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Fruit traceability via mobile application

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Abstract

The traceability of agricultural products is essential to ensure food safety and monitor the production chain, in addition to being required by the Brazilian legislation. This activity can be optimized with the use of digital technologies. The present study verified the efficiency of a mobile application in tracking agricultural products and its use as a digital field diary. The study was developed with 13 participants who used a mobile application to record agricultural activities: applications of phytosanitary inputs and fertilizers; crop management, and recording of georeferenced harvest batches. The use of the application made it easier to record the activities in the digital field diary and monitor the agricultural products throughout the production chain. An alert system for the withholding period and the maximum limit of phytosanitary applications was developed and allowed a greater control of the products used. Both processes are considered critical points in the traceability system. For each harvest batch, a QR Code and cost, production, yield and fruit quality reports were generated by the application. Thus, the mobile application was efficient in tracking agricultural production and served as a digital field diary, in addition to allowing the management of agricultural activities and their production costs, proving to be an innovative and low-cost technology that can be used by fruit producers.

Keywords: digital tools, agricultural products, grapes, production chain

Introduction

The traceability of agricultural products consists of a set of procedures that detects the origin and follows the movement of a product along the production chain, by means of recorded informative and documentary elements (BRASIL, 2018). It is considered a risk and action management tool to increase transparency between the links of the production chain; to reduce the risks of legal liabilities, and to provide an efficient product recall system (Meuwissen et al., 2003; Dai et al., 2015).

Detailing information about the characteristics of a product and its origin has become an essential condition to meet consumer needs and comply with the legislation. In Brazil, applying the traceability of plant products became mandatory, according to Joint Normative Instruction Nº. 2/2018, aiming at food safety and the monitoring of pesticide residues. In said legislation, there are three groups with different crops and deadlines for full validity – occurring in August 2019 (group I), August 2020 (group II) and August 2021 (group III) –, showing the urgency of efficient methods to perform this activity.

Traceability systems are recorded on paper or in digital tools. Agriculture has been modernized through digital technologies such as artificial intelligence, robotics, internet of things, sensors and big data (Wolfert et al., 2017; Rose & Chilvers, 2018). Traceability via digital technologies makes it easier to monitor the entire history of agricultural production in an efficient, accurate and quick manner (Abenavoli et al., 2016) and can be done using mobile applications.

The development of mobile applications is one of the fastest growing technologies in agriculture with the generation of several products (Barbosa et al., 2020). This is due to the fact that most rural producers use mobile phones (Karim et al., 2020) that allow installing these applications, and that the latter are considered

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a low-cost and innovative system in agriculture. Despite advances in technology, there is a lack of studies that assess efficiency in agricultural traceability.

In addition, mobile applications can serve as a digital field diary to record and manage agricultural activities. Field diaries using paper are limited, and it is difficult to keep all the necessary documentation up-to-date for an efficient production planning and management.

Thus, this research sought to verify the efficiency of a mobile application in tracking agricultural products and its use as a digital field diary, with a view to filling existing gaps in the traceability of the fresh-vegetable production chain and comply with the Brazilian legislation and market requirements.

Material and Methods

The work was developed at *Cooperativa Agroindustrial Nova Aliança*, an agro-industrial cooperative whose administrative headquarters is located in the municipality of Flores da Cunha, Rio Grande do Sul, Brazil, in the 2019-2020 cycle. In total, 13 cooperative families with rural properties located in municipalities in the region of Serra Gaúcha participated in the study. Grape production is the main activity of these families, but other crops are produced on their properties, such as avocado, garlic, plum, persimmon, citrus, pecan, peach and tomato, totaling approximately 146 hectares (Table 1).

Table 1. Number of producers and production area of crops used by participating families.

