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ORIGINAL RESEARCH ARTICLE

Commercial classification and physicochemical characterization of beets from a no-till vegetable planting system under different densities of corn stover

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ABSTRACT

The cultivation of sugar beet (*Beta vulgaris* L.) for table or horticultural purposes is largely carried out in the conventional way which is characterized by intense mechanization causing soil degradation and high labor costs. New cultivation techniques are being employed in the production of vegetables aiming to ensure improvements in environmental and economic conditions, such as the no-till farming system. Thus, the objective of this work was to evaluate the vegetable classification and physicochemical characteristics of beets from different corn planting densities. The experiment was conducted in the period from October 2018 to June 2019 in the municipality of Nova Laranjeiras (PR). Corn was used as a cover plant and the vegetable used was beet cultivar Early Wonder Tall Top. The experimental design used was in interspersed blocks in unifactorial scheme (corn densities 40, 60, 80, 100 thousand plants/ha and control) with four blocks, with plots 3.60 m long and 1.20 m wide. The parameters evaluated 60 days after planting were: commercial classification (class, group, subgroup, category), length, diameter, mass, pulp firmness, soluble solids, titratable acidity, pH and ratio, phenolic compounds. Of which the variables that were not significant at 0.5 probability were length, category (defects), firmness, subgroup (flesh color), soluble solids and phenolic compounds. It is concluded that high densities of corn as mulch for SPDH of sugar beet crop negatively affect the grade and physicochemical characterization of the products.

Keywords: *Beta vulgares* L.; SPDH; *Zea mays*; Vegetable; Cover crop

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1. Introduction

The table beet (*Beta vulgaris* L.) belongs to the Amaranthaceae family, and its probable center of origin is North Africa and Southern Europe[1]. The plant is characterized as a species of temperate climate; however, it has cultivars that allow its planting at all times of the year. The culture has a cycle that varies from 60 to 110 days after planting[2]. It has an average annual production of 96,798 tons[3], with an estimated productivity between 15 to 30 tons per hectare for Paraná[4].

The state's production yield has grown by about 80% in the last ten years. Among the main crops, sugar beet production stands out, being the eighth most produced vegetable in the state mainly in family farming regions[3]. Demonstrating the important role in socioeconomic development and encouraging research with the culture.

Sugar beet is traditionally grown in a conventional way, which concentrates the intensive use of mineral fertilizers, pesticides, irrigation and soil management[5]. With the intense and constant use of plowing and harrowing practices providing soil disruption, followed by a high demand for labor[6]. Therefore, it is essential to use technologies that provide product quality and are free of chemical residues[7].

The no-till vegetable cultivation system (SPDH) is a form of cultivation where the planting of a new crop is performed under the remains of the previous crop[8]. It aims to conserve soil and water, consequently reducing the use of inputs, such as agricultural machinery and irrigation, by maintaining soil cover with plant residues[9]. This contributes to the improvement of the physical structure of soils, maintains moisture, infiltration, porosity, permeability, density and holding capacity[10]. In addition, it provides control of spontaneous plants, and reduction of soil erosion[11]. Therefore, the system is considered an alternative to reduce the problems caused by conventional cultivation of various vegetables, including beets[12].

In SPDH, ground cover or mulch is fundamental because it precedes the main horticultural crop. Many materials can be used for this purpose, most of which have no direct commercial use. For example, the leguminous plants Crotalaria (*Crotalaria juncea*) and White lupin (*Lupinus albus* L.) enable high rates of biological fixation of atmospheric nitrogen, low C/N ratio, which favor the successor crop nutritionally[13]. And grasses such as corn (*Zea mays*) provide reduced nitrogen loss, high biomass production and persistence under the soil due to its slow straw decomposition[14].

The accumulated straw provides considerable amounts of nutrients, which vary according to the length of the cycle of return to the soil and the species used[15]. In addition, another important aspect is that with the use of corn, the predecessor crop is also commercial, in which case there is the possibility of commercialization or consumption of the cobs.

