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Establishment of a grafted overhead-sweetpotato cultivation system with root-function spatial division

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ABSTRACT

We report here a new cultivation system for sweetpotato [*Ipomoea batatas* (L.) Lam.] production, named grafted overhead-sweetpotato cultivation (GOSC) system. In this system, sweetpotato (as scions) was grafted with convolvulaceae relatives (as stocks), and the stems of grafted sweetpotato were buried in a solid medium without any nutrient and hung in the air to regenerate overhead-sweetpotato (storage roots). The results showed that *Ipomoea trifida* (6×), Beinong5521 (5×) and SH-2 (6×) were the best stocks. All the tested sweetpotato cultivars could produce overhead-sweetpotato with different yields. The mixture of sand, perlite and vermiculite with a 1:1:1 (v/v/v) ratio was the best solid medium for the GOSC system. The key stage of overhead-sweetpotato formation was about 20 days to 55 days after stem buried. Since storage roots are not regenerated from stocks grown in fertilized soil but from scion stems buried in non-fertilized solid medium, it seemed that the grafted overhead-sweetpotato plants had root-function spatial division (RFSD), i.e. absorbing roots of stocks and storage roots of scions. The graft compatibility with sweetpotato, the stock without underground storage roots, and the stem-buried media without nutrient supply, are the key factors for RFSD and overhead-sweetpotato production. This system could be used as a model for the study of the interaction between stock and scion as well as the source-sink relationship in sweetpotato.

1. Introduction

Sweetpotato [*Ipomoea batatas*(L.)Lam.] is an important crop as vegetable and food for humans and as feed for domestic animals as well as industrial materials. In previous studies, storage root yields as high as 1790 g per plant were produced with an edible growth rate of up to 66 g m^{-2} d^{-1} and a harvest index as high as 89% under greenhouse conditions in a flowing system with recirculation designed to use the nutrient film technique (NFT) system (Hill et al., 1989, 1992). Another hydroponic system for sweetpotato production was developed for nondestructive measurement of tuber growth in a controlled environment (Eguchi et al., 1996), which was different from the NFT system. Sweetpotato Gravel Cultivation (SGC) system (Sawahata, 1989) separated storage roots and absorbing roots through the nutrient solution applied to gravel culture, and by burying the stem to induce the storage roots. Nutrient solution cultivation (NSC) system (Yang et al., 2007) originated from NFT (Morris et al., 1989) and SGC, was very successfully used in a new type of sweetpotato production, in which storage roots could be exposed to the air.

In NSC system, sweetpotato plants were cultivated in the nutrient solution instead of the soil, and their vines were led to the grid in the above, then some stems on the grid were buried in the mixture of sand, perlite and vermiculite with 1:1:1 (v/v/v) and watered. Here, the adventitious roots growing in the nutrient solution are named absorbing roots because of their special function of absorbing nutrients and water, and some of the adventitious root regenerated from the buried stem on the grid developed into storage roots exposed and hanging in the air during mid and late growth. The sweetpotato produced from the NSC system was also named "Kongzhongganshu" in China (Cheng and Yang, 2007) and first termed "overhead-sweetpotato" in the present paper. The NSC

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system requires rigorous supply of mineral nutrients, costs much more, and is only suitable for cultivars with long vines. Further research is required to analyze the mechanism of nutrient solution cultivation and to exploit a cheap and simple technique for overhead-sweetpotato cultivation (Cheng, 2008). In traditional cultivation, sweetpotato is planted in the soil and the underground roots include the absorbing roots and storage roots. The core of the NSC system is that the root functions are divided into absorption and storage, because of the nutrient solution lacking oxygen and pressure (Nakatani, 1994).

Grafting is a magical technique with a long history, and is widely used in plant breeding and cultivation programs in order to modify plant architecture, improve vigor, induce flowering, improve fruit quality, or increase disease resistance (Takeno, 1991; Wang, 2011). Furthermore, it has been widely used in plant biological research, such as substance transport within plant tissues, flowering regulation, and signal transduction mechanisms (Xoconostle-Cázares et al., 1999; Notaguchi et al., 2008; Martin et al., 2009). In sweetpotato, grafting experiments have suggested that the high productivity is due to the sink potential of the storage root (Hahn, 1977). Single leaf grafting was used to estimate the sink potential of sweetpotato cultivars (Nakatani et al., 1988), and used in the analysis of the feed-forward effects of sink activity on the photosynthetic source-sink balance (Sawada et al., 2003). In the SGC system, grafting was also used to research the relationship between the formation and thickening of storage roots of the stocks in the soil (Sawahata, 1989).

In the present paper, grafting is firstly exploited to realize RFSD and to establish a new sweetpotato producing system—grafted overhead-sweetpotato cultivation (GOSC) system, which could be also used as a research platform to study the source-sink relationship in sweetpotato.

