Water Use Efficiency and Yield of Grafted and Non Grafted Sweet Potato Tuber as Affected by Soil Water Conditions

Saraswati Prabawardani
Faculty of Agriculture and Agricultural Technique, Papua State University
Jl. Gunung Salju, Manokwari, Irian Jaya Barat, Indonesia, email: danissa_id@yahoo.com

ABSTRACT. The research was aimed to observe water use efficiency and the yield of grafted and non-grafted sweet potato tubers under soil field capacity conditions. The research was carried out in the glasshouse of the School of Tropical Biology, James Cook University, Townsville, Australia during December 2003 to April 2004. The experimental design included four types of planting materials and two soil water treatments in a factorial design using 40 pots in a complete randomized design with five replications. Planting materials consisted of non-grafted cv Lole, non-grafted cv Wanmun, grafted Lole rootstock and Wanmun scion, grafted Wanmun rootstock and Lole scion. Each sweet potato cultivar was planted in 30% and 80% soil field capacity. Water use efficiency and the tuber yield components were recorded. The results showed that non-grafted Wanmun sweet potato cultivar was planted in the greatest tuber weights under well-watered conditions. Under water stress, however, the Lole scion grafted onto Wanmun rootstock produced the greatest tuber weight. Under water stress, the Lole cultivar and the Lole scion grafted onto Wanmun rootstock had greater water use efficiency.

Keywords: Sweet potato, water stress, water use efficiency, grafting

Sweet potato is a major staple food for people in many parts of the wet tropics and subtropics including Papua, Indonesia. It is commonly propagated by vegetative part, such as vine cuttings. Sexual breeding strategies, on the other hand, have not been very effective (Prakash 1994), as incompatibility or sterility is common in sweet potato (Reynoso et al. 1997). Traditionally, Papuan farmers have selected seedlings from natural (segregating) populations, for specific traits. It is also widely known that polycross seeds have been used to a limited degree and have potential for breeding programs.

The earlier studies indicated that Wanmun and Lole sweet potato cultivars differ in their responses to water stress (Saraswati et al. 2004). Wanmun produced higher tuber yield but it was very susceptible to water stress, Lole however, had lower tuber yield but it was more tolerant to moisture stress. Sexual breeding is a long-term activity requiring a lot of resources and has often been unsuccessful for sweet potato (Prakash 1994), as incompatibility or sterility is common in this plant (Reynoso et al. 1997). Grafting may offer a short-term solution by combining desirable characteristics of different cultivars into one plant. If successful, the grafted plants open up possibilities for enhanced sweet potato production in drought-prone areas.

Grafting is an asexual propagation technique, which can be used to combine the desirable characters of the root and vegetative parts of different plants. Graft has been reported by Hua et al. (2002) stimulating inheritable variations in the progenies of mungbean (Vigna radiata L.) scion with sweet potato rootstock. Graft also changed the fruit shape and colour of eggplant scion (Solanum melongena L.) (Hirata 1980). The grafting method has been used in sweet potato to screen the yield potential and relative sink strength (Kuo and Chen 1992). However, there is a lack of information in relation to the effect of grafting on water use efficiency.

A grafting experiment, therefore, was carried out to observe the water use efficiency and in attempt to obtain the plants that embody Lole’s tolerance to drought and Wanmun’s high tuber yield.

METHODOLOGY

The experiment was carried out from December 2003 to April 2004, in a glasshouse of the Douglas Campus,
James Cook University, Australia. Pots of 10 L volume without drainage holes were used to accommodate 11 kg of growing medium per pot. The medium was clean sand that was washed to remove any soil components, air-dried for several weeks to constant moisture, and its moisture content was determined. The amount of water required to bring the soil in the pots to field capacity was calculated based on the gravimetric method.

