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THE EVALUATION OF TWO METHODS OF HARVESTING 'TOPBUNCH' COLLARDS (*BRASSICA OLERACEA(L.)*) LEAVES FROM PLANS GROWN IN A WIREGRASS TUNNEL HOUSE

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Abstract
A study was conducted to determine if a 100% or 50% harvest intensity of 'Topbunch' collards leaves could be a recommended practice for Tunnel House producers. The experiment was conducted as a split-plot design with harvest dates as main plots, and harvesting intensity of 100% or 50% of leaves as sub-plots. All treatments were replicated three times, drip irrigated, and fertilized according to soil test recommendations. The results showed significant interactions between harvest methods and dates for number and weight of leaves harvested. There were also significant differences for the weight of leaves harvested and numbers. The leaf recovery rates were greater for plants that had 50% of their leaves harvested compared to those which had 100% of their leaves harvested. This higher recovery rate for the former suggests that the harvest interval could be reduced in the future from 21 to 15 or 18 days.
Keywords: Collards, Tunnel House, Topbunch Collards, Hi-Crop Collards, Harvesting Methods

Introduction
Collards are a staple in the diet of many residents in the southeastern United States, and over 14,000 acres are grown in Georgia, North Carolina, South Carolina, and Alabama (Olson and Freeman, 2008). Collards were brought to the new world from its source of origin in Europe or the Mediterranean area of the world via the Columbian exchange, which occurred during the period of the European voyages of discovery (Boswell, 1949; Rubatzy and Yamaguchi, 1997). This crop grows in a wide range of temperatures; however, the best temperature to maintain optimal growth is 60-65^{0}F (Hemphill, 2010). Georgia is the leader in collard production among the Southeastern states of the United States, and most of it is grown for the fresh market (Georgia Farm Gate Report, 2015). Field grown collards are once over harvested between 66-104 days after transplanting,; they are then bunched and sold (Olson and Freeman, 2008).

Published reports of the use of Tunnel Houses (THs) first appeared in the early 1990s in Connecticut and New Hampshire, Ghent (1990), and Wells (1993), published their results on growing early tomatoes. They showed that production was early, and yields increased, and this could lead to higher prices. Shortly after, Khan (1994) working in Alabama reported that a number of vegetable crops, such as collards, turnips, mustards, kale, rutabagas, onions, carrots, snap beans, and tomatoes, can be grown in an unheated TH during the autumn, winter, and spring seasons of the year. Blomgren and Frisch, (2007) described TH as an unorthodox alternative of expanding their growing season in the cold and cool months of the year. Today THs are seen as a valuable production tool to encourage beginning farmers and historically underserved producers to increase their farm revenue. Recently, USDA Natural Resource Conservation Service (NRCS) has begun to offer financial incentives to small producers to encourage them to integrate THs in their farm operations (USDA NRCS, 2014).

The harvesting of whole plants is not a sustainable method of harvesting for TH producers of collards. Harvesting the leaves instead of the whole plant is a more sustainable method of harvesting since the plant remains intact, to produce more leaves for future harvests. However, there is limited research base information recommending what percentage of leaves could be harvested which would result in satisfactory leaf recovery in the shortest time. Therefore, the objectives of this study were to (1) determine how 'Topbunch' collards will respond to 100% and 50% harvesting of total plant leaves when grown in a TH, (2) establish which of the two harvest methods would result in higher yields, and (3) ascertain the leaf recovery rate for each harvest method.

Literature Review

Tunnel Houses

Extending the growing season is the primary advantage that THs offer growers. However, some of the additional benefits are: they protect crops from wind and rain, and in some regions of the country, they elevate the nighttime temperature during the summer months to enhance plant growth. They also increase farm income by producing crops when the competition is low, and prices are high. THs also protect crops from weather-related damage such as sun scalding, hail damage, and produces a higher number of quality vegetables, flowers, and herbs at harvest time (Poole and Stone, 2014).

