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## THE EFFECT OF TWO DIFFERENT HARVESTING METHODS ON THE YIELD OF 'TOPBUNCH' AND 'HI-CROP' COLLARDS (*BRASSICA OLERACEA (L)*) WHEN GROWN IN A WIREGRASS TUNNEL HOUSE

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### Abstract

A study was conducted to determine if 100% or 50% harvesting of collard leaves was a suitable recommendation for Tunnel House producers. The experiment was conducted as a split-split plot design with varieties as the main plots, harvesting 100% or 50% of leaves as the sub-plots, and days after transplanting as the subplots. All treatments were replicated three times, drip irrigated, and fertilized according to soil test recommendations. The results showed significant interactions between varieties and method of harvest, for leaf numbers and weight. Conversely, the varieties showed significant differences for yield but not leaf numbers. Both varieties showed significant increases in leaf numbers and yield at each harvest period when 50% of the leaves were harvested, instead of 100%. This approach led to higher leaf recovery rates suggesting that a 50% leaf harvest would result in higher yields, and reduce the harvest intervals from the present 21 to 12 or 18 days. **Keywords:** Collards, Tunnel House, Topbunch Collards, Hi-Crop Collards, Harvesting Methods

### Introduction

Collards originated in Europe or the Mediterranean region of the world, and is a relative of the wild cabbage (Boswell, 1949; Rubatzky and Yamaguchi, 1997). In 2001, the USDA reported that a total of 14,000 acres of collards were grown in the southeastern US in the following states: Georgia, North Carolina, South Carolina, and Alabama (Olson and Freeman, 2008). In 2013, Georgia reported growing 13,000 acres of collards valued at \$60 M (Georgia Farm Gate Report; 2015). Collards tolerate a wide range of growing temperatures but do best when the temperature ranges from 60-65°F (Hemphill, 2010), 6-8 week old transplants are transplanted in the field, and whole plants are once over harvested, and bunched for sale between 66-104 days after transplanting (Olson and Freeman, 2008).

Tunnel Houses (THs) are structures made from wood or metal and covered with clear polyethylene plastic. Following their introduction in the early 1990s (Ghent., 1990; Khan et al., 1994; Wells., 1993), they are becoming increasingly popular among small-scale vegetable producers, who see them as an unorthodox alternative of expanding their growing season in the cold and cool months of the year (Blomgren and Frisch, 2007). The usage of THs is further enhanced by the Natural Resource Conservation Service of the USDA by offering financial assistance to historically underserved producers, and beginning farmers, to implement various conservation practices which include THs (USDA NRCS, 2014).

Currently, whole plants are harvested for sale when collards are produced in open fields; however, this is not a sustainable harvesting procedure for the production of winter collards in THs by limited resource farmers. Harvesting the leaves instead of the whole plant, seems to be a more

sustainable method of harvesting which would enhance their profitability, since the whole 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 collard cultivars 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**

### **Collards: Varieties and Benefits**

Among the crucifer crops such as cabbages, broccoli, turnips, mustards, and cauliflower, collards rank as the least expensive vegetable on a per cup serving basis when cut and prepared (Stewart et al., 2011). Collards are also ranked as the 4<sup>th</sup> vegetable in its 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 being excreted 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).

### **Enhancing Production of Vegetables and Tunnel Houses**

Production of vegetables, fruits, flowers, and herbs is carried out in open fields where these crops are subjected to the uncertainties of temperature, wind, sunlight, water, and nutrients. In an effort to reduce these risks to production, protective measures such as irrigation, wind-breaker, green and tunnel houses, row covers, and various types of plastic mulches were developed. These advances in production agriculture, modify the natural environment to produce crops, with the aim of increasing yields, quality, stabilizing production, and make available fresh produce at times when outdoor conditions make it difficult to raise garden-fresh vegetables. Tunnel houses (THs) are one of the many protective structures developed since the early 1950s to extend the growing season, and is growing in popularity due to governmental support, and its economic benefits for limited resource farmers (Knewton et al., 2010; USDA NRCS, 2014; Wittwer and Castilla, 1995).

