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Evaluation of Sustainable Production Practices for Asian Vegetables (Luffa and Bitter Gourd) and their Mineral Nutrient Analysis in a Piedmont Soil of North Carolina

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Authors' contributions

This work was carried out in collaboration between all authors. Authors RR and MRR designed the experiment, developed data collection protocols and analyzed the data. Authors RR and KOT carried out the project, collected samples and data. Author RR prepared and revised the manuscript. Author MM assisted in statistical analysis of the data. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To reduce the inorganic fertilizers used to grow Asian vegetables (Luffa and Bitter gourds) by incorporating cover crops without compromising yield in piedmont soils of North Carolina
Study Design: A split-split plot design was used in this study with two main plot treatments and four rates of fertilizer as subplot treatments with four replications.
Place and Duration of Study: The study was conducted at the North Carolina A&T State University Farm, Greensboro, Guilford County, NC. from Fall, 2007 to Summer, 2008.
Methodology: Luffa (*Luffa acutangula* 'Rama') and bitter gourd (*Momordica charantia* 'Comet') were grown in a Mecklenburg Sandy Loam (fine, mixed, thermic ultic Hapludalfs) soil. Two cover crop treatments (Cover crop and no cover crop) and four fertilizer treatments (T1: 0-0-0, T2: 56-28-112, T3: 84-56-168, and T4: 168-112-224 N-P-K kg/ha) were studied to determine the yield of Asian vegetables in the Piedmont of North Carolina. The vegetables were hand harvested at weekly intervals for 9 weeks.

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Results: Both luffa and bitter gourd yields increased with increase in rate of fertilizer. Cover crop treatment produced higher yields of luffa and bitter gourd compared to no cover crop treatment for all four fertilizer treatments. Statistical analysis has shown significantly higher yields (p=0.05) in T3 & T4 treatments for both luffa and bitter gourd. Cover crop residue incorporated in to the soil decomposed and released nitrogen which was utilized by the vegetable crops and the effect was evident in increased yields in cover crop treatment plots.
Conclusion: Asian vegetables (luffa and bitter gourd) were grown in piedmont soils of North Carolina and the study showed that T3 & T4 treatments produced higher yields than all other treatments. This study provides evidence that Asian vegetables – such as luffa and bitter gourd – can be grown successfully in the piedmont region of North Carolina.

Keywords: Asian vegetables; luffa; bitter gourd; cover crop; sustainable; fertilizer; Piedmont soil, North Carolina.

1. INTRODUCTION

Luffa/Ridge gourd/Sponge gourd/Chinese okra (*Luffa acutangula* (L.) ROXB.) and bitter gourd/bitter melon (*Momordica charantia* L.) are two very popular asian vegetables consumed by people from Asian and other cultures. Luffa is consumed at young stage as a vegetable. Mature luffa fruit does not have the same palatability as the immature fruits. Bitter gourd is also harvested and consumed at young stage as mature fruits are more bitter in taste with seeds becoming hard to chew. Both luffa and bitter gourd have alternate uses than their consumption as vegetables.

Luffa consumed as a vegetable can supply some antioxidant constituents to the human body [1]. Mature luffa is very fibrous and used for sponge production [2]. Luffa sponge has fibrous vascular system with continuous network system with a pore size range of 10 – 20 µm. Luffa seeds are high in protein (39%) and fat (44%) content and oleic and linoleic fatty acid content is 68% in the kernel oil [3].

Extracts from both luffa and bitter melon are found to have Free radical scavenging activity (FRSA) [4]. Bitter gourd has medicinal value such as its hypoglycemic nature [5,6,7]. Juice extracted out of the bitter gourd fruit and young shoot and leaves has a number of medicinal properties, such as blood cleansing, immune boost, etc. Bitter gourd consumption in the diet can help decrease blood glucose levels as well as some antioxidant properties [8,9]. Chemical compounds in bitter gourd have the ability to reduce the amount of glucose that is released into the blood by inhibiting the enzymes that breakdown disaccharides (e.g. Sucrose) into monosaccharides (e.g. glucose and fructose) [10,11]. Bitter gourd can regulate the transport channels for glucose transfer thereby reducing glucose transport into the blood [12]. This regulatory action is very significant in treating both Type I and Type II diabetic patients and helps to prevent high blood sugar levels after a meal. In an experiment on mice with Type I diabetes, bitter gourd proved an effective treatment by increasing secretion of insulin from pancreas [13,14]. HIV inhibitor protein MRK 29 extracted from Thai bitter gourd fruit and seeds has shown to reduce the expression of viral core protein (p24) in HIV infected cells by 82% [15].

