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Postharvest Quality of Tablestock Potatoes in Response to Drip Irrigation and Harvest Time

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Effect of irrigation method and harvest time on quality and storability of potato tubers was evaluated. 'Fabula', a tan-skinned, yellow-fleshed tablestock variety, was irrigated using surface drip (SD), sub-surface drip (Sub-SD), or seepage (SP) irrigation. Tubers were harvested 1, 2, and 3 weeks after vine kill (H1, H2, and H3), and then stored for 14 d at 10 °C and 90% to 95% relative humidty. Similar total yields of 26,104 kg·ha^{-1} and 26,983 kg·ha^{-1} were obtained for SP and SD, respectively, while yields were lower for Sub-SD (18,918 kg·ha^{-1}). Changes in tuber fresh weight, dry matter content, bioyield, and ascorbic acid content were evaluated each 7 d during storage. An interaction of irrigation method and storage time had an effect on dry matter content of tubers harvested 1 week after vine kill (H1). However, no significant differences in tuber storage quality were observed at the other two harvest times. The results indicated that comparable tuber yield and quality can be obtained for SP and SD irrigated 'Fabula' plants. This is especially true when tubers are harvested 2 to 3 weeks after vine kill.

Potatoes are the leading vegetable crop in the US, with an average of 60 kg of tubers being consumed annually per person. Florida, together with Arizona, California, North Carolina, and Texas, are the main producers of the high-value spring crop, with Florida contributing a third of the production (USDA, 2011). The potato plant is characterized by a shallow root system, making it highly sensitive to inadequate or excessive amounts of soil moisture. Seasonal variation in rainfall amount and distribution experienced in Florida requires growers to supplement the rainfall with irrigation. Seepage irrigation is the commonly used irrigation method in north Florida because it is less expensive to install and easier to manage than drip irrigation. However, this system needs high natural water tables, or large quantities of water to raise the water table. According to Trippensee (1995), the daily average water withdrawal for potato production alone in the Tri County Agricultural Area (TCAA) of Hastings, St. Johns, and Putnam counties was 171.6 million gallons. An increase in resident population, seasonal droughts and erratic rainfall distribution over the last decade, with 60% of the rain falling between June and September, has led to increased water demand in the area (Fereres et al., 2003). Extended periods of dry weather, with some areas experiencing rainfall deficits of 30 cm, has resulted in a significant decrease in ground and surface water levels (St. Johns River Water Management District, 2012). In addition, seepage increases the incidence of drainage flow and subsequent nutrient leaching and run-off losses from production sites into surrounding water bodies. These shortfalls, coupled with increased competition for water resources over the years have resulted in increased focus on alternative irrigation methods that are more efficient.

Microirrigation systems, such as drip, have proved to be more water-use efficient, using 30% to 50% less water compared to seepage systems (Niebling and Brooks, 1995). With drip irrigation, drip tape is placed on the soil surface (surface drip), or buried below the seed piece (sub-surface drip), with the water being discharged close to the plant root zone, at a controlled rate. This maximizes the amount of moisture in the crop root zone, while minimizing evaporation, runoff, and nutrient leaching (Haman, 1996). Owing to its multifaceted benefits, drip irrigation is currently being used in Florida for numerous commercial crops, including citrus, strawberry, blueberry, peppers, tomato and melons. If feasible as a Best Management Practice (BMP) for potato, drip irrigation could be a viable option to improve crop water and nutrient use efficiency, protect water bodies and environment; while maintaining tuber yield and postharvest quality. Already, some growers in the TCAA have shown great interest in drip irrigation of potatoes, allowing large-scale trials to be set up in their fields (St. Johns River Water Management District, 2012).

Different irrigation methods have varying effects on soil moisture levels throughout the growing season. Seepage irrigation artificially raises the natural water table to just beneath the plant root zone, with water moving up by capillary action into the root zone; drip irrigation transfers water down gravitationally to the root zone. These differences in soil wetting patterns could trigger moisture stress which, in turn, affects yield, tuber growth, and skin development; as well as compositional and nutritional qualities (Tyner, 1997; Wigginton, 1974). To date, research has focused on evaluating the effect of irrigation method on potato yield and grade at harvest. Similar or increased potato yields were observed with sub-surface drip, when compared to surface drip and seepage (DeTar et al., 1996; Sammis, 1980). Robins et al. (1956) observed a 58% decrease in U.S. Number 1 grade and a marked increase in malformed tubers under fluctuating soil moisture levels.

