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EFFECTS OF ALABAMA SOIL TYPES ON THE PLANT BIOMASS AND ELEMENTS IN HOLY BASIL

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ABSTRACT

Holy basil is cultivated in the tropics for its religious, medicinal and food purposes. This study was conducted to determine the effects of the major soil types in Alabama on the vegetative growth and elemental content of basil plant. The effects of different soil types on the vegetative growth and elemental content of Basil were investigated in a Greenhouse setting with soil samples that were collected from the major physiographic units of Alabama -Coastal plain, Appalachian plateau, Piedmont, and Highland rim. The experiment was designed to fit a Completely Randomized Design (CRD).Holy basil seeds were planted in germination trays, allowed to germinate and grow for six weeks in nursery, and transplanted into the plastic pots containing the 4 Alabama soil types. At the end of sixteen weeks observational period after transplanting, plants were uprooted, processed and analyzed. Results showed that vegetative growth of basil measured by plant height, and the number of branches performed best in the Coastal plain soils followed by the Appalachian plateau. These may be due to the pH of the soils that fall within the pH range that basil performs well. Phosphorus and Magnesium in the root and shoot of the plants grown in the soils showed significant differences at $\alpha = 0.05$ probably due to the high content of P in the soil.

Keywords: Alabama soil types, Holy basil, Greenhouse experiment, Vegetative growth, Soil nutrient content

Introduction

Holy basil(*Ocimum tenuiflorum*)is widespread both as a native and cultivated plant throughout the Eastern tropics, where it is cultivated for religious, medicinal, and food purposes. Because of its popularity and many uses, Holy Basil has become a subject of intense studies to understand the morphological characteristics, chemical composition, as well as vegetative growth potential of the plant in temperate environments.

In India and Southeast Asia where Basil is indigenous and sacred, it is thought to provide protection for homes where it is cultivated (Yates, *Plant Intelligence*). Part of this belief is that the smell of the plant is effective in keeping away insects that typically spread disease, such as mosquitoes and flies.

Medicinally, an array of active constituents called flavonoids (Orientin and vicenin) that in studies on human white blood cells were found to protect cell structures as well as chromosomes from radiation and oxygen-based damage have been found in basil (Uma, 2001; and Vrinda and Uma, 2001).

In addition, basil has been shown to have anti-bacterial growth properties associated with its volatile oils (which contain estragole, linalool, cineole, eugenol, sabinene, myrcene, and limonene) that restrict the growth of numerous bacteria, including : Listeria monocytogenes, Staphylococcus aureus, Escherichia coli, Yersinia enterocolitica, Pseudomonas aeruginosa, and Shigella (Opalchenova and Obreshkova, 2003; Bagamboula et al, 2004). Many other health and therapeutic benefits such as adaptogenic, and anti-stress uses have been reported (Cohen, 2014).

Species of this plant have been found to strive well on variety of soils and climatic conditions (Omer etal,2008; Isa et al,2006; Kothari et al, 2004; Daneshian et al, 2009). For instance, field experiments conducted on different species and varieties of Basil have shown that rich loam to poor laterite, alkaline to moderately acidic soils infair to high rainfall and humid conditions are well suited for its cultivation. In other instances, the plant has been observed to prefer warm environment (average daily temperature of 65 to 70 Fahrenheit) under full sun (at least 6-8 hours of bright light per day), well-drained soil conditions, and a pH range of 6.0-7.5. Such ideal conditions encourage a larger, bushier plant that can grow to about 30 to 60 cm high (Renter, 2013; Kooyman, 2007).

Alabama has the atmospheric environmental conditions that are not too different from those that the plant flourishes.But Alabama soil conditions are likely different from those that the plant flourishes, partly because the different major soil areas of the state (Limestone Valleys and Uplands, Appalachian Plateau, Piedmont Plateau, and Coastal Plain) have soils that vary markedly in physical and chemical characteristics and soil nutrients. As Alabama soil and environmental conditions are never completely alike, the effect on the plant will not be exactly the same. So adaptability ofBasil plant under Alabama soils and environment needs to be investigated.

The phytochemical and elemental content of Basil, in general, have been shown to be significantly influenced by the soil in which the plants grow (Gonzalez-Fernandez et al, 2011; Doyle et, 1973). Thus different soils with distinct characteristics in mineral composition and nutrient availability, due mainly to soil genesis are likely to have different effects on the plant.

To investigate the soil conditions under Alabama environment that suits Basil growth and chemical characteristics, a controlled environmental study was conducted in the Alabama A & M University Greenhouse by using four predominant soil types in Alabama. The objective of this study were a) to assess the maturation of Holy Basil in soils from four major soil areas that encompass Alabama soil diversity; b) to determine total dry plant biomass, roots, stems, leaves and inflorescence; c) to determine elemental composition in Holy Basil plant parts when grown in the four different soil types; and d) to analyze data to determine a more suitable soil type for optimal growth of Holy Basil under Alabama conditions.

Materials and Methods

Soil Sampling

The study was conducted in the Greenhouse at Alabama Agriculture and Mechanical University with soil samples collected from the different soil areas in Alabama (Figure 1). The major soil areas of Alabama from which soil samples were collected include Coastal Plain region, Piedmont region, Highland Rim, and Appalachian Plateau. Four soil types representing the major soil areas were sampled for the study. The soil surface horizons (0- 20 cm) of the soils were collected fromHale County for the Coastal Plainarea (T1); Camphill Station, Tallapoosa Countyfor the Piedmontarea (T2); Winfred Thomas Agricultural Research Station, Madison County for the Highland Rim area (T3); and Auburn Horticultural Research Station at Cullman Countyfor the Appalachian Plateau (T4) to grow the Basil plant used for the study.

