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Research Article
Soil Modulation Effect on Growth/yield of *Solanum nigrum* in the Eastern Cape, South Africa

Adijat Funke Ogundola, Callistus Bvenura and Anthony Jide Afolayan

Medicinal Plants and Economic Development Research Niche Area, University of Fort Hare, Private Bag X1314, 5700 Alice, South Africa

Abstract

Background and Objectives: *Solanum nigrum* find in the wild of many places in the Eastern Cape possess some outstanding health benefits. This gives the insight that it could help to alleviate the hunger crisis in South Africa. The aim of this study was to investigate the effect of different soil textures on *S. nigrum* in Eastern Cape, South Africa. **Materials and Method:** Pot experiment made use of soils collected from Research Farm of the University of Fort Hare, Alice in Eastern Cape. The soil was sieved and four different soil types were formulated with the unformulated soil control were used to cultivate *S. nigrum*. **Results:** The results indicates that plant grown on silty clay loam increased in height, stem girth, chlorophyll content, number of leaves, leaf area, fresh weight and dry weight. Plants grown on sandy clay loam and control soils increased in all other parameters but recorded reduced leaf chlorophyll. Plants grown on clay loam and loam soils recorded high number of leaves and chlorophyll. Silty clay loam soil promoted rapid growth of *S. nigrum* leaves and fruits. **Conclusion:** Although the results of the present study are variable, it could be recommended to grow *S. nigrum* on clay loam and loam soils supported production of greener leaves.

Key words: Plant, rare vegetable, cultivation, underutilized, green house, growth parameters, yield potential

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Corresponding Author: Anthony Jide Afolayan, Medicinal Plants and Economic Development Research Centre, University of Fort Hare, Private Bag X1314, 5700 Alice, South Africa Tel: +27822022167

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Generally, green leafy vegetables are known as rich source of micronutrients and other health benefits, however wild vegetables are reported to be richer source of nutrition and bioactive compounds[1-3]. Many indigenous wild vegetables are been neglected, underutilised, not recognized in the dietary base or are attributed as drought/ famine food[4]. One of these underutilised vegetables is *Solanum nigrum* (L.) that belongs to the family of Solanaceae. It provides immense nutritional and therapeutically benefits in human, a testimony of the rural dwellers in Eastern Cape (South African) about its folkloric use also quantify its uses. The vegetable is useful enough to have been considered for cultivation than scavenging for it in the wild. The vegetable however, with regardless to the usefulness, it is underutilised, regarded as weed with some other important wild vegetables[5]. Moreover, malnutrition has remained one of the major challenges with children in South African including the Eastern Cape[6]. The plant having been reported a source of nutrients with immune-boosting properties, if largely made available by cultivation, integrated in food diet; would have a large contribution to alleviating malnutrition in South Africa[7-9].

Cultivation of this vegetable will be considered as a practical guide and sustainable means to fulfilling daily dietary requirements[10,11]. Cultivation on the other hand, depends on that soil characteristics (soil texture) and mineralogy[12]. These factors in turn influence the availability of plant nutrition for plant performances.

In this study, highest priority is given to leaf production which is the edible part of the plant. Leaf is an indicator that reflects the consequence of nutrient deficiency in vegetables, the effect of soil texture types is closely monitored on the leaves of *S. nigrum*[13].

Previous studies reported the effect of different climatic conditions and fertilizer application on *S. nigrum*[14]. Sinclair and Vadez[15] reported that the growth performance of plants is positively related to the minerals available in the soil. Van Averbeke *et al.*[16] also reported the need for the availability of sufficient nitrogen in the soil in order to achieve optimum growth in some *Solanum* species. However, there is a clear lack of studies investigating the growth performance and yield potential of *S. nigrum* in relating to different soil texture types. To achieve the aim of this study, a pot experiment was conducted under controlled environment by cultivating *S. nigrum* on different soil texture types in Alice, Eastern Cape, South Africa. The study then hypothesized that different soil texture types have effect on the growth and yield performances of *S. nigrum*.

MATERIALS AND METHODS

Study area: The study was carried out in October/November, 2015 and February and March, 2016 in the University of Fort Hare, Alice (32°46'47"S and 26°50'5"E and 524 m a.s.l) Eastern Cape, South Africa. *Solanum nigrum* seeds were extracted from the pulp of ripe mature berries in the wild in the same place above. The plant had earlier been identified (BVE11/017)and deposited at Giffen herbarium of the University of Fort Hare[17].

Seed collection: Seeds extracted were washed in distilled water, spread and dried at room temperature in the laboratory for 2 days. The seeds were stored in sealed bottles and sown in nursery trays for seedlings in the glass house.

Soil collection: Soil was collected from the same fallow land for trials 1 and 2 at different times and at a depth of 30 cm in the University of Fort Hare Farm, Alice Campus, Eastern Cape, South Africa. The soil was air-dried, ground, sieved to obtain aggregates of different sizes/ ranges of sand, silt and clay particles which were mixed in different ratios to form soil types[18]. Soil sieving was done traditionally and accomplished by agitating stack of sieves by hand[19]. The soil formulation followed the triangular classification system of Soil Survey Division Staff[20].

Research procedure: The formulated soil types using different ratios of sand, silt and clay are: Sandy clay loam (ST_1)-60, 30, 10%, silty clay loam (ST_2)-10, 60, 30%, clay loam (ST_3)-36, 30, 34%, loam (ST_4)-40, 40 20%. The control soil (ST_0) was the original soil collected, sieved but unseparated into particles Table 1.

Three samples were taken from each of the soil types during the 2 trials, analysed for their nutrient composition as shown in Table 2. The concentrations of Ca, K, Mg, Na, P, Cu, Mn and Zn in the soils were determined using the Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) followed the standard methods outline by AGRILASA[21].

