Effect of Plant Growth-Promoting Rhizobacteria (PGPRs) on Tuber Storage of Two Potato Varieties

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Abstract

El-Allaoui N., A. Douira, A. Benbouazza, M. Ferrahi, E. Achbani and K. Habbadi. 2024. Effect of Plant Growth-Promoting Rhizobacteria (PGPRs) on Tuber Storage of Two Potato Varieties. Arab Journal of Plant Protection, 42(2): 229-233. https://doi.org/10.22268/AJPP-001242

The potato (Solanaceae family) is a cultivated plant primarily valued for its tubers, which serve as a crucial food source for numerous populations worldwide. Losses due to postharvest diseases are significantly high and need to be reduced. To preserve tuber quality without relying on chemical treatments, the application of plant growth promoting rhizobacteria (PGPR) has been employed as a means to extend the shelf life of potato tubers. The objective of this study was to assess the effect of eight PGPRs on the conservation of two potato varieties Siena and Bellini. This was carried out in two trials; in the first trial, thirty potatoes of the Siena variety were treated with PGPRs and covered with wheat straw, and in the second trial, 160 potatoes each of the two varieties Siena and Bellini were treated with PGPRs but covered with wheat straw and black plastic. Results obtained indicated that several PGPR strains performed favorably, the most promising of which was the *Aureobasidium pullulans* (Ach1.1) strain that kept 50% of the treated potatoes healthy for one month in the first trial, and 30% for six months in the second trial, as compared to the negative control where 100% of the potatoes showed signs of rot in both trials. It can be concluded from this study that the Ach1.1 strain of *Aureobasidium pullulans* could be a promising post-harvest bio-control treatment.

Keywords: PGPRs, conservation, post-harvest, potato, rot.

Introduction

Potato is a perennial plant cultivated worldwide for its tubers and is an important food source for a good portion of the world population, with an annual production exceeding 388 million tons in 2020 (FAOSTAT, 2021). The cultivation of potatoes is of major economic and geostrategic importance, ranking as the fourth largest crop in the world after rice, corn, and wheat (Djebbour, 2015).

In Morocco, potato production was around 2.9 million tonnes in 2020, making it the second most cultivated crop after tomatoes and representing about 15% of total agricultural production (African Development Bank, 2021). The primary regions for potato production in Morocco are Meknes-Tafilalet, Souss-Massa, and Marrakech-Safi (National Agency for the Development of Oases and Argan Trees "ANDZOA", 2021).

Extending the shelf life of potato tubers after harvest requires good environmental control, particularly temperature and relative humidity. The recommended temperature ranges from 4 to 8°C for immediate consumption, and above 8°C to increase the accumulation of reducing sugars responsible for the brown color of fried potatoes (ITCMI, 2017). Another method involves covering the tubers with straw and monitoring them daily. It is also important to frequently remove damaged, diseased, or rotted tubers, or to treat these tubers with PGPR microorganisms throughout the storage period (Lahouel, 2015).

Plant growth promoting rhizobacteria (PGPR) are microorganisms that live in association with plant roots and can have beneficial effects on plant growth and development (Mehnaz & Lazarovits, 2006). PGPR can act in different ways, including producing plant growth hormones, solubilizing soil nutrients, fixing atmospheric nitrogen, and protecting plants against diseases and rot (Aloo *et al.*, 2020). These rhizobacteria are often used as inoculants for agricultural crops to promote plant growth and reduce the use of chemical fertilizers (Alamar *et al.*, 2017). Studies continue to reveal new species of beneficial rhizobacteria for plants, and their use can contribute to more sustainable and environmentally friendly agriculture (Van Loon., 2007).

The increasing global demand for organic food and strict regulations on chemical treatments have sparked a rise in research on biological treatments using PGPRs (Borriss, 2011). These PGPRs can offer several beneficial advantages, including enhanced plant resistance to diseases and pests, stimulation of root and plant growth, improvement in crop quality, and increased nutrient content (Mehnaz & Lazarovits, 2006). In the case of potato crops, several studies have shown that the use of PGPRs can improve plant growth, increase tuber weight and size, and reduce fungal diseases in tubers (Quek *et al.*, 2016; Ullah *et al.*, 2016). However, further research is necessary to assess the efficacy and safety of PGPRs on potato crop when used in a large scale.

