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**Effects of soil texture on growth and yield of six varieties of
okra (*Abelmoschus esculentus* [L.] Moench)**

ABSTRACT

A comparative agronomical experiment was conducted at research station/ Department of Horticulture and Landscape/ College of Agriculture/ Tikrit University, to study the effect of two different soil textures (loam and silt loam) on growth and yield of six varieties of okra. The two soil textures were analyzed for pH, nitrogen, organic matter, phosphorous, Ca, K, Mg etc. at the Central Laboratory of Soil Science and Water Resource Department, College of Agriculture, Tikrit University. Six okra varieties of okra were used in this experiment (i. e., Clamson, Hussainawia, Sultani, Btra, Clemson and Clemson spinless). The experiment was carried out with a Randomized Complete Block Design with Split plot arrangement with four replicates. Data were recorded for plant height, stem diameter, branches number on main stem, total number of branches, pod length, pod diameter, pod weight, pods number, yield per plant and percentage of dry matter in pod. Results indicated that plant height, branches number on main stem, pod weight, pod number and yield per plant produced in Loam soil were significantly higher ($P \leq 0.05$) than those produced in Silt loam soil. Irrespective of soil texture, the stem diameter, branches number on main stem and total branches produced in Btra variety, whereas, pod diameter, pod weight, pod number and pod yield per plant produced in Hussainawia variety were significantly higher ($P \leq 0.05$) than those produced in other varieties. But, pod length did not differ significantly ($P \leq 0.05$) between six varieties. It can be concluded from the present findings that Btra and Hussainawia cultivars may be produced in different soil..

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1. Introduction

The environment is a complex of so many factors, all interacting with each other, that it is impossible to isolate any one factor that does not influence another. For the study of environmental effects, however, this complex is usually subdivided into clearly defined units. One of these units is the soil, which is vitally important for plant growth and development. Soil in itself represents a complicated physical, chemical, and biological system by which the plant is supplied with the water, nutrients, and oxygen requires for its development. Although over the centuries plants have adapted themselves to various kinds of soil, the adaptation capacity of certain species is limited.

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This can be clearly seen when soil properties alter. The nature of the soil determines whether a species will thrive and influences its natural distribution. Within small areas, slight local variations in the soil may be sufficient to affect a plant's chances of survival (Roy et al., 2006).

Soil is an important component of the earth's biosphere (Glanz, 1995). Plant-soil relationships in the surface soil layer affect crop productivity, nitrate leaching and plant pest interactions (Wyland et al., 1996). Soil is one of the most important natural resources and a major factor in global food production (Den Biggelaar et al., 2003). There has been an innate interest in soil and land quality since the advent of agriculture (Carter et al., 2004). The soil characteristics below the grounds are recognized as possible key factors in affecting plant species coexistence and community organization (Bonanomi and Mazzoleni, 2005). Inappropriate land use and poor soil management adversely affect the environment and soil's productivity (Jagadamma et al., 2008).

Okra is a vegetable originated from Africa. It is one of the most important vegetables in the world, especially in tropical and subtropical climates (Marin et al., 2017), due to its rusticity and tolerance to heat, not requiring high levels of technology for its cultivation (Oliveira et al., 2008). However, it is sensitive to salinity, with a reduction of up to 70% in the production of fresh fruits in comparison to plants cultivated in non-saline soils (Kamaluldeen et al., 2014). This crop plays an important role in human diet due to the supply of carbohydrates, proteins, fats, minerals and vitamins (Abd El-Kader et al., 2010). It has vitamins A and C, being a source of calcium, iron, niacin, in addition to having medicinal qualities (Oliveira et al., 2014), and it has also attracted recent interest as an industrial source of fiber. Additionally, its seeds provide high-quality oil and the mucilage from its fruit can be used as a thickener in food industry (Alegbejo et al., 2008).

The physical, chemical and biological properties of soil are affecting distribution of plant species. Interest in the quality of soil and its effects on vegetable has been increased since last couple of decade. Such types of studies on vegetable such as on okra are scanty in the country. Therefore, the present study was carried out with the aim to find out the effects of different soil types on growth and yield production of okra. The objective of the present study was also to investigate the edaphic characteristics of the campus areas soil.

