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THE EFFECT OF A FIFTY PERCENT LEAF HARVEST FROM THREE VARIETIES OF COLLARDS (*BRASSICA OLERACEA(l)*/CULTIVAR GROUP ACEPHALA) CROPPED AT SELECTED INTERVALS WHEN GROWN IN A WIREGRASS TUNNEL HOUSE

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Abstract
A study was conducted to determine the effects of a 50% leaf harvest from 'Heirloom', 'Georgia', and 'Hi-Crop Hybrid' collards on yield, when leaves were removed at 18-, 21-, and 25- day intervals, over four harvest periods of 102, 127, 152, and 177 days after transplanting in a Wiregrass Tunnel House. The experimental design used was a split-split plot with three replications, where harvest periods were main plots, cropping intervals (3) were sub-plots, and varieties were sub-sub-plots. Yield data (lbs./acre) showed significant interactions between harvest periods x cropping intervals for leaf numbers and yield, harvest periods x varieties, and cropping intervals x varieties. The 18-day cropping interval had the highest yields over all harvest periods; while varieties responded differently for each harvest period, and cropping intervals. 'Hi-Crop Hybrid' had the highest yield over all harvest periods and cropping intervals, followed by 'Georgia 'and 'Heirloom.'
Keywords: Collards, Collard Varieties, Leaf Harvest, Tunnel House.

Introduction
Tunnel Houses (THs) are structures made from wood or metal and covered with clear 6 mil greenhouse quality polyethylene plastic. These structures were designed to extend the growing season by allowing vegetable producers an early start in spring or extend the growing season during the fall/winter months in the southeastern part of the US (Ghent, 1990; Khan et al., 1994; Wells, 1993). A Wiregrass TH is a protected structure (Blomgren and Frisch, 2007) framed from wood instead of metal and covered with greenhouse plastic. This model TH was designed and built through a grant from the USDA Natural Resource Conservation Service. This agency is currently offering financial assistance to historically underserved producers and beginning farmers to implement various conservation practices which include THs (USDA NRCS, 2014).

The collard plant is an example of a vegetable crop grown in THs. It originated from Europe or the Mediterranean region of the world, and is a relative of the wild cabbage; it was introduced via the Columbian exchange, which occurred during the period of the European voyages of discovery (Boswell, 1949; Rubatzy and Yamaguchi, 1997). It grows under a wide range of temperatures but 60-65^{0}F is considered the optimum for growth during the cool seasons of the year (Hemphill, 2010). It is a staple in the diet of many residents in the Southeastern U.S. Several states, such as Georgia, North Carolina, South Carolina, and Alabama, grow about 14,000 acres of collards per year (Olson and Freeman, 2008; USDA NRCS, 2014). For instance, by 2013 collard production in Georgia increased significantly, and it is currently the leader in collard production in the Southeast, growing approximately 13,000 acres with a market value of $60M (Georgia Farm Gate Report, 2015).

Usually, when mature, the entire plant of field grown collards are once over harvested between 66-104 days after transplanting; they are trimmed, bunched, and sold (Olson and Freeman, 2008). However, this method of harvest is not sustainable for limited resource producers, because of their limited growing area. As a result, farmers extend their harvests over longer periods of time in order to increase their profitability. Recent studies (Sparks et al., 2018; Walton et al., 2018) compared two varieties “Top Bunch” and “Hi-Crop Hybrid” collards under TH conditions and reported that cropping 50% of the total leaves vs. 100% vs. produced significantly higher yields and showed greater leaf recovery rates when compared to 100% cropping.

The leaf recovery rates at 21 days after cropping 50% of the leaves was 174% compared to 42% for plants cropped 100% (Sparks et al., 2018; Walton et al., 2018). This rate of leaf recovery increased as the number of harvests increased when the number of days between harvests was 21 days. As a result of this high rate of leaf recovery at the 50% level of leaf harvest, this study was undertaken to (1) establish if 18, 21, or 25 days’ intervals was the most suitable time to harvest 50% of the leaves from three varieties of collards, (2) ascertain if there were varietal differences across harvesting periods, and (3) To determine if there are varietal differences across cropping intervals.

