

Assessment of the Relative Suitability of Three Different Soils for Dry Season Lettuce Production in Ghana

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Abstract— The research was conducted at the project site of the University of Education, Winneba - Mampong campus between mid - November 2007 and Mid-April 2008. The main objective of the study was to compare the relative suitability of three soils in supporting lettuce production in the dry season. The treatments were Calcic Vertisol (Akuse series), Rodic Nitisol (Ejura series) and Chromic Luvisol (Bediesi series). The randomized complete block design was used in a pot experiment with the three treatments and each replicated three times. Plant height, fresh leaf mass, leaf dry matter yield, fresh root mass, gravimetric moisture content, total porosity, drainability and bulk density were the parameters considered. From the result Bediesi Series recorded the highest growth rate as measured by plant height (266.5mm), fresh leaf weight (30.6g), leaf dry matter weight (4.9g) at 7 weeks after transplanting as well as been the most succulent with 84% succulent. Fresh root weight however, was highest with Akuse Series followed by Bediesi Series and Ejura Series in that decreasing order. Ejura Series recorded the least value for all growth and yield parameters measured. For soil parameters, Akuse Series recorded the highest value for porosity (43.0%) and gravimetric moisture of 6.43 throughout the period of field drying for 8 weeks. Ejura Series Bediesi Series also recorded the highest value for drainability after 25 minutes of drainage, followed by Bediesi Series and then Akuse Series. The result of this work indicated that the Bediesi Series is the best soil type among the soils evaluated for lettuce production in the dry season in Ghana.

Keywords— Calcic Vertisol (Akuse series), Chromic Luvisol (Bediesi series), Lettuce, Rodic Nitisol (Ejura series).

I. INTRODUCTION

The increasing population in the world makes a great demand on food production and consequently calls for an increase in

food supply by various countries. Food supplies are insufficient not only in quantity but also in quality thus the essential nutrients required by man for proper growth and development are lacking. Therefore during the World Food Summit of 1996 (FAO, 1996), some targets were set and among them were to; Give a strong food and nutrition orientation to programming and projects of development co-operation; support the implementation of the right to food for all people; support national and international alliance, network and partnership in the field of nutrition security and the introduction and reinforcement of food security and nutrition aspects information agreements.

Ghana, like many other countries in the sub-Sahara - Africa has poverty as one of the main reasons for malnutrition. However, poverty alone does not account for this precarious situation in the country but other factors such as socio - economic conditions, stability of population growth and government policies also contribute to this state of affairs (FAO, 1998). In order to alleviate poverty among farmers to reduce the rate of malnutrition, there is the need to encourage all year round production, including the use of improved varieties, suitable soils and improved agronomic practices. Vegetable as sources of food forms a major contributing factor for the protection and defense of human body against diseases. According to Addo - Quaye et al (1993), vegetables are rich in minerals; among the elements, iron, sodium, iodine and calcium are the most important for vital activity. Apart from providing income and employment for those involved in its production, vegetables provide nutritional supplements for people and in a way check the high rate of malnutrition in the sub-Sahara Africa.

There is increasing demand for vegetables in the country. This could be attributed to the increasing change in the diet of many Ghanaian in preference for western diets as well as increase in the tourism and the hospitality industry in Ghana. The short shelf life of lettuce, coupled with the fact that the

crop is eaten fresh makes it necessary for all year round production of lettuce. However, most farmers in Ghana depend on rainfall for production which becomes a problem in the dry season. Yields are often very low on poor and unsuitable soils. To ensure continuous production of the crop, there is the need to find out which type of soil will be most suitable for all-year-round lettuce production, especially in peri - urban agriculture in Ghana.

The objective of the study was to find out the relative performance of the three selected soils in supporting lettuce production in Ghana.

II. MATERIALS AND METHOD

2.1 Study Area

The project was conducted at the experimental site of University of Education, Winneba, Mampong campus between December 2007 and April 2008. Mampong Ashanti lies between latitude 0.7°, 0.4° N of the equator and longitude 1°, 0.24° W of the equator. It is also situated at an elevation of 457.5m above sea level. The experimental area, falls within the transitional zone of Ghana's agroclimatology. It experiences two main seasonal rainfalls annually, with the major season rains falling between late April and late June and the minor season rains between September and mid-November (CR1, 2001). The mean monthly rainfall is about 109.4mm and the monthly temperature is about 25-32°C.