At the sampling sites, three1-m^2 areas within a 50-m radius of the land was cleared. About 10 gallons of soil samples from each of the 1m^2 areas was collected. The soils from the 1m^2 areaswere composited for a total of about 30 gallons of soil, and stored in 60 gallon tanks. The soil samples were taken to the Greenhouse where it was prepared for planting Basil.

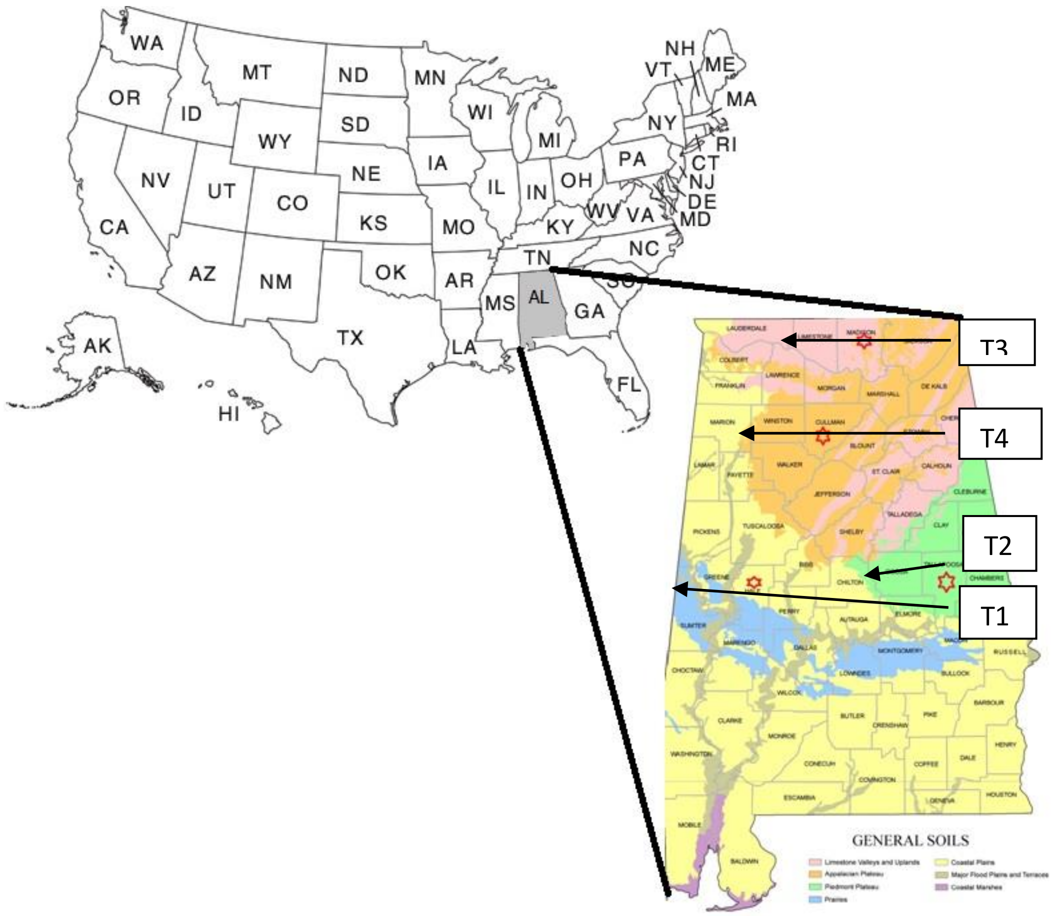

Fig. 1.Location map of the soil sample collection sites of the different soil areas in Alabama. Sampling sites are designated with the red six-point star on the map as follows: T1, Coastal plain, Hale County; T2, Piedmont, Tallapoosa County; T3, Highland Rim area, Madison County; and T4, Appalachian Plateau, Cullman County.

Greenhouse Experiment

At the Greenhouse, Holy basil seeds were planted in germination trays filled with potting mix and allowed to germinate and grow by periodically watering the seedlings in nursery. The seedlings were monitored for sixweeks before transplanting them.

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The soils from the major soil areas were packed into 2.5 gallon plastic pots relative to the natural soil density. The experiment was laid out in the AAMU Greenhouse following a Completely Randomized Design (CRD) layout with the four soil types as treatments (T1, T2, T3, T4) and three replications (R1, R2, R3) for a total of twelve observational units. Each soil type was analyzed before and after planting. Soil samples collected from the sites were air-dried, passed through a 2-mm screen, and characterized for suitability for different crops, pH, and nutrient content (Table 2).

The six-week old seedlings were transplanted into the plastic pots containing the 4 Alabama soil types (Coastal plain, Piedmont, Highland rim, and Appalachian plateau) at one plant per pot. Plants were grown without any soil amendments or fertilizers (Figure 2).

