RFID Tracking of Potted Plants from Nursery to Distribution

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Abstract

Secure identification of individual plants is needed in potted flowers industry to guarantee traceability, quality and origin of plants, to protect quality marks and for genetic heritage preservation. Besides, the identification at single plant level allows automated data collection and contributes to oppose the counterfeit phenomenon.

This paper describes how a RFID based traceability system for single potted plant tracking from nursery to distribution in commercial greenhouses during the whole production process of Camellia and Azalea can be implemented. RFID systems operating at three frequencies were evaluated: LF systems were tested in the case of tag insertion in the soil, while HF and UHF systems were adopted using tags embedded in plastic label strongly anchored to the plant roots. Different combinations of mobile and fixed antennas, readers and transponders were evaluated. Reading tests were performed on single or multiple plants, both in dynamic and static conditions. The LF RFID solution resulted suitable in the case of tag insertion in the potting compost. Multiple identification in HF gates is reliable in the case of plants arranged on a trolley passing, at low speed, through a narrow gate. Multiple dynamic pot reading resulted promising with UHF combination of linear and circular polarization antennas.

Keywords: RFID, potted plants, flowers, greenhouse

Introduction

In recent years, globalization and delocalization of production as well as the emerging of new markets have radically changed the potted plants as well as cut flowers routes. Many of the cut flowers that are sold in Europe are produced in developing countries such as Chile, Colombia, Ecuador, India, Kenia, etc. where the expansion of flowers productions is supported both by low production costs and climatic conditions which favour year-round cultivation (Huges, 2000). New technological solutions are needed to manage and safeguard the valuable production of both small and large sized greenhouses. The identification of each single plant makes substitution errors impossible, and is a useful tool for those controlling the materials (Luvisi *et al*., 2010). Interesting applications using radiofrequency identification technology were recently developed for various tree species (Bowman, 2010) and for grapevine. The first experiences on electronic marking of plant samples were attempted to record experimental data about health and growth monitoring by standard plastic label or wristband tags tied to branches (Kumagai and Miller, 2006). RFID technology offers a wide range of solutions for traceability, with different operating frequencies, modulation techniques, communication protocols, and economic value. The identification at single plant level allows automated data collection, contributes to oppose the counterfeit phenomenon, and promotes the originality of the trademark and genetic heritage preservation. A RFID traceability system of the single potted plant was developed for months-long growing process

optimization in commercial greenhouses tagging reusable pot trays conveyed on belts (Walking Plant Systems - WPS - Horti System, 2007).
The aim of the present work is to propose solutions for the tracking of potted plants through the whole production and distribution chain. A technical solution for production districts or cooperation systems where growers act together from nursery to distribution reaching the necessary critical mass to promote their products and to afford the market has been envisaged. As usually in growers cooperation systems, the first stages of production, which consist in the propagation of the genetic material, are centralized in large high tech nursery greenhouses where the single item level identification of plant in pots is required. Several, less specialized, growers carry out the growth of the plant till the retailer. Information technology for item tracking along the whole production chain could be useful to connect together small and large stakeholders allowing also the management of quality and logistic strategies in collective network.

Materials and methods

In this research three different operating frequency bands were considered for the identification of potted plants: LF (Low Frequency, 125 and 134.2 kHz), HF (High Frequency, 13.56 MHz), and UHF (Ultra High Frequency, 868÷915 MHz). Tags and antennas were firstly evaluated in laboratory where standard as well as customized solutions were tested.
Afterwards, trials were conducted in a nursery flower greenhouse where Camellia and Azalea are produced from cuttings. In the greenhouse, 280 plants were electronically tagged at first transplant (from alveolated trays to 100 mm diameter flower pot), by means of different type of transponders located in different positions. Transponder readability was periodically checked. Trials were performed to evaluate the feasibility of single and multiple reading in greenhouse both in static and dynamic conditions.