Literature Review

Tunnel Houses

THs also referred to as Hoop Houses, Walk-In-Tunnels, or High Tunnels, are considered an important tool in extending or advancing the planting season for many vegetable, small fruit, and cut flower producers in the US. Despite the fact that TH was invented in the US during the fifties, it is only now that growers are utilizing it in their production system (Carey et al., 2009). During the nineties, Ghent (1990) and Wells (1993) reported early yields of spring-planted tomatoes in Connecticut and New Hampshire. Later, in Alabama, Khan et al. (1994) reported that a number of Cole crops can be grown during the coldest period of the year without any supplemental heating.

THs are structures which can be either permanent or moveable. Permanent THs are usually built into the ground by having the posts embedded in concrete, while the moveable houses are built to be pushed or pulled on skids or rollers. There are two models of THs; Quonset and Gothic. The main advantage of the Quonset model is it is easier and cheaper to construct but the sides are so low that they will not permit easy cultivation of tomatoes and similar crops close to the sides. To overcome this shortcoming, the sides are usually modified to be straight or bowed thus allowing more room for the growth of vertical crops (Upson, 2014). The Gothic model THs are preferred by growers who live in areas where there is substantial snowfall. The peek roof does not allow the snow to accumulate but it falls off quickly however, 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 several moveable TH models but the multi-bay models offer the lowest cost per growing space. The three moveable types of THs, which are popular among growers are skid-mounted, the roller, and the lift and tote models. Because these models are moveable, there is a limitation on their sizes which can be 20 ft. wide, and shorter than 96 ft. in length. Some growers who elect to build their THs use polyvinyl-chloride (PVC) pipes in the construction, the use of this material is recommended for small hobby type houses because PVC pipes are not treated to withstand UV degradation for any length of time. Instead of using PVC pipes, the gray wall electrical conduit pipes are recommended because they are treated to withstand UV degradation (Upson, 2014).

Many THs are made from heavy-gauge galvanized steel pipes which can be purchased as a kit or the tubes can be custom bent by the grower. Recently, a wooden model Tunnel House referred to as “Wiregrass” Tunnel House was developed in Alabama (Khan et al., 1994; Khan et al., 2013). This type of house encompasses the best parts of the Quonset and the Gothic styles, and is constructed from wood, polyethylene plastic tubes, and covered with 6 mil greenhouse plastic. It has black canvas roll-up sides, and doors; other special features of the Wiregrass TH include insect, wild animal, and vermin exclusion fences, to reduce the number of spraying operations for insects, and to prevent animals from burrowing into the TH. Flooding due to run-off water from the roof is prevented by elevating the ground floor with topsoil by 1ft. Adding topsoil also serves as an amendment to the ground soil, which may not be suitable for vegetable production; thus, allowing producers to maximize use of their THs.

Collards

Collards can be grown in a variety of soils; however, lighter well-drained soils with a pH ranging from 5.5-6.5 are best for growing collards (Hemphill, 2010; Sanders, 2001). Currently, there are four ways collards are produced commercially. These are (1) plants are planted in early spring and then harvested at approximately 60 days later; (2) grow plants in early spring, harvest the leaves in late spring, and carry plants over to the fall season when the whole plant is harvested; (3) transplant seedlings during August-September and harvest plants from October to December, and (4) plant seeds directly in soil during early spring, thin them after emergence, and carry them over into the fall season (Sanders, 2001). Collards are harvested and sold in bunches of two or three plants. Bunches are then packed 12 to 24 bunches per box or sold by the dozen and are top iced for sale commercially (Coolong, 2017). However, for some markets only the leaves may be harvested or cropped, washed, petioles removed, chopped, and bagged for market (Olson and Freeman, 2008).

Botanically, collards are classified as a biennial, but under selected conditions, they are considered a perennial. The brassica family of plants originated in the Mediterranean region of the world, are best grown in cool climates with relatively high humidity. The optimum temperature for growth is between 50 and 77^{o}F (10 and 25^{o}C). Temperatures above 80^{o}F (27^{o}C) slow or arrest growth. Ideal growing regions are coastal areas where the climate is cool with moderate to heavy rainfall during the vegetative stage of growth, followed by a non-rainy period during the period of seed harvest. Prolong periods of low temperatures during production stages of growth can cause collards to bolt, which is caused by an interaction of plant size (age) and cold temperatures. There is not an exact temperature range at which bolting will occur; however, it is generally accepted that when plants are exposed to temperatures of 39^{O}F-50^{O}F for 4-6 wks., bolting will occur. Large plants are more susceptible to bolting than young plants, which are very resistant to bolting if they were hardened off. There are also varietal differences in susceptibility to bolting (Olson and Freeman, 2008; McCormack, 2005).