Soil types: Three different types of soils were used. And they are the Ejura Series, Akuse Series and Bediesi Series. The soil samples were collected from Ejura, Kpong and Mampong respectively and used in post experiments.

Ejura series is classified as Rhodic Nitisol (FAO UNESCO legend). It is dark brown to brown and has a fine loamy overlying. It has high water permeability, high pH and higher in nutrients, (Adu and Mensah-Ansah, 1995). Alhassan et al. (2004) recorded that Ejura Series promotes the cultivation of maize, groundnut, cowpea, garden eggs and okro. According to Morgan (1972), the Rhodic Nitisol is prone to erosion due to its low structural stability, slacking and caking of surface, prone to leaching and also has low rate moisture content in soil due to the presence of predominant sand particles.

Bediesi series (Chronic Luvisol as classified in the FAO/UNESCO legends) is derived from the voltaian sandstone. It occurs on upper and middle slopes of the catena. It is moderately shallow to moderately deep. Its colour is orange red to reddish brown. The soil is free from stones and concretions, is well drained and friable with satisfactory moisture holding capacity. The soil has an average pH value of 6-6.5 (Opoku, 1993). It is easy to cultivate by hand and machines but care must be taken when machines are used in

tilling the land to avoid the isolated boulders of sandstones (Adu, 1992).

Akuse series is a coluvial material derived from the weathering of garnetiferous hornblende gneiss (Brammer, 1967). It is classified as Calcic Vertisol in the FAO/UNESCO legends. Locally, it is the tropical black clay and belongs to the Akuse series (Adu, 1995). The Akuse Series is very heavy clayey (30-95% clay) soils. It develops deep and wide cracks during dry season. It is sticky and plastic when wet and traffic capability is poor as moisture status is high. It supports crops like millet, sorghum, cotton, rice, wheat, barley, flax and sugarcane. Tree crops are seldom recommended because trees' roots find it difficult to establish themselves in the subsoil without being damaged by shrinking and swelling phenomena.

2.2. Preparation of Site

The experiment was carried out in plastic pots. Ninety plastic pots were assembled and perforated at the base to drain excess water from the soil samples. Each of the soil samples: Akuse series, Bediesi series and Ejura Series were loosened and all unwanted materials found in it removed. Equal quantity of each soil sample was filled into thirty (30) plastic pots for a treatment. The pots filled with the soil samples were saturated with water and allowed to settle for 3 weeks to attain the natural state

2.3. Experimental design and treatments

The Randomized Complete Block Design (RCBD) was used. The experimental field was divided into nine plots with 0.6m paths between each pot for easy movement. There were three- (3) treatments and each replicated three (3) times. Each replication had ten (10) pots.

2.4. Planting materials and method of planting

The lettuce seeds (crispa variety) were used. The seed were planted 2-4cm deep in a prepared seed box at 5-10cm between rows using the trench-drilling method. The nursed seeds were heavily watered and a shed was raised over it with palm fronds to provide shade. Sprouting and germination of seeds was observed on the 4th and 5th day after sowing. The seedlings were pricked out two weeks after planting.

2.5. Post planting activities

Equal volume of water was applied to the lettuce at regular intervals to prevent the plants from wilting since the experiment was carried out in the dry seasons. The soils in the pots were stirred intermittently to improve aeration and seepage of water. Weeds in between the pots were controlled by using a hoe and hand picking respectively, to reduce competition and provision of hide-out for pests. A fungicide

(Top cost) was applied at a rate of 20ml per 21 to control fungi infections like damping off and root rot every two weeks after transplanting; until two weeks to harvesting. An insecticide (Pyral 480 EC) was also administered at rate of 20ml per 15 L (to control insects like grasshoppers, leaf miners, crickets and aphids every week after transplanting until two weeks to harvesting as there was heavy infestation of these insects on the field. Both the fungicide and the insecticide were applied by using a hand pump.