Table 1: Particle composition of formulated experimental soil types

Soil types	Sand particles (%)	Silt particles (%)	Clay particles (%)
Control (ST_0)	60	30	10
Sandy clay loam (ST_1)	66	13	21
Silty clay loam (ST_2)	10	60	30
Clay loam (ST_3)	36	30	34
Loam (ST_4)	40	40	20

Table 2: Analytical result of nutrient composition and physical properties and formulated experimental soil for the first and second trials

Soil types Soil mineral composition ($mg\ kg^{-1}$)	First trial					Second trial				
	ST_0	ST_1	ST_2	ST_3	ST_4	ST_0	ST_1	ST_2	ST_3	ST_4
P	68.0 ± 1^b	84.0 ± 0^a	62.0 ± 1^c	60.00 ± 0^{cd}	63.00 ± 1^c	74.00 ± 0^b	73.00 ± 0^a	67.00 ± 0^c	68.00 ± 0^{cd}	72.00 ± 0^c
K	524.0 ± 0^a	467.0 ± 1^d	524.0 ± 0^a	519.00 ± 1^b	482.00 ± 0^c	582.00 ± 0^a	549.00 ± 0^d	562.00 ± 0^a	549.00 ± 0.5^b	543.00 ± 0^c
N	3.4 ± 1^c	3.6 ± 0^c	5.0 ± 0.5^a	4.80 ± 0^b	4.60 ± 0^b	3.80 ± 0.4^c	4.00 ± 0^c	5.00 ± 0.5^a	4.90 ± 0^b	4.80 ± 0^b
Ca	1389.0 ± 0.5^a	1357.0 ± 0.5^b	1278.0 ± 0.5^e	1318.00 ± 1.0^c	1290.00 ± 0.5^d	1434.00 ± 0.5^a	1399.00 ± 0.5^b	1323.00 ± 0.5^e	1360.00 ± 0.5^c	1393.00 ± 0.5^d
Mg	332.0 ± 0.1^b	347.0 ± 0.5^a	316.0 ± 0.0^d	321.00 ± 0.0^c	330.00 ± 0.5^b	350.00 ± 0.1^b	336.00 ± 0.5^a	328.00 ± 0.0^d	325.00 ± 0.0^c	339.00 ± 0.5^b
Zn	6.0 ± 0.3^b	8.1 ± 0.5^a	5.9 ± 0.1^{bc}	5.30 ± 0.1^c	6.20 ± 0^b	3.90 ± 0.3^b	4.70 ± 0.5^a	8.40 ± 0.1^{bc}	$4.50\pm0.\ 5^c$	5.30 ± 0^b
Mn	29.0 ± 1^d	66.0 ± 0^a	45.0 ± 0^b	38.00 ± 0^c	45.00 ± 0^b	57.00 ± 0.1^d	80.00 ± 0^a	73.00 ± 0^b	77.00 ± 0^c	75.00 ± 0^b
Cu	10.5 ± 0^c	15.6 ± 0^a	10.6 ± 1^c	10.30 ± 0^c	11.40 ± 0^b	8.80 ± 0^c	7.40 ± 0^a	10.00 ± 0.5^c	7.80 ± 0^c	8.00 ± 0^b
Organic content (%)	4.0 ± 0.5^c	3.9 ± 0^c	5.0 ± 1^a	4.50 ± 0^b	4.80 ± 1^a	4.20 ± 0.5^c	4.40 ± 0^c	4.90 ± 0.7^a	4.70 ± 0^b	4.70 ± 0.7^b
pH	6.22 ± 0^a	5.7 ± 1^b	5.7 ± 0^b	5.63 ± 1^b	5.63 ± 1^b	6.32 ± 0^a	5.54 ± 0^b	6.70 ± 0^b	6.50 ± 0^b	6.51 ± 0^b
Clay %	10.00 ± 1^c	21.0 ± 1^b	30.0 ± 0^a	34.00 ± 0^a	20.00 ± 1^b	10.00 ± 0^c	21.00 ± 0^b	30.00 ± 0^a	34.00 ± 0^a	20.00 ± 1^b
Sand %	60.00 ± 1^a	66.0 ± 0.5^a	10.0 ± 0.7^c	36.00 ± 0^c	40.00 ± 0.5^b	60.00 ± 0.5^a	66.00 ± 0.5^a	10.00 ± 0.5^c	36.00 ± 0^c	40.00 ± 0.5^b
Silt %	30.00 ± 1^c	13.0 ± 0^d	60.0 ± 0^a	30.00 ± 0.1^c	40.00 ± 0^b	30.00 ± 0.7^c	13.00 ± 0^d	60.00 ± 0^a	30.00 ± 0.1^c	40.00 ± 0^b

ST_0: Control soil, ST_1: Sandy clay loam soil, ST_2: Silty clay loam, ST_3: Clay loam soil, ST_4: Loam soil, values shown are mean±standard deviation, different letters (a,b,c,d) along a column represent significant differences at $p<0.01$

Two separate pot experiments were conducted in 2 sessions 2015/ 2016.The 2 experiments were carried out in the glass house, Faculty of Agriculture, University of Fort Hare, Alice, South Africa. Each trial was organised in a complete randomised design (CRD) with 3 replicates. Experimental pot used measured 25 cm in diameter and 5 kg soil capacity. A single seedling was transplanted at 4 leaf stage into each of the pots for 1st trial in October, 2015 and for the 2nd trial in February, 2016. The first trial experienced a longer day and higher temperature. The agronomic practices included watering of the plant twice daily. Multi-feed water soluble fertiliser 43 (3 g L^{-1}) was applied once in a week for foliar fertigation. Application started in both trials at the 2nd week after transplanting (ATP) with 100 mL of water/plant stand (per pot). Water and fertiliser were of the same volume applied to all plants of the same age on different soil types, this which increased as plants' age advanced. Loosening of compacted soil to improve aeration was carried out every 2 week by breaking the soil with a mini garden fork during the 2 trials[22].