THs are structures built in the field to protect vegetable crops from adverse weather conditions, and to extend the growing season for small scale-vegetable producers (Poole and Stone, 2014). When compared to greenhouses, THs have no heating or cooling systems but are highly dependent on thermal heating from the sun to create the "Greenhouse" effect which can maintain soil temperatures between 65-70<sup>0</sup>F, and increase air temperatures within the TH at 30<sup>0</sup>F and 15<sup>0</sup>F higher during the daytime and nighttime, respectively, in East Central Alabama (Khan et al. 1994). In the Central High Plains of North America, the air temperature inside the TH ranges between 1-4<sup>0</sup>C higher than the outside air while the soil temperature is 1-7<sup>0</sup>C warmer. These higher temperatures within THs lead to a higher buildup of heat units and early maturity of crops (Knewton et al., 2010).

Some models of THs include the Quonset, gothic, moveable, and multibay. The Quonset is the most popular model used by growers, however, the gothic type is gaining in popularity because it

has a higher peak which allows it to handle snow loads much better than the round shape Quonset houses. These houses are usually constructed with metal or PVC pipes and covered with a single or double layer of 6 mil greenhouse plastic (Poole and Stone, 2014). Recently, a wooden model Tunnel House known as the Wiregrass Tunnel House 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).

The Wiregrass Tunnel House has a gothic style shape where the sides are high enough to allow adequate headroom to cultivate the sides with ease. It also has a center pitch which allows for easy runoff of rainfall. Other special features of the Wiregrass Tunnel House 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**

In many countries in Africa and Asia, selected vegetable crops are grown for multiuse where the leaves from cowpea plants are removed for human consumption, before the pods are ready for harvest, and after the pods are harvested, the remaining plant residue is garnered for livestock feed. Ibrahim et al. (2010), conducted a study to determine how five defoliation levels of 0, 25, 50, 75, and 100%, would affect the final pod yield of vegetable cowpea when the leaves were removed at either the vegetative, flowering, and podding stages of growth. The results showed that pod yield was affected when the intensity of defoliation exceeded 50%, and was carried out at the vegetative and flowering stages of growth. However, yield was not significantly affected when leaf removal was below 50% intensity, and carried out at the podding stage of growth. They indicated that the upper leaves of the plants were more active for photosynthesis than basal ones and therefore could have altered the partitioning of photosynthates.

Gwandu and Isa (2016) investigated what the effect of two garlic clove sizes (small (< 1cm)) and large (> 1cm) in diameter), and defoliation intensity of 0, 40, and 80% would have on yield, plant height, and the number of leaves. They reported that plants, which were defoliated at levels 0 and 40% had larger bulb sizes and increased bulb yields, while plants that were defoliated at levels higher than 40% resulted in smaller bulb sizes, and significantly decreased bulb yields. They attributed this yield reduction to the number of leaves removed from the plants, and the ability of the plants to readily replace the lost leaves.

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 on 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 a study, where the lower leaves of okra plants 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).

## **Materials and Methods**

### **Tunnel House**

This study was conducted in the fall and winter of 2016-2017 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. (Khan et al., 2013; Khan et al., 1994).

### **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 methods described by Khan et al. (1996).

### **Experimental Planting Materials**

'Topbunch' and Hi-Yield hybrid' 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-split plot arrangement and three replications per treatment (Snedecor, 1966). The main plots comprised of the varieties ('Topbunch' and Hi-Yield hybrid') while the subplots consisted of the harvesting methods 100% vs. 50% leaf harvest, and the sub-sub-plots were the harvest periods of 45, 66, 87, and 108 DAT giving four treatment combinations: TopBunch 50%, Hi-Crop 50%, TopBunch 100%, and Hi-Crop 100%

Harvesting of the leaves began at 45 DAT and continued at 21-day intervals up to 108 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 below:

$$\text{Yield/Acre} = (\text{Plot yield} * (\text{Tunnel House Area/Plot Area})) * (43,560 \text{ sqrt ft/Area of Tunnel House})$$

### **Results**

Table 1 shows the number of expanded leaves harvested at 100% for 'TopBunch' and 'Hi-Crop Hybrid' collards. The results showed a significant interaction between varieties x harvest methods. Examination of this interaction (Figure 1) showed 'TopBunch' had a rapid decline in yield by the second harvest followed by a rapid increase. However, the severity of the harvest did not affect 'Hi-Crop Hybrid' the same way, which showed a smaller decline in leaf numbers harvested by the second harvest, followed by increases at the third and fourth harvests. The difference in leaf regrowth among the varieties show that 'Hi-Crop Hybrid' had higher percentages of leaf regrowth than 'TopBunch', which could have accounted for the differences in yield between 66 and 108 DAT.