Two recent studies (Sparks et al., 2018; Walton et al., 2018) reported that when the leaves of two varieties of collards were harvested at 100 and 50% intensity under TH conditions, there were significant differences in yield based on varieties and harvesting intensities. The results indicated that both varieties when harvested at the 50% level of intensity, produced consistently higher leaf weight and numbers, for successive harvests, compared to those harvested at the 100% level. In addition, they showed that there were significant varietal differences; however, when the leaf recovery rate was measured over a 21-day harvest interval, the data showed that plants which had 50% of their leaves harvested, had higher leaf recovery rates ranging from 114 – 224% when compared to 42- 101% for those plants who had 100% of their leaves harvested. Based on these results, they indicated that the harvest interval of 21 days may be reduced to 12 or 18 days.

Among the crucifer crops of cabbages, broccoli, turnips, mustards, and cauliflower, collards rank as the least expensive vegetable on per cup serving basis when cut and prepared. Collards are also ranked as the 4th vegetable in antioxidant capacity behind sweet potato, mustard, and kale greens. In a study to evaluate the effectiveness of collards, kale, mustard, greens, broccoli, Brussels sprouts, spinach, green bell pepper, and cabbages to bind with bile acids, collard greens rated the best in binding with bile acids and excretion from the body, thus lowering blood cholesterol levels. Consumption of collards also offers some protection against cancer risks because it possesses four different glucosinolates (glucoraphanin, sinigrin, gluconasturtiin, and glucotropaeolin), and these can be converted into an equivalent isothiocyanate which supports the body's detox and anti-inflammatory systems thus decreasing our cancer risks (George Mateljan Foundation, 2018).

Previous Studies on Crop Leaf Removal

The leaves of a number of vegetables are routinely removed before crop maturity, and consumed by many people in developing countries as food. This practice has prompted research studies to determine the extent this practice would have on the overall crop production. Badi et al. (2012) defoliated a local variety of vegetable cowpeas at 0, 25, 50, and 75%, and planted it at four intra-row spacings of 20, 30, 40, and 50 cm. They reported that the best combination of intra-row spacing and defoliation rate was 20 cm spacing and 25% defoliation, which resulted in the highest green pod yield, revealing that the removal of the smallest leaf harvest had a positive influence to increase yield.

Khan and Lone (2005) evaluated the removal of 50% of the lower leaves of mustard plants at 40 (pre-flowering) or 60 (post-flowering) days after seeding, to determine how it would impact photosynthesis, growth, and yield. They reported that defoliation at 40 days after planting resulted in a higher rate of photosynthesis, growth, and yield, compared to defoliation at 60 days after planting or the non-defoliated control. In addition, the emergence of new leaves was also highest at 40 days after planting, and these leaves had a higher photosynthetic and assimilatory capacity than those which emerged after defoliation at 60 days after planting. They also reported that the leaves of partially defoliated plants significantly increased light interception, because they were able to harvest more photosynthetic active rays. Their findings were supported by the results of

Alderfer and Eagles (1976), Carmi and Koller (1979), and Cammerer and Farquhar (1984), De Roover et al., (1999), Hoogester and Karsson (1992).

The results from an okra study, where the lower leaves were removed at 5, 6, and 7 weeks after planting, indicated that the number of pods per plant, pod weights, and yield per hectare, were influenced by the leaf pruning regimes. However, the pod diameter and length, time for flower initiation, plant height, and pest resistance were not significantly influenced. Among the defoliation treatments, removal of the lower leaves at 7 weeks after planting produced significantly longer and wider pods compared to the other treatments. However, the control plants which were not defoliated grew taller and were more resistant to pests and diseases compared to the pruned plants. The overall conclusion of this study showed that removal of the lower leaves of okra plants reduced mutual shading, competition for food, and allowed the younger leaves to intensify photosynthetic activity (Politud, 2016).

