking. For example, the fried samples had 78% higher antioxidants content than raw samples.

Fig.30 presents the total phenolic contents (TPC) and total antioxidant activity (TAA) of row produce of sweet potatoes, expressed in dry weight. Phenolic content ranged between 0.87 and 6.44 g GAE kg^{-1} dw. TPC of these four purple ecotypes was about 2-5 times higher than other genotypes. Besides, the TAA of sweet potato roots decreased from purple fleshed>white fleshed> orange fleshed> cream fleshed. Padda and Picha (2008b) compared the phenolic and antioxidant activity from 14 SP varieties and found the similar range of colour variance of the content among the accesses. Indeed, the

higher antioxidant activity was detected in purple fleshed genotypes USA45, BRA1, BRA25 and BRA79 with 6.70, 4.65, 3.56 and 2.56 g $Fe^{2+}E\ kg^{-1}$, respectively. Our results agree with previous studies, where PFSW had a higher amount of phenolic compounds (Cevallos-Casals and Cisneros-Zevallos, 2003; Padda and Picha, 2008; Teow et al., 2007). PFSP showed the higher amount of these compounds and the lower content was recorded in CFSP and WFSP. The phenolic content differences among genotypes may be addressed to genetic variability. The vegetables with red or purple-blue colour had elevated quantities of phenolic compounds and antioxidant, and the level content of some ecotypes of SPs are compared with the strawberries and blackberries (Cevallos-Casals & Cisneros-Zevallos, 2003).