When the intensity of leaf harvest was reduced to 50% the varieties also showed a significant interaction between varieties x harvest methods (Table 2). This interaction (Figure 2) showed that 'TopBunch' leaf numbers never declined but kept increasing from 66 DAT and until 108 DAT. Whereas, 'Hi-Crop Hybrid' showed a slight decline followed by even higher rates of leaf recovery compared to 'TopBunch' for the same period. A comparison of leaf number gathered at the 100% and 50% level of harvest intensity from 45 to 108 DAT showed that the 50% harvest

Table 1. Mean Number of 'Topbunch' and 'Hi-Crop Hybrid' Collard Leaves (Nos./Acre) taken in 100% Leaf Harvest from Plants Grown in a Wiregrass Tunnel House

100% Leaf Harvest (Nos/acre)				
Days After Transplanting (Days)	'TopBunch' (Nos/acre)	Percent Rate of Leaf Regrowth %	'Hi-Crop Hybrid' (Nos/acre)	Percent Rate of Leaf Regrowth %
45	358,938	-0-	229,770	-0-
66	131,652	37	184,437	80
87	180,711	50	229,149	99
108	314,847	88	259,578	113

**Significance of F test from ANOVA**

Varieties	NS
Harvest Methods	**
Harvest Periods	**
Varieties X Harvest Methods	**
Harvest Methods X Harvest Periods	NS
3 Way Interaction	NS

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

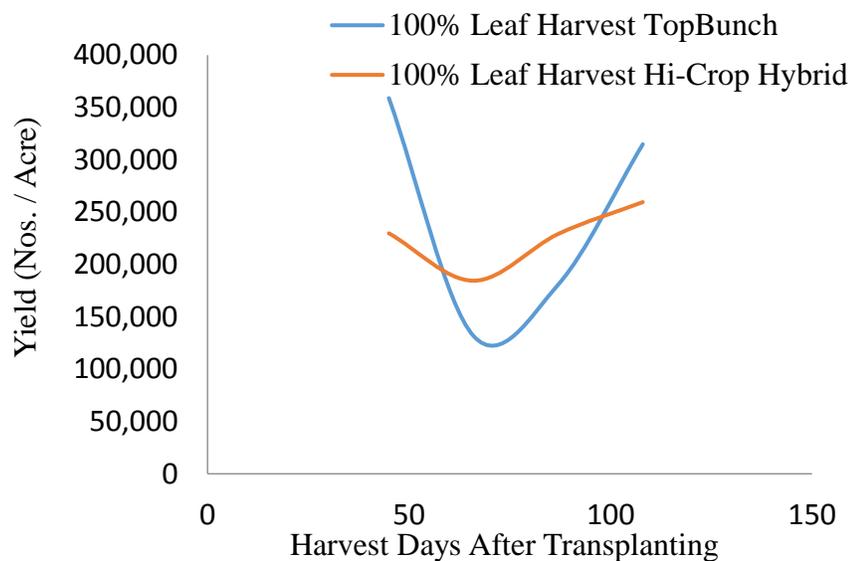


Figure 1. Interaction between varieties and method of harvesting for total number of leaves harvested (Nos./acre) from 'Top-Bunch' and 'Hi-Crop Hybrid' varieties of collards in a 100% leaf harvest

Table 2. Mean Number of 'Topbunch' and 'Hi-Crop Hybrid' Collard Leaves (Nos./Acre) taken in a 50% Leaf Harvest from Plants Grown in a Wiregrass Tunnel House