Low frequency

During the first transplant, 120 potted plants were tagged by different types of LF transponder buried in the soil. Three different models of 125 kHz transponder (Sokymat, IN TAG models) have been evaluated. This transponder model is circular shaped, made in specific modified thermoplastic (PA6) suitable for food, waterproof (IP68), shock and vibration resistant, with operating temperature ranging from -20 to +85 °C. The models differ for dimensions (diameter: 30 and 50 mm) and for memory type, as in 50 mm model the memory is read-only, while the 30 mm model is provided with 2 kbit rewritable memory.
Standard ear-tags for cattle electronic identification (Caisley – model Multiflex) operating at 134 kHz and accomplishing ISO standard 11784 and 11785 were also tested. As the device is expensive due to animal tagging requirement, in case of large-scale use in flower industry, the inlay characteristics must be modified to reduce costs. Transponders were all inserted into the soil, both in horizontal and vertical positions (Figure 1). All pots were arranged on movable rolling benches for single static reading test.
Static readings were performed using a mobile PDA equipped with an integrated LF antenna module or connected to a wand antenna. The PDA was a Psion Teklogix – Workabout PRO equipped with 125 kHz LF module and an Edit ID Bluetooth Wand at 134.2 kHz. Dynamic readings were carried out by a static IDtronic – Bluebox model reader, connected to a 200 x 200 mm panel antenna positioned beside the conveyor belt feeding the machine which automatically arrange pots on movable rolling benches. In the case of 134 kHz transponder an EditID (800 x 600 mm) panel antenna was placed under the conveyor belt.

The reading area of the 134.2 kHz panel and wand antenna was already determined in our previous work on animal identification (Gay *et al*., 2007; Tortia *et al*., 2008; Escobar Fonseca *et al.*, 2008), while for the 125 kHz panel, reading area for different tag/antenna coupling was assessed by laboratory tests. Parallel and perpendicular tag orientations with respect to the panel of the antenna were considered.

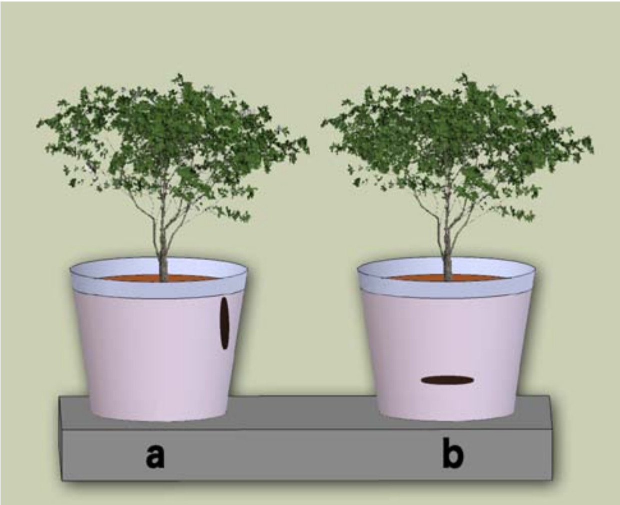

Figure 1. Positions of 125 kHz transponders inside the pot: a) vertical; b) horizontal.

High frequency

80 plants were identified at first transplant by means of custom-made PVC labels embedding HF transponders according to ISO 15693 standard and operating at 13.56 MHz. This label (covered by Italian patent, see Barge *et al*., 2010) consists of two distinct parts: an upper one embedding the transponder (85 x 55 mm) and a holed lower part (80 x 25 mm). The holes allow the roots of the plant, during its growth, to penetrate and surround the label which results strongly linked to the plant and soil. Avoiding the contact of the transponder with the soil, limits the signal attenuation due to water contained in the pot. This solution allows also orienting the transponder in a standard position, which is difficult to accomplish for example with other devices attached to the aerial part of the plant. Static readings were performed using the PDA (Psion Teklogix) changing the RFID integrated module with a 13.56 MHz unit.

Dynamic readings were performed by a static gate composed by an Obid I-Scan HF long range reader (ISO 15693) with 2 W radiating power connected to two single-loop antennas (145 x 85 x 31 mm) in Helmholtz configuration. Gate was 1050 mm wide with antenna center height equal to 1700 mm. Multiple readings were carried out with pots positioned on steel trolleys (1350 x 560, height 1900 mm) commonly used in greenhouse for items handling and shipping. The width of the gate allowed the passage of the trolley carrying the plants. Trolley was manually pulled trough the gate at constant speed ranging from 0.2 to 0.5 m/s (Figure 2). 48 pots were placed on two shelves (740 and 1180 mm respective height) of the trolley with RFID label all oriented in parallel configuration with respect to the reader antenna. In another trial, the same pots were casually set regardless plastic label orientation in order to simulate real production conditions.

Ultra high frequency

A label embedding an UHF transponder was developed as well, composed by the same holed lower part but containing in the upper part an EPCglobal Gen 2, ISO 18000-6 transponder (Figure 4). As this transponder type is smaller than HF tags, it was possible to obtain an aerial part of only 85 x 35 mm, which is more likely to be used in flower production contexts.