Destructive/ systematic sampling method was employed by selecting 6 potted plants in a treatment for weekly data collection and nutrient analysis. Before uprooting, growth measurement were taken on plant height, stem width, chlorophyll content. Yield parameters measured were number of leaves, leaf area and leaf chlorophyll content. Parameters measured after uprooting were fresh weight and dry weight after oven dried at 35°C to get constant weight. The 2 experiments were terminated at the end of 8th week when over 75% of the fruits on each plant were matured and ripe.

Statistical analysis: Data collected were analysed statistically using Minitab Release 17. A one-way analysis of variance (ANOVA) was used to compare the growth and yield among the treatments. Means were segregated using Fisher's LSD paired wise comparison. The means were treated as significantly different at $p<0.01$.

RESULTS

The formulated experimental soil types used in the 2 trials showed that macro and micronutrient elements are in moderate quantities but not very low (Table 2). The results of the current study indicate that growth and yield parameters from the 1st trial recorded higher mean values than in the second trial. However, highest mean values for all parameters except chlorophyll were recorded in silty clay loam in both trials. Statistical analysis showed differences in the mean yield of different treatments when compared to the control plants. Specifically, plant samples grown on silty clay loam (ST_2) increased in all plant parameters except in chlorophyll content when compared to the plant grown on control soils.

Effect of soil types on *S. nigrum* growth and yield parameters: In this study, the values in the 5th week were considered for increasing or decreasing orders among values of plant parameters cultivated on different soil treatments. The reason is that the vegetables were ready for consumption at that particular week 5. The relationship between soil texture types and various growth parameters as the plants matured were better represented by a polynomial model although specific regressions differed in level of significance and degree of association. A strong positive correlation (r^2) was established between all the treatments and each parameter assessed as the plants matured in both seasons (Table 3-6, 8, 9).

Table 3: Effect of soil types on plant height (cm) in the 1st and 2nd trial

Soil types	Plant age (weeks) 0	1	2	3	4	5	6	7	8	Regression correlation R^2
1st trial										
ST_0	1.10±0.47^{d}	5.23±0.16^{a}	13.26±1.23^{c}	19.25±0.70^{d}	33.46±0.45^{b}	56.01±4.10^{b}	65.13±3.53^{b}	67.70±3.54^{b}	71.33±2.42^{b}	0.956
ST_1	1.15±0.13^{b}	5.16±0.22^{a}	13.85±0.97^{c}	20.81±0.65^{c}	33.68±0.49^{b}	59.41±1.18^{b}	64.70±1.65^{b}	68.75±1.63^{b}	71.65±1.50^{b}	0.952
ST_2	1.13±0.12^{c}	5.25±0.12^{a}	16.35±0.63^{a}	26.15±0.66^{a}	39.38±0.76^{a}	73.13±5.03^{a}	76.90±7.45^{a}	78.86±7.47^{a}	80.15±7.52^{a}	0.936
ST_3	1.15±0.13^{b}	5.21±0.14^{a}	14.46±0.57^{b}	23.68±0.49^{b}	35.13±1.87^{b}	50.81±0.81^{c}	56.68±2.30^{c}	59.75±2.33^{d}	62.91±2.22^{c}	0.975
ST_4	1.20±0.08^{a}	5.20±0.16^{a}	14.03±0.17^{b}	20.61±0.66^{c}	35.40±2.23^{b}	48.10±0.94^{d}	52.31±0.82^{c}	56.86±1.54^{d}	60.01±1.73^{c}	0.974
2nd trial										
ST_0	2.83±0.08^{a}	7.38±1.08^{b}	16.35±1.32^{a}	20.39±0.94^{b}	29.58±0.51^{b}	35.73±1.22^{c}	54.29±4.58^{b}	58.93±1.93^{b}	67.58±1.72^{b}	0.987
ST_1	2.78±0.12^{b}	8.54±1.00^{a}	17.48±0.84^{a}	20.67±0.63^{b}	27.70±0.38^{b}	38.46±1.01^{b}	52.68±0.75^{b}	57.66±2.76^{b}	64.52±3.81^{c}	0.987
ST_2	2.75±0.13^{b}	7.71±1.40^{b}	16.38±1.59^{a}	23.07±0.85^{a}	33.56±2.42^{a}	46.16±2.11^{a}	60.77±5.77^{a}	68.55±0.84^{a}	72.70±2.00^{a}	0.986
ST_3	2.86±0.05^{a}	7.70±1.04^{b}	15.70±0.86^{b}	18.16±0.34^{c}	20.58±0.78^{c}	29.01±0.88^{d}	42.51±1.39^{c}	52.54±0.58^{c}	55.80±1.84^{d}	0.978
ST_4	2.78±1.03^{b}	7.21±1.26^{b}	15.96±0.94^{b}	19.24±0.76^{c}	21.21±0.59^{b}	29.05±0.80^{d}	45.46±0.48^{c}	54.26±0.36^{c}	56.90±0.70^{c}	0.972

ST_0: Control soil, ST_1: Sandy clay loam soil, ST_2: Silty clay loam, ST_3: Clay loam soil, ST_4: Loam soil, values shown are mean±standard deviation, different letters (a,b,c,d) along a column represent significant differences at p<0.01

