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YIELD RESPONSE OF 'WHATLEY-LORETAN' SWEETPOTATO (*IPOMOEA BATA-TAS* (L.)) TRANSPLANTED IN SINGLE AND DOUBLE ROW AT DIFFERENT DATES IN A WIREGRASS TUNNEL HOUSE

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Abstract

A split-plot study was conducted to evaluate the yield response of 'Whatley-Loretan' sweetpotato when planted in single and double rows at four planting dates (March, April, May, and June) in a Wiregrass Tunnel House located at S&B Farm in Eufaula, Alabama. The main plots consisted of planting dates, sub-plots single, and double rows, with each treatment combination, replicated three times. The results showed a significant linear and quadratic effect for US#1 grade of sweetpotato and total marketable yields. Yields were highest at the first and second planting dates and declined at the two later planting dates. Single vs. double row planting significantly affected canner grade of sweetpotatoes, while the other grades were unaffected.

Keywords: Sweetpotato, Single Row, Double Rows, Planting Dates, Tunnel House

Introduction

Tunnel Houses (THs), also known as, Hoop Houses, or Walk-in-Tunnels, are structures made from metal or wood and covered with 6 mils thick greenhouse plastic. These structures are designed to either extend the growing season during the cool and cold periods of the year; or allow producers to advance their planting dates during the spring season (Ghent., 1990; Wells., 1993; Khan et al., 1994; Blomgren and Frisch, 2007). A Wiregrass TH is a protected structure (Blomgren and Frisch, 2007; Upson, 2014) framed from wood instead of metal and covered with greenhouse plastic. The aforementioned model was designed and constructed with a grant from the USDA Natural Resource Conservation Service. The agency is offering financial assistance to farmers who are considered historically underserved, and beginning farmers to undertake conservation practices, including THs (USDA NRCS, 2014).

Sweetpotato (*Ipomoea batatas* (L.) Lam) is a member of the Convolvulaceae family and is related to morning glory. It is a native of Central and South America and the tropical islands of the Pacific and northern New Zealand. The early European explorers introduced this crop via the Columbian Exchange to other tropical and subtropical regions of the world (Splittstoesser, 1990). This crop is relatively heat tolerant and is grown mainly in the Southeastern U.S. during the summer months where it requires a frost-free growing period of 110 to 150 days. It does best at an optimum temperature range of 75-85°F (Maynard and Hochmuth, 2007). Sweetpotatoes are traditionally grown in fields on bare soil, and since 1989, sweetpotato production in North Carolina has accounted for nearly 40% of U.S. output, followed by Louisiana, and Mississippi (Offner and Jim, 2004).

Since many growers have been successful in planting Brassica, and other cool cool-seasons such as leaf lettuce, beets, potatoes, spinach, radish, and carrots in their THs during the cool/cold season, a number of growers have expressed intentions of utilizing their THs year-round. Because of the short day length in the fall and winter seasons, the TH does an excellent job of maximizing the “Greenhouse Effect” and provides very favorable growing conditions during this time of the year. However, these favorable winter growing conditions can soon have a negative impact on plant growth because of the longer days of summer, and the closeness of the earth to the sun. Therefore, the “Green House Effect” now becomes a disadvantage because the temperature range inside the TH can become very economically unfavorable for the growth of many crops (Johnson, 2011).

Irrespective of the unfavorable growing conditions which exist in THs during the summer months, TH growers and extension agents are requesting summer planting recommendations for THs. Since sweetpotato is known for its ability to withstand heat and drought conditions, it was selected to determine how it would respond under TH conditions during the summer growing period. Therefore, the main objective of this study was to determine (1) the best planting date under TH conditions which would maximize storage root marketable yield (2) determine if double planted rows would have higher marketable yields vs. single planted rows.

Literature Review

Tunnel Houses

THs are useful in extending the planting season for vegetable, small fruit, and cut flowers producers. These days, many growers are utilizing THs in their production systems (Carey et al., 2009). In the nineties, Ghent (1990) and Wells (1993) found that spring-planted tomatoes were produced early in Connecticut and New Hampshire, respectively. Later, in Alabama, Khan et al. (1994) also found that several Cole crops can be cultivated in the coldest period of the year in a TH without any supplemental heating.

THs can be either permanent or moveable. The permanent ones are normally constructed in the ground by embedding the posts in concrete. However, the moveable ones are constructed in such a way that they can be pushed or pulled on skids or rollers. There are two main models of THs, Quonset and Gothic. A major advantage of the Quonset model is that it is easier and cheaper to construct. However, its sides are so low that they will make cultivation of tomatoes and similar crops, especially those that get close to the sides, difficult. To correct this, the sides are normally modified to be straight or bowed, resulting in more room for the growth of vertical crops (Upson, 2014). The Gothic model THs are preferred by growers who live in places where there is substantial snowfall. In these places, the peak roofs do not allow the snow to accumulate but fall off quickly. The downside is that because of the shape of the roof, the plastic does not adhere closely to the rafters and causes it to flap constantly under windy conditions.