Crops	Number of producers	Production area (ha)
Avocado	1	0.15
Garlic	1	2.37
Plum	3	9.99
Persimmon	5	8.29
Citrus	5	7.02
Pecan	1	0.10
Peach	6	20.72
Tomato	1	0.05
Grapes	13	97.66

The rural properties were georeferenced using the Google Earth Pro software, with the identification of the production plots, and characterized in accordance with the cultivar. The data obtained were inserted into a web platform via ASP.NET and C# technologies, kept in an IIS web server and stored in an SQL Server database. This information was synchronized with the mobile application by means of Java technology for native Android, developed through the GeneXus software. The mobile application stored an information database using SQLite, allowing online and offline use.

The participants personal data, crops and cultivars, crop managements and treatments, agricultural inputs and main diseases and pests found in the crops that the participants produce on their properties were recorded in the web platform as well (Figure 1).

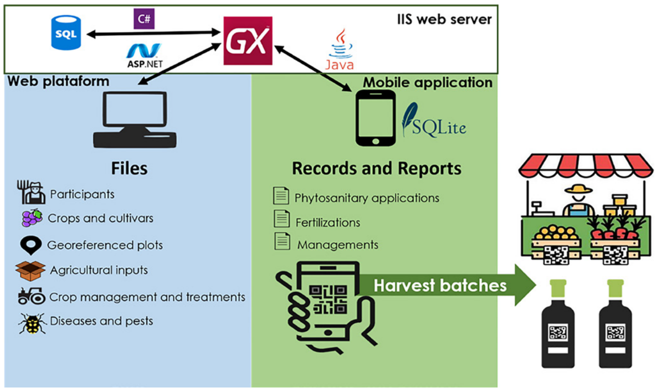

Figure 1. Traceability scheme using web platform and mobile application. Participants, crops/cultivars, georeferenced plots, agricultural inputs, crop management and treatments, diseases and pests were recorded in the web platform. In the mobile application, the participants recorded phytosanitary applications, fertilizations, harvest management and batch, which generated a QR Code that served to track production aimed at marketing as fresh vegetables or for processing. The information in the web platform and in the mobile application was developed using the Genexus software.

The mobile application was organized to record the agricultural activities involved, from the production to the receipt of the grapes in the processing units for the making of the cooperative's juices and wines. In addition, this information flow was adapted to also record the production stages of other crops for marketing as fresh vegetables.

All agricultural activities were recorded by the participants through the mobile application. To this end, monthly training sessions were held to demonstrate how to use the tool to record the following agricultural activities: (i) applications of fungicides, herbicides, insecticides and foliar fertilizers; (ii) applications of fertilizers and soil amendments; (iii) crop managements such as pruning, leaf removal, shoot positioning, shoot thinning, mowing and harvesting; (iv) recording of harvest batches, with each batch being characterized by the identification of the producer, of the cultivar, the production plot number, the date of harvest, the National Viticulture Register number, the field diary number, and batch conformity.

At the time of harvest, the participants would enter the cultivar, the production plot and the date of harvest. The mobile application would generate a traceability code in QR format containing 23 characters, including numbers and separators. The combination was unique, allowing security in batch tracking and information integrity.

Batch conformity was inspected using an algorithm developed in the mobile application, considering withholding period, number and maximum doses of phytosanitary applications, and use of products allowed for the crop, in accordance with the legislation (BRASIL, 2003).

The glucometric degree was measured on a Brix scale with conversion to Babo degrees, which represents the amount of sugar, in mass, contained in 100g of grape must. A UR24-Maselli digital refractometer installed in the industrial processing line was used, recording all readings with the application of a temperature correction to 20 °C. This measurement was performed directly after the fruit was unloaded into the industrial processing unit. The Babo degree value of the unloaded load was calculated from the average of all readings done every 11 seconds.

The costs of the inputs were obtained and recorded in the application through the values recorded in the collective-purchase project of the cooperatives of Serra Gaúcha. To compose management expenses, the amount of 100 BRL (one hundred reais) per person per day was used, as defined by the participants, and the total cost was defined by summing input and management expenses.