2.6 Determination of parameters

The dry bulk density was determined from soil cores collected with core sampler (Klute, 1986). Moisture content was determined on gravimetric basis using the formula $\theta_g = \left(\frac{M_w}{M_s}\right) \times 100$ (Hillel, 1982) where, M_s is the mass of the solid components of the soil and M_w is the mass of water contained in the soil. Total porosity was calculated by the formula; $f = 1 - \rho_b/\rho_s$ where f is total porosity, ρ_b is bulk density and ρ_s is particle density (2.65 g cm^{-3}) (Hillel, 1982). With drainability, soil sample of each soil treatment were collected

and sifted through a sieve. Soil samples were air dried for 48 hours before they were sifted. 100g of soil from each treatment (three replication each) was weighed and poured on the funnels with cotton stuck in their necks. 75ml of water was poured onto soil in the funnels which had been placed on 100ml measuring cylinders. The volume of water drained in each measuring cylinder was recorded every minute for the first 10 minutes, and every 5 minutes for the next 20 minutes. The mean of the volume of water drained for each treatment was determined and the data presented graphically.

Plant height measurement began three weeks after transplanting. Ten plants from selected pots of each of the treatments were chosen for the measurement of this parameter. A meter rule as used to measure the height of the plant (from the soil level to the tip of the leaf of the plant). The fresh roots weight were measured with an electronic balance after they had been allowed to dry off the water on the roots when the soil particles was been washed off it.

The initial summary of mechanical and chemical analysis of the various treatments are shown in Table 1 and Table 2.

Table.1. Soil mechanical analysis of treatments

Treatments	% Sand	% Silt	% Clay	Texture
Akuse Series	39.6	13.2	47.0	Clay
Ejura Series	75.52	20.05	4.11	Loamy sand
Bediesi Series	66.92	27.05	6.03	Sandy loam

Table.2: Results of soil chemical analysis or the treatments

Treatment	pH H ₂ O	Org.C %	Total N	OrgM	Exchangeable cations me/100g				E.C.E.C Me/100g
					Ca	Mg	K	Na	
Akuse Series	7.81	0.65	0.07	1.12	17.62	10.15	0.68	1.31	29.8
Ejura Series	4.66	0.12	0.02	0.21	0.80	0.27	0.07	0.05	1.54
Bediesi Series	6.42	0.46	0.04	0.79	7.48	6.14	0.53	0.22	14.4

III. RESULTS AND DISCUSSION

3.1 Plant height

From Fig.1, Bediesi Series recorded the highest mean height of lettuce plant at 7 weeks after transplanting (7WAT) followed by Akuse Series and Ejura Series in that decreasing order. When the result was subjected to statistical analysis it

was observed that the mean value for Bediesi Series was significantly ($p=0.005$) higher than that of Ejura Series but not significantly different from that of Akuse Series. It was also observed that of Akuse Series was not significantly different from that of Ejura Series ($p=0.005$).