These Asian vegetables are popular and multipurpose and hence, successful and sustainable growing practices must be developed. The city of Greensboro NC and surrounding areas have large Asian communities and hence a good market for Asian vegetables exists. Growing these vegetables on small farms can help the small farms generate income where the cash crop tobacco had been grown previously. Keeping the needs of the small farms, existing market demand and sustainable growing practices in mind, this study was conducted at North Carolina A&T State University Agricultural Farm to both evaluate and demonstrate the cultivation practices of these vegetables. The goal of this study was to reduce the use of inorganic fertilizers by incorporating cover crops to grow Asian vegetables without compromising yield.

2. MATERIALS AND METHODS

2.1 Field location and Experimental Section

The experiment was conducted at the North Carolina A&T State University Research Farm in Guilford County, North Carolina (lat: 36.06733º, long: -79.73447º). The landscape at the experimental location was representative of many regions in the Piedmont and southeastern United States. The soil was a Mecklenburg Sandy Loam (fine, mixed, thermic ultic Hapludalfs). The experimental design was split-split plot with 4 replications under cover crop (CC) and no-cover crop (NC) systems. Four different fertilizer treatments (T1: 0-0-0, T2: 56-28-112, T3: 84-56-168, and T4: 168-112-224 N-P-K kg/ha) were applied in both CC and NC systems. In each treatment 50% of the fertilizer was applied and incorporated in to the soil with a disc plough and raised beds were prepared. The remaining 50 % fertilizer was supplied by fertigation. Raised beds 2' (W) and 30' (L) covered with black plastic and lined with drip tape for irrigation and fertigation were prepared prior to seed planting. Seeds were planted in the beds in the Spring 2008. Harvesting of the vegetables was done between Aug 8, 2008 and Oct, 9, 2008 for a total of 9 times at weekly intervals when the vegetables were at marketable stage (54 days after planting).

Cover crop treatments plots were studied to determine the rate of decomposition and release of plant nutrients in to the soil. Crimson clover (*Trifolium incarnatum*) and cereal rye (*Secale cereale*) were planted in the plots (cover crop system) in fall, 07 and were incorporated into the soil in Spring, 08. The cover crop mixture (Crimson clover + cereal rye) was collected before incorporating in to the soil. A 40 g (9.2 g crimson clover + 30.8 g cereal rye) sample of the over crop mixture of was placed in a fiber glass mesh bag. Five bags per each fertilizer treatment plot within the cover crop treatment were placed at 3” depth and 24” apart. A total of 80 mesh bags (5 bags per treatment X 4 fertilizer treatments X 4 replications) were placed in the cover crop treatment plots. The mesh bags were collected at 3 week intervals during the luffa and bitter gourd growth period. Each time the mesh bags were collected, they were washed carefully to get rid of the soil without losing any cover crop residues. Washed cover crop residues were dried at 65°C for 48 hrs and their dry weights were recorded. Dried cover crop residues were then ground using a Wiley Laboratory Mill Model 4 (Thomas Scientific, Philadelphia) in to 1mm size particles. Samples from the sieved plant material were analyzed for total C and N by dry combustion method.

2.2 Mineral Nutrient Analysis

Luffa and bitter gourd tissues were analyzed to determine the nutrient content by Dry ashing procedure [16] given in SSSA book series: 3. A 0.5 g of dried 20-mesh plant tissue was taken in a 15ml porcelain crucible and heated at 500ºC for 8 hrs in a muffle furnace. The crucibles were taken outside of the furnace and cooled down to room temperature. The ash was dissolved by adding 10 ml of dilute acid (300 ml of HCl and 100 ml of HNO_3 in 1 L of pure water) and allowing the mixture to settle down at the bottom of the crucible. The supernatant was filtered and diluted to 50 ml for elemental assay.

2.3 Experimental Design and Statistical Analysis

A split-split-plot design was used in this study with two cover crop treatments as main plots and four fertilizer treatments as sub-plots and replicated four times (32 experimental units in total). Each sub-plot was 3 m x 10 m size. Data for the experiments were subjected to analysis of variance using Statistical Analysis System, Version 9.2 [17].

3. RESULTS AND DISCUSSION

Luffa and bitter gourd were harvested 9 times between August and October, 2008. Total yield obtained with each fertilizer as well as cover crop treatments are presented in Table 1. Both luffa and bitter gourd produced consistently high yields with increase in fertilizer, T4 was the highest yield treatment in both crops for cover as well as no cover crop treatments.