A report module was developed inside the mobile application to allow searching for all records referring to the plots of the whole agricultural production. However, the present research used detailed reports on phytosanitary applications, fertilizers, managements, harvest batches, production costs and production indicators for grapes, as this crop is the participants' main agricultural activity. The results were analyzed by means of descriptive statistics.

Results and Discussion

First, each participant delimited the production plots using a standardized recording of information containing plot code, crop, cultivar, area, geographical location and altitude (Figure 2).

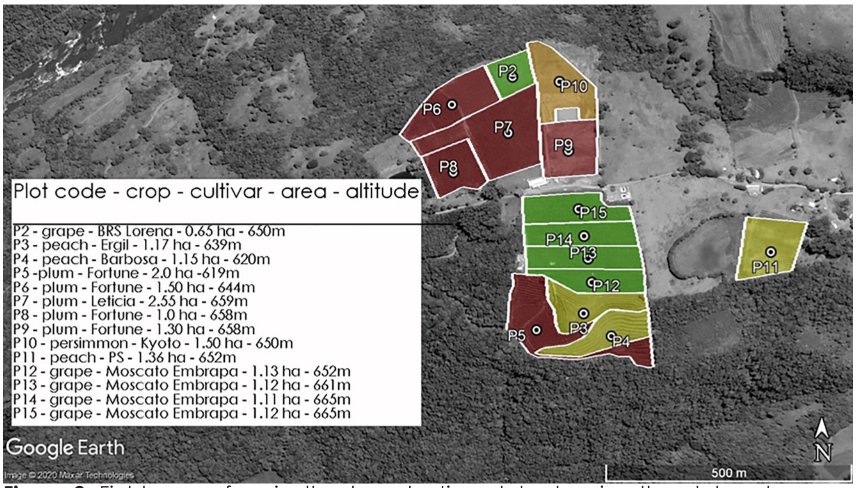

Figure 2. Field map of agricultural production plots, showing the plot code, crop, cultivar, production area (ha), geographical location and altitude(meters).

This information is basic to locate the origin of a product and can be inputted into a computer system for the traceability of agricultural products. In total, 252 plots with an average area of 0.56 ha were marked. Grapes and peaches were the crops with the highest number of plots – 179 and 28, respectively.

After the plots were established, the participants recorded in the mobile application the agricultural activities carried out in each production plot. This recording was important to characterize the cultivars, management practices, and to control the applications of fertilizers and phytosanitary products considered as critical points within the traceability system.

In the grape crop, the main cultivars recorded were Isabel (21.2%), Bordô (13.6%), BRS Violeta (11%), BRS Cora (8.45%), Isabel Precoce (8.14%), Moscato Embrapa (7.34%), while the other 26 cultivars represented 30.27% of the area. In 2015, the Isabel and Bordô cultivars presented the largest planted areas in the state of Rio Grande do Sul, with 10,522.77 ha and 9,319.24 ha, respectively (Mello et al., 2015).

For each cultivar, the participants recorded the number and date of the phytosanitary and fertilizer applications, as well as product doses and application rate. These products present a risk of chemical contamination in vegetables when the use of products allowed for the crop, the maximum number of applications, the doses and the withholding period are not observed. Thus, in order to warn the participants about the recommendations for each product, an alert system for the maximum application limit was developed in the mobile application, in accordance with the registration of the products in the Phytosanitary Pesticide System – Agrofit (BRASIL, 2003). Other authors reported that mobile applications are considered a simple and innovative tool that provide information such as agricultural management, as well as pest and disease control (Barbosa et al., 2020), being able to monitor the use of phytosanitary products within the production chain, in addition to managing the risks of chemical contamination of vegetables and the costs of these products.