Recently, a wooden model TH known as the Wiregrass TH has been introduced. 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 also has black canvas roll-up sides, and doors. (Khan et al., 2013). Other special features of the Wiregrass TH include an insect, wild animal, and vermin exclusion fence, to reduce the number of spraying operations for insects. In order to prevent flooding due to rainfall and runoff water from the roof of the house, the floor is elevated to a minimum of 1 ft. above ground level by the addition of suitable topsoil. Adding topsoil also serves as an amendment to the ground soil, which may not be suitable for vegetable production, thus allowing the producers maximum use of their THs (Khan et al., 2013).

Previous Studies

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).

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 spacing 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.

In another study to evaluate the effects of leaf removal on the yield of pumpkins 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.

In a similar study, Ahmed et al. (2015) evaluated what the effect of three different levels of defoliation would have on garlic yields when taken at three distinct stages of vegetative growth. They indicated that defoliation intensity levels when applied at the different the stages of vegetative growth significantly affected yield parameters such as plant height, number of leaves per plant, bulb weight per plant, and cured bulb yield. Yields were significantly higher when defoliation was between 0-40% and done at the seedling and reproductive stages, compared to the vegetative stage and when defoliation was higher than 40%. They compared their findings to the earlier work of Muro et al. (2001), who reported that the impact of defoliation intensity depends on the foliar surface area eliminated, and that crop losses increased with increasing level of defoliation.

In a defoliation study using okra, Pere (2011) reported that when a large number of leaves were removed the plants produced flowers earlier, remained short, and were more resistant to pests. However, there were no significant differences in yield across defoliation intensities, and rates of organic fertilizers applied. In a similar study, Iremiren (1986) removed the upper and lower leaves of okra plants before the reproductive stage of growth to evaluate how this would impact yield. He reported that removal of the upper leaves significantly affected yield when compared to the removal of the lower leaves. Therefore, it was concluded that the upper leaves of the okra plants contributed more to yield, and overall plant development than the lower leaves.

Materials and Methods

Tunnel House

This study was conducted during the fall-winter of 2016-17 in a Wiregrass TH located at S & B Farm in Eufaula AL. 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. All planting is done directly in the soil and not in raised beds or containers.

The TH has several special characteristics which include the following: (1) it is framed entirely of wood with black polyethylene tubing for rafters; (2) it has roll up canvas curtains for the sides which allow ventilation; (3) it has roll-up doors, and (4) it is covered with 6 mils clear greenhouse plastic. The dimensions are 48 ft. long X 20 ft. wide, giving a gross area of 960 sq. ft. and a net planting area of 828 sq. ft.

Soil Type

The soil type at the study site is characterized as Norfolk sandy loam (fine, siliceous, thermic Typic, Paleudults). Recently, 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. After this, rows were 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 108 days after transplanting (DAT) based on the methods described by Khan et al. (1996).

Experimental Planting Materials

'TopBunch' 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'x1.5'. They were spaced 12 inches within plots for a total of sixteen plants per plot. Weeds growing between and in rows were manually controlled, and no insecticides were sprayed on the plants because the study was conducted during the late fall and winter months when insect populations and activities are relatively low.

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 dates (H_1, H_2, H_3, and H_4) while the subplots consisted of the harvesting methods 100% vs. 50% leaf harvest, giving eight treatment combinations: H_1 TopBunch 50%, H_1 TopBunch 100%, H_2 TopBunch 50%, H_2 TopBunch 100%, H_3 TopBunch 50%, H_3 TopBunch 100%, H_4 TopBunch 50%, and H_4 TopBunch 100%.