However, the persistence of the stubble in the soil is a factor that depends, besides the plant species used as cover, on the climatic conditions of the region, which makes it difficult to make a generalized recommendation of the crop to be used in SPDH. And yet, the effect of corn-based ground covers on the plant classification and physicochemical characteristics of sugar beets is not known. Thus, the objective of this work was to evaluate the vegetable classification and physicochemical characteristics of beets from different corn planting densities.

2. Material and methods

The experiment was performed in two stages, one in the field and the other in the laboratory. The field part was developed in a private rural property located in the city of Nova Laranjeiras—PR. latitude 25°20'33" S, longitude 52°31'11" W and approximate altitude of 729 meters, in the period from October 2018 to June 2019. The soil type present at this site is classified as Latossolo, according to the soil map of the State of Paraná[16].

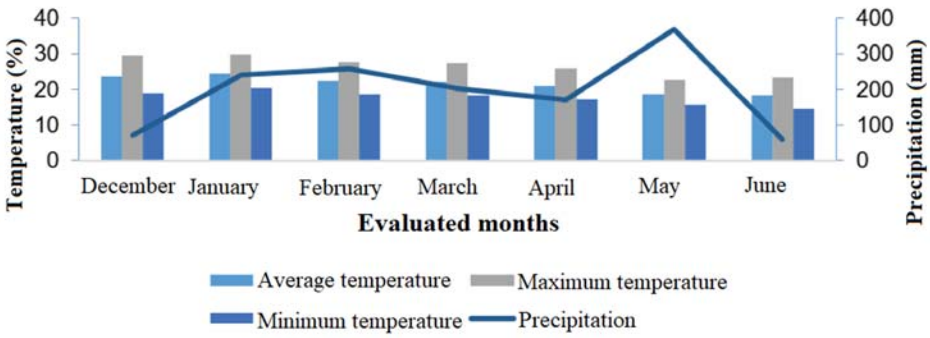

Figure 1. Average values of precipitation (mm), minimum, average and maximum air temperatures (°C) in the evaluation months from December 2018 to July 2019, Nova Laranjeiras-PR.

The climate of the region is classified as (Cfb), temperate climate according to the classification of Koeppen[17], with average annual temperature between 18 and 19 °C and precipitation from 1,800 to 2,000 mm/year[18]. During the period of the experiment, the average temperatures were between 14.4

and 29.6 °C respectively, and the accumulated precipitation for the period was approximately 1,306.4 mm (**Figure 1**).

Beet cultivar Early Wonder Tall Top (Horticeres®) was used as a vegetable and as a soil cover super early hybrid corn Pioneer 32R48 VYHR R3. Soil preparation in this experiment was performed in the conventional way with plowing and harrowing operations. The construction of the beds was performed with the aid of a hoeing machine. Four beds were built, each 20 m long, 1.20 m wide, 0.40 m high and 0.50 m apart.

Corn planting for ground cover purposes was done manually in December 2018. The densities used were 40, 60, 80 and 100 thousand plants ha-^{1} plus witness/control without cover.

The corn was planted by opening a furrow (0.10 m deep) and spacing between rows of 0.40 m. The base fertilization for corn culture was performed in the furrow, at planting time with the commercial formulation 2-23-23 (NPK). The top dressing was applied 40 days after planting.

After the green corn was harvested in the beds and the number of ears harvested in the different straw densities was quantified (**Table 1**), the plant was then manually lodged. Subsequently, the beet seedlings were transplanted in April 2019. The spacing used was 0.25 × 0.40 m. The seedlings used in the experiment were purchased from a commercial nursery located in the municipality of Laranjeiras do Sul-PR. They had average height values of 8.00 cm, 6.00 cm root length, 1.00 mm neck diameter, and 3 leaves. Drip irrigation was applied to each line of beets.