3.1 Luffa Yield

Luffa yield increased consistently with increase in fertilizer treatment in both cover and no cover crop treatments. Yields were consistently higher in cover crop plots compared to the no cover crop plots, except for T3 (Luffa) (Table 1). Duncan grouping of the yield data has shown that significantly higher yield (P = 0.05) was observed in luffa and bitter gourd from T3 & T4 plots compared to the other treatment conditions. Statistical analysis has shown that luffa yield was significantly affected by fertilizer treatments (Table 2) but not by cover crop treatment.

3.2 Bitter Gourd Yield

Bitter gourd yield was higher with T4 treatment in both cover crop treatments (Table 1). Similar to luffa, bitter gourd also showed a significant effect on yield with fertilizer treatments but not with cover crop treatments (Table 2).

3.3 Cover Crop vs No Cover Crop Treatment in Luffa and Bitter Gourd

Luffa and bitter gourd produced higher yields with the inclusion of cover crop residues. Among the cover and no cover crop treatments, yield in cover crop incorporated plots was higher for both the vegetables. The increase in yield can be attributed to the decomposition and release of extra nitrogen and other nutrients that are utilized by plants. The decomposition and release of nitrogen is supported by the data collected from another study conducted in the same plots [18], according to the study 13.33 – 18.32 g/kg of nitrogen was released from the cover crop residue that was buried in the soil for decomposition. Bitter gourd yield was comparatively higher in the cover crop plots than in the no cover crop plots for all N-fertilizer treatments. The yield data of luffa and bitter gourd in cover crop treatment plots indicates that the nitrogen released from the cover crop residue is utilized by the vegetable crops and thereby increased the yield over the no cover crop treatment yields.

Temperature (Fig. 1) during the luffa and bitter gourd growing period was on the decline after the month of august when the first harvest occurred. Since Luffa and bitter gourd are Asian vegetable, they tend to perform better and produce higher yields at warmer temperatures. Cover crop was incorporated for the first time in these plots during the growing period and hence the release of nitrogen from the crop residues was in low quantities.

Rainfall (Fig. 2) was not uniform during the growing period. August and September months have received rainfall close to 6 and 5 inches respectively and October month has received only an inch of rainfall which might have contributed to the slower decomposition of the cover crop residues incorporated in to the soil and there by releasing less nitrogen. Cover crop residue incorporation to improve crop yield is a long term process because of the slow decomposition rate of the plant residues and release of nutrients.

Table 1. Yield data for luffa and bitter gourd at different fertilizer treatments under cover and no-cover crop systems

N-P-K rate (kg/ha)	Luffa (t/ha)		Bitter gourd (t/ha)	
	No cover crop (NC)	Cover crop (CC)	No cover crop (NC)	Cover crop (CC)
0-0-0 (T1)	25.9^{C}	27.0^{C}	5.5^{B}	8.5^{B}
56-28-112 (T2)	40.3^{B}	44.9^{B}	8.1^{B}	11.7^{B}
84-56-168 (T3)	56.8^{BA}	41.2^{BA}	10.9^{BA}	12.5^{BA}
168-112-224 (T4)	57.3^{A}	61.1^{A}	15.9^{A}	16.6^{A}

NC – No cover crop; CC – Cover crop; Treatment means with same letter are not significantly different

Table 2. SAS analysis of variance results showing the significance of treatments on luffa and bitter gourd yield

Luffa (t/ha-1)					
Factor	***DF***	**Sum of squares**	**Mean square**	***F***	***P***
Fertilizer rate (FR)	3	4542.46	1514.15	9.16	0.004
Cover crop (CC)	1	19.84	19.84	0.12	0.73
(FR) x (CC)	3	541.9	180.63	1.09	0.4
Error	9	1487.59	165.28		
CV=29.02					
Bitter gourd (t/ha-1)					
Factor	***DF***	**Sum of squares**	**Mean square**	***F***	***P***
Fertilizer rate (FR)	3	363.55	121.18	4.73	0.03
Cover crop (CC)	1	39.82	39.82	1.55	0.24
(FR) x (CC)	3	10.15	3.38	0.13	0.93
Error	9	230.7	25.62		
CV=45.03					

