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Transplanting for Conversion to Warm Season Turfgrass

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Warm season turfgrass species (like bermudagrass) seem to be very suitable to Mediterranean climate conditions. They also give an excellent wear resistance to the sport pitches. Transplanting of pre-cultivated warm season turgrass plants (similar to horticultural nursery) is a promising technique which can be efficiently used for turf conversion. It is based on the quick ground cover capacity of these species by means of stolons and rhizomes. Transplanting can be performed both in tilled and untilled soil. A working yard for the conversion of a professional football pitch was assessed in order to evaluate the performaces.
The transplant was performed with a 4-row mechanical transplanter which had been adjusted to work in the untilled mowed football pitch. The mechanical transplanter accommodates 4 back-seated operators and 4 walking operators who can manually transplant the plants in case of failure. The working speed of the tractor was less than 1 km h^{-1}, theoretical working time was about 15 h ha^{-1}, actual working time was 28 h ha^{-1}, thus the work efficiency was about 0.52. Fuel consumption was about 28 kg ha^{-1}. Such a low efficiency was due to the difficulty of the operators to remove the plants from the trays and supply the transplanter's delivery system. In this concern, an automatic transplanter was modified in order to work in untilled soil within a second specific trial. This machine had an automatic system for removing the plants from the trays, like the most advanced robotic transplanters for vegetable crops. Moreover, a specific system for plant deposition in untilled soil was developed by mounting a double disc in front of the furrowers. Plant deposition was tested and a maximum variation of 6 cm in the row was assessed with respect to the expected value. This gap is completely in accordance with this kind of crop.

1. Introduction

In the XXI th century man and nature are often far between since their interaction is close to none, especially in large urbanized areas. Consequently the importance of urban turf areas has widely increased during the XX th century. Turf areas can help people to enjoy the benefits of nature and to come in touch with natural elements, upgrading individual wellness. Most turfgrass species belong to the family Gramineae. Inside this family there are two main groups: cool season turfgrass species and warm season turfgrass species (Turgeon, 2012).
The maximum growth of cool season turf species in Mediterranean climate occurs during spring and autumn. Cool season turf species thrive in mild climates with cool summer temperatures and abundant rain, typical of northern countries. Conversely, the maximum growth of warm season turf species in Mediterranean climate occurs during summer, with a dormancy period during winter. In fact, warm season turf species are native to tropical countries with high summer temperatures and drought (Turgeon, 2012).
Warm season turf species need less water. Water consumption of warm season turf species is 20 % to 45 % lower than that of cool season turf species (Kim et Beard, 1988; Volterrani and De Bertoldi, 2012). Warm season turf species are well adapted to seek for water since their root system that can reach a depth of 2 m, while cool season turf species root system will reach a depth of just 50 cm (Croce et al., 2004).
Thus, warm season turf species are more suitable for mediterranean climate as their growth is higher in conditions of water stress and high temperature compared to cool season species (Volterrani and De Bertoldi, 2012). Warm season turf species have superior wear resistance (Lulli et al., 2012). This is probably the most important reason why many Italian professional football pitches and in general Italian sport turfgrasses are now often converted to warm season turfgrass species.