Preharvest factors can also affect tuber compositional and nutritional qualities, and subsequently their storability. Therefore,

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the goal of this in-depth study was to determine how irrigation method and harvest time after vine kill affect tuber quality during postharvest storage. The hypothesis was that sub-surface drip irrigation promotes improved tuber growth, development, and quality. In addition, it was hypothesized that tubers harvested 2 weeks after vine kill would have a prolonged shelf-life and better postharvest quality, in terms of tuber dry matter content, firmness, weight loss, and ascorbic acid content.

Materials and Methods

The tan-skinned, yellow-fleshed tablestock variety 'Fabula' was grown in the spring months of 2011 at the UF/IFAS Florida Partnership for Water Agriculture and Community Sustainability, Cowpen Branch in Hastings, FL. The field experimental layout followed a split-plot design (n=4), with irrigation method as the main plot (3 levels) and variety as the sub-plot (2 levels). Plants were irrigated using three methods: seepage (SP), surface drip (SD), or sub-surface drip (Sub-SD). For the Sub-SD, the drip tape was placed 10.2 cm below the soil surface.

Recommended nitrogen rate for potato in the region is 224 $kg \cdot ha^{-1}$ (Hochmuth et al., 2001). Granular fertilizer (N–P–K) was applied at pre-plant (56, 112, 168 $kg \cdot ha^{-1}$), and two side dressings at emergence (84 $kg \cdot ha^{-1}$ N and 125 $kg \cdot ha^{-1}$ K). The remaining $kg \cdot ha^{-1}$ N was applied when plants were 15 to 20 cm high. Hilling was carried out as necessary, and appropriate pesticides applied according to IFAS recommendations. Upon maturity (about 90 d after planting), plant tops were killed off using a single application of the chemical desiccant glufosinate ammonium (Rely® Herbicide, Bayer, NC). The herbicide was applied at a rate of 3506 mL/ha, and the first harvest was conducted 7 d after application. Temperature probes were placed in the beds to record soil temperatures, while soil moisture levels were recorded using a Time-Domain Reflectometer (TDR). Weather data was obtained from the Florida Automated Weather Network (http://fawn.ifas.ufl.edu/).

Harvest times were selected according to weeks after vine kill, ranging from 1 to 3 weeks (H1–H3). At each harvest, tuber specific gravity was measured by weighing the sample in air and under water and calculated as follows: specific gravity = weight in air / (weight in air – weight in water). Tuber total and marketable yields were determined at the final harvest (H3) from a 6.1-m (20-ft) section per plot. For the storage experiments, tubers were hand-dug to avoid skin injury, placed in well-ventilated plastic crates and transported to the Postharvest Horticulture Laboratory at the University of Florida, Gainesville. Upon arrival from the field, average-sized tubers (150–200 g) were selected, carefully hand-washed, and allowed to fan-dry for 30 min. Tubers were then placed in simulated commercial storage conditions of 10 °C and 80% to 85% relative humidity (RH) for 14 d. Evaluations for tuber fresh weight, dry matter content, firmness, and ascorbic acid content were conducted every 7 d.

Whole tuber weight loss was determined over time using a digital scale and expressed as a percentage of the initial fresh weight. Dry matter content was determined from 2-cm-thick longitudinal sections, which were weighed and oven-dried at 65 °C until they reached constant weight. Dry matter content was expressed as a percentage of the initial fresh weight. Pulp firmness was evaluated using a puncture test, with a 4-mm-diameter probe attached to a TA HD Plus Texture Analyzer (Texture Technologies Corp., Scarsdale, NY). Potato tissue sections (15 mm thick) were made by slicing longitudinally through the middle of each sample. Potato sections were punctured at the stem and bud end and firmness reported in newtons. Ascorbic acid content was determined using 2 g of tissue, according to Association of Official Analytical Chemists (AOAC) method 43.064, "Vitamin C in vitamin preparation in juices 2,6-dichloroindophenol titrimetric method" (AOAC, 1984).

Statistical analysis was carried out using the Statistical Analysis System 9.3 software (SAS® Institute Inc., 2002, Cary, NC). A general linear model (PROC GLM) was used to determine at harvest and postharvest tuber quality responses as a result of an interaction of three irrigation methods, three harvest times, and postharvest storage time. Tukey's test was used to separate significantly different main factor and/or interaction factor means.