Medicinal Plant Study Treatments were as follows:

T1	=	Costal plain soil (sampled from, Hale County)
T2	=	Piedmontsoil (sampled from, Camphill Station, Tallapoosa County)
T3	=	Highland Rim soil (sampled from Winfred Thomas Agricultural research Station, WTARS, Madison County)
T4	=	Appalachian Plateau soils (sampled from Auburn Horticultural Res. Station, Cullman County)

T = treatments (4 treatments)
R = replications (3 replications)

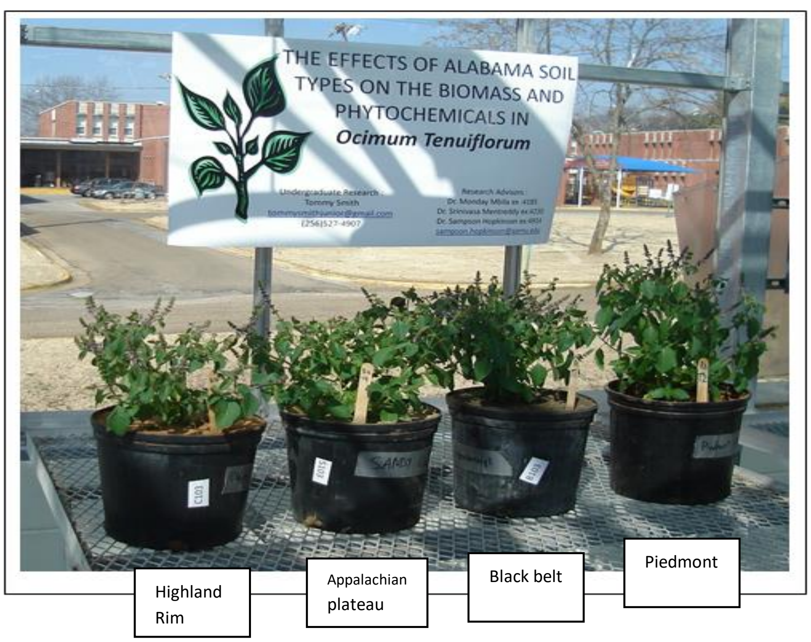

Fig. 2. The six-week old seedlings were transplanted into the plastic pots containing the 4 Alabama soil types.

At the end of the six weeks observational period, plants were uprooted, rinsed, dried, and the roots, leaves, stems, and inflorescent were separated and prepared for analysis. The plant preparation involved placing the plant parts in a forced air drier set at 50°C for three days. Dry weights were recorded when they were dried to constant weight. Whole plant biomass, shoot to root ratio and dry matter partitioning among different plant parts: plant height, number of branches per plant, fresh weight of roots, leaves, stems and inflorescence, root length were recorded. The dried pant parts (dried roots, stem, leaves, and inflorescences) were ground and sieved using 2mm sieve for elemental analyses. The samples were stored for analysis.

After harvesting the plants, soil samples from the root zone of each pot were collected, air-dried, passed through a 2-mm screen, and stored for analysis.

Laboratory Soil and Plant Analyses

Soil analysis performed on the samples included Soil pH (1:1 soil/H_2O) measured with a glass electrode. Total K, Ca, and Mg, Na and Al were extracted by the Microwave Accelerated Reaction System (MARS) using the EPA method #3052 for complete digestion. In the procedure, 0.5 g of representative soil sample was reacted with 9 mL of concentrated nitric acid and 3 mL hydrofluoric acid in microwave vessels in a closed vessel MARSXpress digestion within a total time of 20 minutes and desired temperature of about 180 ^{o}C (EPA method #3052). The samples were cooled, filtered through #42 Ashless Whatmann Filter paper and the filtrate stored for analyses. The elemental concentrations of the extracts from the soil samples were determined with a Perkin Elmer 2100 ICP-OES (inductively coupled plasma –optical emission spectroscopy) following the standard operating procedures required for the ICP.Soil texture was determined by the pipette method (Day, 1965).

Laboratory Plant Analyses

Similarly, the plant samples that were previously prepared for analysis were analyzed for metal contents by utilizing using the EPA method #3052 for complete digestion by solubilizing 0.5 g of plant sample with 9 mL of concentrated nitric acid and 3 mL hydrofluoric acid in microwave vessels in a closed vessel MARSXpress digestion within a total time of 20 minutes and desired temperature of about 180 ^{o}C (EPA method #3052). The samples were cooled, filtered through #42 Ashless Whatmann Filter paper and the filtrate stored for analyses. The elemental concentrations of the extracts from the soil samples were determined with a Perkin Elmer 2100 ICP-OES (inductively coupled plasma –optical emission spectroscopy) following the standard operating procedures required for the ICP.

Statistical Analyses

A one-way classification ANOVA was used to compare the mean observations of the experiment with treatment as the only criterion for classifying data. Twelve experimental units were used to observe the effects of four soil types in three replications on Basil. All statistical analyses were performed manually by using the guidelines of the completely randomized design method at a significant level of 0.05 (Steel and Torrie, 1980). The analysis of variance (ANOVA) procedure was employed to calculate the means of the assessed parameters focusing on different class information as required for the Basil plant partsand elements analyzed (Table 4).

Results

Soil Test results

Soil test results from soil samples collected from the different major soil areas in Alabama indicated differences in pH, and elemental content of the soils (Table 2).

For the Coastal Plain soils, the soils were alkaline (pH 7.7), high in Ca^{2+}(9999 pounds per acre), Mg^{2+} (496 pounds/acre), and K^{+}(353 pounds/acre) but low in P (33pounds/acre).Soils from the Appalachian Plateau areas were slightly acidic (pH 6.4), high in Ca^{2+} (1825 pounds per acre), Mg^{2+} (266 pounds/acre), and K^{+} (250 pounds/acre) but medium in P (48 pounds/acre). Similarly, soils from the Highland Rim, and Piedmont areas were within the very acid soils (pH 5.7) range, high in Ca, Mg, and K, but medium to very low P content. For the Highland Rim soils, the nutrients wereCa^{2+} (728 pounds per acre), Mg^{2+} (138 pounds/acre), K^{+} (286 pounds/acre), and P (11 pounds/acre). That of the Piedmont were Ca^{2+} (1682 pounds per acre), Mg^{2+} (146 pounds/acre), K^{+} (184 pounds/acre), and P (30 pounds/acre).