There are a number of moveable TH models; however, the multi-bay models have the lowest cost per unit growing space. There three moveable types of THs that are popular with producers. These are skid-mounted, the roller, and the lift and tote models. The shortcoming of these models is their size limitation, 20 ft. wide but shorter than 96 ft. in length. Many of the growers who choose to build their THs use polyvinyl-chloride (PVC) pipes. However, this material is recommended for small hobby type houses. The reason is that PVC pipes are not treated to withstand

UV degradation for longer periods. Therefore, the gray wall electrical conduit pipes are recommended for moveable THs, because they are more able to tolerate UV degradation (Upson, 2014).

Ordinarily, THs are made from heavy gauge steel pipes. These can be purchased as a kit or the tubes can be custom bent by the grower. Also, the “Wiregrass” Tunnel House, developed in Alabama (Khan et al., 1994; Khan et al., 2013), combines the best aspects of the Quonset and the Gothic styles. Specifically, it is constructed from wood, polyethylene plastic tubes, covered with 6 mil greenhouse plastic, and has black canvas roll-up sides, and doors. The Wiregrass TH has other unique features of the Wiregrass TH including insect, wild animal, and vermin exclusion fences, to reduce the number of spraying for insects and to prevent other animals from burrowing into the TH. To prevent flooding, the ground floor with topsoil by 1ft. This has a secondary benefit; that is, it amends the top soil, which may not be suitable for vegetable production, thus allowing the growers maximum use of their THs.

Sweetpotatoes

Sweetpotato is an important root crop in tropical and subtropical regions of the world, and it is ranked as the seventh major food crop in the world. In the Southern U.S., it is considered as a vital vegetable crop (USDA ARS, 2004), and it contributed more than \$500 million to the country's economy in 2012 (USDA, 2013). The sweetpotato crop matures at either 80 or 90 days after transplanting. Alternatively, the vines are removed and mechanical harvesters are then used to remove the potato storage roots from the soil. After harvesting, the storage roots are taken to a storage facility and they are graded and cured. The period of curing lasts for 5-days where the storage roots are kept at a temperature of 80°F-90°F with a relative humidity of 80-90%. The curing process is carried out to rapidly heal wounds present on the roots caused by the harvesting procedure. After the curing process has been completed the roots are then stored at 55°F-60°F with a relative humidity of 85-95% (McCollum, 1975).

The time of planting commercial sweetpotatoes in the Southern U.S. is from late May to late June; certainly, no later than July 4. Some growers may attempt early planting near the ending of April but this may not be helpful since sweetpotato is a tropical-season plant that is grown in a temperate climate, and thrive when daytime temperatures are near 90°F and nighttime temperatures are in the upper 60s°F or 70s°F. These temperatures are more common from June into September. If one chooses to grow early, such as in April, a slight improvement in growth and shortening the length of the season could be gained. However, this limited gain could be off-set if cold weather persists into mid-May. A successful crop can be obtained if the variety selected has a relatively short growing season and growing conditions are favorable. On average, 50% of the sweetpotato crop is planted by June 10 with harvest beginning as early as late August through October (Jennings et al., 2019).

Previous Work

Gajanayake et al. (2014) evaluated the effect of temperature on storage root growth and development of “Beauregard,” and reported that temperature treatments applied during early stages of sweetpotato growth significantly affected crop growth and development. They also reported that storage root developmental rates exhibited sigmoidal growth patterns across all temperature ranges, while storage root developmental rates estimated from these functions showed quadratic trends, with a maximum at 85°F in 16.7 days. The optimum temperature rates reported for vine

elongation and leaf area expansion rates were 88 and 85°F, respectively. Leaf addition rate, however, increased linearly with an increase in temperature. Even though total stem and root biomass increased quadratically with temperature, the optimum temperatures varied significantly among the growth processes; 85°F for total biomass, 86°F for stem biomass and 60°F for root biomass. Leaf biomass; however, increased linearly with an increase in temperature. As the temperature increased, the proportion of biomass partitioned to storage roots significantly declined, while the leaf and stem biomass increased.

Velumani and Saravanan (2012) in a review indicated that sweetpotatoes express three growth phases based on the partitioning of dry matter. The first phase is characterized by the diversion of a large amount of dry matter directed to shoot growth. The second phase is characterized by the division of dry matter between the shoot and storage roots. At the third stage, a major proportion of the dry matter produced by the plant is diverted to the storage roots. However, high soil moisture prolongs the production of dry matter but the amount diverted towards the storage roots is reduced because a larger portion is allotted to shoot growth.