Results and Discussion

Total yields of 26,104 $kg \cdot ha^{-1}$ and 26,983 $kg \cdot ha^{-1}$ were obtained for SP and SD, respectively, while yields were significantly lower for Sub-SD (18,918 $kg \cdot ha^{-1}$). A similar trend was observed with marketable yields (Table 1). Data obtained in this study contradict previous studies where higher yields were reported for Sub-SD, compared to SD and sprinkler methods (De Tar et al., 1996; Sammis, 1980). Smajstrla et al. (1995) also reported similar yields from SP and Sub-SD irrigated potatoes. The lower Sub-SD yields observed in this study could possibly be due to some form of moisture stress during plant growth. Unlike in SD where water moves down gravitationally, in Sub-SD the drip tape is placed below the seed piece, which means the water moves up by capillarity. Inadequate wetting of the plant root zone in the Sub-SD method could have triggered moisture stress, which in turn affected various physiological processes, such as transpiration, photosynthesis, cell enlargement, and enzymatic activities. Such stress has been found to negatively affect leaf growth and carbon partitioning; thereby reducing yield, tuber growth, skin development, compositional and nutritional qualities (Tyner et al., 1997; Wigginton, 1974).

The results in this study also showed that an interaction between irrigation method, harvest time and postharvest storage affected dry matter content of tubers. Freshly dug (0 d in storage), SD irrigated tubers, harvested 1 week after vine killing (H1), had significantly lower dry matter content (14.6%), whereas SP tubers averaged 16.7% (Fig. 1). Dry matter content of SD tubers increased to 17.2% after 7 d in storage, and no changes were observed in either SP or Sub-SD tubers. Potatoes from either H2 or H3 had no significant differences in any of the quality parameters (specific gravity, dry matter content, firmness, ascorbic acid content).

These results suggest that the immature skin of SD tubers harvested 1 week after vine kill could have led to differences in storage quality. Irrigation has been reported as one of the management factors affecting plant growth, senescence, efficiency of vine kill, and subsequent tuber skin maturation (Haderlie et al., 1989; Lulai and Orr, 1993; Sanderson, 1984). The effect of the tuber skin

Table 1. Total and marketable yield ($kg \cdot ha^{-1}$) for 'Fabula' tubers harvested 3 weeks after vine kill (H3).

Irrigation method	Total yield	Marketable yield	Total culls
Seepage (SP)	26,104	17,696	8,409
Surface Drip (SD)	26,983	17,947	9,036
Sub-SD (SSD)	18,198	13,429	4,769

[z]Means within a column followed by the same letter do not differ significantly according to Tukey's multiple range test, 5% level.

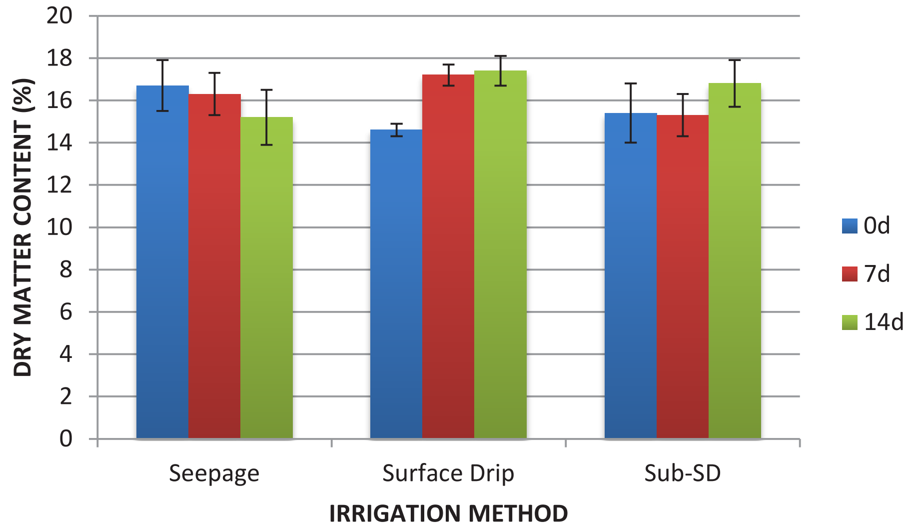

Fig. 1. Interaction of irrigation method and storage time on dry matter content (%) of 'Fabula' potato harvested 1 week after vine kill (H1).

quality on storability is further supported by the increase in dry matter content observed during storage of SD tubers. The increase in dry matter content observed in these tubers was likely due to increased water loss through the immature skin during storage.

In conclusion, these results indicate that comparable tuber yield and quality can be obtained for SP and SD irrigated 'Fabula' plants, especially when tubers are harvested 2 to 3 weeks after vine kill. Further work to determine the effect of irrigation method on tuber skin maturation is suggested.

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