Table 2. Selected soil characteristics of soil samples from the different areas.

Soil Type	Texture	pH	P	K	Mg	Ca
			Pounds/Acre			
Coastal Plain	C	7.7	33	353	496	999
Piedmont	SCL	5.7	30	184	146	1682
Highland Rim	SCL	5.7	11	286	138	728
Appalachian Plateau	SL	6.4	48	250	266	1825

*** C = clay; SCL = sandy clay loam; SL = sandy loam**

Effect of Different Soil Types on the vegetative growth of Basil

The results of the effects of the soil types on the vegetative growth of basil are presented in Fig. 3. Among the Coastal plain soil, Appalachian plateau soil, Piedmont soil, and Highland Rim soil, the Coastal plain soil produced the tallest plants (29 cm). This was followed by the Appalachian plateau soils and Piedmont soils with a plant height of 27.3 cm and 26.7 cm, respectively. Highland rim soils showed poor plant growth with average plant heights of 23.7 cm.

Maximum number of branches per plant of holy basil was recorded in the Coastal plan soils (65 branches), followed by the Appalachian plateau soils (59 branches) (Fig. 3). Basil grown on soils from the Highland Rim and Piedmont produced 51, and 46 branches, respectively.

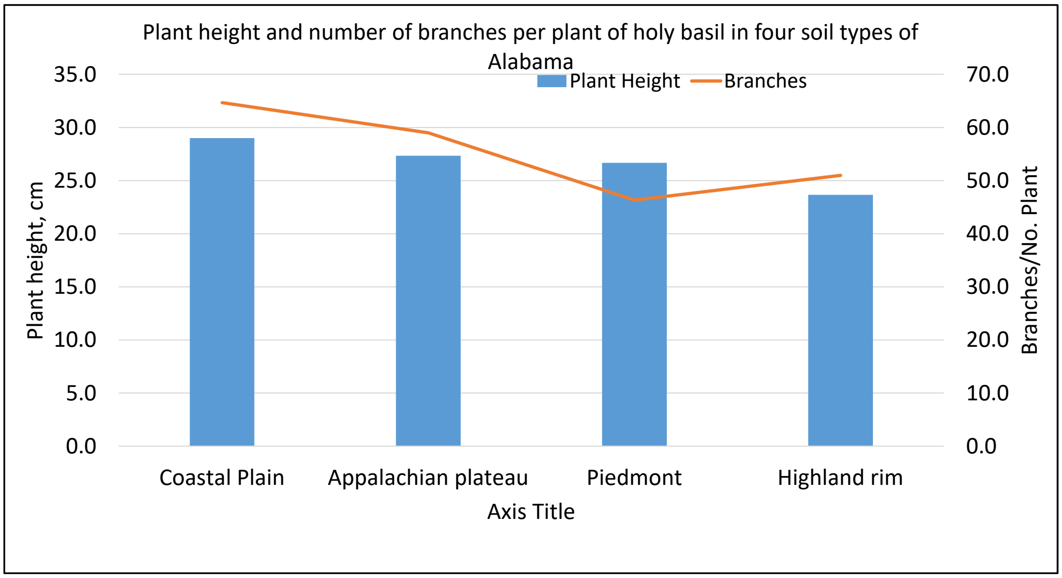

Fig. 3: Effect of different soil types on growth on plant height and branches of holy basil (3-months-old plants). a) Highland Rim soil; b) Appalachian plateau soil; c) Coastal plain soil; and d) Piedmont soil.

The total plant fresh weight of basil decreased from the Coastal Plain soils wth (121 g) to 93 g in the Appalachian plateau soils (Fig. 4). Total plant fresh weight of basil was 76 mg and 73 mg in the Highland Rim, and the Piedmont soils, respectively. The vegetative growth of basil showed that the Leaf Fresh Weight among the four soil types ranged from 25 mg (Highland Rim) to 37 mg Coastal Plain soils. Thus, the Coastal plain soils had more leaf fresh weight followed by Appalachian plateau soils, Piedmont soils, and the Highland Rim soils.