Table 1. Number of ears of corn harvested at different straw densities (0, 40, 60, 80 and 100 thousand plants ha^{-1}), Laranjeiras do Sul-PR ,2019.

Stubble density (thousand plants ha^{-1})	Nº ears of corn
0	0
40	148
60	161
80	225
100	255

Harvesting was performed 60 days after planting the seedlings. Evaluations were then made using eight tubers harvested for each repetition. The following were evaluated: a) root length (RC); b) average root diameter (RD) (average of longitudinal and transversal measurements); c) fresh root mass (FRM). To obtain the RC, the distance from the neck of the plant to the tip of the main root was considered, using a digital pachymeter. The RD was determined as the average of the longitudinal and transversal measurements, using a digital pachymeter. MF was determined by weighing the roots separately from the leaves and stems using a precision balance.

Commercial classification of beets was according to the standards Instituto Agronómico de Campinas—IAC[15] followed the following criteria: classification diameter divided into: class 50 (> or equal to 50 and < 90), class 90 (> or equal to 90 and <120), class 120 (> or equal to 120). Number of beets according to the shape of the tuberous part: cylindrical, elliptical, spherical and transverse/flat. Number of beets according to the coloration of the pulp: white, yellow, red and mixed (pulp with white and red rings interspersed). For the determination of firmness, a digital fruit penetrometer with a 2.62 mm diameter disk was used, duplicates of the analysis were made, the holes for the analysis were made in the largest diameter of each beet, results expressed in Newton (N).

The physicochemical analyses performed were: soluble solids (°Brix) with portable digital refractometer, with temperature correction of 20 °C, using a drop of pure juice; titratable acidity by titulometry (% of citric acid) using the methodology recommended by IAL[19], by titration and neutralization, titration in NaOH 0.1 N solution and phenolphthalein indicator using pH meter. The pH value of the pulp was determined by means of a table pH meter, calibrated with standard buffer solutions of 4.0 and 7.0; the ratio was obtained by calculating the ratio between soluble solids and titratable acidity and phenolic compounds by the Folin-Ciocauteau method, according to Bucic-Kojic *et al.*[20], being that the readings of the absorbance of the samples of the citric extracts in spectrophotometer at the wavelength of 765 nm, after 2 hours of reaction results expressed in mg of gallic acid equivalent (mg/GAE)[21].

The analyses were performed individually on the beets contained in the repetitions, which totaled

36 beets analyzed per density (0; 40; 60; 80; 100 thousand plants/ha), accounting for 180 tubers analyzed for the tests of this experiment, 60 days after transplanting the seedlings.

The variables obtained were subjected to variance analysis in the Sisvar software and compared among themselves by the Tukey test at 5% significance level, the average effect of the different densities of corn straw was obtained by regression analysis being the linear, 2nd degree polynomial and exponential models. The regression equations were based on the significance of the coefficients of the variables.

3. Results and discussions

For the length variables, group (flat, spherical, and cylindrical), category (defects), firmness, subgroup (flesh color), soluble solids, and phenolic compounds the factors were not significant at the 5% level.

Regarding the vegetable classification, we observed a lower number of beets in the commercial class (class 50) as the corn straw density increased (**Figure 2A**). Class 50 (diameter greater than or equal to 50 mm and less than 90 mm) is preferable for consumers in the southern region, being one of the most sought after classifications in commerce[15]. However, the opposite behavior was verified for the beets classified as no class (no commercial standard), where there was an increase in the amount of commercially unviable beets as the corn straw densities increased (**Figure 2B**).

Similar results were obtained by Tivelli *et al.*[22], when evaluating the same Tall Top Early Wonder cultivar in relation to the effect of sowing and transplanting beet seedlings under no-till system in sawdust, they observed low numbers of commercially classified beets. These results may be related to corn straw, which contains allelopathic substances with growth regulating properties that reduce germination, root growth and seedling sprouts. The intensity of these effects will depend on the source material and its incorporation or not to the soil[23].