50% Leaf Harvest (Nos/acre)				
Days after Transplanting (Days)	'TopBunch' (Nos/acre)	Percent Rate of Leaf Regrowth %	'Hi-Crop Hybrid' (Nos/acre)	Percent Rate of Leaf Regrowth %
45	240,948	-0-	222,318	-0-
66	276,966	114	219,033	99
87	362,043	150	370,116	166
108	459,540	190	499,284	224

**Significance of F test from ANOVA**

Varieties	NS
Harvest Methods	**
Harvest Periods	**
Varieties X Harvest Methods	**
Harvest Methods X Harvest Periods	NS
3 Way Interaction	NS

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

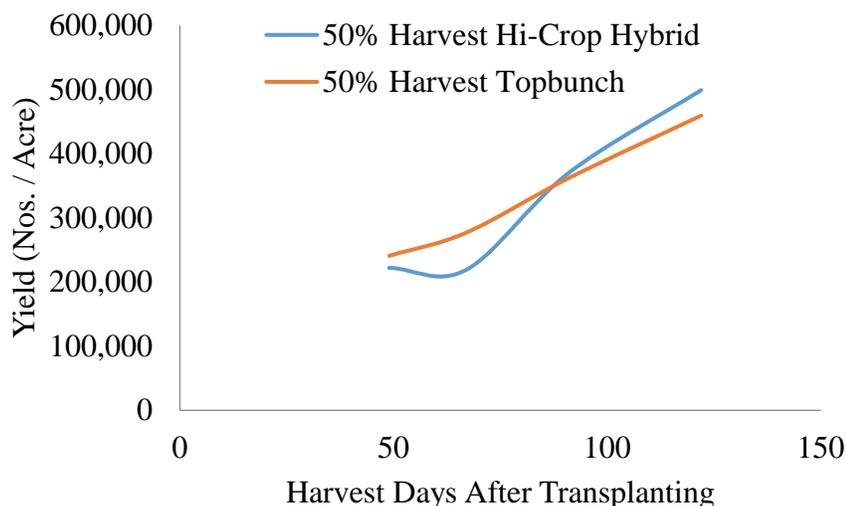


Figure 2. Interaction between varieties and method of harvest for a partial 50% harvest of total number of leaves (Nos./acre) from 'Top-Bunch' and 'Hi-Crop Hybrid' varieties of collards

system produced a higher number of leaves for both varieties, which exceeded those gathered at the 100%. This outcome probably was due in part to a stimulatory effect which resulted in higher percentage of leaf number recovery for both varieties at the 50% harvest.

Table 3 shows the yield data for both varieties of collards at the 100% harvest density, and it indicates a significant interaction between varieties x harvest method. This interaction shows

Table 3. Mean Yield of 'TopBunch' and 'Hi-Crop Hybrid' Collard Leaves (lbs./acre) taken in a 100% Leaf Harvest from Plants Grown in a Wiregrass Tunnel House

100% Leaf Harvest (Lbs/acre)				
Days After Transplanting (Days)	'TopBunch' (Lbs/acre)	Percent Rate of Leaf Regrowth (%)	'Hi-Crop Hybrid' (Lbs/acre)	Percent Rate of Leaf Regrowth (%)
45	1,921	-0-	2,463	-0-
66	820	42	1,368	56
87	1,018	53	2,066	84
108	1,822	95	2,484	101

**Significance of F test from ANOVA**

Varieties	**
Harvest Methods	**
Harvest Periods	**
Varieties X Harvest Methods	**
Harvest Methods X Harvest Periods	NS
3 Way Interaction	NS