The objective of this study was to assess the effect of eight PGPRs on the conservation and reduction of damage during storage of two potato varieties, “Siena” and “Bellini”.

https://doi.org/10.22268/AJPP-001242

Materials and Methods

PGPRs strain and culture conditions

Eight PGPRs strains used in this study are listed in Table 1. The selected bacteria were provided by the Laboratory of Phytobacteriology and Biological Control of the National Institute of Agronomic Research in Meknes, Morocco. The selection of the PGPRs strains was based on their ability to promote and protect other crops in previous studies (Aloo *et al.*, 2020; Abd El-Malik & Abd El-Azeem, 2022). The bacterial strains were cultivated on YPGA medium (yeast extract, 5 g/L; peptone, 5 g/L; glucose, 10 g/L; agar, 15 g/L) and incubated for 48 h at 28°C. A bacterial suspension of each strain was prepared and adjusted to 10^8 CFU/mL and used as an inoculum.

Potato tubers treatments

Potato tubers were imported from Italy, developed in 1993 by the National Institute of Agronomic Research (INRA) in collaboration with the University of Tuscia, and those with a diameter of 5 to 10 cm were used. Two trials were conducted in this study; in the first trial which lasted for 30 days, only Siena variety was used, each treatment included 30 tubers and then covered with wheat straw. In the second trial which lasted for six months, both Siena and Bellini varieties were used, and each treatment included 160 tubers. Additionally, treatments were covered with a layer of opaque black plastic on top of the wheat straw described for the first trial. Potato tubers were surface sterilized with 3% sodium hypochlorite and then rinsed with sterile distilled water, they were then soaked left to imbibe in the different treatments for 3 hours. The control treatment was soaking in sterile distilled water. Potatoes were carefully placed above a bed of wheat straws and then covered with additional straws until potatoes are no longer visible (Figure 1). For both tests, daily observations were made. If any mold, rot, or greening was observed on any potato tuber, it was noted and then removed to avoid further contamination.

Data analysis

Statistical analyses of the data was conducted using SPSS 21 and Excel 2019 statistical analysis software, and significant differences between treatments was calculated at P=0.05.

Table 1. Bacterial strains tested for their protective capability of potato tubers during storage.

Strain code	Species	Origin	Region
GAJ222	*Pseudomonas koreensis*	Rhizosphere of *Phoenix dactylifera*	Draa-Tafilalet
GAB111	*Serratia nematodiphila*	Rhizosphere of *Phoenix dactylifera*	Draa-Tafilalet
2066-7	*Pantoea agglomerans*	*Olea europea* (Picholine variety)	Taounat
Ach1.1	*Aureobasidium pullulans*	Apple tree washing (var. Golden Delicious)	Storebought
Ach1.2	*Aureobasidium pullulans*	Apple tree washing (var. Golden Delicious)	Storebought
GLM10	*Klebsiella* sp.	Rhizosphere of *Phoenix dactylifera*	Draa-Tafilalet
2332-A1	*Rahnella aquatilis*	Apple tree	El Hajeb
2515-3	*Bacillus subtilis*	Apple tree	Imouzzer Kandar

Figure 1. Methodology used for protecting potato tubers during storage. (A) Siena variety, (B) Bellini variety, (C and D) tubers were treated with microbial strains and covered with wheat straw, (E) covered with black plastic.

Results

PGPR effect on the conservation of the Siena variety over one month period

Progress in the rate of spoiled tubers of the Siena variety following different treartments are shown in Figure 1. Over a storage period of one month, best results were obtained by using the Ach1.1 and Ach1.2 strains of *Aureobasidium pullulans* (Figure 2).

Overall, these results indicated that the tested bacterial strains have an impact on potato preservation, even when conventional methods are employed. Furthermore, observations revealed that the majority of potato losses were due to the presence of green sprouts. Consequently, it was found that the conventional use of wheat straw, which slightly blocks direct sunlight, proved insufficant in preventing sprout formation. Therefore, a second test was conducted, involving the covering of potato tubers with an opaque black plastic to completely block direct sunlight.