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Warm season turf species produce stolons and rhizomes which hold the soil together preventing erosion if the turf is worn and allowing quick recovery. Wear resistance is not compromised during winter dormancy although there is no vegetative activity. However winter dormancy is a relevant limit for the use of these species because they completely get yellow during winter period and the turfgrass can not be pleasant from an aesthetic point of view. This is the reason why often professional sport warm season turfgrasses are painted or overseeded with cool season turf species in winter time (Volterrani and De Bertoldi, 2012).
Cool season turf is often replaced by warm season turf where water resources and precipitations are limited (Schiavon et al., 2013). Several warm season turf species have been studied to select the most suitable for mediterranean climate along with good results in turf quality. In Italy, hybrid cultivars of *Cynodon* spp. have given the best results (Volterrani and De Bertoldi, 2012). These hybrid cultivars do not produce seeds since they are unfertile, so several vegetative reproduction techniques have been experimented.
The most common vegetative reproduction techniques are stolonizing, plugging, sodding and transplanting.
Stolonizing involves stolons and rhizomes to be delivered on the ground surface and then mechanically buried, rolled and subsequently top dressed. The quantity of stolons delivered is approximatively 0,3 to 0,8 m^3 for 100 m^2 of turf area (Croce, 2013).
Plugging consists in planting small plots (from 5 to 20 cm wide) at 30-50 cm one from the other on untilled soil. Plugging is widely used for Zoysia spp. and Stenotaphrum secundatum but leaves many areas exposed to weed invasion since the plots take several months to cover the ground completely. Plugging requires from 5 to 10 % material that would be needed to cover the entire surface (Croce, 2013).
Sodding consists in transplanting a mature turf that has been grown and cared for in a professional way. The turf must be transplanted very quickly after it has been cut, ideally before 24 hours, and is usually laid on untilled soil. A turf fulfilled by sodding can be used immediately after the transplant, even on sloped areas with erosion problems. The disadvantages of sodding are high costs and high labour, since the sod must be as fresh as possible (Croce, 2013).
Transplanting of single potted plants an innovative technique developed in Italy that has been recently internationally patented (Volterrani et al., 2008; Del Viva, 2012). Turf plants Up to 1.2 ha of turf can be fulfilled during one day by transplanting. Transplanting can be performed on untilled soil and is significantly cheaper than sodding. Transplanting is the most suitable technique to convert a cool season turf to a warm season turf when soil tillage is not performed.
The aims of this study are: 1) characterize a turfgrass transplanting ordinary work yard for the conversion of a professional football pitch from cool season to warm season turfgrass in untilled soil; 2) develop a specific automatic transplanter for this task.

2. The trials

The first part of this work was focused on the characterization of the working yard to perform turf conversion of the “Stadio Comunale Sant'Elia” football pitch, placed in Cagliari, Italy. The stadium’s turf was converted from a cool season turf to a warm season turf transplanting bermudagrass (Cynodon dactylon (L.) Pers x transvaalensis Burtt-Davy). The yard was assessed from May 31 2011 to June 1 2011. The aim of the yard was to transplant in untilled soil single potted bermudagrass plants grown in common nursery trays (Figure 1a,b). The preliminary cultural practices consisted in herbicide treatment, mowing with a single reel cylinder mower with clipping collection, scalping with a flail mower with clipping collection, fertilization with an ordinary spreader. The work yard was characterized by the following machines/operators:
•a 4WD tractor;
•a common 4-row mechanical transplanter, adjusted to work in the untilled mowed football pitch and to accommodate 4 back-seated operators (one per row, planting distance: 25 cm inter-row and 24 cm intra-row) (Figure 1c);
• 4 walk behind operators who manually transplanted the plants in case of failure or of plants placed out of the furrow (Figure 1d).
After transplanting the field was rolled. The yard was organized by the company Azienda Agricola Pacini-Erbavolgio Hi-Turf (San Giuliano Terme, Italy). All the operative characteristics of the work yards were assessed (tractor speed, theoretical working time, total working time, effective working capacity, working efficiency, fuel consumption). Moreover, specific assessments on the quality of the work were carried out like plant density before and after the machine passage, percentage of plants out of the furrow, plant density after the passage of the walk behind workers, plants out of furrow after the passage of the walk behind workers.
The second part of this work was aimed to develop, test and improv an automatic transplanter, specific for transplanting the single potted warm season turfgrass species directly in untilled soil. The automatic transplanter was developed in collaboration with Centro di Ricerche Agro-Ambientali Enrico Avanzi and with Azienda Agricola Pacini-Erbavolgio Hi-Turf company (San Giuliano Terme, Italy). The automatic machine, with

respect to the ordinary semiautomatic ones, does not have the need of the back seated operators feeding the plant delivery system, saving labour time and increasing work efficiency. Moreover, the machine was equipped with specific tools to properly deliver plants in untilled soil. Different machine working speeds and different in-row plant distances were tested. A t-test was used to compare the real in-row distance with the theoretical in-row distance.

Figure 1: Work yard for the transplanting of single potted plants of bermudagrass in untilled soil.