Fertilizers and phytosanitary inputs represented an important fraction of the grape production costs. On average, a grape production plot received 4.2 of foliar fertilizers, 1.2 applications of herbicides, 2.3 applications of insecticides, and 14.2 applications of fungicides, with average costs per application of 33.38 BRL, 76.98 BRL, 54.19 BRL, and 121.49 BRL, respectively. Among the cultivars with the largest production area, the Bordô cultivar presented the lowest application rate, with 3.1 of foliar fertilizer, 8 of fungicides, and one of insecticide (Table 2). This cultivar is considered rough and has greater resistance to attack by pests and fungal diseases (Maia & Camargo, 2005). Thus, it was possible to obtain information on number of applications and on the costs of each phytosanitary input and fertilizers used by the participants, showing that the application, in addition to tracking production, can be useful to manage costs and inform the needs of each cultivar.

Table 2. Average number of applications (ANA) carried out in the 2019 and 2020 cycle and average cost in BRL for each of the phytosanitary applications in the 6 main grape cultivars registered in the mobile application.

	Foliar Fertilizers		Fungicides		Herbicides		Insecticides	
Cultivar	ANA	Cost	ANA	Cost	ANA	Cost	ANA	Cost
Bordô	3.10	12.30	8.00	115.10	1.40	101.10	1.00	103.40
BRS Cora	4.20	36.20	14.60	131.90	1.00	97.30	2.10	35.10
BRS Violeta	4.00	31.60	15.60	122.90	1.50	60.60	2.20	45.80
Isabel	4.30	28.80	14.10	131.40	1.40	64.20	1.80	46.40
Isabel Precoce	4.00	39.90	13.60	127.70	1.00	31.30	2.50	41.40
Moscato Embrapa	3.90	33.50	18.10	188.00	1.70	255.30	3.80	57.50

Input and management costs totaled 33.79% and 66.21% of the total cost, respectively. Management, which included pruning, leaf removal, shoot positioning, shoot thinning, mowing and harvesting, was performed in a non-mechanized way, with the participants themselves and temporary workers as manpower, thus representing most of the expenses. The last information regarding management was recorded in the mobile application at the time of harvest.

Harvesting is a fundamental step in traceability. For the grape batches received by the cooperative, the producer presented the QR Code at the load inspection point of each receiving unit, through the mobile application (Figure 3). In the crops intended for marketing as fresh vegetables, labels containing the information required by the legislation were used (BRASIL, 2018).

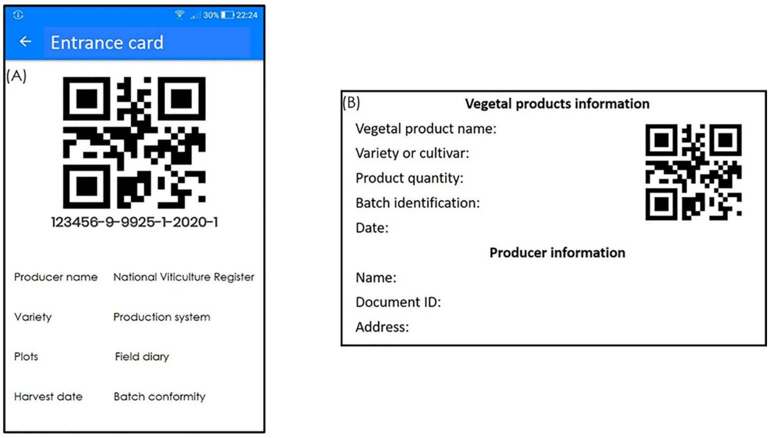

Figure 3. Harvest batch with traceability code in QR format generated on the mobile application (A) and ont the labels generated for printing (B).

The identification of the batches and detailed harvest information, such as participant, cultivar, production plot, date of harvest, and compliance with the use of phytosanitary products, were linked via QR Code and received in the web platform for them to be stored. The incorporation of identification technologies increases transparency and facilitates the rapid identification of the product (Qian et al., 2020). This identification must be connected to a central data storage system to allow access to all links in the production chain (Furnalaneto & Manzano, 2010).