In a study that evaluated the effects of leaf removal on the yield of pumpkins was evaluated; Isutsa and Mallowa (2013), reported that 21-29 weekly removal of 3-4 leaves from pumpkin vines resulted in reduced fruit yield but high vine yields. They also concluded that plants, where leaves were not removed, had a shorter lifespan than those that were defoliated. This was attributed to the older leaves turning into sinks on the non-defoliated plants. The plant soon begins the flowering process, and when the fruits mature the plant shortly dies because maturing fruits have a strong sink relationship which depletes the plant of photosynthates. These findings were similar to those of De Roover et al. (1999), and Hoogesteger and Karlson (1992) who reported that defoliated plants undergo a shortage of carbohydrates and increases the allotment of photosynthates to shoot growth, and decreases distribution to fruit and root growth.

Materials and Methods

Tunnel House

This study was conducted during the fall-winter of 2017-18 in a Wiregrass TH located at S & B Farm in Eufaula, Alabama. A TH is defined as a low-cost Quonset structure made from wood or metal, polyethylene pipes, and covered with clear greenhouse plastic film, without any supplemental heat or cooling (USDA/NRCS, 2014). All planting is done directly in the soil and not in raised beds or containers.

Soil Type

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

Tunnel House Site Preparation

The site was rototilled with a mechanical rototiller; rows were then prepared manually. Each plot was 16 ft. X 1.5 ft. in dimension. At the time of preparation, a NPK (13-13-13) mix of fertilizer was banded in each plot, based on soil test recommendations. All rows were orientated in a North/South direction. Plastic tube drip irrigation lines (Chapin Drip Tape) were then placed in the center of each row to provide irrigation water to the plants. All plots were drip irrigated for three hours every other day until the end of the study at 177 days after transplanting (DAT) based on the methods described by Khan et al. (1996).

Experimental Planting Materials

'Heirloom', "Georgia-Collards", and Hi-Crop Hybrid" collard plants were raised in plug trays in the greenhouse and were transplanted when they were six weeks old into the plots that were 16'x 1.5'. They were spaced 12 inches within plots for a total of sixteen plants per plot. Weeds growing between and in rows 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 three replications per treatment (Snedecor, 1966). The main plots comprised of four harvest periods (102, 127, 152, and 177 DAT) while the subplots consisted of two harvesting methods 100% vs. 50% leaf harvest, and the sub-sub-plots were three varieties of Collards giving 24 treatment combinations: 'Heirloom' 50%, 102 days; "Georgia-Collards" 50%, 102 days;" Hi-Crop Hybrid", 50%, 102 days; 'Heirloom' 100%, 102 days; 'Georgia-Collards' 100%, 102 days; 'Hi-Crop Hybrid', 100%, 102 days; 'Heirloom' 50%, 127 days; 'Georgia-Collards' 50%, 127 days; 'Hi-Crop Hybrid', 50%, 127 days; 'Heirloom' 100%, 127 days; 'Georgia-Collards'100%, 127 days; 'Hi-Crop Hybrid', 100%, 127 days; 'Heirloom' 50%, 152 days; 'Georgia-Collards' 50%, 152 days 'Hi-Crop Hybrid', 50%, 152 days; 'Heirloom' 100%, 152 days; 'Georgia-Collards' 100%, 152 days; 'Hi-Crop Hybrid', 100%, 1152 days; 'Heirloom' 50%, 152 days; 'Georgia-Collards' 50%, 177 days; 'Hi-Crop Hybrid', 50%, 177 days; 'Heirloom' 100%, 177 days; 'Georgia-Collards' 100%, 177 days; 'Hi-Crop Hybrid', 100%, 177 days.

Harvesting of the leaves began at 102 DAT and continued at 18, 21, and 25-day intervals up to 177 DAT. At each harvest period, all of the expanded leaves except the apical ones on each plant were counted to determine how many leaves will be constituting the 100 and 50% level of harvest, respectively. All leaves starting from the bottom whorls were removed and stopped when the 50% level was achieved; while all the expanded leaves except the apical ones were removed in the 100% leaf harvest.