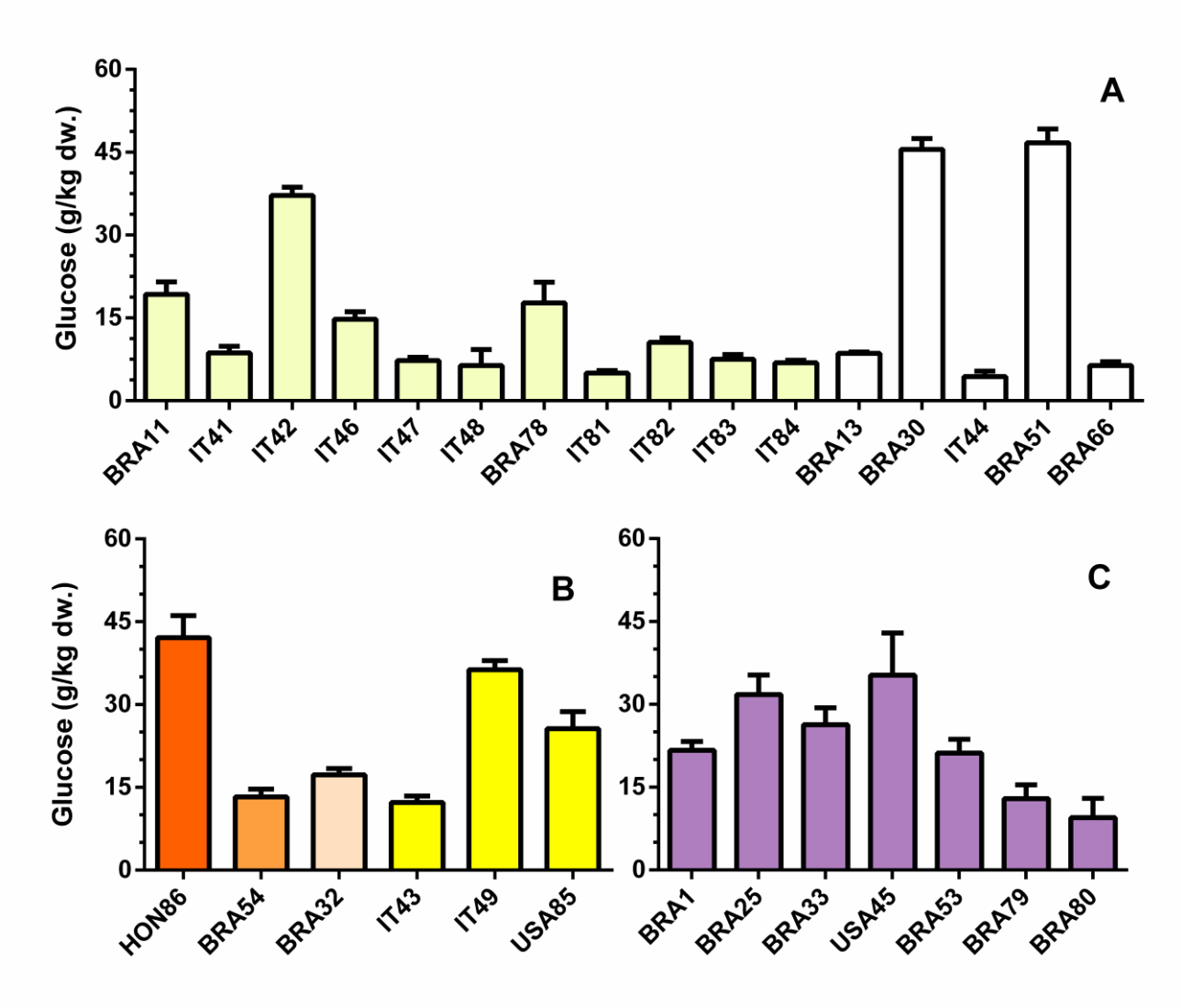

FIGURE 27 - GLUCOSE CONTENT IN SWEET POTATO GENOTYPES. A) WHITE/CREAM FLESH; B) ORANGE/YELLOW FLESH; C) PURPLE FLESH.