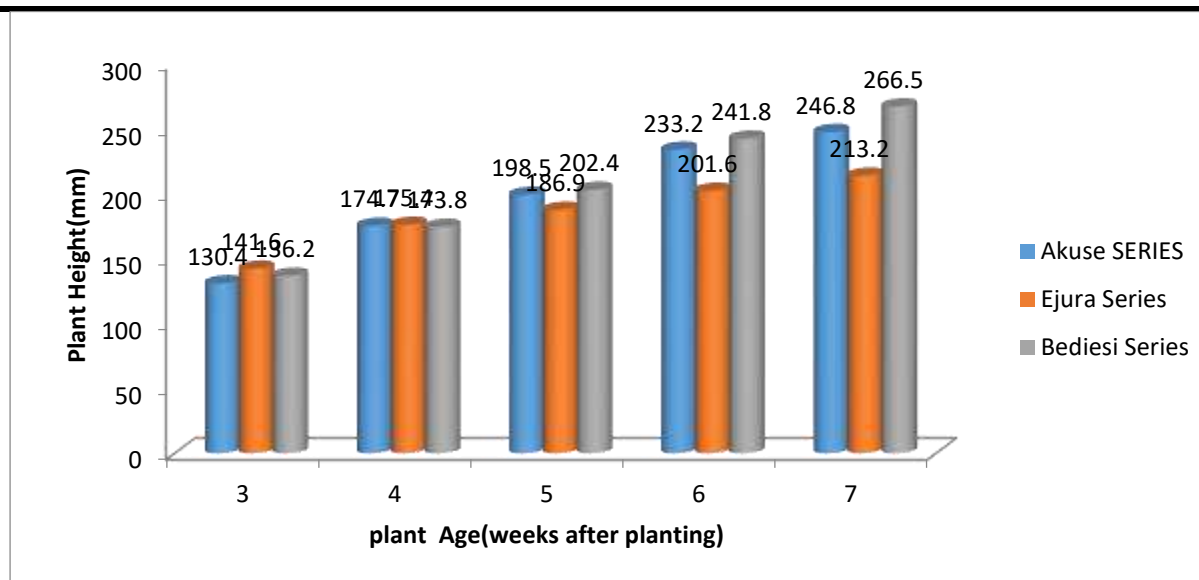


Fig.1: Weekly plant height of lettuce on treatments

Bediesi Series recording the highest value for plant height could be attributed to its contained adequate quantity of nitrogen when the three treatments were chemically analysed (Table 2). This assertion is in conformity with Akinyosaye (1986) findings that, moderate to high nitrogen supply to plants promotes vegetative growth where in this case can be equated to plant height. The result also confirms the finding of Tweneboah (2000) that adequate quantity of nitrogen leads to leaf growth which is reflected increase in height.

Although, Akuse Series had the highest nitrogen value (Table 2) it did not support the highest plant height. This could be attributed to nitrogen not being the only factor for the growth of a plant but there are other domineering factors. E.g. Bediesi Series had the higher amount of potassium than Akuse Series which promotes the efficient use of water, nitrogen uptake and protein synthesis (Tisdale et al, 1985). Bediesi Series recording the highest plant height value might

also be due to suitable drainage and pH conditions it recorded. Tindall (1983) stated that well drained sandy loams with pH of 6.0-6.8 are generally considered preferable for the lettuce crop. Ejura Series however, had a pH of 4.66 which is acidic. Acidic soils promote phosphorus fixation and unavailability of some basic cations like Ca, Mg, and K which are needed for healthy and proper growth of the plants.

3.2 Fresh Leaf Weight and Dry Leaf Mater Yield of lettuce

From the statistical analysis of the data on the mean fresh leaf weight, it was observed that mean value for Bediesi Series was significantly higher than that of Ejura Series and Akuse Series at 0.05 probability level. This could be attributed to suitable nitrogen content of Bediesi Series which conforms to research work by Kwakye et al (1995) that, different crops including lettuce respond to moderate to high content of nitrogen in the soil.

Table.3: Fresh leaf weight and Dry leaf mater yield of lettuce.

Treatment	Fresh Leaf Weight (g)	Leaf Dry Matter Yield (g)
Akuse Series	19.50	4.1
Ejura Series	12.40	3.7
Bediesi Series	30.60	4.9
LSD (0.05)	5.77	0.555
C.V.	12.34%	10.02%

The difference could also be attributed to the fact that the pH of Bediesi Series falls within the require pH range for lettuce production as stated by Tindall (1983) that, a pH of 6.0-6.8 is considered preferably for lettuce production while Akuse

Series and Ejura Series recorded pH of 7.81 and 4.66 respectively. From Table 2, it can observed that the pH of Ejura Series was too acidic for the lettuce plant. This can explain why Ejura Series T₂ recorded the lowest mean leaf

weight. Although, Akuse series retained the highest amount of water in the soil, it did not record the highest mean fresh leaf weight. This might be due to the peculiar physical and hydrological characteristic of the Vertisol. It was observed that when water was applied to the treatments, Akuse Series always retained much water at the base of the crop for longer time which could have been detrimental to be the proper growth of the lettuce crop. Baffour (1998) confirms this observation, that suitable aeration and adequate supply of water, among others, affects seedling emergency, growth and yield.