As in the HF experimental set-up, 80 plants were identified. Workabout PRO PDA equipped with UHF module (400 mW radiating power) was used for mobile readings. Both linear Calearo Compact Directional Antenna (170 x 155 x 75 mm) and circular polarization antenna Caen WANTENNAX005 (245 x 235 x 40 mm), were used. In order to evaluate static reading area of UHF antennas, a specific laboratory trial was developed. 128 potted flower were set into a 16 x 8 rectangular grid (3200 x 1600 mm), identified by UHF labels, all parallel oriented with respect to the antenna, which was placed at the centre of the longer side. Reading number of every single transponder in a set time period was used to assess the reading area. Another trial was carried out with 40 plants arranged into a 5 x 8 square grid in order to evaluate reading efficiency simulating reading of plants set on benches of the greenhouse by two UHF linear antennas positioned in different configurations at a constant height of 650 mm with respect to the plane where pots were laying. Then, multiple dynamic readings were conducted in greenhouse on pots placed both on movable rolling bench (5800 x 1630 mm) and on trolleys. To enhance the pots number, some pots were filled by soil and identified with the label. Dynamic multiple reading tests were performed with Camellia and Azalea potted plants set on rolling bench moving at 0.07 m/s forward speed with 2 linear polarization antenna in staggered configuration. The efficiency improvement occurring adding a circular polarization antenna was assessed. A specific 1950 x 2200 mm wide gate with 4 linear and circular polarization antenna was built for multiple dynamic reading of 129 potted flowers set on five shelves of a trolley, which was spinning on a platform commonly used for trolleys wrapping with plastic film before shipping (Figure 3).

Figure 2. Multiple dynamic reading of 48 potted plants electronically identified by HF plastic label transponders.

Figure 3. Dynamic multiple reading of 129 potted plant identified by means of plastic label UHF transponder during wrapping process before shipping.

Results

At the end of the trial all transponders resulted in good operating conditions after 8 months spent in greenhouse. Tag presence in the soil didn't affect normal plant development along all greenhouse production cycle. The growth of the aerial part of the identified plants has not been affected by the presence of the transponder with respect of control plants (without tag). Tags buried in the soil resulted completely enclosed in the plant roots and they were even difficult to find without the aid of RF detection.

The lower part of HF and UHF electronic labels were firmly fastened to the soil. At the growth stage reached at the end of the trial, both for Camellia and Azalea plants, the whole potted plant could be even raised from the bench grasping the label without risk of label detachment (Figure 5).

Figure 4. Insertion into the soil of custom-made PVC label embedding an UHF transponder at first transplant.

Figure 5. After 8 months of growing the whole potted plant could be even raised grasping the label without risk of detachment.

Low frequency

The 125 kHz panel antenna reading area resulted similar in shape to the 134.2 kHz one, but, due to the smaller dimensions and the lower radiated power, maximum reading distance in the air, between tag and panel antenna ranged from 180 to 250 mm respectively for perpendicular and parallel orientation. When the transponder was surrounded by the soil, maximum reading distance decreased on average by 20%. In greenhouse dynamic reading tests of flowerpots spaced out at 650 mm and moving on the conveyor belt at 0.2 m/s constant speed, only the configuration beside the belt was effective on vertically inserted transponders (Fig. 1- a) Transponder models INTAG 300 and INTAG 500 resulted always readable in any orientation with respect to the antenna. However, due to the low reading area the antenna should be placed very close to the pots.

On the contrary, the 134 kHz Edit-ID panel antenna placed under the conveyor belt allowed 100% dynamic single reading of tags inserted both in horizontal and vertical position when plants were moving on the conveyor belt spaced at 650, 400 and 300 mm mean distance among each other. At distances among pots lower than 250 mm, the 134.2 kHz panel antenna reading performance decreased. As during the transplant in normal operating conditions, the pots are usually placed on the conveyor very close to each other this configuration results not suitable for greenhouse application. In laboratory trials conducted simulating the conveyor by a trolley, it was observed that the collision among tag contemporarily present in the reading area affected the reading performance. However, reducing reading area by means of two metal screens, leaving only a 2 cm of the panel uncovered, 100% reading performance on pots close to each other was obtained only in the case of tag placed parallel to the antenna (Fig 1b). LF tags reading by means of mobile device (PDA) resulted very difficult and sometimes impossible, while 134.2 kHz wand antenna allowed maximum reading distance ranging from 200 to 300 mm depending on mutual tag-wand orientation. Reading distance resulted not to be affected by water presence in soil. By means of the wand, an operator can identify each potted plant arranged on the greenhouse bench.