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

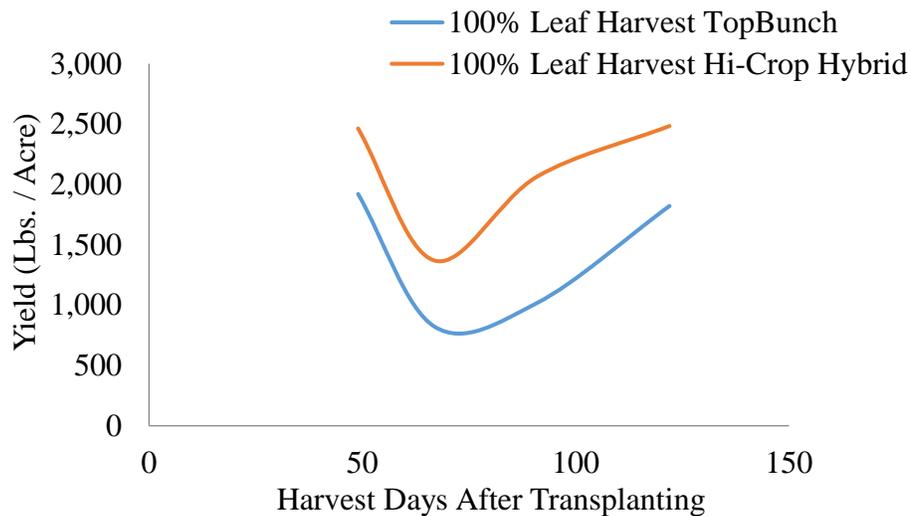


Figure 3. Interaction between varieties and method of harvest 100% leaf harvest of leaves (Lbs./acre) from 'Top-Bunch' and 'Hi-Crop Hybrid' varieties of collards

(Figure 3) the varieties declined in production after the first harvest at 45 DAT and increased in yields after that with 'Hi-Crop Hybrid' showing a higher magnitude of leaf production compared to 'TopBunch' as evident by the percentages of leaf regrowth.

Table 4. Mean Yield of 'TopBunch' and 'Hi-Crop Hybrid' Collard Leaves (Lbs/Acre) taken in a 50% Leaf Harvest from Plants Grown in a Wiregrass Tunnel House

50% Leaf Harvest (Lbs/acre)				
Days After Transplanting (Days)	'TopBunch' (Lbs/acre)	Percent Rate of leaf recovery %	'Hi-Crop Hybrid' (Lbs/acre)	Percent rate of leaf recovery %
45	1,174	-0-	1,553	-0-
66	2,049	174	2,197	141
87	3,995	340	4,860	312
108	5,225	445	5,858	377

**Significance of F test from ANOVA**

Varieties	**
Harvest Methods	**
Harvest Periods	**
Varieties X Harvest Methods	**
Harvest Methods X Harvest Periods	NS
3 Way Interaction	NS

\*,\*\*

and

NS,

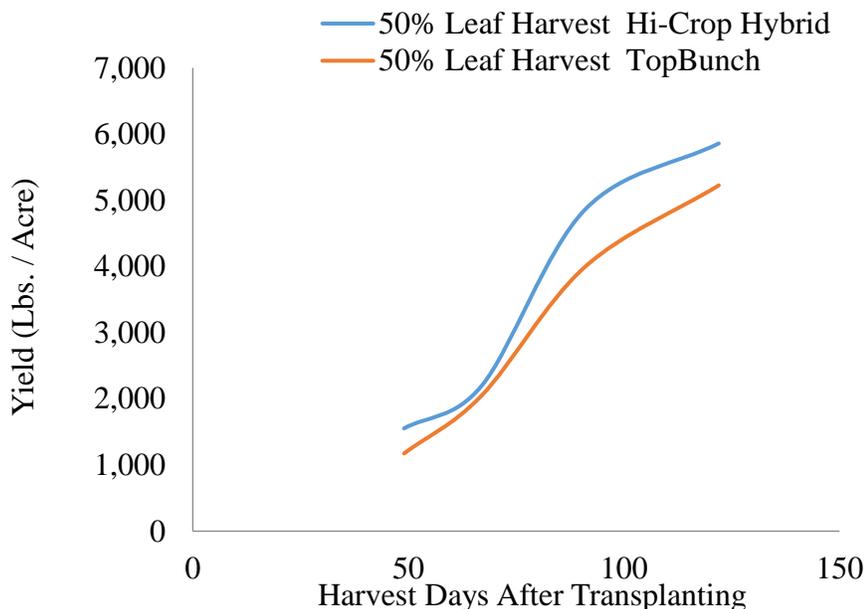


Figure 4. Interaction between varieties and method of harvest for partial 50% leaf harvest of leaves (Lbs./acre) from 'Top-Bunch' and 'Hi-Crop' varieties of collards

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

The total yield of collards at the 50% level of intensity (Table 4) showed a similar interaction between varieties x harvest methods (Figure 4). The two varieties differed in the amplitude of

their response where ‘Hi-Crop Hybrid’ had higher yields than ‘TopBunch’. When comparing yields derived from the 100 and 50% levels of harvest, it was noted that the 50% produced almost twice the yield compared to that obtained at the 100% level of harvest. The percent leaf recovery for both varieties of collards seems to indicate a stimulatory effect which appears to be greater when a partial harvest of 50% was conducted compared to a complete harvest of 100%.