Leaf dry matter yield also follows the same trend as fresh leaf weight. Just that, for dry matter yield, mean values for Akuse Series and Ejura Series were not significantly from each other at 0.05 probability level. The difference in values may be explained with the same reasons as fresh leaf weight since their pattern of growth is not different from each other.

Comparing the difference between mean fresh leaf weight and mean leaf dry matter yield of treatment, it was observed that lettuce leaves from Bediesi Series had the highest moisture content, which means Bediesi Series produced the

most succulent leaves among the treatments followed by Akuse Series and Ejura Series with 84%, 79% and 71.8% moisture respectively. In the marketing of lettuce, the more succulent the leaves are the more appealing they become to the eyes of the buyer. Therefore, if succulence correlates positively with high market value, then lettuce from Bediesi Series having the highest level of succulence will have higher market value than produce from the rest of the treatments.

3.3 Fresh Root Mass

The results (Table 4) indicates that, fresh root mass from Akuse Series and Bediesi Series were significantly different from that of Ejura Series. However, there was no significant difference between the root mass value for Akuse Series and Bediesi Series at 0.05 probability level. Akuse Series recording the highest root mass could probably be as a results it having the highest nitrogen and organic matter levels from the chemical analysis (Table 2). This is in conformity with Akinyosaye (1986), that an increase in nitrogen supply to plants promotes vegetative growth which includes plant roots.

Table.4: Fresh Root Mass

Treatment	Mean Fresh Root Mass (g)
Akuse Series	3.4
Ejura Series	2.4
Bediesi Series	3.2
LSD (0.05)	0.453
C.V.	6.667%

Akuse Series had the least bulk density (Table 5) which is a measure of how soil particles are compacted together. Therefore, it could be deducted that the relatively less compaction of Akuse Series might have resulted in best root growth. Ejura Series recording the least value in root weight could that Ejura Series recorded the lowest value for porosity which means that there were not enough spaces between soil particles for air and water to occupy which could affect the growth of roots growth. It confirms the assertion by Russell (1997) that, the rate of root growth depends on water and air supply in the soil. It could also be explained that since

porosity is inversely proportional to bulk density and Ejura Series had the least porosity, therefore, had the highest bulk density and high bulk density which means more compaction of soil might have hindered the growth in the roots of the soil.

3.4 Gravimetric Moisture Content

The moisture contents retained by the soils during the eight weeks of filed drying were found to be significantly different from each other at 5% probability level at the terminal reading. Akuse Series retained the highest moisture of 6.433% followed by Bediesi Series with 4.1% and then Ejura Series with 0.8%.