Statistical Analysis

Data for the number of leaves harvested were square-root transformed before analysis. All yield data were extrapolated to numbers and yield per acre before being analyzed using Factorial Analysis of Variance with mean separation by Fisher's F test (Snedecor, 1966). Tunnel House yields were converted to pounds per acre using equation 1 below, and Chilling hours were calculated using the F model using the procedure described by Fraisse and Whidden, (2010).

Equation 1. Yield/Acre = (Plot yield*(TH Area/Plot Area)) *(43,560 sqrt ft./area of TH)))

Results

Table 1 shows that the overall numbers of leaves harvested in the study showed a significant interaction between harvest periods and cropping intervals. Examination of this interaction (Figure 1) showed that the 18 and 21-day cropping intervals produced approximately, the same number of leaves compared to the 25-day interval. However, the highest number of leaves were obtained at the second harvest period (127 DAT) for all cropping intervals (3,094,140/acre at 18 days, 3,656,576/acre at 21 days, and 3,390,940/acre at 25 days). Conversely, yields began to decline at the third and continued through the fourth harvest periods for the 18 and 21-day cropping methods. The data also indicated that there were no significant differences among varieties of collards for the number of leaves produced.

Table 1. Number of leaves removed in a 50% partial harvest of leaves from three varieties of collards at 18, 21, and 25 days' cropping intervals over four harvest periods.

	Harvest Period 102 DAT (Nos./Acre)		
	Varieties		
Cropping Intervals	**Heirloom (Nos./Acre)**	**Ga-Collard (Nos./Acre)**	**Hi-Crop Hybrid (Nos./Acre)**
18	110,558	99,181	111,053
21	123,172	104,127	109,569
25	102,891	112,042	137,270
		Harvest Period 127 DAT	
18	168,929	156,809	189,952
21	162,993	161,014	285,423
25	148,400	176,843	239,913
		Harvest Period 152 DAT	
18	96,707	98,191	113,773
21	62,575	71,974	104,375
25	62,575	92,255	101,407
		Harvest Period DAT 177	
18	64,801	87,556	127,377
21	45,262	65,791	105,859
25	0	194,404	200,340
Significance of F Test from AOV			
Harvest Periods		**	
Cropping Intervals		*	
Varieties		**NS**	
Harvest Periods X Cropping Inter.		**	
Harvest Periods X Varieties		**NS**	
Cropping Intervals X Varieties		**NS**	
3-way Interaction		**NS**	

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

Table 2 shows that the total yield data followed a similar trend as that for the number of leaves. However, analysis of the data showed significant interactions between all factors evaluated.

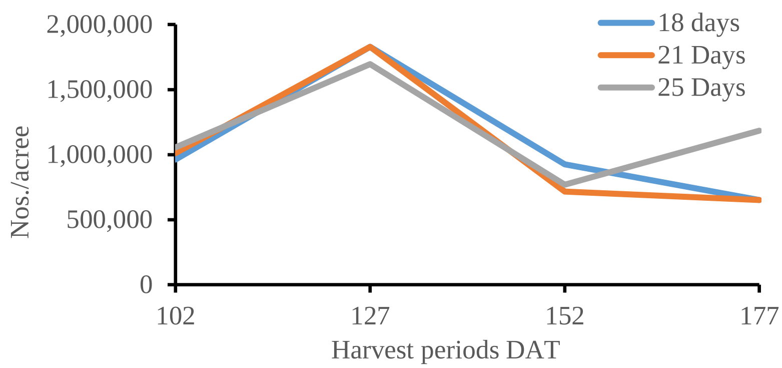

Figure 1. Interaction of harvest periods X cropping intervals for a 50% partial harvest of number of leaves over 4 harvest periods from 3 varieties of collards grown in a Wiregrass Tunnel House

Table 2. Yield (lbs./acre) from three varieties of collards when a 50% partial harvest of leaves was taken at 18, 21, and 25 days cropping intervals over four harvest periods.