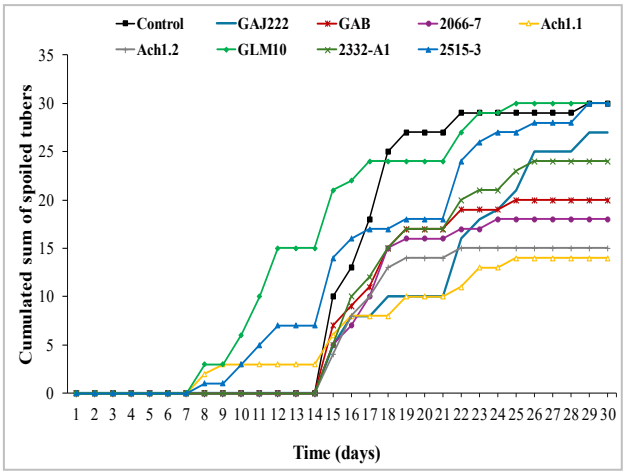

Figure 2. Cumulative sum of the number of spoiled potato tubers in each treatment of the variety Siena during 30 days.

PGPR effect on the conservation of the Siena and Bellini variety over six months period

This test aimed to evaluate the effectiveness of a preservation method for potatoes, which involved covering them with opaque black plastic to extend their shelf life. The results indicated that certain bacterial strains were more effective than others in preventing potato decay. Strains Ach1.1 and Ach1.2 showed the lowest decay rate throughout the test, making them the most suitable treatment for long-term storage. Strains 2515-3, GLM10, and Ach1.1 began to rot one week earlier than the control and other treatments (Figure 3). Strain 2066-7 showed signs of decay only on the 75th day, making it a potential short-term treatment for a period of up to five months. However, the Bellini variety proved to be very sensitive, posing challenges for long-term storage. In addition, these results suggest that the preservation method used may be effective in preventing the formation of potato greening and decay, with certain bacterial strains, such as Ach1.1 and Ach1.2 offering improvements in potato preservation during storage.

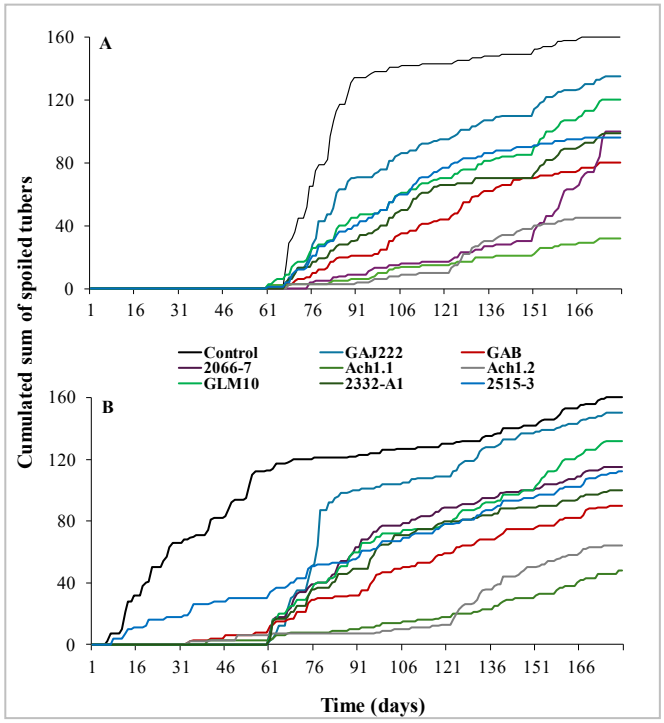

Figure 3. Graphical representation of the cumulative sum of the number of spoiled potato tubers in each treatment of the (A) Siena and (B) Bellini varieties during 6 months of storage.

Results obtained indicated that the bacterial strains Ach1.1 and Ach1.2 showed remarkable effectiveness in extending the storage life of both potato varieties, up to six months. Strains 2332-A1, 2066-7, and 2515-3 showed moderate effectiveness, whereas strain GAJ222 proved to be ineffective for the storage of these potato varieties.

Discussion

Previous studies indicated that there are several methods to protect potato tubers during storage depending on the available resources and conservation objectives, with each method presenting advantages and disadvantages (Achbani, 2016; Chibane, 1999; Krochmal-Marczak *et al.*, 2020; Fan *et al.*, 2016; Kayacan *et al.*, 2020). In this study, the traditional pile (bulk) storage method was adopted as commonly used by farmers in the Ghareb and Loukkous regions of Morocco (Achbani, 2016). This method involves utilizing sheds, which are simple structures, designed to create optimal storage conditions for a period not exceeding 30 to 60 days. The utilization of this method offers the advantage of reducing storage costs while maintaining potato quality (Ojeda *et al.*, 2021). Precautions must be taken to ensure the long-term storage of potato tubers, which often involves the removal of green, sprouting, and rotted tubers. Tuber rot can become serious if favorable storage conditions of humidity and temperature are present (Devaux *et al.*, 2017). One approach to extend the storage period of potato tubers involves the use of antagonists that have an inhibitory effect

on the growth of the bacteria causing tuber rot (Li *et al.*, 2021; Xiao *et al.*, 2021).