1. Materials and Methods

2.1. The Location of Research

Field experiment was carried out at the research station/Horticulture and Land scape Department/ College of Agriculture/ Tikrit University/ Salah Aldeen, Iraq. The coordinates of the research station are lies on latitude $34^{\circ} 40' 51.93''$ N and longitude $43^{\circ} 38' 59.87''$ E . The data associated with the soils properties are as shown in Table 1.

Table 1. Some of chemical and physical properties of applied soils in the experiment.

Parameters	Unit	Soil (1)	Soil (2)
Sand	(%)	38.5	49.5
Silt	(%)	58.5	31.5
Clay	(%)	3	19
Textural class		Silt loam	Loam
CEC	cmol kg ⁻¹	20.75	21.5
pH		8.7	7.9
N	(ppm)	39.2	71
P	(ppm)	7	12
K	(ppm)	104	107
Mg	mg L ⁻¹	3.78	2.52
Ca	mg L ⁻¹	6.90	15
OM	(%)	1.13	1.72
Na	mg L ⁻¹	3	2

2.2 Experimental Design and Field Layout

The field experiment was carried out in a flat and homogeneous area. The land area used for the each soil type had dimensions of 123 m² (20.5 m x 6 m). The replicates were separated from each other by 75 cm lanes, while the individual sections were separated by 30 cm lanes.

The experimental outline was a split-plot model with 4 replicates. The major plots were allotted to soils and the smaller plots to okra varieties

2.3 Treatments

The treatments consisted of two soils and six varieties i.e. Clamson, Hussainawia, Sultani, Btra, Clemson and Clemson spineless. The experiments were laid out in a randomized complete block design (RCBD) with split plot arrangement with four replications.

2.4 Treatment Applications

Ploughing was done in the first week of April. Planting was done at the spacing of 75cm x 30cm. Three seeds of okra were directly sown per hole at a depth of 2 cm on 10th of April. After germination, seedlings were thinned to one plant per stand three weeks after planting. Soil samples from (0 – 30cm) were collected from 12 different spots in the study area and were composited, air-dried and sieved through a 2 cm sieve and their physical and chemical characteristics were determined before planting.

2.5 Cultural Practices

The experimental units were kept free from weed by weeding as per the requirements using physical methods.

2.6 Measurements of growth and yield parameters

After harvest following parameters were recorded; plant height (cm), stem diameter (mm), number of branch on main stem (branch main stem⁻¹), total of branch (branch plant⁻¹), pod length (cm), pod diameter (mm), pod weight (g), pod number (pod plant⁻¹), yield (g plant⁻¹) and percentage of dry matter in pod (%).

2.7 Data Analysis

The analysis of variance (ANOVA) was derived from the common diverse model for a split-plot architecture. All measured parameters were assumed to be generally distributed and numerical analysis by ANOVA was carried out using the SAS software (version 9). The importance of the differences among treatments was approximated using the Duncan's compound range test, and a primary effectors interaction was found to be significant at $P \leq 0.05$.

3. Results and Discussion

3.1 Effect of soil texture on growth parameters of okra

The growth parameters of okra as affected by soil are given in Table 2. The heights plant length and the greatest number of branches on main stem per plant for okra were produced when in Loam soil 89.533 cm and 4.741 branch main stem⁻¹, respectively. In contrast, the greatest stem diameter was obtained from Silt loam soil 31.813 mm. The total branches of okra planted at different soils showed no significant difference.

Table 2. Effect of soil texture on growth of okra

Characteristics Soils	Plant height (cm)	Stem diameter (mm)	Number of branch on main stem (branch main stem ⁻¹)	Total of branch (branch plant ⁻¹)
Silt loam	72.025 b	31.813 a	3.950 b	17.799 a
Loam	89.533 a	27.275 b	4.741 a	17.721 a

*Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$)

Higher N content in Loam soil resulted in higher growth parameters and healthiest shoot of the amaranth lines compared to that in Silt loam soil (Table 1). Similarly, several studies reported that N is more significant than other nutrients for vegetative growth of plants (Sarker et al., 2002; Akamine et al., 2007; Razaul Haque Chowdhury et al., 2008; Hossain et al., 2012). In addition, higher K, P, N, and pH, and lower Na probably made better combination in Loam soil for better growth of amaranths, as compared to Silt loam soil (Table 1). Other studies reported similar effects of balanced nutrients for higher biomass production in various crops (Oya, 1972; Mazid, 1993; Hao

and Papadopoulos, 2004; Akamine et al., 2007; Hossain et al., 2012; Masanobu et al., 2016). The pH 7.9 in Loam soil was probably better for amaranth growth than in Silt loam soil (pH 8.7).