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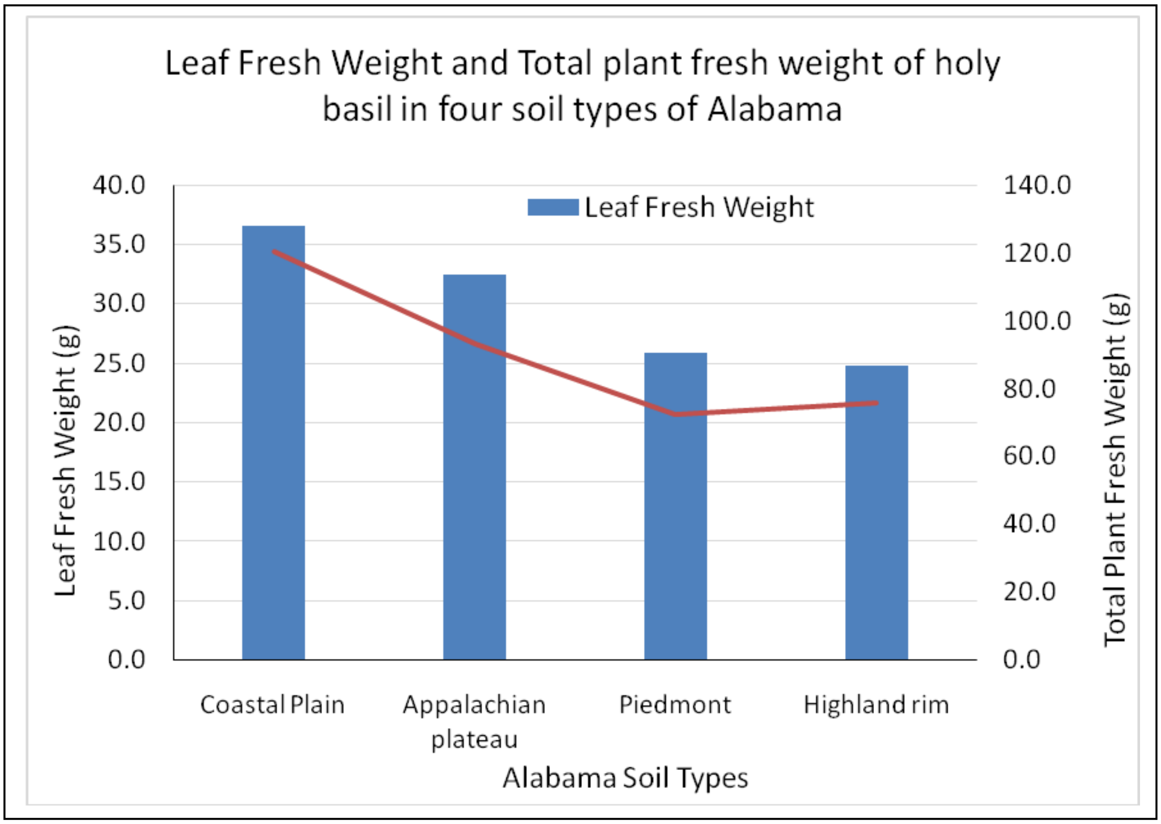

Fig. 4: Effect of different soil types on the leaf fresh weight and total plant fresh weight of Holy basil (3-months-old plants). a) Highland Rim soil; b) Appalachian plateau soil; c) Coastal plain soil; and d) Piedmont soil.

Analysis of Plant Materials grown on the Different Soil Types

The results of the analysis for potassium (K), magnesium (Mg), phosphorus (P), and iron (Fe) contents of dried basil plant materials from above and below ground plant parts grown in the different soil types are presented in Fig. 5.

Potassium:

For all four Alabama soil types, concentrations of K in the shoot was higher than K concentrations in the root. Basil grown on Highland rim soils accumulated the highest amounts of K (39 mg g^{-1} soil), followed by those grown in Coastal plain soils (36 mg g^{-1} soil),

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Appalachian plateau soils (33 mg g^{-1} soil), and Piedmont soils (24 mg g^{-1} soil), respectively. Root K contents were lower, ranging from 11 mg g^{-1} soil (Appalachian plateau soils) to 13 mg g^{-1} soil.

Magnesium:

Magnesium content of Basil was similarly higher in the shoot (10-16 mg g^{-1} soil) than in the roots (2-5 mg g^{-1} soil). But the highest Mg content was found in the shoot of plants that were grown on Appalachian plateau soils. The Mg content of the Piedmont soils, Highland Rim soils, and Coastal plain soils were 12.7, and 12.4, and 9.9mg g^{-1} soil, respectively.