The traceability batch was composed of fruits harvested on the day the batch was recorded. The number of batches with only one plot was 328, batches with two plots, 17, and batches with three plots, 2, totaling 347 recorded batches, and about two million and two hundred thousand kilograms of grapes. The differences in the number of plots per batch are due to the fact that some participants harvested multiple plots on the same day, because the maturation of the fruit occurs at the same time in different plots of the same cultivar.

In the cooperative's previous model, all information described about phytosanitary applications and management practices were recorded in paper field diaries and delivered when the loads were received. However, with the records in the mobile application, this information was integrated with the web platform and product traceability.

With all the harvest records and the respective traceability batches, it was possible to generate production, yield and quality reports for each production plot (Table 3). These reports at the end of the 2019/2020 cycle were available for consultation in the mobile application. Thus, each participant was able to know the production of each batch and its respective geographic location. Mapping the origin of each batch can show yield variation areas, and this is a determining factor in crop management decisions (Furnalaneto & Manzano, 2010).

Table 3. Area, number of plots, production of the 2019/2020 harvest, productivity in kilograms per hectare and sugar content in Babo degree in the 6 main grape cultivars registered in the mobile application.

Cultivar	Area (ha)	Number of plots	Production (kg)	Productivity (kg/ha)	Babo degree
Bordô	11.80	20	189,110.00	16,584.80	14.40
BRS Cora	7.30	12	157,510.00	21,301.70	16.50
BRS Violeta	10.80	12	280,930.00	26,212.70	16.00
Isabel	20.10	31	571,930.00	29,570.90	15.40
Isabel Precoce	7.60	10	157,120.00	24,349.60	15.50
Moscato Embrapa	6.90	12	237,560.00	35,918.50	16.00

In total, 571,930 kg of Isabel grapes were harvested from 20.10 ha, resulting in an average yield of 29,570.9 kg ha^{-1}. However, the cultivar with the highest average yield was Moscato Embrapa, with 35,918.5 kg ha^{-1}. Such results showed that, in addition to monitoring all agricultural activities, the application allowed the participants to check production results, facilitating decision making for future investments. These numbers prove that the success of agricultural activities is partly due to decision making by producers when they choose what, how and when to perform certain managements and, specifically, for each production plot on their property.

The mobile application also made it possible to identify non-conformities in the batches generated by the participants, but none of the batches presented non-conformity. Thus, it can be stated that the data collected by the traceability system becomes strategic when problems occur in a batch, and when the location and retrieval of its information is required (Abenavoli et al., 2016).

Traceability techniques have been making great strides in recent years. Traceability through laboratory techniques has advanced with the use of liquid and gas chromatography, isotope ratio and DNA-based technologies for authentication of the geographical origin of the food (Wadood et al., 2020). Besides tracking along the production chain, it serves to discriminate cultivars with Denomination of Origin and Geographical Indication (Violino et al., 2019). However, despite advances in analytical techniques, there is still a lack of use of technologies to track agricultural production in an easy, simple and low-cost way. The results presented in this study showed that the adoption of accessible and innovative technologies such as the mobile application made it possible to fill the existing gap to track agricultural production. Furthermore, it allowed producers to comply with the Brazilian legislation, improved the efficiency of production processes by controlling expenses and costs, and ensured the monitoring of risks of contamination by chemical products.

It is worth noting that the present study gave rise to new needs and opportunities in the agricultural production chain with the use of digital technologies to optimize results and meet market demands, including the scheduling of deliveries of agricultural production at companies/cooperatives, meteorological monitoring of different productive areas, harvest season prediction, and use of data science to assist in decision making.

Conclusions

The mobile application was efficient in tracking agricultural production and served as a digital field diary. It allowed managing agricultural activities and their production costs, resulting in an innovative and low-cost technology that can be used by fruit producers.

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