2. Materials and methods

2.1. Materials

Stock materials included three types of the Convolvulaceae: TypeI, *Ipomoea purpurea*, *Ipomoea nil* (long vine), *Quamoclit pennata*, *Ipomoea hederiflia* (2×), *Ipomoea nil* (2×, dwarf and short vine), *Ipomoea obscure* (2×), *Ipomoea postigridis* (2×); TypeII, *Ipomoea trifida* (6×, belongs to the wild relatives of sweetpotato), Beinong 5521 (5×, belongs to interspecies hybrids of the sweetpotato and wild relatives, and was created by Prof. Qingchang Liu, China Agricultural University); Type III, SH-2, Tanzania, Yantai green, Taiwan purple, Fushu 18, Fushu 7-6. All Type III sweetpotato has poor storage roots grown in Chengdu, Sichuan province, China.

Scion materials listed in Table 1 included 15 sweetpotato cultivars with different flesh and skin color of storage roots, and length type of vine. These cultivars set storage roots well.

2.2. Grafting

Approach grafting was carried out on stock plants with approximately 30 to 35 cm in height. The cambium of stock and scion were exposed by cutting the epidermis and cortex using a razor blade with sections 2 to 3 cm. The sections were combined by low-density polyethylene film (LDPE) to prevent water evaporation, and enlaced by string to assure the surfaces closely combined. The scion was immersed approximately 3 cm into a plastic cup with water. At last, the grafted plant was fixed and the tip of the stock on top of the graft union was cut off. About two weeks later, when a new leaf grew out from the scion, the scion stem below the graft union was cut off and the water cup was removed.

Table 1
Main traits of different scions.

Variety	Storage roots	Type of vine
	Skin color/flesh color	
Nanzi 008	Purple/purple	Long
Xuzi No.1	Purple/purple	Long
CS1-21-1	Red/dark orange	Long
Chuanshu 217	Red/white	Long
Yanzi No.1	Purple/purple	Long
Nanshu 88	Light red/light orange	Mid
Chuanshu 34	Red/white	Mid
Chuanzi No.1	Purple/purple	Mid
Xushu 22	Red/white	Mid
Xushu 18	Red/white	Mid
Wanshu No.7	Light red/orange	Short
Chuanshu 294	Orange/orange	Short
Xuzi 20-1	Purple/purple	Short
Chuanshu 20	Orange/orange	Short
Xinxiang	Red/light orange	Short

The long vine is defined as the length of the longest vine is longer than 2.5 m, the mid is defined as the length of the longest vine is between 1.5 m and 2.5 m, and the short is defined as the length of the longest vine is shorter than 1.5 m, in traditional cultivation pattern.

2.3. Determination of suitable stocks for GOSC system

To detect suitable stocks for overhead-sweetpotato production, Xushu22 was used as the scion to graft 15 different stocks. The control was the non-grafted Xushu22. The plants were cultivated in soil in bamboo baskets with the size of 40 cm × 50 cm × 50 cm (length × width × height) for upward cultivation (Fig. 1a). The soil of one bamboo basket was mixed with 120 g complex fertilizer ($N{:}P_2O_5{:}K_2O = 2.5{:}1{:}3$) and 6% humus. One plastic flowerpot (Fig. 1a-C) with the size of 33 cm × 26 cm (diameter × height) per plant was used to bury the scion stem and was 2 m high from the ground. The stem was buried in a medium that was the mixture of sand, perlite and vermiculite with a 1:1:1 (v/v/v) ratio (Cheng, 2008). Grafted overhead-sweetpotato was harvested at 90 days after burying stem, nine plants for each grafting combination. Grafting compatibility, underground roots with or without storage roots, and yields of overhead-sweetpotato were used as the standards for stock selection. This experiment was conducted in 2011 and 2012.

The lateral bud of the grafting plant must be cut off before burying the stem. No fertilizer was added to the burying medium. Two to three nodes of the scion stem were buried into the medium with a depth of 2 to 3 cm, then watered and kept moisture for two weeks, after which watering stopped. All the grafted plants and controls were transplanted and buried stem for the same group experiments at the same time.

2.4. Determination of suitable growing media for GOSC system

To select appropriate media for producing overhead-sweetpotato, eight different stem-bury media were employed to bury scion stem of grafted plant SH-2/Xushu22 (stock/scion, the same as below). One flowerpot was used to bury scion stem for one grafted plant. The methods of cultivation and burying stem were same as the stock selection experiment described above. Six grafted overhead-sweetpotato plants for each medium were collected at 90 days after burying stem. The shape and yields of grafted overhead-sweetpotato was the standard for media determination. This experiment was also conducted in 2011 and 2012.

Eight different stem-bury media were consisted of five basic components: perlite, vermiculite, sand, soil (loam); humus (Chengdu Happy Farm Ltd., China), Farm Soil (Chengdu Happy Farm Ltd., China).