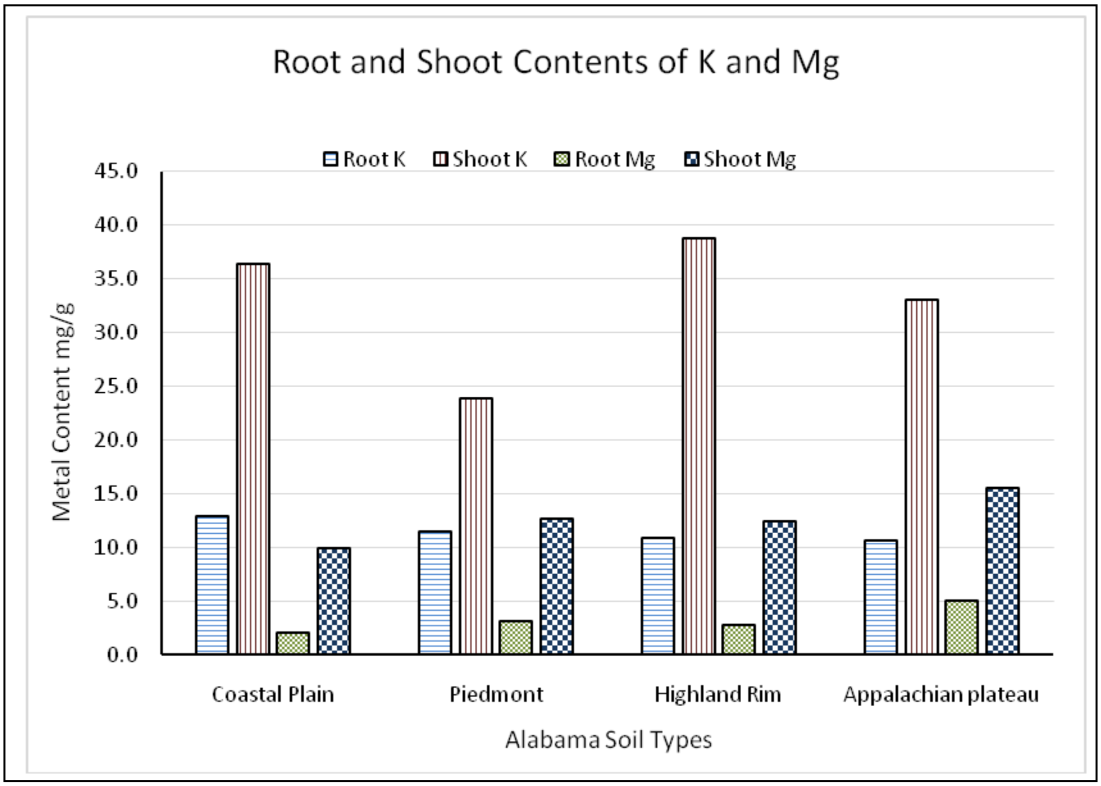

Fig. 5: Effect of different soil types on the root and shoot content of K and Mg of Holy Basil (3-months-old plants). a) Highland Rim soil; b) Appalachian plateau soil; c) Coastal plain soil; and d) Piedmont soil

Iron:

For all four Alabama soil types, Fe concentrations in the root of Basil were higher than concentrations in the shoot (Fig.6). Concentrations averaged 4.6 mg Fe g^{-1} soil (Piedmont), 3.4mg Fe g^{-1} soil (Coastal Plain), 3.0 mg Fe g^{-1} soil (Highland Rim), and 2.0 mg Fe g^{-1} soil (Appalachian Plateau). But Fe in the shoot averaged 0.4, 0.5, 0.9, and 0.4 mg g^{-1} soil for Piedmont, Coastal Plain, Highland Rim, and Appalachian Plateau soils, respectively.

Phosphorus:

Shoot concentrations of P were higher than in the roots of Basil (Fig. 6). Shoot P concentrations averaged 5.5 mg g^{-1} soil, 4.8mg g^{-1} soil, 4.3mg g^{-1} soil, and 4.1 mg g^{-1} soil for Appalachian Plateau, Piedmont, Highland Rim, and Coastal Plain soils, respectively. Root P content of the soils averaged 1.2 mg g^{-1} soil, 0.7 mg g^{-1} soil, 0.6 mg g^{-1} soil, and 0.6 mg g^{-1} soil for the Appalachian Plateau, Highland Rim, Coastal Plain, and Piedmont, respectively.

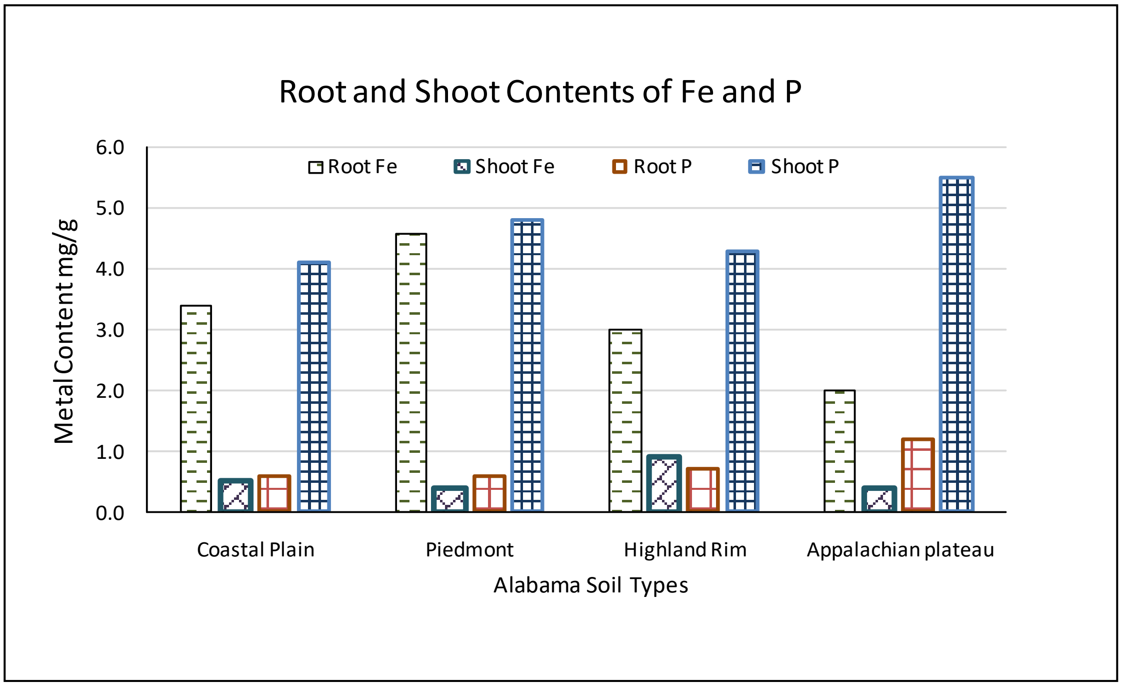

Fig. 6: Effect of different soil types on the root and shoot content of Fe and P of Holy Basil (3-months-old plants). a) Highland Rim soil; b) Appalachian plateau soil; c) Coastal plain soil; and d) Piedmont soil

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Discussion

The soil test results from soil samples collected from the different major soil areas in Alabama indicated no major nutrient limitation for the soils to be utilized for growing annual crops such as basil. However, for optimal plant growth for annuals such as basil, NPK fertilizer recommendation rates of 120-100-0; 120-70-0; 120-50-0; and 120-40-0 for Highland Rim, Coastal Plain, Piedmont, and Appalachian Plateau soils, respectively have been suggested (Mitchell and Huluka, 2015).