3. Operative characterization of the work yard for bermudagrass transplanting in untilled soil

The work yard was composed of 9 operators: 1 driving the tractor, 4 backseated on the semiautomatic transplanter, 4 walking behind for manual transplanting in case of failures. The tractor was powered by a 41 kW engine. The average tractor speed was 0.7 km h^{-1}, which is appropriate for this kind of machine considering the operational conditions in untilled soil. However, real working time was 28 h ha^{-1}, thus very far from theoretical working time (15 h ha^{-1}). The effective working capacity was 0.036 ha h^{-1} and the effective working efficiency was only 52%. Fuel consumption was 28 kg ha^{-1} (Table 1).

Table 1: Operative characteristics of the work yard for bermudagrass transplanting.

Characteristics	Units	Values
Tractor engine power	kW	41
Tractor speed	km h^{-1}	0.7
Theoretical working time	h ha^{-1}	15
Total working time	h ha^{-1}	28
Effective working capacity	ha h^{-1}	0.036
Working efficiency	%	52
Workers	n.	9
Fuel consumption	kg ha^{-1}	28

The low efficiency of the working yard was mainly due to the frequent clogging of the plant delivery system, causing the machine to stop. The long stolons of the single potted bermudagrass plants would easily get stuck. Walk-behind workers needed extra time to fill the numerous failures once the transplanter reached the end of the field because they were not able to go as fast as the machine. Walk-behind workers needed time to provide the bermudagrass trays to the back seated operators. The reason of the numerous failures was mainly due to a large number of plants ending out of the furrow because the transplanter did not have specific furrowers for no tillage. Moreover, the back seated operators did not have enough time to properly fill the plant delivery devices. In fact, bermudagrass plants were often chained to each other by their stolons and it was not easy to quickly separate them (Figure 2). Plant chaining can be avoided with frequent cutting operations in the nuersery.

Figure 2: Chained single potted bermudagrass plants.

These aspects relevantly affected work quality. Before the passage of the walking operators, real plant density was lower than the expected plant density (12 vs 17 plants m^{-2}) and 11% of the plants were out of the furrow. After the passage of walk behind workers, plant density increased to 23 plants m^{-2}, resulting in over-transplanting, and the percentage of plants out of the furrow was only 1% (Table 2).

Table 2: Quality of the work for bermudagrass transplanting.

Variables	Units	Values
Expected plant density	n. m^{-2}	17
Plant density before walking workers	n. m^{-2}	12
Plants out of the furrow	%	11
Plant density after walking workers	n. m^{-2}	23
Plants out of the furrow	%	1

4. Development and test of the automatic transplanter for warm season turfgrasses in untilled soil

The automatic transplanter prototype for warm season single potted turfgrasses was developed in order to overcome the numerous limits emerged from the ordinary work yard assessed in Cagliari. The machine is equipped with a robotic system for trays and plant pick up (the same adopted in the advanced automatic transplanters) and a specific system for plant deposition in untilled soil (Figure 3).
The principal devices of the machine are:
•trays pick up system;
•plant pick up system with 10 claws running in specific rails (Figure 3);
•plant delivery system to plant furrowers. It is made by a sliding chassis which collects 5 plants to the delivery pipes.
•plant deposition systems made by 5 furrowers with couples of inclined discs, for a total working width of 1 m.
The machine is connected to the tractor by the three point hitch. The motion of the different tools is made by hydraulic, pneumatic and electric motors. The machine is equipped with a front roll 1.2 m wide which helps the machine to “float” in tilled soil and provides the signal for real time speed based plant delivery in both tilled and untilled soil (Figure 3).

Figure 3: Automatic machine for warm season turfgrasses transplanting: a) machine view and detail of the front roll; b) claws for plant pick up; c) sliding chassis to deliver plants to furrowers; d) furrowers.