Effect of soil texture on yield parameters of okra

The results of yield parameters are presented in Table 3. The result shows that pod weight, pod number per plant and yield per plant increased by 17.17, 101.61 and 113.95 % with the Loam soil, respectively, compared with the Silt loam soil. Whereas, the pod length, pod diameter and percentage of dry matter show no significant difference between soils.

Table 3. Effect of soil texture on yield of okra

Characteristics Soils	Pod length (cm)	Pod diameter (mm)	Pod weight (g)	Pod number (pod plant ⁻¹)	Yield (g plant ⁻¹)	Percentage of dry matter in pod (%)
Silt loam	5.1371 a	14.1563 a	5.7487 b	19.592 b	124.00 b	11.2691 a
Loam	5.2079 a	14.1150 a	6.7354 a	39.500 a	265.30 a	10.3455 a

*Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$)

Yield and quality of okra was affected with field conditions, soil types, and soil chemical properties as reported earlier (Ghassan, 2008). Loam soil contributed to greater vegetative growth and shoot biomass of the plant, which probably affected soil aeration, soil microbial activities, and nutrient absorption. The amount and ratio of sand, silt, and clay in Loam soil are found to be better than that in Silt loam (Hossain and Ishimine, 2005), which maybe resulted in favorable environment for better nutrient absorption and growth of the amaranths. Similarly, Donald and Katherine (1999) reported that nutrient availability, absorption, and plant growth differ significantly with the physical, chemical, and biological factors of soil.

Higher values of okra in Loam (Table 3), indicating that higher content of available soil minerals are the common phenomena to increase mineral contents, and a certain level and combination of available soil minerals may be required to increase minerals in a plant species or variety, which agreed with the results in redflower ragleaf, turmeric, red amaranth, okra and broccoli (Johnson et al., 2003; Hossain and Ishimine, 2005; Ghassan, 2008; Razaul Haque Chowdhury et al., 2008; Omirou et al., 2009; Hossain et al., 2011;). Loam soil, and Silt loam soil had different levels of pH which was probably another factor to influence mineral availability in the soils and affected yield of okra.

Effect of varieties on growth parameters of okra

Significant differences were observed among okra varieties for all characteristics of growth (Table 4). Sultani variety had a better performance over the season with the plant height of 103.616 cm comparing to another varieties. While, Clemson spinless variety gave less value of plant height 67.604 cm. Clamson, Hussainawia and Clemson had results with no statistic differences with Clemson spinless in plant height 73.786, 80.567 and 72.875 cm, respectively.

Table 4. Effect of varieties on growth of okra

Characteristics Varieties	Plant height (cm)	Stem diameter (mm)	Number of branch on main stem (branch main stem ⁻¹)	Total of branch (branch plant ⁻¹)
Clamson	73.786 bc	28.846 b	3.762 c	16.166 b
Hussainawia	80.567 bc	28.719 b	5.046 b	19.605 ab
Sultani	103.616 a	30.485 b	3.037 c	16.666 b
Btra	86.216 b	33.608 a	6.208 a	23.996 a
Clemson	72.875 bc	28.084 b	3.867 c	14.375 b
Clemson spinless	67.604 c	27.825 b	3.702 c	15.750 b

*Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$)

Also, effect of varieties were found to be statically significant at stem diameter ($P \leq 0.05$) number of branch on main stem ($P \leq 0.05$) and significant at total of branches ($P \leq 0.05$). At stem diameter number of branch on main stem and significant at total of branches 33.608 mm, 6.208 branch main stem⁻¹ and 23.996 branch plant⁻¹, respectively, were found in Btra variety. Whilemean, smallest were found in Clemson spinless variety 27.825 mm, Sultani 3.037 branch main stem⁻¹ and Clemson variety 14.375 branch plant⁻¹, respectively. The differences observed among the six varieties could be attributed to their genetic make-up since significant between varieties were observed in the study. Zedan, 2010 affirmed that differential growth of crops under similar environmental conditions is normally the result of differences in the genetic make-up of these crops. Theyield differences observed among the two varieties corroborates the work of Ghassan et al., 2018 who observed significant variation in the growth of okra varieties. They attributed this observation to the choice of cultivar grown and its specific genetic make-up.

Effect of varieties on yield parameters of okra

The effect of variety on pod length of okra was non-significant at all varieties (Table 5).