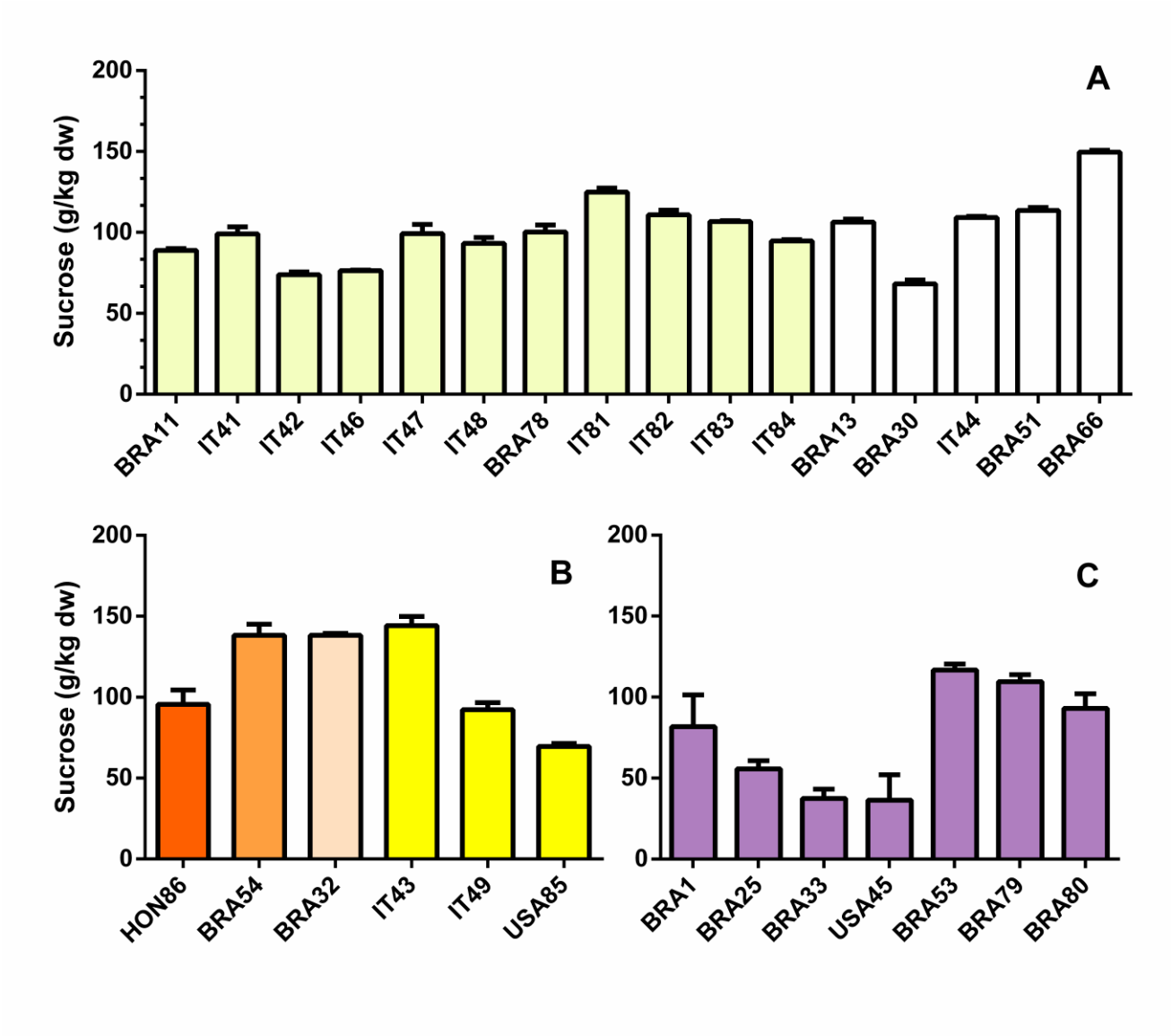

FIGURE 28- SUCROSE CONTENT IN SWEET POTATO GENOTYPES. A) WHITE/CREAM FLESH; B) ORANGE/YELLOW FLESH; C) PURPLE FLESH.