		Harvest Period 102 DAT	
		Varieties	
Cropping Intervals	**Heirloom (lbs./Acre)**	**Ga- Collards (lbs./acre)**	**Hi-Crop Hybrid (lbs./acre)**
18	7,529	5,382	6,619
21	4,788	4,472	8,241
25	3,581	7,034	9,349
		Harvest Period 127 DAT	
18	7,648	5,985	8,825
21	2,988	4,185	10,972
25	1,979	4,511	6,401
		Harvest Period 152 DAT	
18	3,621	4,106	4,591
21	2,315	3,146	4,472
25	2,592	3,601	4,551
		Harvest Period 177 DAT	
18	3,829	5,699	9,517
21	1,801	4,729	7,262
25	0	5,867	7,113

Significance of F Test from AOV

Harvest Periods	**NS**
Cropping Intervals	**

Varieties	**
Harvest Periods X Cropping Inter.	**
Harvest Periods X Varieties	**
Cropping Intervals X Varieties	**
3-way Interaction	**NS**

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

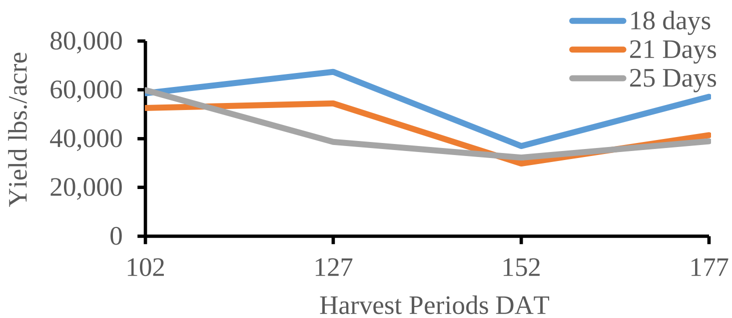

Figure 2. Interaction of harvest periods X cropping intervals for a 50% partial harvest of leaves over four harvest periods from three varieties of collards grown in a Wiregrass Tunnel House

The interaction between harvest periods x cropping intervals (Figure 2) showed that the 18 and 21-day intervals had the highest yields which peaked at 127 DAT, and then began a decline at the third harvest. In comparison, the 25-days cropping interval had the lowest yield which steadily declined after the first harvest at 102 DAT.

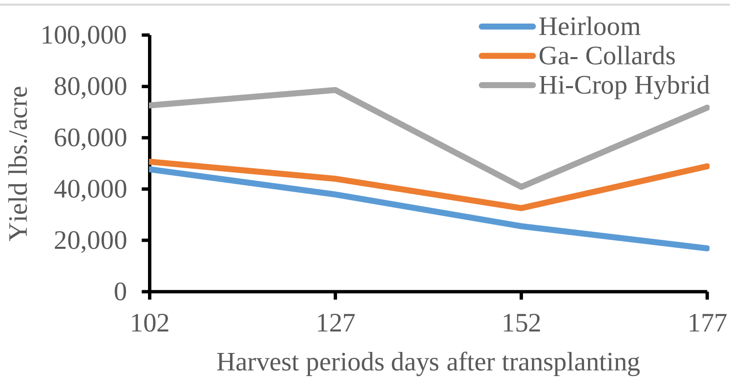

Figure 3. Interaction of harvest periods X varieties for a 50% partial harvest of leaves over four harvest periods from three varieties of collards grown in a Wiregrass Tunnel House

The response of the 3-varieties of collards used in the study showed a significant interaction of harvest periods x varieties (Figure 3). 'Hi-Crop Hybrid' had the highest overall yield throughout the study period, while 'Heirloom' and 'Georgia-Collards' varieties showed a steady decline in yield after the first harvest in comparison to "Hi-Crop Hybrid" whose yield declined at 152 DAT.