Vegetative growth of Basil measured by both plant height, and the number of branches shows that Holy basil performed best in the Coastal plain soils followed by the Appalachian Plateau soils. Vegetative growth of holy basil grown in soils from Piedmont and Highland rim were comparable in having fewer branches, but with plants from Piedmont slightly taller than those of Highland rim. Similarly, when the plants were compared on the basis of plant shoot productivity (combined stem weight, leaf weight, and inflorescent weight), and root density, Basil grown in the Coastal Plain soils grew more vigorously and were taller and bushier, followed by those that were grown in the Appalachian Plateau, Piedmont soils, and Highland Rim soils, respectively (Fig. 3).

However, when the mean differences of the heights of plants grown in the different soils were compared using ANOVA, there was no significant difference ($p > 0.0786$) (Table 4). Similar results obtained for the root density of basil plants grown in the four soils did not show statistical significant difference as well. These data suggest that although the difference in means of the vegetative growth of Basil that were grown in the four Alabama soil types did not show statistical significant difference at $p = .05$, there were visual differences that was recorded from measurements. Coastal plan and Appalachian plateau soils in which the vegetative growth of Basil performed slightly better have a pH rang of 6.4 - 7.7 (neutral to alkaline range). This result is supported by studies of Basil elsewhere that indicates that Basil performs well in the pH range of 6.0 - 7.5 (Kooyman, 2017).

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Table 4. ANOVA Table to test significant differences among and between the treatments.

	Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	F-Table (0.05)	P-Value
Root Growth	Treatment (Soil types)	4-1 =3	8.5	2.81	0.64	4.07	0.610
	Error (Within soil types)	3(3-1) =8	35.0	4.375			
	Total	4*3-1 =11	45.5				
Shoot Growth	Treatment (Soil types)	4-1 =3	30.9	10.27	2.99	4.07	0.096
	Error (Within soil types)	3(3-1) =8	27.5	3.44			
	Total	4*3-1 =11	58.4				
Plant Height	Treatment (Soil types)	4-1 =3	44.7	14.9	3.31	4.07	0.079
	Error (Within soil types)	3(3-1) =8	36.0	4.5			
	Total	4*3-1 =11	58.4				
# of branches	Treatment (Soil types)	4-1 =3	601.0	200	3.1	4.07	0.089
	Error (Within soil types)	3(3-1) =8	509.0	64			
	Total	4*3-1 =11	58.4				
Root Fe	Treatment (Soil types)	4-1 =3	41.1	13.7	1.05	4.07	0.422
	Error (Within soil types)	3(3-1) =8	104.1	13.01			
	Total	4*3-1 =11	145.2				
Shoot Fe	Treatment (Soil types)	4-1 =3	27.7	9.23	0.83	4.07	0.514
	Error (Within soil types)	3(3-1) =8	89.1	11.14			
	Total	4*3-1 =11	116.8				
Root K	Treatment (Soil types)	4-1 =3	34.9	11.63	0.34	4.07	0.797
	Error (Within soil types)	3(3-1) =8	278.0	34.75			
	Total	4*3-1 =11	312.9				
Shoot K	Treatment (Soil types)	4-1 =3	607.0	202.3	3.67	4.07	0.063
	Error (Within soil types)	3(3-1) =8	440.7	55.1			
	Total	4*3-1 =11	1047.7				
Root Mg	Treatment (Soil types)	4-1 =3	60.3	20.1	18.3	4.07	0.001
	Error (Within soil types)	3(3-1) =8	8.9	1.1			
	Total	4*3-1 =11	69.2				
Shoot Mg	Treatment (Soil types)	4-1 =3	104.0	34.7	11.7	4.07	0.003
	Error (Within soil types)	3(3-1) =8	23.7	2.96			
	Total	4*3-1 =11	128.7				
Root P	Treatment (Soil types)	4-1 =3	2.9	0.97	16	4.07	0.001
	Error (Within soil types)	3(3-1) =8	0.5	0.06			
	Total	4*3-1 =11	3.4				
Shoot P	Treatment (Soil types)	4-1 =3	2.9	0.9	15	4.07	0.001
	Error (Within soil types)	3(3-1) =8	0.5	0.06			
	Total	4*3-1 =11	3.4				

Soil pH which measures soil acidity is a useful indicator of availability of nutrients, and the general state of a soil. In acid soils (pH < 6), many of the exchangeable sites in the clay minerals and humus are occupied by hydrogen or aluminum ions leading to loss of and low concentrations of nutrient cations. In veryacidic soils, cations such as Fe^{3+} and Al^{3+} appear in the soil solution, and these are quite toxic. However, pH range, in basic soils (pH > 8), generally results in the cation nutrients generally becoming less available. Soil pH differences of the soils is also important because soil CEC varies with pH.Cation exchange capacity (CEC) is a measure of the total negative charges within the soil that adsorb plant nutrient cations such as calcium (Ca2+), magnesium (Mg2+) and potassium (K+). As such, the CEC is a property of a soil that describes its capacity to supply nutrient cations to the soil solution for plant uptake.

Another major difference in the physical properties of the soils used for the study is the soil texture. The soil textural classes ranged from clay in the Coastal Plain soils to sandy clay loam in the Piedmont, and Highland Rim, to sandy loam in the Appalachian Plateau soils. The clayey texture of Coastal plain soils showed the highest plant vegetative growth compared to less clayey soil textures of the other soils that we studied. This may be due to the fact that the high clay content of the Coastal plain soils promotes higher water holding capacity that is necessary for good plant growth, without necessarily impeding infiltration and drainage. Water holding capacity is the amount of water that a given soil can hold for crop use. Such advantage could benefit shrubs that lack extensive tap root system to survive long growing periods that spans into periods of water deficit. However, other soil physical properties that that affect water holding capacity are organic matter, and clay mineral types as well as soil micro-topography.