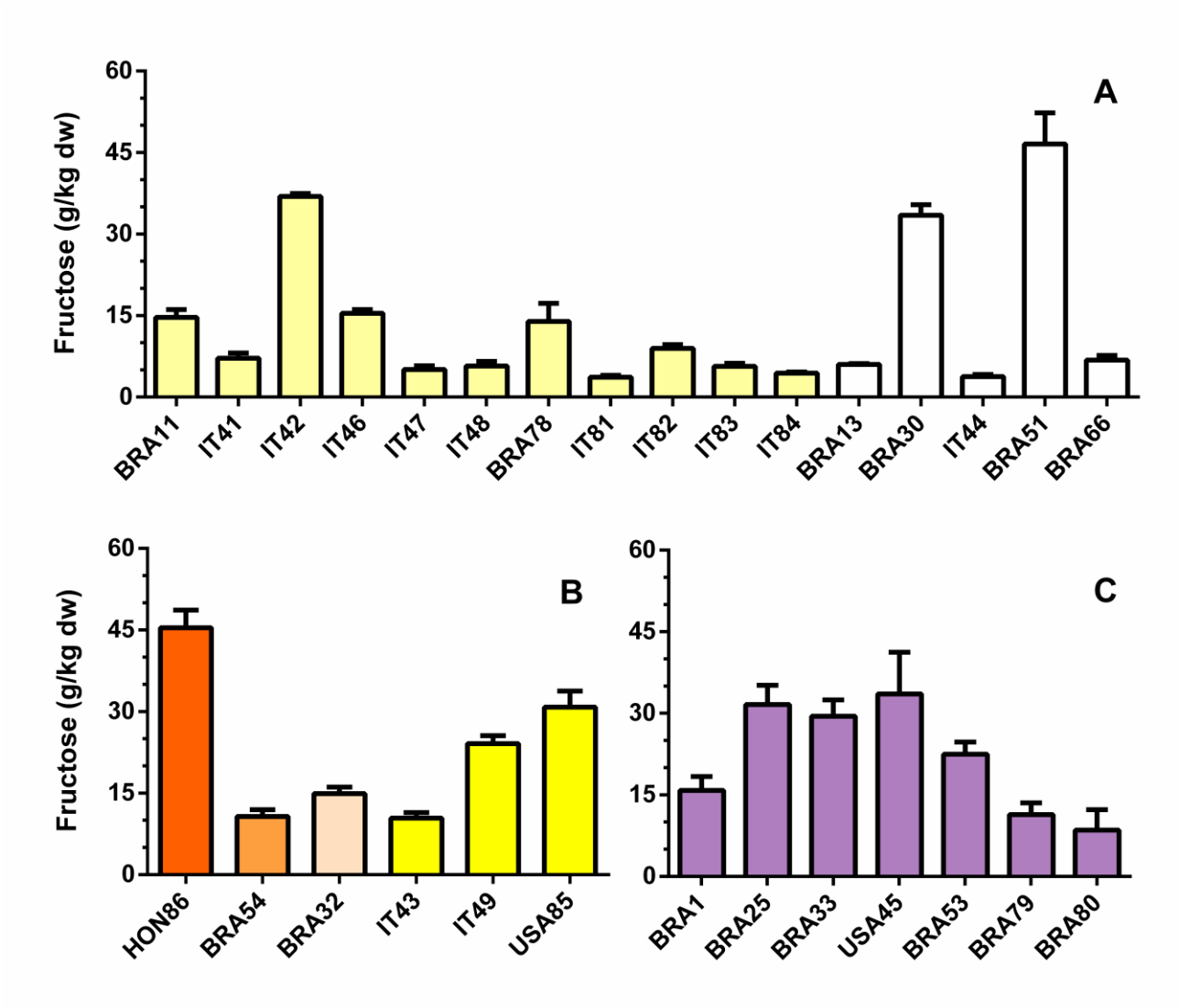

FIGURE 29- FRUCTOSE CONTENT IN SWEET POTATO GENOTYPES. A) WHITE/CREAM FLESH; B) ORANGE/YELLOW FLESH; C) PURPLE FLESH.