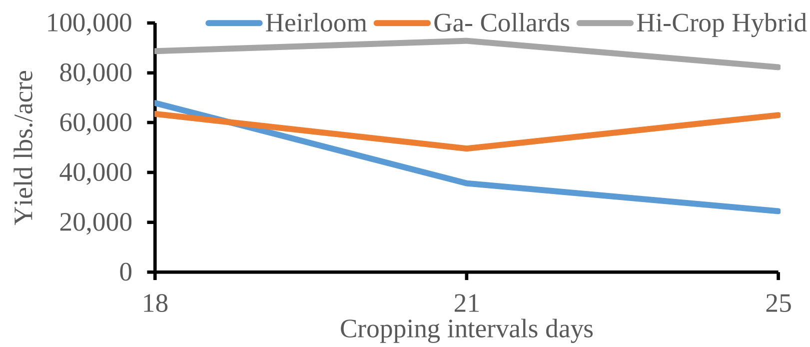

Figure 4. Interaction of cropping intervals X varieties for a 50% partial harvest of leaves over three cropping intervals for three varieties of collards grown in a Wiregrass Tunnel House

Figure 4 shows that 'Hi-Crop Hybrid' had the highest overall yield across all of the cropping intervals, but had its highest yield at the 21-day interval. This was in contrast to 'Heirloom' and 'Georgia-Collards' which had their highest yields at the 18-day interval and declined in yields thereafter.

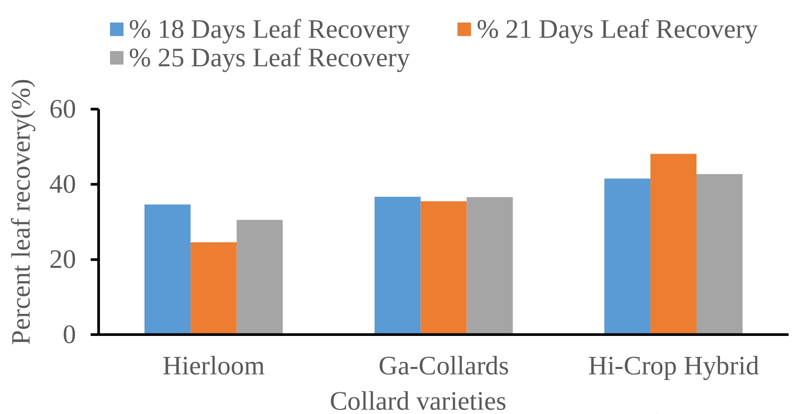

Figure 5. Percent leaf recovery for three varieties of collards cropped at 18, 21, and 25 day intervals between harvest periods at 102 and 127 DAT.

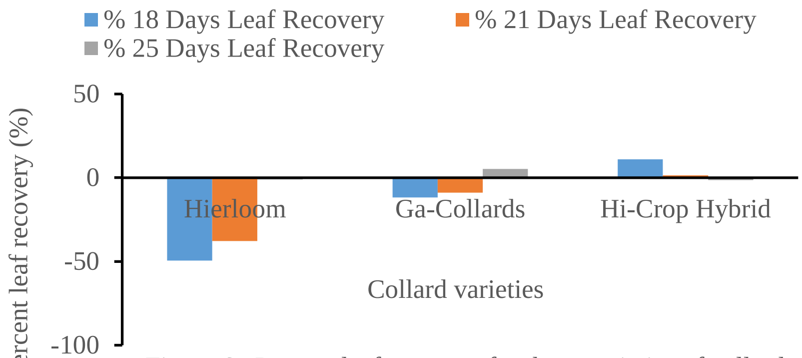

Figure 6. Percent leaf recovery for three varieties of collards cropped at 18, 21, and 25 day intervals between harvest periods at 152 and 177 days after transplanting.

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The leaf recovery rates for the varieties evaluated in this study was divided between the first (102-127 DAT), and the second (152-177 DAT) half of the study (Figures 5 & 6). All of the collard varieties during the first half of the study, showed positive leaf recovery rates, in contrast to the second half of the study, where the recovery rates were negative. During the first half, the 18-day cropping cycle had the highest leaf recovery rates compared to the 21 and 25-day intervals. Whereas ‘Hi-Crop Hybrid’ had its highest leaf recovery rate at the 21-day interval, and the highest overall recovery rates compared to the other varieties in the study.

Table 3 shows the cumulative chilling hours recorded for the inside and outside of the TH for the months when the study was conducted. The data indicated that the inside of the TH received lower chilling hours than those recorded for the outside however, the differences between the two environments were small.

Table 3. Cumulative number of chilling hours recorded over three months inside and outside of the experimental Wiregrass Tunnel House.