Table 4: Effect of soil types on stem width (mm) in the 1st and 2nd trial

Soil types	Plant age (weeks) 0	1	2	3	4	5	6	7	8	Regression correlation R^2
1st trial										
ST_0	0.77±0.03^{a}	1.78±0.11^{b}	3.83±0.13^{b}	4.15±0.32^{c}	7.40±0.08^{b}	8.28±0.22^{b}	8.73±0.26^{c}	8.96±0.26^{c}	9.28±0.22^{b}	0.965
ST_1	0.76±0.05^{a}	1.83±0.08^{a}	3.95±0.05^{b}	4.88±0.27^{c}	7.69±0.31^{b}	8.89±0.46^{b}	9.26±0.54^{b}	9.39±0.56^{b}	9.63±0.42^{b}	0.975
ST_2	0.79±0.05^{a}	1.83±0.09^{a}	4.06±0.07^{a}	6.61±0.33^{a}	9.90±0.78^{a}	10.61±0.34^{a}	10.59±0.20^{a}	10.83±0.19^{a}	10.90±0.20^{a}	0.964
ST_3	0.77±0.04^{a}	1.78±0.07^{b}	3.88±0.16^{b}	4.24±0.24^{c}	6.49±0.29^{c}	7.33±0.26^{c}	8.04±0.34^{c}	8.25±0.44^{c}	8.32±0.24^{c}	0.981
ST_4	0.75±0.04^{a}	1.80±0.08^{b}	3.97±0.04^{b}	5.01±0.15^{b}	7.00±0.27^{b}	7.73±0.21^{c}	8.27±0.43^{c}	8.65±0.46^{c}	8.53±0.42^{c}	0.988
2nd trial										
ST_0	0.75±0.05^{a}	1.58±0.07^{b}	3.36±0.19^{a}	3.93±0.08^{c}	6.31±0.44^{b}	7.04±0.13^{b}	7.45±0.06^{c}	7.75±0.17^{c}	8.09±0.07^{b}	0.977
ST_1	0.78±0.05^{a}	1.58±0.11^{b}	3.20±0.54^{a}	4.21±0.21^{b}	6.65±0.39^{b}	7.14±0.12^{b}	8.03±0.06^{b}	8.21±0.13^{b}	8.33±0.17^{b}	0.977
ST_2	0.75±0.05^{a}	1.63±0.13^{a}	3.63±0.12^{a}	6.23±0.25^{a}	7.85±0.29^{a}	9.18±0.58^{a}	9.94±0.17^{a}	10.17±0.08^{a}	10.28±0.14^{a}	0.982
ST_3	0.75±0.05^{a}	1.53±0.05^{b}	2.75±0.28^{b}	3.17±0.11^{c}	5.20±0.15^{c}	6.81±0.27^{c}	7.45±0.11^{c}	7.28±0.13^{c}	7.57±0.15^{c}	0.959
ST_4	0.77±0.05^{a}	1.61±0.14^{a}	2.95±0.10^{b}	3.28±0.16^{c}	5.51±0.17^{c}	7.14±0.09^{b}	7.61±0.27^{c}	7.45±0.14^{c}	7.69±0.13^{c}	0.956

ST_0: Control soil, ST_1: Sandy clay loam soil, ST_2: Silty clay loam, ST_3: Clay loam soil, ST_4: Loam soil, values shown are mean±standard deviation, different letters (a,b,c,d) down a column represent significant differences at p<0.01

Table 5: Effect of soil types on number of leaves in the 1st and 2nd trial

Soil types	Plant age (weeks) 0	1	2	3	4	5	6	7	8	Regression correlation R^2
1st trial										
ST_0	3.33±0.51^{a}	5.83±0.40^{a}	19.27±1.26^{c}	52.28±0.89^{a}	199.16±9.80^{c}	221.33±1.21^{c}	237.33±7.14^{c}	246.33±9.77^{c}	249.16±9.32^{ab}	0.886
ST_1	3.33±0.51^{a}	5.83±0.40^{a}	20.50±1.76^{b}	51.50±1.04^{a}	197.83±6.21^{c}	226.66±3.88^{c}	240.00±8.36^{c}	246.66±10.23^{c}	250.50±12.46^{b}	0.885
ST_2	3.33±0.40^{a}	5.67±0.51^{a}	24.33±1.78^{a}	53.66±1.63^{a}	227.66±9.80^{a}	287.83±6.43^{a}	303.33±8.64^{a}	312.33±9.33^{a}	320.33±9.37^{a}	0.890
ST_3	3.32±0.51^{a}	5.83±0.51^{a}	20.55±1.63^{b}	46.33±2.58^{b}	207.16±5.68^{b}	243.33±2.40^{b}	253.33±3.44^{b}	265.00±6.28^{b}	269.33±8.61^{b}	0.881
ST_4	3.33±0.51^{a}	5.66±0.51^{a}	21.33±1.03^{b}	49.50±0.83^{b}	230.83±6.33^{a}	257.50±7.75^{b}	294.33±4.27^{a}	299.33±3.50^{a}	310.00±4.85^{a}	0.890
2nd trial										
ST_0	4.33±0.75^{a}	6.50±1.22^{b}	22.33±1.96^{c}	42.52±13.17^{b}	188.33±2.08^{a}	193.00±4.19^{c}	198.00±2.00^{d}	275.16±12^{b}	283.00±14.48^{b}	0.918
ST_1	4.36±0.51^{a}	6.33±1.36^{b}	23.83±3.17^{b}	44.34±2.48^{b}	175.00±11.09	198.33±13.77^{c}	221.16±14.14^{c}	280.00±10.37^{b}	291.83±2.58^{b}	0.940
ST_2	4.33±0.51^{a}	6.66±0.98^{b}	27.00±1.89^{a}	49.00±8.04^{a}	186.33±8.39^{c}	226.00±12.49^{a}	297.33±10.77^{a}	300.00±12.11^{a}	308.16±10.10^{a}	0.921
ST_3	4.33±0.51^{a}	7.16±1.21^{a}	24.00±1.02^{b}	46.32±3.88^{a}	182.16±5.79^{b}	217.66±3.62^{b}	208.66±7.74^{c}	246.66±9.30^{c}	251.83±13.77^{c}	0.899
ST_4	4.36±0.51^{a}	6.66±1.21^{b}	22.83±1.02^{c}	48.33±3.88^{a}	183.66±25.79^{b}	222.66±33.62^{a}	267.83±47.74^{b}	317.33±39.30^{a}	352.50±33.77^{a}	0.955