Another factor that may have influenced the responses regarding the commercial classification of beets is the tuber formation period, because until the first leaves are formed the tuber growth is slow, characterizing little accumulation of photo-assimilates compared to the swelling that occurs 42 days after transplanting in the Tall Top Early Wonder cultivar, where there is an increasing accumulation of photo-assimilates until the time of harvest[24].

This swelling period coincided with the period of high rainfall during the end of the cycle (367.5 mm), which contributed to the decrease in the incident photosynthetic radiation available to the plants and the slow decomposition of the corn straw, resulting in a lower accumulation of photo-assimilates in the tubers[25], and consequently their commercial standard was also reduced.

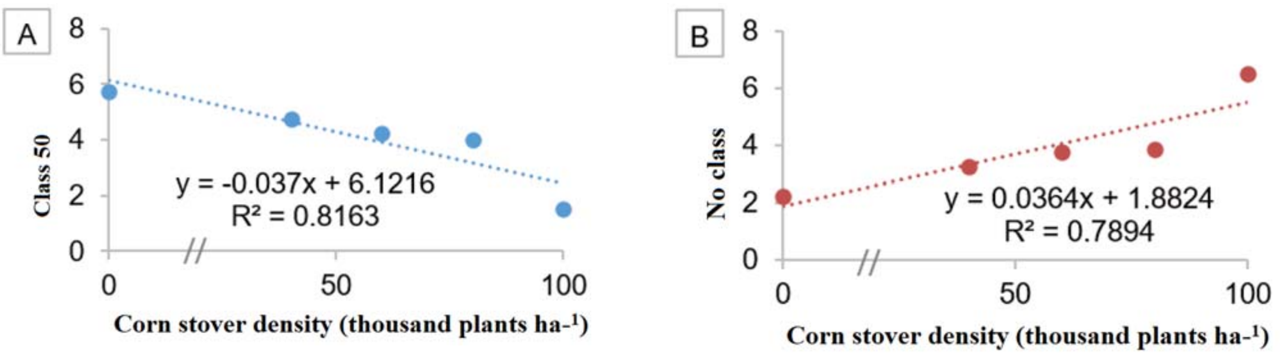

Figure 2. Number of beets commercially classified class 50 **(A)** non-commercial without class **(B)** as a function of different corn straw densities (0, 40, 60, 80 and 100 thousand plants. ha^{-1}).

For the shape of the elliptical group of beets, it was found that the control and the density of 100 thousand plants of maize ha^{-1} provided a greater number of units in this format, in relation to the other densities (**Figure 3**). However, in the literature, there is no information on this group variable (tuber shape) for sugar beet, the seed supply companies inform that a variation in its shape may occur.

Since the preferred type is beets classified as spherical group (globular shape) or flattened group (globular-plate shape)[15].

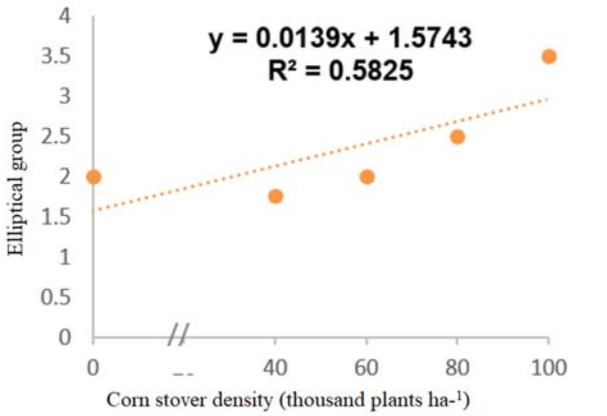

Figure 3. Number of beets classified in the elliptical group as a function of different densities of corn straw (0, 40, 60, 80 and 100 thousand plants ha^{-1}).