Analysis of the plant materials reveal that for all soils Fe was predominantly present in the root while K, P, and Mg were mainly present in the shoot of plants. But there was no consistent pattern of plant tissue elemental content differences in the soils that we studied.

Root Fe content of basil decreased from Piedmont, Coastal Plain, Highland Rim, and Appalachian Plateau soils (Fig. 6). And there was no clear pattern of shoot Fe content of the soils. But high content of root Fe compared to shoot Fe is notable because this suggests some physiological or chemical mechanism of basil to exclude Fe from the shoot by retaining them in the root. Such mechanism has been observed for elements in other plants (Pettersson, 1976; Koeppe, 1977;Sauerbeck, 1991) to cope with high concentrations of certain elements in soil.

Potassium was predominantly found in the shoot (stems, leaves, and inflorescence). The shoot being the edible part of Basil. But differences in the concentration of K in the plant was not statistically significantly different for root K content (at p = 0.79), and shoot K content (p = 0.06).

Basil that was grown in Appalachian plateau soils contained at least 18% more shoot Mg and at least 39% more root Mg than the other soils. Both root Mg content and shoot Mg content of plants that were grown in the different soil types were significantly different at p = 0.006, and p = 0.0027 for root Mg, and shoot Mg, respectively. Similarly Basil that was grown in Appalachian plateau soils contained at least 12% more shoot P and at least 41% more root P than the other soils. Both root P content and shoot P content of plants that were grown in the different soil types were significantly different at p = 0.0010, and p = 0.0012 for root P, and shoot P, respectively.

Generally, differences in the elemental content of the soils seem to have played less role than the soil physical properties of texture for the growth and development of basil since the elemental content of the plants did not always reflect the concentrations of the elements in the soil. Furthermore, the elemental contents did not reflect the vegetative growth differences of basil in the different soils.

A notable exception to this observation is that the highest P content of the Appalachian plateau soils translated to highest p content of basil grown in the Appalachian soils. Similarly, highest K content of the Coastal plain soils translated to highest K content of Basil that was grown in Coastal plain soils. In general nutrient element content of the basil grown in the soils did not follow the trend of vegetative growth differences.

Soil is a three-phase system of solid (minerals and organic matter), liquid, and air, in which the interaction of the mineral and organic components of the solid phase with the liquid and air phases determine the behavior and differences among soils. Themineral component contain the cationic nutrients (such as K^+, Na^+, Ca^{2+}, Mg^{2+}, Fe^{3+}) while the organic component provide the main reserve of nitrogen, phosphorus and sulphur. The liquid phase of the soil (the soil water content) is responsible for nutrient cation transport in the soil. The gaseous phase of the soil supplies the roots and other living soil organisms with oxygen from the atmosphere and removes carbon dioxide produced by respiration back into the atmosphere. The nature of the interaction of these phases differ from soil to soil and likely influence plant growth differently in different soils.

Conclusion

Holy Basil is cultivated in the tropics for its religious, medicinal and food purposes. We studied the effects of the major soil types in Alabama on the vegetative growth and elemental content of the plant to determine if the soils can support its growth in Alabama. Soil samples were collected from Coastal plain, Appalachian plateau, Piedmont, and Highland rim, repacked into 2.5 gallon plastic pots, and laid out in the following a Completely Randomized Design (CRD. Holy basil seeds were planted in germination trays and allowed to germinate and grow for sixweeks. The six-week old seedlings were transplanted into the plastic pots containing the 4 Alabama soil types. At the end of sixteen weeks of growth and observations, the plants were uprooted and analyzed. Data on plant height, number of branches per plant, fresh weight of roots, leaves, stems and inflorescence, root length, and elemental content of the parts were recorded. Results showed that vegetative growth of basil measured by plant height, the number of branches, and total plant weight showed were highest in the Coastal plain soils followed by the Appalachian plateau. Those differences may be due to the pH of the soils that fall within the pH range that basil performs well. Vegetative growth of holy basil grown in soils from Piedmont and Highland rim were comparable in having fewer branches, but with plants from Piedmont soils comparable with those of Highland rim. Nutrient content (P and Mg) of basil in the root and shoot of the plants grown in the soils showed significant differences at $\alpha = 0.05$ probably due to the high content of P in the soil. But the trend of the differences did not follow the vegetative growth trend of Coastal Plain, Appalachian Plateau, Piedmont, and Highland Rim soils.

Table 3. Other measured vegetative parts of Holy Basil grown in the four soil types

Soil Type	Root Length	Root dry weight	Root fresh weight	Plant Height	**Number of Branches**	**Shoot dry weight (SLI)**	Leaf fresh wt (LFW)	Total Plt Biomass	Total plt fresh wt. (WPltFW)
	cm	(g)	(g)	(cm)	(#)	(g)	**(g)**	wt (g)	**(g)**
Coastal Plain	32.2	4.7	29.16	29.0	**64.7**	15.6	36.5	74	**120.5**
Appalachian plateau	29.0	3.1	25.1	27.3	**59.0**	12.8	**32.4**	64.3	**93.2**
Piedmont	32.0	2.3	11.25	26.7	**46.3**	12.4	**25.8**	43.7	**72.5**
Highland rim	29.0	3.0	19.84	23.7	**51.0**	11.2	**24.7**	50.6	**76.0**

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