ST_0: Control soil, ST_1: Sandy clay loam soil, ST_2: Silty clay loam, ST_3: Clay loam soil, ST_4: Loam soil, values shown are mean±standard deviation, different letters (a,b,c,d) down a column represent significant differences at p<0.01

Effect of soil types on plant height: In the 1st week of the 1st trial, the plant height experienced a slow growth, however, there was an exponential increase from 2nd-4th week after transplanting (ATP). It maintained constant growth till the 6th week and stabilised till 8th week ATP which is the end of the experiment. However, in the 2nd trial, the plant height experienced an exponential rate from week 0-2 ATP, it was constant in the 3rd week. Plant height recorded gradual

Table 6: Effect of soil types on leaf area (cm) in the 1st and 2nd trial

	Plant age (weeks)									Regression correlation
Soil types	0	1	2	3	4	5	6	7	8	R^2
1st trial										
ST_0	0.22 ± 0.01^a	2.54 ± 0.32^a	12.32 ± 1.07^b	32.02 ± 0.19^b	56.77 ± 2.08^b	97.52 ± 3.22^b	125.42 ± 5.92^a	127.34 ± 6.23^a	130.23 ± 6.25^a	0.942
ST_1	0.23 ± 0.02^a	2.05 ± 0.90^b	15.16 ± 4.11^a	32.16 ± 0.21^b	54.14 ± 1.49^b	88.53 ± 13.38^b	130.22 ± 3.15^a	132.27 ± 3.12^a	134.08 ± 3.87^a	0.946
ST_2	0.22 ± 0.01^a	2.27 ± 0.98^b	13.66 ± 1.58^a	33.06 ± 1.24^b	61.58 ± 1.80^a	113.41 ± 6.52^a	137.18 ± 2.20^a	139.65 ± 1.71^a	141.23 ± 1.87^a	0.932
ST_3	0.21 ± 0.01^a	2.56 ± 0.33^a	12.98 ± 0.90^b	33.26 ± 1.67^b	52.68 ± 0.95^b	84.72 ± 2.90^b	117.63 ± 1.18^b	119.31 ± 3.12^b	123.69 ± 2.63^b	0.953
ST_4	0.21 ± 0.00^a	2.67 ± 0.13^a	11.77 ± 0.64^c	32.07 ± 0.29^b	51.62 ± 2.59^b	85.41 ± 1.97^b	109.86 ± 3.75^b	118.10 ± 2.26^b	124.42 ± 2.49^b	0.963
2nd trial										
ST_0	0.23 ± 0.02^a	4.92 ± 2.61^a	8.99 ± 2.24^b	28.48 ± 1.37^b	50.96 ± 1.41^b	95.60 ± 2.91^b	128.78 ± 1.49^a	131.53 ± 2.54^a	134.73 ± 3.32^a	0.937
ST_1	0.23 ± 0.02^a	2.51 ± 0.09^b	9.76 ± 0.77^a	27.70 ± 2.05^b	50.70 ± 3.63^b	86.16 ± 3.86^b	125.89 ± 2.17^a	129.66 ± 1.67^a	132.48 ± 1.27^a	0.944
ST_2	0.24 ± 0.02^a	3.16 ± 0.64^a	9.65 ± 0.88^a	31.93 ± 1.64^a	61.07 ± 3.05^a	108.57 ± 7.46^a	138.48 ± 3.03^a	139.31 ± 2.40^a	140.87 ± 2.87^a	0.931
ST_3	0.23 ± 0.01^a	2.50 ± 0.22^b	9.58 ± 0.90^a	26.86 ± 1.93^b	49.91 ± 1.51^b	83.09 ± 4.71^b	114.59 ± 5.33^b	123.28 ± 1.33^b	125.40 ± 1.94^b	0.952
ST_4	0.24 ± 0.01^a	3.23 ± 0.88^a	9.50 ± 0.68^a	26.27 ± 1.52^b	54.57 ± 3.91^b	89.95 ± 0.97^b	123.88 ± 3.02^b	127.31 ± 1.44^b	129.11 ± 1.54^b	0.940

ST_0: Control soil, ST_1: Sandy clay loam soil, ST_2: Silty clay loam, ST_3: Clay loam soil, ST_4: Loam soil, values shown are mean±standard deviation, different letters (a,b,c,d) down a column represent significant differences at $p<0.01$

increase from 4th-5th week ATP and stabilised till the end of the experiment. Significant ($p<0.01$) increase in plant height was recorded in silty clay loam (ST_2) plants which is followed sandy clay loam (ST_1) samples. However, lowest mean plant height was observed in clay loam (ST_3) and loam (ST_4) soils in the 1st and 2nd trials, respectively. A strong positive correlation (r^2) was established between all the treatments and plant height as the plants matured in both trials Table 3, respectively.

Effect of soil types on stem width: In the 1st trial of this study, exponential rate of growth was observed in the stem width between week 0 and 2 ATP. The growth stabilised till the 5th and the 6th week ATP and the stem width recorded reduction in the mean values till the end of the experiment in the 1st and 2nd trials, respectively. At 4 weeks ATP, *S. nigrum* cultivated on silty clay loam soils significantly increased ($p<0.01$) in stem width compared to the plant stem on control soils. The plant stem width on silty clay loam soils increased by 25 and 5% compared to those of plant samples on control soils during the 1st and 2nd trial, respectively. The stem width increased in the following order: ST_3 =S $T_4<ST_1<ST_0<ST_2$ and $ST_3<(ST_4 = ST_0 = ST_1)<ST_2$ in the 1st and 2nd trials, respectively. A strong positive correlation (r^2) was established between all the treatments and plant stem width as the plants matured in both trials Table 4, respectively.

Effect of soil types on number of leaves: *Solanum nigrum* being an edible leafy vegetable, number of leaves is other important yield parameter. Regardless of treatments in both trials of this study, number of leaves increased from week 1-3. Number of leaves increased at exponential rate between week 3 and 4 ATP. From week 4-8 (end of the experiment), there was a gradual increase in the mean number of leaves.