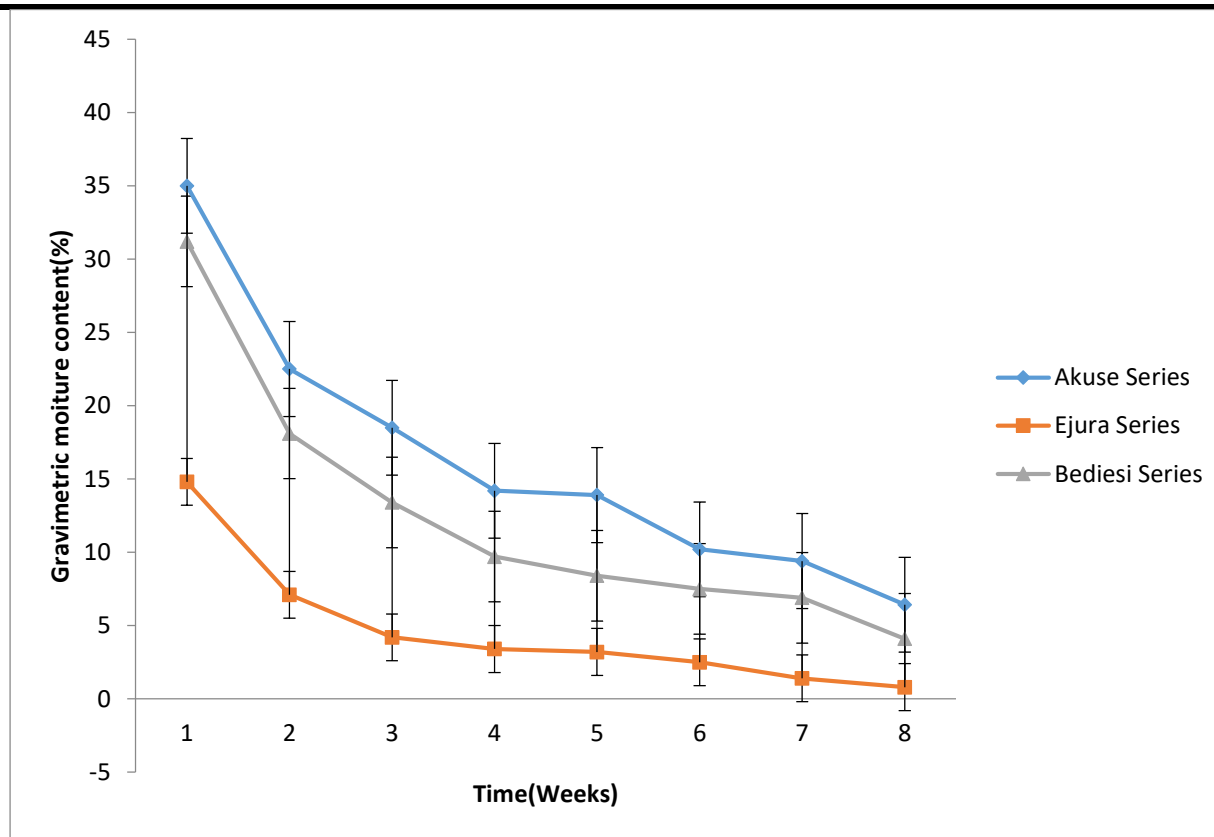


Fig.2: Soil drying of the treatments

The significant difference in gravimetric moisture of the treatments may be attributed to the fact Akuse Series recorded the highest organic matter which helps it to retain moisture better than the other treatment. This observation confirms with what Elliot and Wilding (1992) reported that, soil organic matter has a marked influence on soil structural development, it reduces seals, and crust information, improves soil micro-climate, infiltration and moisture retention of soils. This explains why the treatment which had the least organic matter recorded the least gravimetric moisture. Also, Akuse Series recording the highest value for total porosity followed by Bediesi Series and Ejura Series could be a contributing factor to its highest gravimetric content. This is because Akuse Series which has high clay

content has many micropores than macropores which turn to have strong adhesive forces to hold water for longer period for plant use than Ejura Series whose large soil particle size allows more macropores and drains moisture fastest after irrigating or rainfall.

3.5 Total porosity and Bulk density

From Table 5, Akuse Series is the most porous followed by Bediesi Series and Ejura Series with mean total porosity values of 43.0%, 40.67% and 38.5% respectively. There was no significant difference between mean value of Bediesi Series and Akuse Series, and Bediesi Series and Ejura Series at 0.05 probability level but there was a significant difference between mean values of total porosity for Akuse Series and Bediesi Series.

Table.5: Total Porosity of the Soils

Treatment	Mean Total Porosity (%)	Mean Bulk Density(g/cm ³)
Akuse Series	43.00	1.50
Ejura Series	38.50	1.60
Bediesi Series	40.67	1.53
LSD (0.05)	3.81	
C.V.	4.12%	4.32

This may be attributed to their relatively lower bulk density value recorded by the Akuse series, thus the less compacted the soil is, the higher the pores. Also the organic matter content and the particle sizes of the Akuse Series could have resulted in the observed difference. This is confirmed by Akinsanmi (1987) that organic matter opens the soil particles, increases aeration and hence makes the soil porous and the higher the pore space the better for crops production.

The mean bulk densities determined showed no significant different at 0.05 probability level.

3.6 Soil Drainability

The study showed that water drains fastest through Ejura Series followed by Bediesi Series and then Akuse Series. When the amount of water drained at the 25th minute was analyzed statistically, it was realized that the values for Ejura Series was significantly ($p=0.005$) higher than the mean value for Bediesi Series and Akuse Series.

