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Growth and physiological response of *Solanum nigrum* L. to organic and/or inorganic fertilisers

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Summary

A pot experiment was conducted to determine the effect of fertilisers on the growth and physiological response of *Solanum nigrum*. The experiment was laid out in a Randomised Complete Block Design with five treatments: Control (T1); 100 kg N/ha (T2); 8.13 t manure/ ha (T3); 100 kg N/ha + 8.13 t manure/ ha (T4) and 50 kg N/ha + 4.07 t manure/ ha (T5). Plant height, total number of leaves, chlorophyll, moisture, root: shoot ratio, leaf area and stem diameter were measured using standard growth indicator methods. Fertilisers improved the yield, quality and growth of *Solanum nigrum*. Application of 100 kg N/ha produced the best total number of leaves; root: shoot ratio and stem diameter values; 100 kg N/ha + 8.13 t manure/ha produced the best chlorophyll values and 50 kg N/ha + 4.07 t manure/ha increased moisture, leaf area and plant height. The control showed signs of nutrient stress and inorganic fertiliser applied independently did not significantly affect the growth parameters. Although parameters responded differently to each fertiliser treatment, applying a combination of organic and inorganic fertiliser may be a good option to poor resource farmers who may not be able to afford inorganic fertilisers.

Introduction

Humanity relies on a wide range of cultivated crops and yet only a few staple crops produce the majority of food supply in the world. Notwithstanding this, the contribution of minor species should not be under estimated. Researchers have focussed mainly on staple crops and paid little attention to minor species. One such specie is *Solanum nigrum* L. (Black nightshade). This plant is a short lived perennial shrub of Eurasian origins which was introduced to South Africa (Edmonds and Chweya, 1997), although no information is available on when it was introduced. While *Solanum nigrum* is viewed as a notorious and important weed in many crops (Ogg and Rogers, 1989; Defelice, 2003), the plant is an important wild vegetable in many African countries including South Africa and has a high nutritional value, providing an important source of Ca, Fe, proteins, Vit A and fibre among other nutrients (Edmonds and Chweya, 1997; Husselman and Sizane, 2006). *Solanum nigrum* leaves are cooked either fresh or dry for food while ripe berries are consumed as a fruit or made into a bread spread jam. In South Africa, the plant's medicinal uses include treatment of ringworms, diarrhoea, dysentery, wounds, ulcers, fever and headache among other ailments and conditions (Husselman and Sizane, 2006). A preliminary survey in the Eastern Cape province of South Africa indicated that although *Solanum nigrum* is consumed as a vegetable especially during the rainy season and in the case of a drought, no efforts have been made to cultivate it. Soils in the Eastern Cape Province generally contain low amounts of the macronutrients N and P, while micronutrients such as B, Cu, S, Mn and Zn are abundant (Mandiringana et al., 2005). Inadequate supply of N frequently results in slow growth, low protein levels and low, poor quality yield hence N is one of the most limiting elements to efficient and profitable crop production (Mikkelsen and Hartz, 2008). Soils with low levels of nutrients need to be boosted with soil amendments in order to improve them for crop production. Organic fertilisers or manures are a good option as they improve the soil structure and microbial mass (Bin, 1983; Dauda et al., 2008; Suresh et al., 2004) as well as provide nutrients through mineralisation. However depending on the quality and source of the manure, minerals are often slowly mineralised and may not be available during the first season of application. Inorganic fertilisers are the most preferred by farmers because they quickly become available to the plant after application, however, they may be toxic to soil, organisms and humans (Arisha and Bardisi, 1999).

The present experiment was therefore conducted to evaluate the effects of organic and/or inorganic fertilisers on the growth and physiological response of *Solanum nigrum*. Yield (total number of leaves), quality (chlorophyll, moisture and root: shoot ratio) and growth indicators (height, stem diameter and leaf area) were measured to determine the effects of the fertilisers on *Solanum nigrum* in comparison with the control to determine if successful cultivation of this wild vegetable requires the use of fertilisers and the quantities that produce favourable results under the current conditions. *Solanum nigrum* is intended for domestication in efforts to ensure food security in the Eastern Cape.

Materials and methods

This study was conducted from October to December 2012 at the University of Fort Hare Alice campus glass house located at 32º 46' 47" S and 26º 50' 53" E. Average temperatures were 15.62, 16.53, 18.41, 19.67 and 17.42 ºC for September, October, November, December 2012 and the whole year respectively. Mean annual humidity and evaporation were 63.71% and 3.32 mm respectively. The chemical properties of the soil and organic manure used in this experiment are shown in Tab. 1.