However, in the 2 trials of this study, significantly high ($p<0.01$) mean number of leaves was reported in plants cultivated on silty clay loam (ST_2) soils. At 4 weeks ATP, number of leaves increased by 45.9 and 22.7% in trials 1 and 2, respectively when compared to number of leaves on plant on the control soil. The decrease followed orders: $ST_2>ST_3>ST_4>ST_O>ST_1$ in both trials. A strong positive correlation (r^2) was established between all the treatments and number of leaves as the plants matured in both trials Table 5.

Effect of soil types on leaf area: *Solanum nigrum* being an edible leafy vegetable, the leaf area is an important yield parameter, the higher the leaf area, the better the yield. However, in the 2 trials of this study, the leaf area increased at exponential rate from 1st-16th week ATP from area was constant till the end of the experiment. The greatest yield leaf area was recorded in plants cultivated on silty clay loam (ST_2) soils. At 4 weeks ATP, the leaf area increased by 16.55 and 7.81% in trials 1 and 2, respectively when compared to leaf area of plant samples on control soil. Least leaf area was recorded in plants grown on clay loam soil and loamy soils in the 1st and 2nd trials, respectively. Leaf area generally follow the increasing order as follows: $(ST_3 = ST_4 = ST_1 = ST_0)<ST_2$ in both trials, respectively. A strong positive correlation (r^2) was established between all the treatments and leaf area as the plants matured in both seasons (Table 6).

Effect of soil types on chlorophyll contents of the leaves: Chlorophyll content recorded exponential increase between week 0 and 3 after which it maintain constant values till week 4, it then increase up to week 5 ATP. There was reduction in the mean value from week 7 ATP till the end of the experiment in the first trial. Exponential increase was observed between week 0 and 6 in the second trial, the mean

Table 7: Effect of soil types on leaf chlorophyll content in the 1st and 2nd trial

	Plant age (weeks)									Regression correlation
Soil types	0	1	2	3	4	5	6	7	8	R^2
1st trial										
ST_0	1.53±0.04[a]	28.63±0.42[a]	37.13±4.06[b]	46.38±5.71[b]	46.60±1.78[b]	50.33±1.78[b]	52.88±2.07[b]	53.62±2.51[b]	54.27±0.86[c]	0.973
ST_1	1.53±0.04[a]	28.23±0.38[a]	38.56±1.32[b]	45.96±0.68[b]	47.10±4.06[b]	50.40±3.06[b]	52.93±6.45[b]	53.60±1.09[b]	54.33±3.65[c]	0.974
ST_2	1.53±0.05[a]	28.55±0.64[a]	39.65±3.67[b]	47.24±0.63[b]	49.26±1.08[b]	53.08±3.36[a]	54.63±1.80[a]	55.45±1.80[a]	56.18±0.85[b]	0.979
ST_3	1.54±0.04[a]	28.30±0.58[a]	44.86±1.00[a]	52.25±2.68[a]	53.48±2.10[a]	57.05±2.51[a]	59.49±1.50[a]	59.64±1.20[a]	62.34±3.73[a]	0.974
ST_4	1.54±0.04[a]	28.28±0.43[a]	41.85±1.61[a]	50.75±4.23[a]	52.07±1.85[a]	55.80±2.44[a]	57.35±1.80[a]	58.00±1.39[a]	60.05±2.90[a]	0.959
2nd trial										
ST_0	3.73±0.62[a]	29.36±2.67[c]	33.33±1.01[c]	44.69±1.25[b]	47.65±3.96[b]	50.91±0.57[c]	51.18±1.94[b]	51.63±0.69[b]	52.20±1.36[b]	0.952
ST_1	3.73±0.62[a]	29.45±2.01[c]	36.38±1.57[b]	45.28±1.22[b]	49.06±0.67[b]	52.05±0.85[b]	52.16±0.94[b]	52.48±0.83[b]	52.90±0.92[b]	0.954
ST_2	3.73±0.62[a]	30.91±3.98[b]	37.58±2.99[b]	47.80±1.39[b]	48.87±1.73[b]	51.86±1.50[c]	51.49±1.52[b]	52.46±0.97[b]	53.41±1.04[b]	0.932
ST_3	3.73±0.62[a]	30.55±3.28[b]	48.75±0.64[a]	52.40±2.97[a]	54.19±3.42[a]	56.09±3.17[a]	56.51±3.10[a]	57.35±2.62[a]	58.68±2.85[a]	0.914
ST_4	3.73±0.62[a]	33.56±2.46[a]	48.45±1.51[a]	50.06±0.75[a]	50.85±1.07[a]	53.61±0.82[b]	54.70±2.74[a]	55.00±2.66[a]	56.91±2.44[a]	0.876

ST_0: Control soil, ST_1: Sandy clay loam soil, ST_2: Silty clay loam, ST_3: Clay loam soil, ST_4: Loam soil, values shown are mean±standard deviation, different letters (a,b,c,d) down a column represent significant differences at p<0.01