The differences between length and diameter in beet shape are relatively low. These values do not influence their commercial quality, thus fitting within the established standards that are provided by the company that sells seeds, since for the commercialization of beets up to 10% of mixture with the class and group is tolerated[26]. For the unit mass (g) of the harvested beets, it was verified that the highest values obtained were at straw density 40 thousand plants ha^{-1}, while the lowest masses (g) were verified with straw at density 100 thousand plants ha^{-1} corn (**Figure 4**). The values obtained for the mass of class 50 beets are within the prescribed average for the cultivar, which have an average unit mass between 100 g and 250 g, and in the southern region the values are even higher, reaching a mass of 300 g and commercial classification in class 90[26].

Mass, as well as root diameter, are parameters that are of commercial interest because they are associated with purchase intent and also the commercial value of beets[27].

The management of the cover crops is a factor that can regulate the permanence of the straw on the soil surface and the release of nutrients to the commercial crop. The C content is high in relation to the N content as the plant develops[28]. Thus, at the stubble density of 40,000 plants ha^{-1}, the amount of stubble was lower in relation to the other densities. Thus, the release of allelopathic substances from corn was lower, favoring the uptake of nutrients, and the high C:N ratio may have been efficient in the cycling of these nutrients.

The greater the amount of straw the lower the growth and development of beet plants because it can lead to a lower accumulation of photo-assimilates, thus reducing the productive potential of the vegetable. This reduction in the concentration of photo-assimilates can be a limiting factor for both the development of vegetative structures and the formation and growth of roots[29].

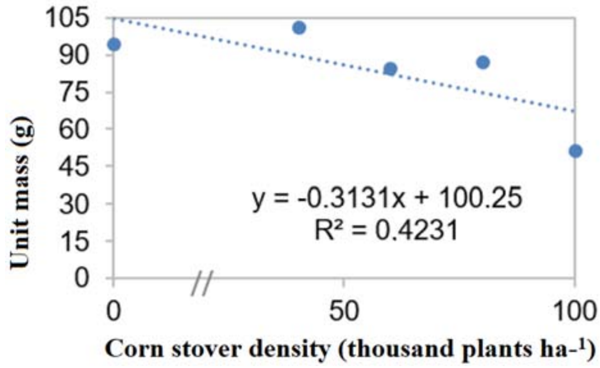

Figure 4. Unit mass g of beets as a function of different corn straw densities (0, 40, 60, 80 and 100 thousand plants ha^{1}).

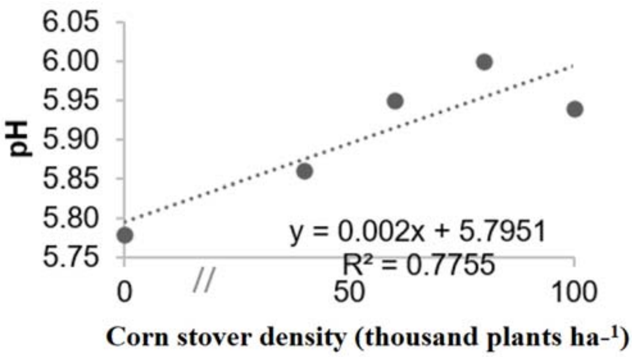

Figure 5. pH of beets as a function of different densities of corn straw (0, 40, 60, 80 and 100 thousand plants ha-^{1}).

For the evaluated variable pH, an increase in the values was observed until the corn straw density of 80 thousand plants ha^{-1} (**Figure 5**). Similar results to those observed in this work were verified by Oliveira *et al.*[30], when evaluating pH of beet extracts of two cultivars (Tall Top Early Wonder and Itapuã 202) produced in organic cultivation system.

The pH has a direct influence on the color and chemical substances of the pigments present in beets, especially betalains, which are highly un-stable substances. The range of stability of these pigments is between pH 5.0 and 6.0 in the presence of oxygen, and varies in the presence of light after extraction of the fruits from the soil[30]. Barcelos[31] points out that pH values above 7 and below 3 cause the degradation of these pigments, thus changing the color of the beet pulp from the characteristic purplish-red color to pale violet-blue, and consequently causing the loss of commercial value of the final product.