Results obtained in this study suggested that the use of opaque black plastic cover allowed four times longer storage period than the simple wheat straw cover, which is in agreement with prior research (Li *et al.*, 2020). Several recent studies have highlighted the beneficial effect of certain bacterial strains on the preservation of potato tubers (Heltoft *et al.*, 2016). This is consistent with the results obtained in this study using the strains Ach1.1 and Ach1.2 of the bacterium *Aureobasidium pullulans*. These results suggest that the use of specific bacterial strains could be an effective strategy to improve potato tuber conservation and reduce post-harvest losses. However, it is important to note that the beneficial effects may vary depending on the bacterial strain used and the potato variety studied, and that further research is needed to evaluate the long-term effects on tuber quality and the environment.

الملخص

العلاوي، نادية، علال الدويرة، عبد اللطيف بن بوعزة، موحا فراحي، الحسن اشباني وخولة حبادي. 2024. تأثير البكتيريا الجذرية المعززة لنمو النبات (PGPRs) على تخزين درنات صنفين من البطاطا/ البطاطس. مجلة وقاية النبات العربية، 42(2): 229–233.
https://doi.org/10.22268/AJPP-001242

ينتمي نبات البطاطا/البطاطس إلى العائلة الباذنجانية ويُزرع من أجل درناته والتي تعدّ غذاءً رئيساً للعديد من السكان في العالم. ومع ذلك، خلال فترة ما بعد الحصاد، قد يكون تخزين درنات البطاطا/البطاطس أمراً صعباً، حيث تصبح هدفاً رئيساً للأمراض، للاخضرار وللتعفن، وتنجم كلها عن سوء التعامل أثناء الحصاد. وللحفاظ على جودة درنات البطاطا/البطاطس دون اللجوء إلى المواد الكيميائية، لجأنا إلى استخدام "البكتيريا الجذرية المعززة لنمو النباتات" للحفاظ على درنات البطاطا/البطاطس أثناء التخزين. هدفت هذه الدراسة إلى معرفة تأثير ثمانِ سلالات من البكتيريا الجذرية المعززة لنمو النباتات على تخزين صنفي البطاطا/البطاطس Siena و Bellini. وتم ذلك من خلال تجربتين، الأولى لمدة شهر واحد والثانية لمدة ستة أشهر داخل سقيفة. في التجربة الأولى، تمّت معالجة ثلاثين درنة بطاطا/بطاطس من صنف Siena بالسلالات البكتيرية الثمانية، وتمت تغطيتها بقش القمح. أما في التجربة الثانية، فقد تمت معالجة 160 درنة بطاطا/بطاطس لكلٍّ من الصنفين Siena و Bellini بالسلالات البكتيرية نفسها مع تغطيتها في هذا الاختبار بقش القمح والبلاستيك الأسود. أشارت النتائج إلى أن السلالات البكتيرية الثمانية كانت ذات فعالية جيدة، وكان أكثرها تأثيراً السلالة البكتيرية Ach1.1التي حافظت على 50% من درنات البطاطا/البطاطس المعالجة بحالة صحية جيدة خلال الاختبار الأول لمدة شهر و 30% خلال الاختبار الثاني لمدة ستة أشهر، بالمقارنة مع الشاهد غير المعامل حيث أصيبت كامل الدرنات (100%) بالتعفن في كلا الاختبارين. لذلك يمكن اعتبار البكتيريا *Aureobasidium pullulans* (السلالة Ach1.1) علاجاً حيوياً واعداً بعد الحصاد.

كلمات مفتاحية: البكتيريا الجذرية المعززة لنمو النباتات، تخزين، ما بعد الحصاد، البطاطا/البطاطس، التعفن.

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Received: April 4, 2023; Accepted: August 28, 2023

تاريخ الاستلام: 2023/4/4؛ تاريخ الموافقة على النشر: 2023/8/28