### **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 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. Results from other studies (Gwandu and Isa, 2016; Ibrahim et al., 2010) where leaves were removed from cowpeas and garlic plants showed that the stage of growth, intensity of defoliation, and days after planting when defoliation occurred, affected the final yield of these crops. Ibrahim et al. (2010) showed that when leaf defoliation intensities ranged from 0 to 100%, the lower percentages of leaf removal (25 and 50%) did not have a negative impact on the pod yield of cowpeas. Similarly, in this study when 50% of collard leaves were removed significantly higher yields were obtained compared to the 100% defoliation pressure. Ibrahim et al. (2010) concluded that the younger leaves on the plants seemed to be more involved and active in photosynthesis than the older leaves, and their removal can alter the partitioning of photosynthates. In this study, the oldest leaves were removed from plants which were 50% defoliated leaving the younger leaves. The presence of the younger leaves was the difference between plants that were 50% and 100% defoliated, and based on the leaf recovery results for plants 50% defoliated, the study agrees with the conclusions of Ibrahim et al. (2010).

At the 100% defoliation level, there was a very slow leaf recovery response for the number of leaves and leaf weight from both varieties. It appeared that this level of leaf defoliation diminished the ability of the plants to replace these leaves at their pre-harvest levels at 45 DAT. Gwandu and Isa (2016) reported that crop yield is usually affected when 40% or more of its foliar surface area is removed, and this affected yield. In addition, De Roover et al. (1999), and Hoogesteger and Karlson (1992) also reported that defoliated plants experience a shortage of carbohydrates and increase its allocation of photosynthates to shoot growth and decrease distribution to fruit and root growth. In this study, where both the younger and older leaves were removed in 100% defoliation intensity, the plants were denied a source to produce photosynthates for leaf replacement, and this impacted the plant's ability recover quickly.

Plants which were 50% defoliated in this study showed very rapid leaf recovery at each harvest compared to the 100% leaf removal treatment. Khan and Lone (2005) reported higher a rate of emergence of new leaves and rates of photosynthesis, growth, and yield when mustard plants were defoliated at 50% intensity and harvested at 40 compared to 60 days after planting. Furthermore, they reported that the leaves of partially defoliated plants significantly increased light interception, and had higher assimilatory capacity because they were able to harvest more photosynthetic active rays. This finding was supported by the findings of Alderfer and Eagles (1976), Carmi and Koller (1979), and Cammerer and Farquhar (1984). This explanation seems applicable in this study because plants which were defoliated at the 50% intensity, had high percentages of leaf recovery from the second to the fourth harvests, where leaf yield increased by more than 100% then increased to over 300% at the final harvest. Also, Politud (2016) reported that the removal of the older leaves of okra plants at 7 weeks after seeding, significantly produced longer and wider pods compared to removing the lower leaves at 5 and 6 weeks after seeding. By removing the older leaves mutual shading was reduced, competition for food was reduced, and the younger leaves were able to increase their photosynthetic activity. A similar inference can be made for the results obtained in this study when 50% of the leaves were removed.

### **Conclusion**

The two varieties of collards used in this study responded differently under TH conditions when they were subjected to 100% and 50% leaf harvest. They showed a decline in leaf numbers and yield, between harvest 2 and 3. However, when the leaf harvest intensity was reduced to 50%, leaf numbers and yield, significantly increased. Leaf recovery rates exceeded 100% at this level of harvest intensity and showed a trend to be increasing at each harvest interval of 21 days. This result suggests that TH producers of collards can increase their yield by harvesting 50% of the leaves instead of 100% which is the current practice. The leaf recovery data strongly inferred 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.

### **Acknowledgement**

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