Islam (2006) suggested that sweetpotato cultivars can be developed for multiple uses, especially for nutritional purposes of protecting human health against the diseases linked to oxidation such as cancer, allergies, aging, HIV, and cardiovascular problems. This crop contains high concentrations of polyphenolics when compared with the major commercial vegetables such as spinach, broccoli, cabbage, and lettuce. Thus, sweetpotatoes offer the possibility of adding greatly to the available food supply and to the supply of bioactive compounds necessary for maintaining good human health. Furthermore, the leaves of sweetpotato can be considered physiologically functional food which can also be used as a tea, in bread, confectioneries, noodles, and as a nutritional supplement. Consequently, the foliage of the sweetpotato has the potential of becoming a new alternative crop, and due to the high level of phytonutrients in the leaves, it could also serve as a new food additive product to the food processing industry as a functional food enhancer.

The use of low-density polyethylene (LDPE) black plastic mulch (BM) increased yield and earliness for some warm-season crops such as cantaloupes and watermelons (Wilson et al., 1987; Khan, et al., 1989; Khan et al., 1993). Similar studies using (BM) were conducted to evaluate the response of sweetpotatoes. Results from these studies (Brown et al., 1998; Hochmuth, 1983; Khan et al., 1999; 1996) reported increased sweetpotato storage root yields as well as above-ground plant biomass. In a recent TH, study Walton et al. (2018) evaluated two varieties of sweetpotatoes under two different growing conditions (conventional and trellised), and concluded that the yield data was varietal dependent and contingent upon growing the growing system. They suggested that additional studies should center around other varieties of sweetpotatoes and planting dates because time of planting is known to affect yield.

Materials and Methods

Tunnel House

The research was conducted during the summer of 2015 in a Wiregrass TH located on the premises of S & B Farm in Eufaula, Alabama. A TH is a low-cost Quonset structure constructed from wood or metal, polyethylene pipes, and protected by clear greenhouse plastic film, without any additional heat or cooling. All planting is done directly in the soil. The TH has several special characteristics, which are: it is framed of wood and with black polyethylene tubing for its rafters;

it has roll-up canvas curtains on the sides and these allow adequate ventilation; it has roll up doors, and it has for its covering with 6 mils of clear greenhouse plastic. The dimensions of the TH are 48 ft. long x 20 ft. wide. This translates to a gross area of 960 sq. ft. and a net planting area of 828 sq. ft.

Soil Type

The soil type at the research site was characterized as Norfolk sandy loam (fine, siliceous, thermic Typic, Paleudults). However, it was later reclassified as Kinston fine-sandy loam (fine loamy, siliceous, semiactive, acid, thermic Fluvaquentic Endoaquepts) (USDA, 2004).

Tunnel House Site Preparation

The site was prepared first by using a mechanical rototiller, and second, by preparing and shaping raised beds manually with a wooden mold. The dimension for each plot was 16 ft. x 1 ft. Also, used on each plot was a NPK (13-13-13) mix of fertilizer, based on soil test recommendations. The rows were orientated in a North/South direction, and all plots were side dressed with muriate of potassium at 65 days after transplanting. Chapin Drip Tape irrigation lines were also placed in the center of each bed to provide irrigation water to the plants, and the beds were covered with white on black plastic mulch. Using methods described by Khan et al. (1996), all plots were irrigated for two hours every other day until the end of the study at 120 days after transplanting.

Sweetpotato Variety

The sweetpotato variety used in this study was “Whatley-Loretan”, which was released by Tuskegee University in 2005 as a dual purpose sweetpotato which can be grown under field and hydroponic conditions, and matures within 80-120 DAT (Tuskegee University, 2005).

Experimental Planting Materials

Five-inch-long vine plugs of “Whatley-Loretan” were raised in the greenhouse in plug trays for six weeks. After the six weeks, they were transplanted 12 inches within plots for a total of sixteen plants for single planted plots and 32 plants for double planted plots. A 2” PVC pipe was used to punch holes through the plastic mulch in which the plugged sweetpotato transplants were planted. Weeds growing between rows and on beds were manually controlled.

Field Experimental Design and Data Collection

All plots were arranged into a randomized complete block design with a split-plot arrangement and four replications per treatment (Snedecor, 1966). The main plots were planting dates (March, April, May, and June); sub-plots were single or double planted rows giving eight treatment combinations: March single or double planted, April single or double planted, May single or double planted, and June single or double planted. At 45 DAT a strip of plastic mulch 15’ long and 8” wide was removed from each treatment to reduce the risk of predisposing the storage roots to soft rot diseases (Khan et al., 1999).