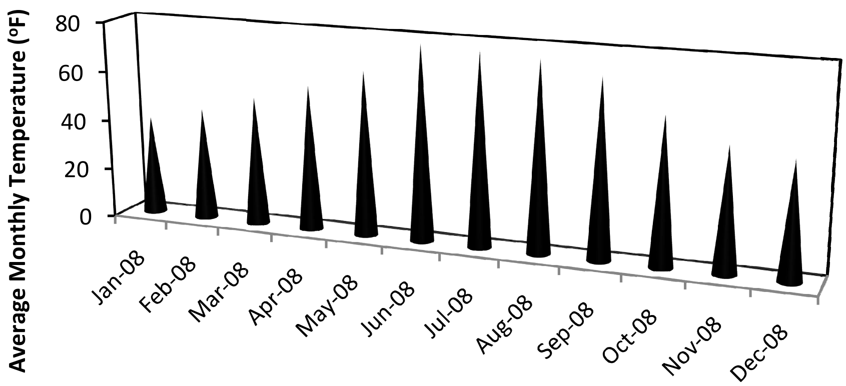

Fig. 1. Average monthly temperatures in Guilford county area of North Carolina during the study conducted on luffa and bitter gourd

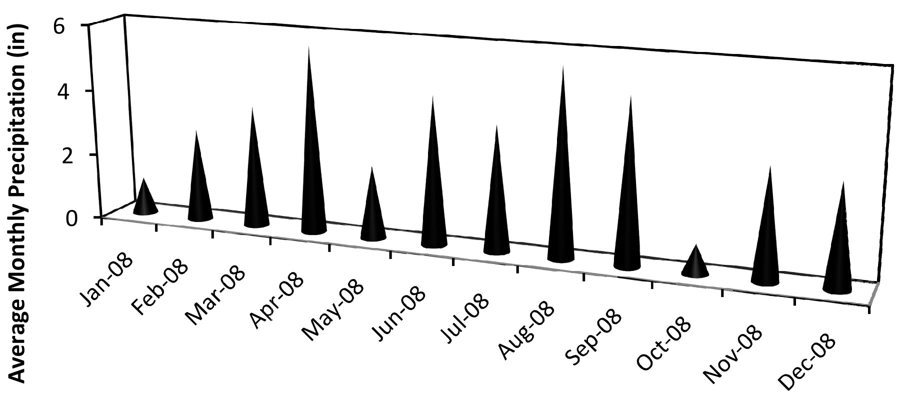

Fig. 2. Monthly average precipitation during the year 2008 in Guilford county area of North Carolina

3.4 Mineral Nutrient Analysis

Luffa and bitter gourd tissue analysis (Table 3) for nutrient elemental concentrations has shown that both the vegetables have good amounts of all the elements that were analyzed.

Bitter gourd has significantly high concentrations of potassium (K) which when consumed as vegetable can help control high blood pressure. In addition to potassium bitter gourd is also significantly high in copper, magnesium and manganese (Table 3). Luffa has significantly high concentration of calcium, sulfur and zinc. Nutritionally, both vegetables are good source of mineral nutrients. Bitter gourd has phytochemicals that control blood glucose level (glycemic index) and antioxidant components [15,16].

Table 3. Mean concentration of mineral nutrient content of luffa and bitter gourd

Element	Luffa (mg/g)	Bitter gourd (mg/g)
Ca	2.27 A	1.64 B
Cu	0.001B	0.01A
Fe	0.02A	0.02A
K	12.8 B	20.48 A
Mg	2.24B	2.57A
Mn	0.01B	0.02A
Na	1.66 A	1.60A
P	4.14A	4.30 A
S	0.94A	0.67B
Zn	0.03A	0.02B

Means values for each nutrient with the same letter are not significantly different

4. CONCLUSION

Results indicate that both luffa and bitter gourd produced higher yields in the cover crop treatment plots than in the no-cover crop plots. Significant yield differences (P=0.05) were observed in the luffa vegetable yield from the plots applied with treatment T3&T4 kg/ha than from the other treatment conditions for both the vegetables. Although yields were not significantly different between the cover crop and no-cover crop treatments, we may recommend growing luffa and bitter gourd under cover crop treatment and T3 fertilizer application. The consistently higher yields observed in case of both luffa and bitter gourd suggest that cover crop residue incorporation in to the soil will relatively increase the yields, even in short term. Cover crop residue inclusion in to the soil helps in building the organic matter of the soil and in general improve soil health for greater productivity in the long run. Small farms will be encouraged to incorporate cover crops in to their crop rotations in order to obtain higher yields as well as improve the soil conditions. Bitter gourd is a good source of potassium to include in the diet of patients with high blood pressure and to control blood glucose level.

CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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