The soils (sandy loam) used in this study were collected from the University of Fort Hare research farm located at 32º 46' 47" S and 26º 50' 53" E at an altitude of 524 m a.s.l. The soils were dried and sieved through a 2 mm mesh sieve and packed in 5 kg black polythene bags prior to the experiment. The experiment was laid out in a Randomised Complete Block Design (RCBD) with five treatments. Each treatment had 5 replicates but each replicate had 10 experimental units to ensure a sufficient number of plant samples for the duration of the trial. The treatments were: Control (T1); 100 kg N/ha (T2); 8.13 t goat manure/ha (T3); 100 kg N/ha + 8.13 t goat manure/ha (T4) and 50 kg N/ha + 4.07 t goat manure/ha (T5). N was supplied in the form of N-P-K (2:3:4) and Limestone Ammonium Nitrate (LAN) fertiliser. Furthermore, goat manure and N-P-K were applied at transplanting and LAN fertiliser applied 4 weeks after transplanting. The goat manure was obtained from the University of Fort Hare Research farm.

Ripe and mature *Solanum nigrum* L. berries were harvested between the 3rd and 26th of April 2012 from the wild in Alice. The seeds were separated from the pulp, washed, dried and kept in sealed glass bottles at ambient temperatures until further use. The seeds were planted in cavity trays in the greenhouse on the 18th of September 2012 and transplanted into the prepared polythene bags containing

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Tab. 1: The chemical properties of the experimental soil (Upper 0-30 cm depth) and organic fertiliser.

	Soil	Organic fertiliser
pH(KCl)	6.54	7.17
Bulk density (g cm^{-3})	1.20	-
EC (μS/cm)	162.05	10.75
CEC_{sum} (meq/ 100g)	12.10	-
Available P (mg kg^{-1})	71	8 500
Exchangeable K (mg kg^{-1})	406	26 000
Exchangeable Ca (mg kg^{-1})	1653	29 700
Exchangeable Mg (mg kg^{-1})	335	9 900
Exchangeable acidity (cmol/L)	0.06	-
Total cations (cmol/L)	12.10	-
Saturated acid (%)	0	-
Zn (mg kg^{-1})	10.2	172
Mn (mg kg^{-1})	17	582
Cu (mg kg^{-1})	5.7	54
Organic C (mg kg^{-1})	10000	-
N (mg kg^{-1})	1400	24 800
Clay (%)	17	-
Na (mg kg^{-1})	-	1 564
Fe (mg kg^{-1})	-	12 439
Al (mg kg^{-1})	-	5 335

5 kg of soil on the 12^{th} of October 2012. The seedlings had at least 6 true leaves and at this stage were about 10 - 15 cm tall. To measure the growth, quality and yield parameters, at least 9 plants per treatment were randomly selected, uprooted and tagged for data collection on the following parameters:

Plant height and number of leaves: A meter rule was used to measure the shortest distance between the upper boundary of the main photosynthetic tissues on the plant and the ground level (Cornelissen et al., 2003). However, plant height was measured before the plants were uprooted. Leaves formed were physically counted from each plant and the average determined.

Stem diameter: Using a vernier calliper, stem diameter was measured about 2.5 cm above ground level (Us Epa Pow, 2001).

Leaf area (LA): Leaf area was determined by the non destructive length × width method (Saxena and Singh, 1965) using the relation: LA = 0.75(length × width), where 0.75 is a constant.

Chlorophyll: Using a spectrophotometer (Konica Minolta SPAD -502 PLUS) the non-destructive approach method was used to determine total chlorophyll in fresh, healthy looking leaves.

Moisture: The method of Osborne and Voogt (1978) was used. About 2 g of plant samples were dried to a constant weight in an oven at 110 ºC in clean and dry porcelain crucibles. Using the final and initial weight of the samples, the percentage content was determined.

Root: Shoot ratio: Roots were separated from the whole plant and dried in the oven at 40 ºC to a constant weight. The ratio was determined as the dry weight of the roots to the dry weight of the top of the plant (Harris, 1992).
This experiment was terminated when all the berries on the plant were mature and ripe (9 weeks after transplanting).

Statistical analysis
Data collected were subjected to statistical analysis using MNITAB Release 12. A one way analysis of variance was used to compare the means of various growth parameters among the treatments and a two way analysis of variance was used to determine the interaction between plant age (weeks after transplanting) and treatment on particular growth parameters. Means were segregated using Duncan's multiple range test. The means were treated as significantly different at $p < 0.05$.

Results and discussion

Plant height and number of leaves
There were significant differences ($p < 0.05$) among the treatment means on plant height and total number of leaves (Tab. 2 and 3). Plant height and leaf number increased with plant maturity. The height means for the duration of the trial were highest in T5 (54.33 cm) and lowest in the control (34.41 cm) while the total number of leaves were highest in T4 (174) and lowest in the control (101). However, the total number of leaves harvested throughout the trial decreased in the order 1416 (T2) > 1393 (T4) > 1150 (T5) > 804 (T1) > 713 (T3). Analysis showed an interaction between plant age and fertiliser treatment on plant height and number of leaves. Regression analysis with plant height and number of leaves as the dependable variables and time (plant age) as the regressor showed a coefficient of determination (R^2) of 97 and 96 % respectively indicating that

Tab. 2: Effect of organic and inorganic fertilisers on plant height (cm) of *Solanum nigrum* L. cultivated in the greenhouse.