Harvest Procedure and Statistical Analysis

At 80 DAT, all treatments were harvested by first the vines and the remainder of the plastic mulch. Plants were then manually dug up with a garden spade, and storage roots were graded

into the following grades: US#1, Cannery, Jumbo, and Culls. Total marketable yield was then obtained by combining US#1, Cannery, and Jumbo yields, while total yield was obtained by combining total marketable yield, and culls (USDA ARS, 2004). Each grade was then weighed and counted by treatments and all data were analyzed using Factorial Analysis of Variance with mean separation by Fisher's F test (Snedecor, 1966).

Weather data

The ambient temperatures within and outside the TH were monitored with an AcuRite 01512 Wireless Weather Station. This unit complies with the temperature on a 12-minutes cycle, the data was downloaded every 14-days and the average temperature was then calculated by taking the mean of the daily maximum and minimum. Degree growing days (GDD) is defined as a day when the when the average daily temperature is at a minimum of one degree above the lower developmental threshold. It was calculated using the procedure described by Miller et al. (2001).

Results

The TH indoor average and outdoor (field) daily temperature, and the GDD which was recorded for the growing period are shown in Table 1. The data show that the ambient temperature inside the TH increased with time and ranged between 11-15 °F above the outside field temperature, and GDD also showed a similar trend.

Table 1. Comparative air temperature and growing degree days for Tunnel House and open field conditions during the growing period of the study.

	Tunnel House	Outdoor Open Field	Differences	Indoor Tunnel House	Outdoor Open Field	Differences
Months	Average (°F)	Average (°F)	Differences (°F)	Growing Degree Days	Growing Degree Days	Growing Degree Days
March	75	64	11	473	290	183
April	83	68	15	507	375	132
May	89	76	13	588	412	176
June	96	85	11	1,068	651	417

Table 2 shows that there were no significant interactions between the main factors of the study. However, there was a significant linear and quadratic effect for US#1 grade of sweetpotatoes and total marketable yield. On average, yields for all market grades decreased as the planting dates advanced into the warmer months of the year. Also, significantly higher yields of canner grade sweetpotatoes were harvested in the double compared to the single planting.

Discussion

One of the objectives of this study was to determine the best planting date for sweetpotatoes in a TH, and if better yields can be obtained by planting the crop in single or double rows. Table 2 shows that there was a significant linear and quadratic component at each monthly planting date for US#1 and marketable yield, which decreased at each successive planting date (Walton et al., 2018). However, the quadratic factor best fits the data and showed that marketable yields were

Table 2. Yield of US#1, Canners, Jumbos, and Total Marketable grades (lbs. /acre) of 'Whatley-Loretan' sweetpotatoes harvested from a Wiregrass Tunnel House at Eufaula AL.

Planting Dates	Market Grades (lbs./acre)							
	Single Planting (lbs./acre)				Double Planting (lbs./acre)			
	US#1	Canners	Jumbo	Total Marketable	US#1	Canners	Jumbo	Total Marketable
March	3,287	203	2,387	4,904	3,105	836	1,139	5,080
April	4,893	743	1,902	7,539	4,167	1,312	832	6,311
May	1,116	335	1,877	3,865	1,950	811	1,437	4,198
June	1,292	364	1,118	2,774	1,689	571	1,014	3,275
Significance of F Test from ANOVA								
Planting Dates								
Linear					-	-	-	-
Quadratic					*	NS	NS	*
Planting Methods					NS	NS	NS	*
Planting Methods X Planting Dates					NS	**	NS	NS
Planting Methods					NS	**	NS	NS
Planting Methods X Planting Dates					NS	NS	NS	NS

**, * and NS, significant at the 1, and 5% level of P, and not significant respectively.

highest at the March and April planting dates and gradually decline thereafter. The growing conditions, especially the temperature, within the TH increased at each monthly planting as shown in Table 1. During March and April, the temperature was within the optimum range (Maynard and Hochmuth, 2007; Gajanayake et al., 2014) for growing sweetpotatoes, while May and June temperatures exceeded the optimum range. When the number of GDD exceeded 375, storage root yields began to decline. Canner grade of sweetpotatoes was the only market grade affected by single or double planting, concluding that there might be no advantage to planting double rows of sweetpotatoes in a TH.

Conclusion

The results from this study have shown that high storage root yields of sweetpotato can be obtained if planted in March or April. Planting in May and June reduced yields, which could be due to the high ambient air temperatures and very high GDD. The results of the study further showed that there was no advantage of planting single vs. double rows of sweetpotatoes because the Canner grade was the only grade affected that was significantly higher when planted on double rows.

Additional studies are needed to evaluate more varieties of sweetpotatoes and to determine the optimum GDD suitable for growing sweetpotatoes in the TH.

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