Harvesting of the leaves began at 45 DAT, and continued at 21-day intervals up to 108 DAT, respectively, 45, 66, 87, and 108. 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 below:

Yield/Acre = (Plot yield*(Tunnel House Area/Plot Area)) *(43,560 sqrt ft/area of Tunnel House)**)**

Results

Table 1 shows the number of expanded leaves harvested at 100% and 50% for ‘TopBunch’. The results show a significant interaction between harvest periods x harvest methods (for the total number of leaves removed). The interaction shows that plants which had 100% of their leaves harvested had a

Table 1. Mean Number of ’Topbunch’ Collard Leaves (Nos. / Acre) obtained in Four 100% and 50% Leaf Harvest from Plants Grown in a Wiregrass Tunnel House

Days After Transplanting	Number of Leaves 100% Harvested	Percent Rate of Leaf Recovery	Number of Leaves 50% Harvested	Percent Rate of Leaf Recovery
(Days)	(Nos./acre)	%	(Nos./acre)	%
45	121,634	-0-	41,878	-0-
66	44,613	37	49,033	117
87	61,238	50	63,342	151
108	106,693	88	77,442	184
Significance of F test from ANOVA				
Harvest Dates		**		
Method of Harvesting		**		
Harvest Dates X Methods		**		

**significant at the 1% level of P

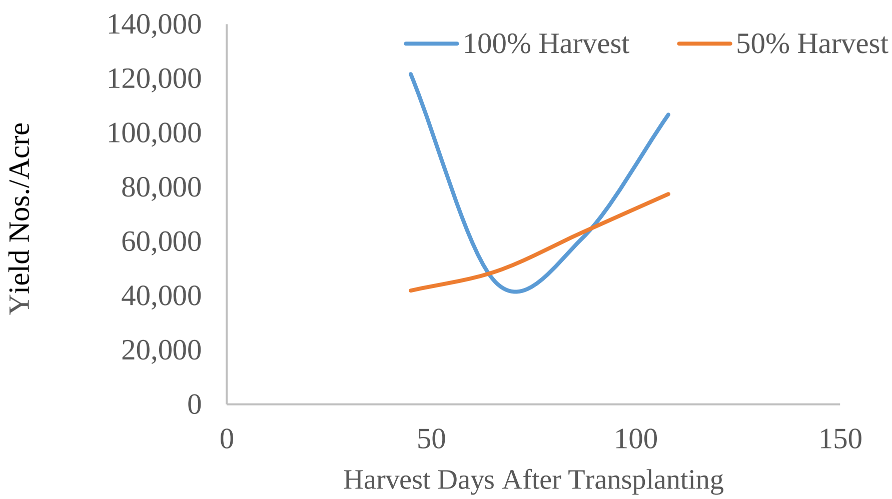

Figure 1 . Interaction between harvest dates and method of harvesting for total number (nos./acre) of 'Top-Bunch'' collard leaves removed at harvest

a drastic reduction in leaf numbers at the second harvest followed by a sharp increase by the third harvest. In contrast, plants which had 50% of their leaves harvested showed a steady increase in leaf numbers for each harvest. These results are reflected in Figure 1.

Table 2 shows the average yield obtained when 100 and 50% of the leaves were harvested from ‘Topbunch’ collard plants growing in a TH. The results indicate a significant

Table 2. Mean Weight (lbs. / Acre) of 'TopBunch' Collard Leaves obtained in Four 100% and 50% Harvest of Leaves from Plants Grown in a Wiregrass Tunnel House

Days After Transplanting	Weight of Leaves 100% Harvested	Percent Rate of Leaf Recovery	Weight of Leaves 50% Harvested	Percent Rate of Leaf Recovery
(Days)	(lbs./acre)	%	(lbs./acre)	%
45	1,953	-0-	1,193	-0-
66	833	42	2,083	174
87	1,035	52	4,061	340
108	1,852	94	5,312	443
<u>Significance of F test from ANOVA</u>				
Harvest Dates		**		
Method of Harvesting		**		
Harvest Dates X Methods		**		