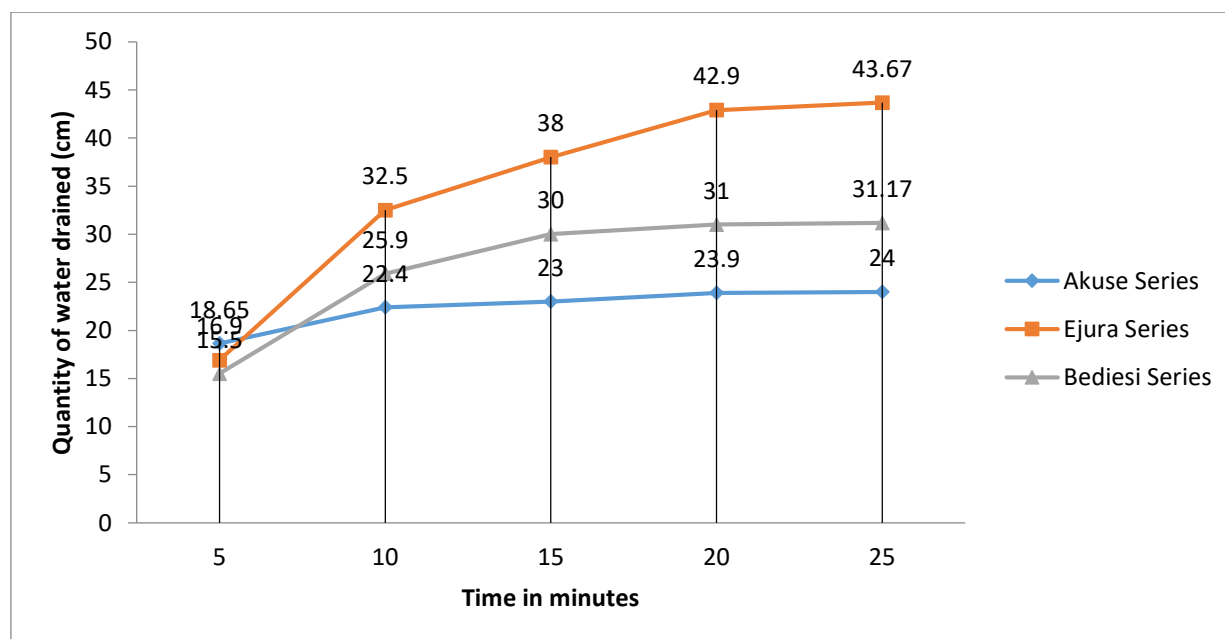


Fig.3: Soil drainability of treatments

This may be as a result of the particle sizes of Ejura Series being relatively larger than Bediesi Series and Akuse Series and hence has more macro-pores which drains water easily (faster) than the many micro-pores that may be present in Akuse Series and Bediesi Series which have stronger adhesive force to hold much water.

On the other hand, the least volume of water drained through Akuse Series after 25 minutes is an indication that much water was retained which was equally not very good for lettuce production as asserted by Thompson and Kelly (1957) that, soils for lettuce production should be well drained but retentive of moisture.

IV. CONCLUSION

Bediesi Series which drained water moderately had the capacity to retain adequate moisture for plant use without suppressing the air requirement of the roots which explore the soil for moisture and nutrients and hence recorded the highest value in most of the plant parameters measured in the

experiment. Mordi et al. (1992) confirm this assertion by reporting that drainage improves soil aeration and enables crops to develop deeper root system for good plant growth and yield.

Finally, for dry season lettuce production, Bediesi Series is found most suitable since it retained moderate moisture with time hence produced the highest yield in terms of leaf height, fresh weight and leaf dry matter yield. It also produced the most succulent leaves and will therefore give a higher economic return to farmers. The Akuse Series (Calcic Vertisol (Akuse Series)) can provide relatively high yield of lettuce if some interventions are made to reduce water saturation at the base and root zone of lettuce since the plant required a well-drained soil for proper growth. Perhaps, a moderation in the quantity of water applied during irrigation may be necessary to realize the full potential of the vertisol.

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