Table 8: Effect of soil types on plant fresh weight (g) in the 1st and 2nd trial

	Plant age (weeks)									Regression correlation
Soil types	0	1	2	3	4	5	6	7	8	R^2
1st trial										
ST_0	0.01±0.00[a]	2.66±0.12[b]	8.25±0.21[b]	30.71±1.28[a]	84.60±1.23[b]	129.50±2.13[a]	137.78±1.18[b]	141.46±2.62[a]	146.71±3.30[a]	0.914
ST_1	0.01±0.00[a]	2.90±0.08[a]	9.00±0.14[a]	32.43±1.20[a]	87.17±1.67[b]	135.03±1.74[a]	141.53±2.77[a]	144.85±2.40[a]	148.95±2.19[a]	0.911
ST_2	0.01±0.00[a]	2.98±0.06[a]	10.21±0.11[a]	35.43±1.79[a]	101.84±0.95[a]	142.02±3.54[a]	147.71±7.40[a]	150.80±5.77[a]	160.88±5.58[a]	0.914
ST_3	0.01±0.00[a]	2.90±0.10[a]	9.50±0.08[a]	28.50±1.92[b]	81.36±1.90[b]	124.57±1.34[b]	132.86±1.00[b]	134.75±0.80[b]	137.91±2.34[b]	0.910
ST_4	0.01±0.00[a]	2.96±0.04[a]	9.86±0.10[a]	27.35±4.51[b]	84.98±1.27[b]	126.46±2.40[b]	134.98±2.05[b]	142.93±1.19[a]	148.74±2.99[a]	0.920
2nd trial										
ST_0	0.01±0.00[a]	2.61±0.09[b]	9.00±0.66[a]	25.28±1.28[c]	75.2±1.74[c]	120.53±7.00[a]	125.46±0.99[a]	131.4±3.87[a]	134.80±1.75[a]	0.910
ST_1	0.01±0.00[a]	3.00±0.08[a]	10.26±0.58[a]	30.66±3.19[b]	72.66±1.90[c]	115.09±0.87[b]	122.40±3.02[a]	127.12±1.76[b]	130.40±3.40[a]	0.923
ST_2	0.01±0.00[a]	3.08±0.06[a]	10.40±0.52[a]	35.26±2.99[a]	97.06±3.72[a]	129.76±3.44[a]	136.13±3.55[a]	142.07±3.52[a]	146.80±1.92[a]	0.917
ST_3	0.01±0.00[a]	3.01±0.07[a]	9.63±0.58[a]	31.71±2.40[a]	76.48±2.42[b]	100.25±1.74[b]	110.09±1.81[b]	117.61±2.75[c]	121.50±3.08[b]	0.936
ST_4	0.01±0.00[a]	3.00±0.04[a]	10.00±0.60[a]	25.63±3.96[c]	82.08±1.53[b]	109.63±4.18[b]	117.66±2.68[b]	122.14±4.69[b]	127.00±2.35[a]	0.916

ST_0: Control soil, ST_1: Sandy clay loam soil, ST_2: Silty clay loam, ST_3: Clay loam soil, ST_4: Loam soil, values shown are mean±standard deviation, different letters (a,b,c,d) down a column represent significant differences at p<0.01

chlorophyll was constant from week 6 till the end of the experiment in the 2 trials. However, there was disparity in the mean chlorophyll contents between plants on clay loam, loam soils and other soil treatments between week 1 and 3 ATP. Highest mean chlorophyll in the 1st trial was recorded in clay loam (ST_3) and followed by loam (ST_4) soils. Control (ST_0) recorded the lowest mean value for chlorophyll (Table 5). However, a strong positive correlation (r^2) was established between all the treatments and plant chlorophyll contents as the plants matured in both seasons Table 7.

Effect of soil types on plant fresh weight: Plant fresh weight varied in different soil types on which they are cultivated. However, in all the soil types, plant recorded very low mean fresh weight in the 1st 2 weeks ATP. Exponential fresh weight was recorded from week 2-6 ATP. Significantly high plant fresh weight was recorded in plants on silty clay loam soils Table 8. The values were significantly (p<0.01) varied among plant samples from different soil types in the 1st trial but not as such in the 2nd trial. However, treatments followed almost the same increasing order in 1st and 2nd trials as follows: $ST_3 = ST_4<(ST_2 = ST_1<ST_0)$ and $ST_3 = ST_4 = ST_1<(ST_0 = ST_2)$. A strong positive correlation (r^2) was established between all the treatments and plant fresh weight as the plants matured in both seasons Table 8.

Effect of soil types on plant dry weight: Significantly high (p<0.01) plant dry weight was observed in plant samples cultivated on silty clay loam when compared to plant samples on the control soils. The weight increased by 24.95 and 22.4% in trials 1 and 2, respectively. Lowest dry weight was recorded in clay loam soils in both trials. The results indicate that the highest biomass in both trials was accumulated in plants cultivated on silty clay loam soil which may be attributed to the nitrogen content of the soil type. A strong positive correlation (r^2) was established between all the treatments and plant dry weight as the plants matured in both seasons Table 9.

Table 9: Effect of soil types on plant dry weight (g) in the 1st and 2nd trial

	Plant age (weeks)									Regression correlation
Soil types	0	1	2	3	4	5	6	7	8	R^2
1st trial										
ST_0	0±0.00[a]	0.13±0.05[a]	0.40±0.08[b]	1.56±0.05[b]	4.50±0.08[a]	5.50±0.08[b]	6.35±0.10[b]	7.46±0.05[b]	7.74±0.10[a]	0.947
ST_1	0±0.00[a]	0.11±0.07[a]	0.35±0.05[b]	1.86±0.08[a]	4.35±0.05[b]	5.26±0.10[b]	6.15±0.10[b]	7.23±0.05[b]	7.60±0.05[a]	0.956
ST_2	0±0.00[a]	0.13±0.05[a]	0.50±0.08[a]	1.90±0.10[a]	4.93±0.05[a]	6.10±0.05[a]	7.15±0.10[a]	7.95±0.16[a]	8.12±0.05[a]	0.943
ST_3	0±0.00[a]	0.15±0.05[a]	0.40±0.08[b]	1.33±0.13[c]	3.73±0.10[c]	4.60±0.05[c]	5.66±0.10[c]	6.45±0.05[c]	7.22±0.05[b]	0.963
ST_4	0±0.00[a]	0.15±0.05[a]	0.50±0.08[a]	1.45±0.05[b]	3.80±0.09[c]	4.78±0.08[c]	5.78±0.09[c]	6.73±0.07[c]	7.38±0.05[b]	0.966
2nd trial										
ST_0	0±0.00[a]	0.08±0.0[b]	0.25±0.05[a]	1.38±0.07[b]	3.53±0.11[a]	4.53±0.29[b]	5.23±0.13[a]	6.48±0.08[b]	6.96±0.28[b]	0.963
ST_1	0±0.00[a]	0.11±0.11[a]	0.20±0.06[b]	1.30±0.08[b]	3.33±0.08[b]	4.66±0.19[b]	4.86±0.11[b]	6.72±0.16[b]	7.12±0.13[a]	0.961
ST_2	0±0.00[a]	0.10±0.08[a]	0.25±0.05[a]	1.46±0.12[a]	3.83±0.05[a]	5.23±0.08[a]	5.50±0.08[a]	7.00±0.13[a]	7.56±0.22[a]	0.956
ST_3	0±0.00[a]	0.10±0.10[a]	0.20±3.04[b]	1.10±0.15[e]	3.18±0.08[b]	4.31±0.05[c]	4.28±0.10[b]	6.18±0.07[c]	6.48±0.11[b]	0.953
ST_4	0±0.00[a]	0.10±0.08[a]	0.26±0.05[a]	1.20±0.20[c]	3.23±0.07[b]	4.51±0.07[b]	4.75±0.05[b]	6.56±0.05[b]	6.94±0.15[b]	0.962