		Months	
Locations	January 2018	February 2018	March 2018
Number of cumulative chilling hours reached inside the Tunnel House	24	94	153
Number of cumulative chilling hours reached outside of the Tunnel House	28	100	158

Discussion

The first objective of this study was to determine if 18, 21, or 25 days was the most appropriate time to conduct a 50% harvest of the total leaves from three varieties of collards. The results of this study indicated that a cropping interval of 18 or 21 days resulted in higher leaf numbers, but leaf weight was highest at 18 compared to 21 and 25 days under TH conditions (Figures 1 and

2). Sparks et al. (2018) and Walton et al. (2018) reported high yield and leaf recovery rates, under similar growing conditions when plants had 50% of their leaves harvested every 21 days. The data also showed that both leaf numbers and weight declined after the second harvest at 127 DAT. This decline in production was probably due to the extreme cold weather experienced during the growing season of 2017-18. Table 3 shows the cumulative chilling hours recorded from January – March 2018. McCormack (2005) and Olson and Freeman (2008) reported that there is not an exact temperature range at which bolting will occur in collards, but exposure for 4-6 wks. at temperatures of 39^{O}F-50^{O}F would induce bolting. The chilling hours accumulated inside the TH as shown in Table 3, were computed whenever the temperature was between 32^{O}F and 45^{O}F. This decline in yield at 127 DAT could be related to the factors responsible for inducing bolting in collard plants.

The second objective of this study was to determine if there are varietal differences across harvesting periods. The data showed that there were a significant interaction between varieties x harvest periods (Figure 3). The variety “Hi-Crop Hybrid” had the highest overall yield, followed by “Georgia-Collard” and “Heirloom”. The response of “Georgia-Collard” and “Heirloom” showed a steady decline in yield after the first harvest, this was in contrast to “Hi-Crop Hybrid” which declined in yield after the second harvest period. The increase in yield between 152-177-days for “Hi-Crop Hybrid” and “Georgia-Collard” was due to the fact that all the leaves were harvested from the plants at 177 DAT because 100% of the plants had bolted, and this may have increased the yield. This decline in yield for “Georgia-Collard” and “Heirloom” after the first harvest could be attributed to the high chilling hours the plants received during the growing season (Table 3) and may have initiated the physiological processes within these varieties to bolt earlier than expected (McCormack, 2005). In addition, Olson and Freeman (2008) indicated that “Hi-Crop Hybrid” showed a high degree of cold tolerance compared to other varieties of collards evaluated in North Florida.

The third objective of the study was to determine if there are varietal differences among the varieties of collards evaluated and cropping intervals; Figure 4 shows that there were significant differences among the varieties. The data showed that “Hi-Crop Hybrid” had higher yields when cropped at 21-days; this was similar to results reported by Walton et al. (2018). In contrast, “Georgia-Collard” and “Heirloom” showed higher yields at 18-days, and lower yields at 21 and 25 days cropping intervals. Similar results were reported by Khan and Lone (2005) when they harvested 50% of the leaves of mustard plants at 40 and 60-days after seeding (DAS). Yields were higher from plants harvested at 40 DAS, and they also stated that the emerging new leaves from plants defoliated at 40 DAS, had higher photosynthetic and assimilatory capacity. In this study, these factors could have influenced the high leaf recovery rate at 18-days during the first half of the study for these two varieties (Figure 5); however, it should be noted that the leaf recovery rates were lower than those reported by Sparks et al. 2018) and Walton et al. (2018). Leaf recovery rates during the second half of the study showed mainly negative rates for all varieties in the study (Figure 6). This could be due to the extreme cold and high chilling hours (Table 3) the plants experienced in the TH.

Conclusion

The three varieties of collards evaluated in this study produced higher leaf numbers when cropped at 18 and 21-days but higher leaf weight was obtained when the varieties were cropped at 18 instead of 21 or 25-days under TH conditions. The varieties also differed in their response to yield over the four harvest periods (102, 127,152, and 177 days) and the three cropping intervals (18, 21, and 25 days), 'Hi-Crop Hybrid' had the highest overall yield overall harvest periods and cropping intervals, followed by 'Georgia-Collard', and 'Heirloom'. Leaf recovery rates were lower than those previously reported under TH conditions. The extreme cold conditions during the time of the study could have influenced the yield response of these varieties.

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