Table 5. Effect of varieties on yield of okra

Characteristics Varieties	Pod length (cm)	Pod diameter (mm)	Pod weight (g)	Pod number (pod plant ⁻¹)	Yield (g plant ⁻¹)	Percentage of dry matter in pod (%)
Clamson	4.97 a	14.245 ab	6.178 ab	27.325 c	176.03 b	10.811 b
Hussainawia	5.02 a	15.563 a	7.306 a	50.725 a	379.15 a	9.610 b
Sultani	5.2975 a	10.775 c	4.692 c	12.625 d	60.23 c	13.045 a
Btra	4.8938 a	15.337 a	5.842 bc	37.150 b	228.10 b	10.886 b
Clemson	5.27 a	13.401 b	7.070 ab	21.825 c	163.50 b	10.772 b
Clemson spinless	5.5838 a	15.491 a	6.527 ab	27.625 c	187.23 b	10.152 b

*Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$)

At the same time, Hussainawia variety gave superior results on pod diameter, pod weight, pod number and yield per plant 15.563 mm, 7.306 g, 50.725 pod plant⁻¹ and 379 g plant⁻¹, respectively (Table 5). Whereas, Sultani variety gave least values on these characteristics. In contrast, Sultani variety gave significantly increment on percentage of dry matter in pod 13.045%, but Hussainawia gave significantly reduce in this characteristic 9.610%. There was no any significant difference in another varieties for percentage of dry matter in pod compared with Hussainawia. The reason for higher pod diameter, pod weight, pod number and yield per plant in Hussainawia variety is its genetic constitution which contributed in the higher these parameters. Vikash et al., (2016) and Ghassan et al., (2018) reported similar results.

Effect of soil texture on growth parameters of okra varieties

The least plant height was obtained from Clemson spinless variety in Silt loam soil 55.33 cm, while Sultani variety in Loam soil increased significantly in plant height of okra 111.33 cm (Table 6).

The thickest stem diameter was produced from Btra variety in Silt loam soil 36.333 mm, but at Clemson spinless under Loam soil, stem diameter decreased in okra 24.275 mm (Table 6). Again, Btra variety gave improving significantly in number of branches on main stem but in this time under the Loam soil 7.100 branch main stem⁻¹, whereas, Sultani variety in Silt loam soil gave least value in this parameter 3.210 branch main stem⁻¹.

At the same time Btra variety in Silt loam soil showed significantly increment in total branch 26.243 branch plant⁻¹ compared to the most treatments, but Clemson variety under Loam soil gave significantly reduce in this parameter 13.375 branch plant⁻¹.

Table 6. Effect of soil texture on growth of okra varieties

Characteristics		Plant height (cm)	Stem diameter (mm)	Number of branch on main stem (branch main stem ⁻¹)	Total of branch (branch plant ⁻¹)
Treatments					
Silt loam	Clamson	67.41 de	30.735 bc	3.500 d	15.125 b
	Hussainawia	71.43 de	31.430 b	4.342 bcd	19.250 ab
	Sultani	95.90 abc	31.825 b	3.210 d	15.583 b
	Btra	72.84 cde	36.333 a	5.317 bc	26.243 a
	Clemson	68.75 de	29.183 bcd	3.855 cd	15.375 b
	Clemson spinless	55.83 e	31.375 b	3.480 d	14.750 b
Loam	Clamson	80.17 bcde	26.958 cde	4.025 cd	17.208 b
	Hussainawia	89.73 abcd	26.008 de	5.750 ab	19.960 ab
	Sultani	111.33 a	29.145 bcd	2.806 d	17.750 b
	Btra	99.60 ab	30.883 bc	7.100 a	21.750 ab
	Clemson	77.00 bcde	26.985 cde	3.883 cd	13.375 b
	Clemson spinless	79.38 bcde	24.275 e	4.000 cd	16.750 b

*Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$)

Effect of soil texture on yield parameters of okra varieties

Although pod length was not significantly ($P \leq 0.05$) different, the pod diameter was greater for Hussainawia variety planted in Silt loam soil 15.805 mm, compared to that obtained from Clemson variety planted in same soil 12.483 mm, and Sultani variety planted in tow soils (Silt loam and Loam) 11.808 and 9.743 mm, respectively (Table 7).