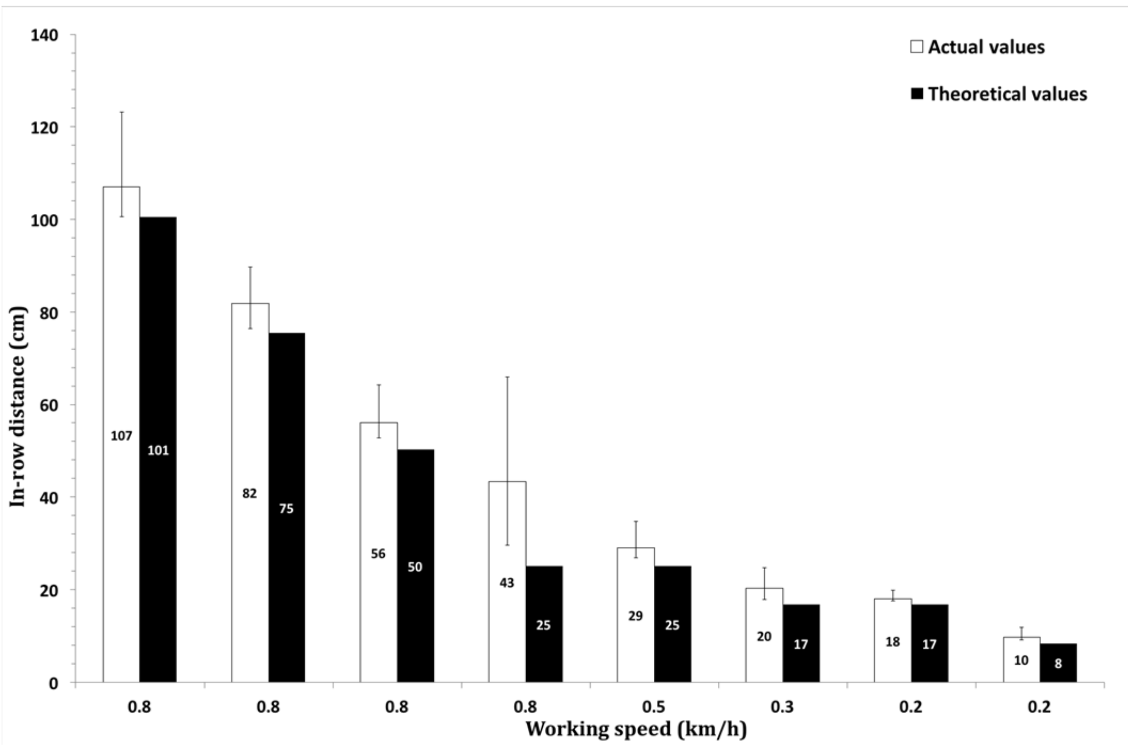

Figure 4: Work quality of the automatic machine for warm season turfgrass transplanting as comparison between actual and theoretical in-row distance, at different speed and in-row distance settings.

From the field test of this prototype, work quality seemed to be relevantly affected by the working speed of the machine (Figure 4). When the working speed of the machine was low, like 0.2 km h^{-1}, the actual in-row distance values of the plants resulted very close to the theoretical values (9.76 vs 8.40 cm). When a higher working speed was adopted the gap became more relevant (on average about 6 cm of gap from the actual to the theoretical in-row distance). From the t-test, the actual in-row distance value was always significantly higher then the theoretical value. This is probably due to the automatic plant pick up and delivery devices which need time to work properly. However, from an operative point of view, a 6 cm gap between the actual value and the theoretical value can be acceptable in the field. 0.8 km h^{-1} is approximately the same working speed assessed in the case of the semi-automatic machine used at Sant'Elia Stadium in Cagliari (Italy).

5. Conclusions

Warm season turgrasses are optimally suitable to mediterranean climate and have a very high wear resistance. Warm season turfgrass transplanting in untilled soil resulted a very functional and cheap alternative to the use of sods (precultivated turf rolls) for turfgrass convertion. From a farm mechanization point of view, the use of a common semi-automatic transplanter with back seated operators, followed by walk-behind operators, appeared to be effective but required a large amount of labor and had low efficiency. The precision of the plant delivery system and the efficiency of the plant deposition in untilled soil were not satisfactory. Performing frequent stolon cutting in the warm season turfgrass nursery could be a first step to increase transplant efficiency since it will prevent plant chaining. In fact, chained plants take much more time to be handled by the back seated operators and can lead to plant deposition failures in the field.
The development and test of a specific automatic transplanter with specific furrowers for untilled soil showed a significant improvement in plant deposition efficiency. Moreover, the absence of the back seated operators highly reduced labour demand. However, plant deposition precision was highly affected by working speed.

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