According to the results obtained in this experiment, the pH variation among the samples of beets obtained from different densities of corn straw had no interference in the degradation of betalains and resulted in uniformity of the color of the harvested fruits. These pigments were stable within the pH range of the evaluated pulps.

For the titratable acidity variable, it was verified that the greater proportions of straw under the beds reduced the quantity of citric acid present in the beets (**Figure 6**). Results superior to this work were found by Marques *et al.*[32] when evaluating increasing doses of bovine manure, which guaranteed positive results in relation to the application, providing higher quantities of citric acid in the harvested beets.

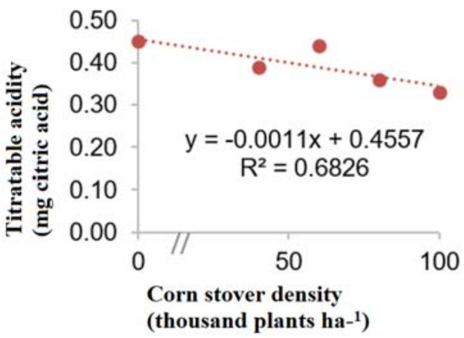

Figure 6. Titratable Acidity (mg citric acid) of beets as a function of different densities of corn straw (0, 40, 60, 80 and 100 thousand plants ha^{-1}).

It can be stated that this variable is influenced by the environmental conditions to which the plants were exposed, and may vary even within each species[33]. However, titratable acidity can also be influenced by the physiology of the plant due to the season, temperature, management, place of cultivation and rainfall[31]. Given this statement, the results obtained can be explained by the management of the plants with corn stover, combined with the high rainfall and temperature variations in the month of May, which preceded the harvest.

The ratio is a combination of SS/AT (ratio between soluble solids and titratable acidity) and showed a significant reduction with increasing densities of corn straw under the beds. The variations in the ratio were large with values of 20.44 to 13.39, with an average among the densities of 18.07 (**Figure 7**). Similar values were found by Lima[9], when evaluating the same cultivar in organic and conventional cultivation system, obtaining an average of 18.74 in the organic management system. The SS/AT ratios found by Ferreira[34] were higher in organic cultivation ranged from 25.45 to 18.05 between treatments of different fertilizations with the same cultivar, obtaining sweeter beets.

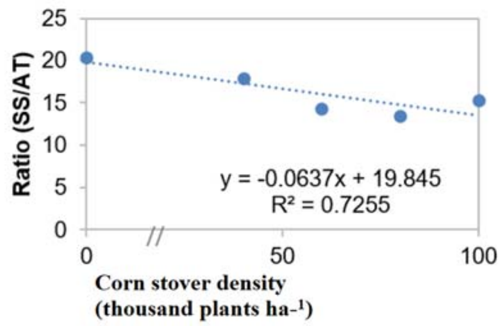

Figure 7. Ratio (SS/AT) of beets as a function of different densities of corn straw (0, 40, 60, 80 and 100 thousand plants ha^{-1}).

The SS/AT ratio indicates the maturity and flavor of the fruit. Thus, the higher the value of the coefficient, the higher the content of soluble solids (°Brix), thus resulting in a fruit with a sweeter flavor and consequently less acidic[35]. This result serves as an indicator of the degree of sweetness of a given product, highlighting its predominant flavor, being sweet or acidic, or if there is a balance between them[36].

In this case, with the increase in the proportions of corn straw overlaid under the beds, the amount of citric acid in the beets was reduced, which made them more acidic compared to the witness, which had a sweeter taste due to the greater amount of acid present in the fruit.

4. Concluding remarks

High corn population densities generate high straw volumes, a factor that negatively affects the grading standards and physicochemical characterization of sugar beets when employing the no-till vegetable gardening system (SPDH) for the crop under these conditions.

Conflict of interest

The authors declare no conflict of interest.

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