Table 7. Effect of soil texture on growth of okra varieties

Characteristics		Pod length (cm)	Pod diameter (mm)	Pod weight (g)	Pod number (pod plant ⁻¹)	Yield (g plant ⁻¹)	Percentage of dry matter in pod (%)
Treatments							
Silt loam	Clamson	5.237 a	14.558 abc	5.967 abc	24.700 cde	150.65 defg	10.560 abc
	Hussainawia	4.867 a	15.805 a	7.045 ab	30.200 cd	216.80 cd	10.113 bc
	Sultani	5.167 a	11.808 cd	4.130 c	10.300 f	42.75 g	13.273 a
	Btra	4.562 a	15.068 ab	5.220 bc	18.150 def	97.05 fg	11.180 abc
	Clemson	5.260 a	12.483 bcd	6.740 ab	15.450 ef	127.60 defg	11.268 abc
	Clemson spinless	5.727 a	15.218 ab	5.632 abc	18.750 def	109.15 efg	10.933 abc
Loam	Clamson	4.702 a	13.933 abc	6.390 ab	29.950 cd	201.40 cde	11.147 abc
	Hussainawia	5.172 a	15.323 ab	7.567 a	71.250 a	541.50 a	9.107 c
	Sultani	5.427 a	9.743 d	5.255 bc	14.950 ef	77.70 fg	12.590 ab
	Btra	5.225 a	15.608 ab	6.460 ab	56.150 b	359.15 b	10.593 abc
	Clemson	5.280 a	14.320 abc	7.317 a	28.200 cd	199.40 cde	10.278 abc
	Clemson spinless	5.440 a	15.765 a	7.422 a	36.500 c	265.30 c	9.373 c

*Different alphabets in the same column show significant difference using Duncan's Multiple Range test ($P \leq 0.05$)

The greatest pod weight, pod number and yield were obtained from Hussainawia variety planted in Loam soil 7.567 g, 71.250 pod plant⁻¹ and 541.500 g plant⁻¹, respectively, whereas Sultani variety planted in Silt loam soil gave smallest values in these parameters 4.130 g, 10.300 pod plant⁻¹ and 42.750 g plant⁻¹, respectively.

In contrast, Sultany variety planted in Silt loam soil increased significantly in percentage of dry matter in pod 13.273%, but Hussainawia variety planted in Loam soil reduced significantly 9.107%.

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تأثير نسجة التربة في نمو و حاصل ستة أصناف من الباميا (*Abelmoschus esculentus* [L.] Moench)

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الخلاصة

نفذت تجربة حقلية في محطة الأبحاث التابعة لقسم البستنة و هندسة الحدائق / كلية الزراعة / جامعة تكريت، لمعرفة تأثير نوعين من التربة هما مزيجة غرينية و مزيجة في نمو و حاصل ستة أصناف من الباميا (كلامسون وحسناوية وسلطاني وبترا وكليمسون وكليمسون سبائيليس)، وزعت المعاملات حسب تصميم القطاعات العشوائية الكاملة R.C.B.D. باستخدام نظام القطع المنشقة Split Plot وبأربعة مكررات. تم تحليل بعض صفات نسجة الترتين قبل الزراعة في مختبر قسم التربة و الموارد المائية/ كلية الزراعة/ جامعة تكريت. بينت النتائج أن التربة المزيجة أعطت تفوقاً معنوياً في كل من صفة ارتفاع النبات و عدد الأفرع على الساق الرئيس ووزن القرنة و عدد القرون لكل نبات و حاصل النبات الواحد. وفيما يتعلق بالأصناف، أظهر الصنف بترا تفوقاً معنوياً في كل من صفة قطر الساق و عدد الأفرع على الساق الرئيس و عدد الأفرع الكلي، بينما أعطى الصنف حسناوية تفوقاً معنوياً في صفات الحاصل كقطر القرنة ووزن القرنة و عدد القرون لكل نبات و حاصل النبات الواحد. فيما يتعلق بالتداخل فقد أعطى الصنف بترا النامي في تربة مزيجة غرينية تفوقاً معنوياً في صفتي قطر الساق و عدد الأفرع الكلي، فيما أظهر الصنف حسناوية النامي في تربة مزيجة تفوقاً معنوياً في أعلي صفات الحاصل كوزن القرنة و عدد القرون و حاصل النبات الواحد.

الكلمات الافتتاحية: مزيجة غرينية، مزيجة ، باميا ، وزن القرنة ، الحاصل