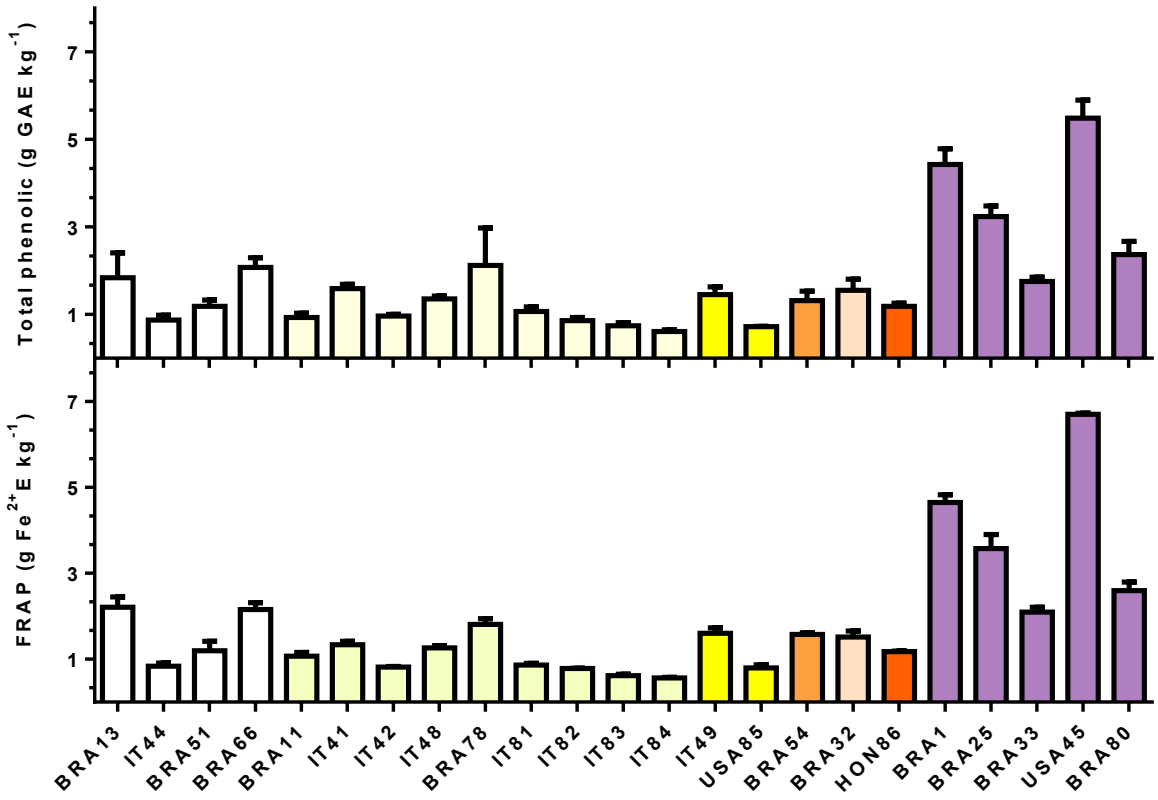

FIGURE 30- TOTAL PHENOLS CONTENT AND TOTAL ANTIOXIDANT ACTIVITY OF SWEET POTATO GENOTYPES

TABLE 14 - DRY WEIGHT AND STARCH PERCENTAGE OF SWEET POTATO GENOTYPES

Genetic Materials	%Starch	%Dry weight	Genetic Materials	%Starch	% Dry weight
Bra 6	63,6	41,5	IT49	79,5	30,4
Bra13	64,6	32,3	IT43	n.a	33,2
Bra30	69,5	30,7	USA85	60,1	35,9
Bra51	69,6	29,5	Bra32	71,8	32,0
IT44	78,9	36,8	Bra 54	77,9	36,6
Bra78	69,8	41,8	Hon86	52,3	35,9
IT84	69,9	39,6	Bra53	70,5	34,3
IT81	72,2	36,2	Bra79	71,2	37,2
Bra11	72,4	34,7	Bra25	71,6	35,9
IT42	72,6	34,3	USA45	81,4	35,9
IT82	73,4	33,9	Bra33	82,5	35,9
IT83	76,8	39,5	Bra80	74,4	43,1
IT41	82,9	36,6	Bra1	69,5	35,9
IT48	89,2	40,4			
IT47	91,3	35,7			
IT46	n.a	34,2			

According to WHO the inappropriate intake of minerals is one of the main risk for health worldwide. In some countries this factor is intensified because of the resources shortage, becoming a leading concern to the public health. In 2000, malnutrition caused 3.7 million deaths and a high correlation between children malnutrition, and daily household income is widely known. Family living with 2 $ per day has 2-3 times less risk of childhood malnutrition than the family living with 1 $30. The diary intake of the food with a high amount of antioxidants, phenolic content and vitamins could be an alternative strategy to their shortcoming.

The World Health Organization and National Institute of Health (USA) have the guidelines about nutrients ingest and the level of necessary intake to satisfy the demand of nutrients healthy individuals. The recommended daily intake (RDI) is the levels of nutrients that a person would need to ingest to stay healthy, are defined by age and sex of the individual. The % Daily Value indicates the content of nutrients has in one serving of the food.

Table 15 represents the contribution of the nutrients (%) intake of the 100 g of the sweet potato. Phosphorus has a role in the metabolism of the carbohydrates and fats. Also,

his take part in the ATP molecule makes it indispensable for the human body. The higher levels of the phosphorus contribution were found for USA45, IT43, BRA53 and BRA 54. For potassium Sweet potato contribution to Daily Value, 100g of raw SP may provide kind of 21% of the daily needs. The lowest values belong to the clearer colour ecotypes (cream, pale yellow or orange). Instead, the accessions with pale colours had the highest Sweet potato contribution to Sweet potato contribution to Daily Value for the potassium. Potassium participates in osmoregulation of cells, and its absorption to the body is about 90% (Stone et al., 2016). According to Instituto Nacional de Saúde Ricardo Jorge", Portugal, the SP do not have significant phosphorus and potassium losses during the cooking.

The same behaviour was observed for the magnesium contribution, though the ecotypes with the lowest Sweet potato contribution to Daily Value were IT42, BRA11, BRA33 and BRA32, 10.33%, 13.45%, 13.95% and 14.03%, respectively. The calcium Sweet potato contribution to Daily Value ranged between 6.7% and 12.96%. Except for IT84, ecotypes from Brazil had the highest levels of the Sweet potato contribution to Daily Value (BRA80, BRA54, BRA79, HON 86 and USA85). Vitamin C is an essential antioxidant that protects the cells about free radicals damages. Also, it relates to the synthesis of collagen and the iron absorption. The assimilation of Vit C is elevated and, 70-90% is absorbed during digestion (World Health Organization, 2009). The Vitamin C Sweet potato contribution to Daily Value exerted the high variation among the ecotypes analyzed with values ranging from 29.49% to 222.1%. The CFSP and PFSP are the higher supply of Vit C Sweet potato contribution to Daily Value.