Stem tips of about 25 cm length of Lole and Wanmun cultivars were grafted onto the rootstocks of Wanmun and Lole that had been growing in the pots for 2 months at 80% of soil field capacity. The scions and rootstocks were cut using grafting tool. Grafting unions were covered with a 3 cm length of a plastic drinking straw and held in place with parafilm. The grafted plants were kept humid by spraying them with water regularly throughout the day and were kept in a shaded area for one month until the graft union was established and healed.

After one month, the tip-grafted plants were cut-off 15 cm below the graft union and 15 cm above the union. The cuttings were kept in water for 2 days until roots appeared from the nodes and were then planted in 10 L pots containing 11 kg of sand. Cuttings were planted into pots, then watered to 100% field capacity. Water was then withheld until the pots reached the desire treatments (30% or 80%) of field capacity. After which, watering was done every second day to maintain the pots at either 30% or 80% of field capacity throughout the rest of the growing period.

Fertilizers were supplied as required by adding soluble osmocote, every second week at the rate of 1 g/plant for the first three months. Additional potassium was given as 1 g of potassium sulphate/plant at one week after planting.

The treatments were as follow: (1) 4 planting materials: (a) Non-grafted Lole; (b) Non-grafted Wanmun; (c) Grafted: Lole rootstock and Wannmun scion; (d) Grafted: Wannmun rootstock and Lole scion, and (2) 2 soil water regimes: (a) 30% of soil field capacity and (b) 80% of soil field capacity. The experiment was laid out in a factorial design using a complete randomized design with 5 replications. Analysis of variances was calculated to examine the treatment effects on water use efficiency and tuber yield components. Water use efficiency was the ratio of the total dry biomass gain to the total mass of water used during the growing period (Lambers et al. 1998) as follows:

\[
\text{Water use efficiency} = \frac{\text{dry biomass (g/plant)}}{[\text{g/kg of } H_2O]} \times \text{the amount of water used (kg/plant)}
\]

Significant treatments or combination of main effects were observed based on the Duncan Multiple Range Test at a 0.05 probability level.

RESULTS AND DISCUSSION

Water Use Efficiency

Water use efficiency (WUE) plays an important role in productivity and survival under drought stress (Da Matta et al. 2003). WUE was found to be significantly greater in plants grown under water stress. Lole scion grafted onto Wanmun rootstock had the greatest WUE, followed by non-grafted Lole, non-grafted Wanmun, and the Wanmun scion. This indicated that a plant that has higher WUE will resist to drought better (Taiz and Zeiger 2002).

Under well-watered conditions, non-grafted Wanmun had greatest WUE, followed by Lole, the Lole scion, and the Wanmun scion. These results were comparable to those reported by Taufatofua (1994) who recorded that an average WUE of 3-4 g/kg for well watered sweet potato cultivars. Wanmun consumed the greatest amount of water for its growth and development as a consequence of its high biomass production and heavy tuber yields.

Tuber Yields

Tuber weight declined under the imposed water stress (Figure 2). Wanmun had the greatest tuber weight under the well-watered regime. Under water stress, however, the tuber weight of Wannmun declined by 63%. The tuber weight of non-grafted Lole was 640.4 g/plant, and it declined by 49% under water stress. This decline was slightly

![Figure 1. Water use efficiency of Lole and Wanmun cultivars, Lole scion grafted onto Wanmun rootstock (L-W), and Wanmun scion grafted onto Lole rootstock (W-L), grown under 30% and 80% of soil field capacity.](image-url)
higher than that of the Lole scion grafted onto Wanmun rootstock (46%).

The Wanmun scion grafted onto Lole rootstock produced luxuriant top growth but few, small tubers under both soil water regimes; this response might be attributed to the graft incompatibility. Under the well-watered condition, this plant only produced 102 g tuber/plant compared to the Lole scion grafted onto Wanmun (640.4 g/plant). The fibrous root system of Wanmun grafted onto Lole rootstock was extensive and penetrated deeper into the soil similar to non-grafted Lole cultivar grown under well-watered conditions. It shows that the root part of Lole somehow reduces the tuber storage sink and may affect partitioning of the assimilate into storage roots.