** significant at the 1% level of P

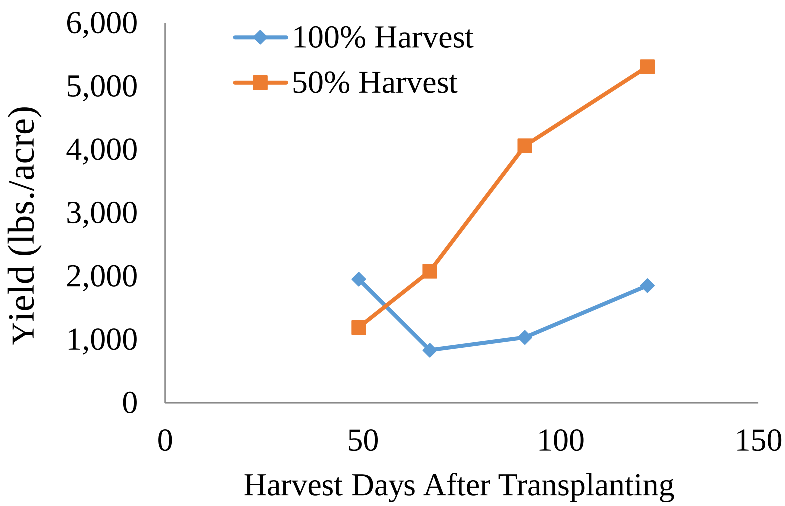

Figure 2. Interaction between harvest dates and method of harvesting for total yield (lbs./acre) of 'Top-Bunch" collard leaves

interaction between harvest periods and harvest methods (for total yield). The interaction showed plants which had 100% of leaves harvested had a drastic decrease in yield after the first harvest, followed by an increase for the third and fourth harvests. On the contrary, plants which had 50% of their leaves removed showed a consistent increase in yield. This trend is reflected in Figure 2. Plants which had 50% of their leaves harvested seemed to be more stimulated in replacing the harvested leaves at each successive harvest as shown by the leaf recovery rates.

Discussion

In this study, two levels (100% and 50%) of collard leaf defoliation were evaluated, and the results showed that the 100% defoliated treatment had lower yields of leaf numbers and yield (weight of leaves), compared to those plants where 50% of their leaves were removed. Plants that were 100% defoliated had all of their mature and younger leaves removed, compared to the 50% leaf removal treatment, where the lower whorls of mature leaves were removed, leaving the whorls of younger leaves on the plants. This result is similar to the findings of Iremiren (1986) who removed the lower and upper leaves of okra plants and reported a decline in yield when the younger leaves were removed. These results suggest that when the younger leaves remain on the plant, production will not be affected because they appear to be more photosynthetically active than the older leaves.

The removal of 100% of the leaves repressed the production of leaf numbers and yield, and according to Muro et al. (2001) crop losses can be expected depending on the amount of foliar surface area removed with increasing levels of defoliation. Results presented by Ahmed et al. (2015), showed that when defoliation of garlic plants was kept between 0-40% and carried out at the seedling and reproductive stages of growth yield and plant growth increased. In this study, the removal of 100% of the leaves seemed to have exceeded a critical threshold necessary to maintain growth, whereas removal of only 50% of the foliar surface of the plants appeared to be threshold necessary to maintain growth and yield.

The results in studies conducted by De Roover et al. (1999), Hoogesteger and Karlson (1992), and Isutsa and Mallowa (2013) suggest that when plants are defoliated they undergo a shortage of carbohydrates, and to compensate for this deficit, plants usually allocate most of their photosynthates to shoot growth and reduce the amount distributed to the roots and fruit growth. The preceding phenomena were observed in this study, where the plants that were 100% defoliated had lower leaf recovery rates compared to those which were 50% defoliated. The recovery rates for the latter usually exceeded more than 100% at each harvest which was 21 days apart. This result suggests that 50% defoliation intensity could be a critical threshold, and that the remaining younger leaves on the plants were efficient in replacing the older leaves that were removed.

Conclusion

In this study, there were significant differences between harvest periods and the number of leaves and harvest periods and the yield (weight of leaves), for 100% and 50% harvesting of collard leaves. The 50% harvest of collard leaves showed consistent leaf recovery at higher rates at each succeeding harvest. The results suggest that tunnel house producers of collards can increase their yields by harvesting 50% of the leaves instead of 100% which is the current practice. The leaf recovery data also strongly infer that future work is needed to determine if the current harvest interval can be reduced from its current 21 days to 15 or 18 days.

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