Vitamin A is a group of compounds fat soluble that including retinol, retinal and some esters. It has a fundamental role in the visual system, immunity, and maintenance of the cells function. The body needs a small amount but can not synthesise it. The demands are more critical in infancy, adolescence, and pregnancy/lactation (Almeida and Penteado, 1988). Prevalence of Vitamin A deficiency is an important matter to the underprivileged population, and further in limited-resource countries. Despite the losses due to the cooking process, about 26% (Huang et al., 1999), the were OFSP evaluated showed the higher contribution to the Sweet potato contribution to Daily Value. These results are in agreement with Burri (2011); Huang et al. (1999) and Tumwegamire et al. (2011)

Regarding the Sweet potato contribution to Daily Value contribution to Vit A, some genotypes did not have relevant values. However, the ecotype HON86 was observed

with the highest Sweet potato contribution to Daily Value, 3830%. The white fleshed ecotypes had the lower contribution among the accessions with 20%, 21% and 58%. Thus, the accessions with the cream or light orange pulp had the intermediate levels.

Therefore, SP can be a considerable resource for that population. For example, Burri (2011) calculates how much one person needs eat of sweet potato to supply the requirement of Vit A, and to satisfy 100% needed just enough half cup of OFSP.

Thereby, data from this study assign the consumption of SP could help the intake of P, K, Mg, Ca, Vit C and Vit A, in particularly OFSP and PFSP has a significant contribution to human provide about antioxidants and vitamin. Sweet potato is considerate a staple food and breeding it to biofortification and enhance the nutrients values, could be the key to enrich the dietary population in many regions. In Europe, the growing demand for this product has attracted farmers, that are now looking for new opportunities.

The crop production in temperate zones is quite recent, and the research is scarce. This study tries to give guidelines for more profound work and to expand the production of sweet potatoes in Europe. A depend on the purpose we can highlight some interesting genotypes, for fresh consumption, the USA45 and BRA33 are an appropriate choice but depends on the consumer's preferences. For the process, food or industry alimentary has the great potential BRA33, USA45, and IT48.

TABLE 15 - PERCENTAGE VALUES OF GENOTYPES FOR CONTRIBUTION TO RECOMMENDED DAILY INTAKE (RDA) OF NUTRIENTS BASED ON 100 G FRESH SWEET POTATO ROOT CONSUMPTION PER DAY

Genetic Materials	Phosphorus	Potassium	Magnesium	Calcium	Vit C	Vit A
Bra1	16,34	9,53	14,19	8,55	209,80	n.r
Bra11	19,64	18,12	13,45	7,65	134,01	n.r
Bra13	15,84	11,84	22,75	8,00	119,16	n.r
Bra25	14,72	12,68	15,11	9,43	133,92	n.r
Bra30	10,15	9,07	17,86	9,23	n.r.	58,12
Bra32	11,26	12,95	14,03	9,19	188,30	540,64
Bra33	17,48	12,24	13,95	7,09	174,17	n.r
IT41	17,15	19,43	21,03	7,81	96,56	n.r
IT42	16,51	19,29	10,33	7,09	222,20	89,31
IT43	21,19	25,10	15,30	8,11	n.r.	n.r
IT44	20,19	14,82	26,12	8,85	77,81	n.r
USA45	21,69	13,23	23,19	8,11	29,49	n.r
IT46	14,08	17,44	18,69	7,04	n.r.	n.r
IT47	11,65	12,24	20,29	7,74	n.r.	n.r
IT48	12,32	13,70	21,57	8,94	103,67	n.r
IT49	10,68	13,64	21,32	6,78	52,71	131,63
Bra 51	13,64	13,87	16,17	6,70	142,21	21,05
Bra 53	20,94	15,36	15,82	9,88	0,00	n.r
Bra 54	20,47	12,21	25,59	12,02	104,66	435,65
Bra 66	18,42	22,09	25,13	9,31	119,59	20,62
Bra 78	19,85	14,32	26,22	9,45	65,62	n.r
Bra 79	18,38	22,58	18,25	11,52	n.r.	n.r
Bra 80	14,25	12,74	25,08	12,96	213,80	n.r
IT81	12,48	22,02	26,02	8,70	115,03	n.r
IT82	16,14	21,94	20,77	7,61	116,77	n.r
IT83	16,65	17,31	29,81	10,04	81,40	n.r
IT84	10,56	9,74	36,83	11,06	146,07	n.r
USA85	12,35	16,08	19,34	10,15	71,47	n.r
Hon86	17,46	21,36	20,96	10,23	110,99	3830,45

TABLE 16 – ABSOLUTE VALUES OF MINERALS CONTENT OF SWEET POTATO (MG/100 G DW).