ST_0: Control soil, ST_1: Sandy clay loam soil, ST_2: Silty clay loam, ST_3: Clay loam soil, ST_4: Loam soil, values shown are mean±standard deviation, different letters (a,b,c,d) down a column represent significant differences at p<0.01

DISCUSSION

In the present experiment, the analytical result of nutrient composition in both trials showed high concentrations of N, P, K, Ca and Mg (Table 2). The soil results which deviate a bit from the lower quantities of minerals in soils of Eastern Cape as reported by Mandiringana *et al.* [23]. According to Porter and Semenov[24] and Fasina[25], the role of the fallow phase is to facilitate the regeneration of soil productivity which is likely the reason soils in this study contained high quantities of macronutrients and micronutrients composition.

In both trials of the present study, it was observed that the lengths of the vegetative and flowering stages 28 days were shorter than 35 days reported by Aluko *et al.*[13]. The results also deviate from the findings of Fasina[26], who reported that the growth duration from seedling to flowering phase was 35 days and from flowering phase to the maturity phase was 60 days. However, reduction of days in length of day from vegetative to flowering stage in our own study could be as a result of increase in day length and temperatures (13 h and 38-42°C, 10 h 38-40°C) experienced in this study. The results conform to reports of ++ Wei *et al.*[27] that an increase in temperature hastens the flowering stage of plants. However, the shorter flowering period experienced in this study is advantageous to early harvest of the vegetable for consumption.

Increased parameter values in the first trial when compared to those of the second trial could be attributed to the increased day length and temperature in trial 1 especially from 2nd-4th week ATP. All growth parameters recorded exponential increase in their mean values from second to fourth week ATP which could be as a result of soil loosening operation carried out in the previous days[22]. It was observed across all the soil treatments in this study, that *S. nigrum* exhibited above ground traits such as height, early figure and canopy architecture, a mechanism for out-competing weeds on cultivated plots[28].

Ability of the silty clay loam soils to record the highest growth and yield parameters could be attributed to its good aggregate stability that increased the soil quality for efficient water and nutrients retention[29]. Higher nitrogen content in silty clay loam soil type is a function of its high silt and clay soil particle contents which contributed to the soil ability to support increase in *S. nigrum*'s growth and yield parameters (Plant height, stem width, leaf area, fresh weight and dry weight) Table 3, 4, 6, 8 and 9, respectively. The increase in result of the plant heights on all soil treatments from week 0-3 ATP is in line with those of Janet *et al.*[30] on their studies on the effect of organic and inorganic fertilizer on *S. nigrum* growth and yield. However, significant height was recorded in plant grown on silty clay loam Table 3 in the first and second trial respectively. Plant grown on clay loam and loamy soils recorded significantly number of leaves and chlorophyll content Table 5 and 7.

From the 2 trials of the current study, chlorophyll content was influenced by different soil treatment which is related to the nitrogen content. Furthermore, plants grown in the control and sandy clay loam developed yellowish leaves which could be the plant's response to the soil inability to retain sufficient mobile nutrients such as nitrogen and phosphorus[31]. In addition, Aluko *et al.*[13] in their reports intensified that the leaf is an indicator that reflects the consequence of nutrient deficiency in vegetables, the effect of soil texture types is closely monitored on the leaves of plants. In this study, the results of the chlorophyll content were at variance with those of Ondieki *et al.*[32], who reported variations in chlorophyll contents of 3 *Solanum* species in 2 seasons.

Optimum performance of the vegetable (*S. nigrum*) was recorded from all the formulated soil types in this study, however, it all depends on the purpose of cultivating the vegetable. For the purpose of dark green leaves production which is necessary in cruciferous leafy vegetables, clay loam and loam soils gave the best.

CONCLUSION

In conclusion, the current findings indicate that cultivation of *Solanum nigrum* in silty clay loam gave the best yield. This result could be related to the soil's good aggregate stability that could possibly have helped in retaining sufficient water and nutrients for plant use. However, dark green leaves were produced on clay loam and loam soils which could be due to the influence of clay fraction on carbon content of the soil. In addition, the retention of nitrogen is possibly more improved in clay loam and loam soils as they produced dark green leaves. All assessed growth and yield parameters were variably influenced by soil types probably due to their variability in nitrogen contents. However, all tested soil types in this study, were found supportive for the cultivation of *S. nigrum*.

SIGNIFICANCE STATEMENT

This study discovered the soil texture type that can be beneficial for successful cultivation of *S. nigrum* in large quantity for human health sustainability. This study will help the researchers to uncover the critical areas of soil compatibility for cultivating this beneficial vegetable that many researchers were not able to explore. Thus a new theory on the growth and yield of *S. nigrum* may be arrived at.

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