The Lole scion grafted onto Wanmun rootstock produced slightly higher tuber yield than the non-grafted Wanmun under water stress. Under water stress, the Wanmun scion grafted onto Lole rootstock produced much lower tubers/plant than non-grafted Lole. According to Kuo and Chen (1992) both source potential (leaves) and sink strength (tuber roots and its components) play a vital role in regulating the yield of sweet potato. Sink strength, more than source potential, affects photosynthesis and translocation. The sink thereby controls dry matter production and the development of storage roots (Kuo and Chen 1992).

Lole produced significantly more tubers under well-watered conditions, at the expense of lower weight per tuber (Figures 3). This productivity is higher compared to Lole grown under water stress, which produced the fewest tubers. Wanmun produced an average of 3 tubers per plant under water stress, which was slightly lower than the 4 tubers/plant when grown under well-watered conditions. The Lole scion grafted onto Wanmun rootstock produced the same number of tubers as non-grafted Wanmun under both soil water regimes. It is suggested by Kuo and Chen (1992) that graft with strong sink (storage roots) will show greater tuber yields than those with weak sink strength irrespective of source (leaves) potential. On the other hand, Wanmun scion grafted onto Lole rootstock produced more fibrous root. It was probably due to the grafting incompatibility, in that; from 4 grafted plants (Wanmun scion onto Lole rootstock) only 2 plants produced tubers, which were smaller than the original non graft Lole.

According to Kuo and Chen (1992) the ability of clones to develop storage roots early or late was determined by their sinks, not by their sources. Therefore, a graft with a strong sink appeared to have greater response of sink to source than a graft with a weak sink; likewise, a graft with a large source appeared to have a greater response of source to sink (Kuo and Chen 1992).

There is an association between mean tuber weight and tuber number found in many crops, wherein high tuber numbers are likely related to low individual tuber weight (Lowe and Wilson 1975 in Norman et al. 1995). The highest average of tuber weight produced under well watered conditions were from non-grafted Wanmun followed by the Lole scion grafted onto Wanmun rootstock, Lole, and the Wanmun scion grafted onto Lole rootstock. Under the water stressed conditions, however, the Lole scion grafted onto Wanmun rootstock, and Lole produced the greatest tuber weight (Figure 4).

Wanmun and the Lole scion grafted onto Wanmun rootstock started tuber growth early under well-watered conditions. This helped determine their potential in maximizing tuber yield faster than the others on sweet potato plants studied.
CONCLUSIONS

1. Reducing water availability to 30% of soil field capacity, decreased the yield of the non-grafted and grafted sweet potato plants.
2. Scion and rootstock control both aspects of the growth and development of vegetative and reproductive parts.
3. Wanmun showed poor compatibility when grafted as scion onto Lole rootstock and produced very few tubers compared to the other plants. Lole produced the largest number of tuber under well-watered conditions. Under water stress, however, the number of tubers declined in all plants particularly in Lole, but brought about an increase in average tuber weight.
4. Biomass reduction maturity, water use by the non-grafted and grafted plants was lower during the entire growth period under water stress. The non-grafted Wanmun cultivar and the Wanmun scion grafted onto Lole rootstock used large amounts of water as a consequence of greater transpiring leaf surface area and its anatomical properties.
5. Under water stress, the Lole cultivar and the Lole scion grafted onto Wanmun rootstock had greater water use efficiency. On the other hand, the Wanmun cultivar had the greatest water use efficiency under well-watered conditions.
6. The ability of sweet potato genotypes to partition carbon into the tubers is important in determining storage root yields.
7. Selection for greater water use efficiency is useful criterion in coping with water deficit problems.
8. Combining the traits between an efficient leaf transpiring organ and potential sink strength led to the production of greater yield and water use efficiency.

ACKNOWLEDGEMENT

The author expresses appreciation and gratefully acknowledge support from Dr. M. Johnston, Assoc. Prof. R. Coventry and Dr. J. Holtum as the supervisors for this project from which this work is reported.

REFERENCES