Genetic Materials	Phosphorus	Potassium	Magnesium	Calcium	Vit c	beta carotene
Bra1	114,41	190,56	53,21	68,41	167,84	n.r
Bra11	137,50	362,31	50,42	61,24	107,21	n.r
Bra13	110,85	236,78	85,32	64,02	95,33	n.r
Bra25	103,02	253,60	56,65	75,43	107,14	n.r
Bra30	71,07	181,47	66,98	73,87	n.r	2,79
Bra32	78,81	258,96	52,61	73,52	150,64	25,95
Bra33	122,39	244,78	52,32	56,73	139,34	n.r
IT41	120,02	388,67	78,87	62,50	77,25	n.r
IT42	115,54	385,90	38,74	56,69	177,76	4,29
IT43	148,32	502,05	57,39	64,84	0,00	n.r
IT44	141,33	296,40	97,94	70,81	62,25	n.r
USA45	151,82	264,61	86,96	64,89	23,59	n.r
IT46	98,56	348,79	70,08	56,34	0,00	n.r
IT47	81,54	244,71	76,09	61,96	0,00	n.r
IT48	86,22	274,09	80,89	71,50	82,94	n.r
IT49	74,79	272,81	79,95	54,28	42,17	6,32
Bra 51	95,49	277,40	60,66	53,59	113,76	1,01
Bra 53	146,57	307,16	59,33	79,07	n.r	n.r
Bra 54	143,30	244,22	95,96	96,14	83,72	20,91
Bra 66	128,92	441,88	94,23	74,48	95,67	0,99
Bra 78	138,98	286,33	98,31	75,59	52,49	n.r
Bra 79	128,66	451,60	68,43	92,20	0,00	n.r
Bra 80	99,78	254,76	94,04	103,70	171,04	n.r
IT81	87,39	440,45	97,58	69,63	92,02	n.r
IT82	112,98	438,85	77,89	60,87	93,42	n.r
IT83	116,53	346,25	111,78	80,29	65,12	n.r
IT84	73,92	194,89	138,11	88,46	116,85	n.r
USA85	86,46	321,56	72,53	81,18	57,17	n.r
Hon86	122,20	427,12	78,60	81,82	88,79	183,86

Conclusions

The results obtained in this work allow concluding that the morphological, agronomic and biochemical characterisation was efficient to show the significant divergence between the accessions, being essential tools for the knowledge and use of the genotypes.

Furthermore, highlighted the possibility of cultivating them in the Veneto region with excellent results. It is difficult to identify the most interesting genotypes since there has been considerable variability both concerning production and quality.

Moreover, the response given by these new genotypes has highlighted their characteristics of growth and development. The genotypes with purple and orange fleshed pulp are potentially very interesting because the pulp pigmentation can have good contents of anthocyanins and β-carotene useful for health purpose.

Besides, we can say that the binodal cuttings can develop a good root system and to colonise the plug in a brief time, without spiralling root. The tray with 96 cells has led to the achievement of the highest yield, with the most significant production of first choice roots and a limited amount of non-standard marketable.

The ADRs application in the cultivation of sweet potato can support the crop production with a yield comparable with that obtained using the classical mineral fertilisation. T75 and T100 were the best solutions in the fertilisation management of the crop under the productive point of view. T75 treatment presented the highest N apparent recovery efficiency and utilisation efficiency. Under the qualitative point of view also the sugar quantity was affected by fertilisation with a concentration of glucose and fructose increase with the increase of the N amount supplied with ADRs.

These results make it possible to state which there is considerable potential both regarding production and quality for the cultivation of sweet potatoes in Italy. Some of the genotypes considered could find ample space in the Italian and European market. This perspective manifests itself as an alternative and an opportunity for local producers who traditionally cultivated this species providing an innovative, productive space potentially exploitable. It is hoped that for the European market the interest in these new genotypes will increase and with this, commercial demand will expand the national cultivation area.

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