High frequency
Maximum reading distance of a 35 mm diameter transponder loop placed in parallel position in front and at the centre of a single Obid long-range antenna resulted 700 mm, while the shape of the reading area obtained in laboratory is similar to LF panel antennas. Thus, the 1050 mm wide gate employed, allowed 350 mm reading area overlapping. The results of both dynamic trials whit HF gate are reported in Table 1.

Table 1. Dynamic multiple reading of 48 potted plants electronically identified by means of HF plastic label. Plants were set on a two shelves pot plant trolley.

Tag/antenna orientation	*Trolley forward speed (m/s)*	*Reading efficiency (tag read/tag present)*
parallel	0.20	100%
	0.35	100%
	0.50	85%
random	0.20	83 %

Dynamic multiple reading trial at trolley linear speed up to 0.35 m/s of plastic electronic labels arranged all in parallel orientation gave good results (Tab. 1) while, when the trolley speed reached 0.5 m/s, only 85% of tags were correctly detected. In case of randomly orientated labels, only 83% tag reading efficiency was obtained at the lower speed tested (0.2 m/s linear speed).

Ultra high frequency
Static reading test showed that a single linear polarization UHF antenna can cover an hypothetic area of the bench of 1000 x 1400 mm, detecting correctly all the tags in parallel configuration. Only by two linear polarization antennas set in parallel and staggered configuration at a distance of 800 mm, all the considered area was covered.
Dynamic multiple reading tests of a total of 160 Camellia and Azalea plants set on rolling bench with 2 linear polarization antenna in staggered configuration showed a maximum reading efficiency equal to 96% (Table 2). Antenna orientation was parallel with respect to bench forward direction. No reading efficiency improvement occurred with additional circular polarization antenna installed upon the bench in perpendicular orientation with respect to bench forward direction. A 1950 x 2200 mm wide gate composed by 4 linear and circular polarization antennas was built for multiple dynamic reading of potted flower set on trolley.

This latter was spinning on a platform commonly used for trolleys wrapping with plastic film before shipping (Figure 3).

Figure 6. Psion Workabout Pro PDA reading 40 potted Camellia and Azalea electronically identified by means of plastic label UHF transponder.

In a first trial, where all circular polarization antennas were mounted on the gate, the reading cycle began when the trolley was already placed on the platform and lasted 47" which was the normal elapsed time for the wrapping process. After 8 repetitions, a mean number of 127.7 on 129 tags were read (Table 3).

Table 2. Dynamic multiple reading on movable rolling bench of 80 potted plant electronically identified by means of UHF plastic label by means of different configuration of linear polarization antennas.

Antennas configuration	*Gate dimension (m)*		*Bench speed (m/s)*	*Mean reading efficiency (tags read/tags present)*
	width	*height*		
2 parallel-frontal	1.63	1.2	0.07	86 %
2 parallel-staggered			0.07	96 %

Table 3. Dynamic multiple reading of potted plants identified by means of UHF plastic label by a gate composed by different combination of linear and circular polarization antennas.

Gate configuration	*Reading cycle time (s)*	*Mean reading efficiency (tags read/tags present)*
4 circular	47	99%
4 circular	57	100%
2 linear + 2 circular	57	100%

In a second trial the reading time was extended of 10", which was the time employed for the loading on the spinning platform by an operator. In this case, after 8 repetitions, 100% reading efficiency was obtained. The last test was performed alternating linear and circular polarization antennas in the gate. Reading cycle lasted 57" and started 10" before trolley load on spinning platform. Also in this case 100% mean reading efficiency was attained. The

Workabout PRO PDA was used in greenhouse to periodically check the operational status of UHF label transponders (Figure 6). This device could read simultaneously 40 pots identified by labels staying at the end of the bench.

Conclusions

LF technology at 125 kHz is a viable solution only if the tag must be buried in the soil, however the short reading distances are limiting. LF identification is possible on benches only using a wand, which is a very time-consuming solution. LF dynamic identification on conveyor belts is not optimal, as major changes with respect to the normal working parameters must be adopted.
HF systems resulted suitable for the single reading by the PDA, but in multiple dynamic reading of RFID plastic label tags, position highly influences reading performance.
UHF systems can be applied in greenhouse both for single static and multiple dynamic identification of plants tagged by means of the label adopted in the project.
Plant traceability management by UHF systems can be performed at item level and identification can be performed by an operator with a PDA both on single or a group of plants or by gates both on bench and on trolley. The particular shape of the HF and UHF labels allow to fasten strongly the tag to the plant roots not compromising the normal growth.

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