	Plant age (Weeks after transplanting)							
	0	3	4	5	6	7	8	9
T1	8.97±0.11	21.33±2.07^{a}	35.33±2.08^{ab}	36.33±1.37^{a}	41.00±4.73^{a}	43.33±2.25^{a}	44.00±3.37^{a}	45.00±6.26^{a}
T2	8.97±0.11	25.10±3.81^{b}	40.67±5.03^{a}	44.00±0.89^{b}	70.00±3.23^{b}	76.67±1.37^{b}	77.67±1.86^{b}	88.00±10.16^{b}
T3	8.97±0.11	20.33±0.52^{a}	30.67±2.08^{b}	44.00±3.23^{b}	46.33±1.03^{a}	51.33±6.28^{c}	54.00±6.99^{c}	67.17±0.93^{c}
T4	8.97±0.11	22.33±0.93^{ab}	40.00±1.00^{a}	49.00±0.89^{c}	66.67±6.09^{b}	75.33±2.73^{b}	77.00±1.79^{b}	80.33±4.13^{b}
T5	8.97±0.11	23.67±1.37^{ab}	41.00±2.65^{a}	49.67±3.14^{c}	64.667±1.37^{b}	75.33±1.03^{b}	81.00±3.10^{b}	90.33±0.52^{b}

0 represents data collected at the time of transplanting
Values shown are mean ± SD
Means with different letters down the same column represent significant differences at $p < 0.05$.

Tab. 3: Effect of organic and inorganic fertilisers on leaf number of *Solanum nigrum* L. cultivated in the greenhouse.

	Plant age (Weeks after transplanting)							
	0	3	4	5	6	7	8	9
T1	6.00±1.03	82±11.04^{a}	89±3.61	110±26.39^{ab}	115±4.98^{a}	126±2.25^{a}	131±3.39^{a}	145±19.62^{a}
T2	6.00±1.03	74±16.50^{ab}	86±49.07	90±6.26^{a}	190±20.83^{b}	259±17.12^{b}	349±3.39^{b}	361±5.75^{b}
T3	6.00±1.03	62±8.31^{b}	80±18.60	99±10.55^{a}	103±18.85^{a}	107±8.20^{a}	124±9.96^{a}	133±3.39^{a}
T4	6.00±1.03	66±9.40^{ab}	86±16.57	124±7.17^{b}	229±46.66^{b}	255±52.23^{b}	300±19.72^{c}	327±24.57^{c}
T5	6.00±1.03	53±8.53^{b}	71±12.94	99±14.72^{a}	188±55.92^{b}	236±16.27^{b}	245±38.40^{d}	253±19.78^{d}

0 represents data collected at the time of transplanting
Values shown are mean ± SD
Means with different letters down the same column represent significant differences at $p < 0.05$.

plant age had a significant effect on plant height and number of leaves.

GOHARI and NIYAKI (2010) reported that excess N increases plant height and shading of lower leaves leading to auxin production which eventually stops the plant's growth. MILLSPAUGH (1974) reported *Solanum nigrum* plant height of between 30.48 and 60.96 cm in his study and this is lower than the results of this present study. EDMONDS and CHWEYA (1997) recorded 70 cm as the maximum height of *Solanum nigrum* in their study; however this is lower than the maximum height recorded in the present experiment (90.33 cm). Comparing results obtained from different parts of the world, different agro-ecological conditions presumably produce different plant heights of the same plant. Nitrogen generally stimulates vegetative growth (ZHANG et al., 2010) meaning the formation of more buds and a subsequent increase in the number of leaves. From this study, it is conceivable that as the height increased due the uptake of N in its nitrate form, an increase in vegetative growth as indicated by the leaves became inevitable. In addition, 100 kg N/ha produced the highest leaf yield throughout the trail while 50 kg N/ ha + 4.07 t manure/ha produced the highest average height throughout the trial.

Stem diameter

Treatment means were significantly different ($p < 0.05$) except in the 4th week. Stem diameter increased exponentially in all the treatments between the time of transplanting and the 4th week after which it continued to increase steadily until the 9th week (Tab. 4). The means for the trial period were highest in T2 (5.83 mm) and lowest in T3 (4.46 mm). However, statistical analysis showed an interaction between plant age and the fertiliser treatment on stem diameter. Regression analysis with stem diameter as the dependable variable and time (plant age) as the regressor showed a coefficient of determination (R^2) of 81 % indicating that plant age had a significant effect on stem diameter.

ONDIEKI et al. (2011) reported a smaller diameter (6.64 mm) in *Solanum scabrum* as compared to the best treatment (7.35 mm) of the current study. The stem acts as a mechanical support structure on which sub-stems, leaves and fruits are formed. In this experiment, a positive increase in stem diameter due to the application of 100 kg N/ha (T2) conceivably led to the generation of more buds on which the leaf count improved as well as height of the plant. Although the absence of water or subjecting a plant to a dry cycle drastically slows down stem diameter and height growth (KLEPPER et al., 1972), an earlier report (KLEPPER et al., 1971) proposed that stem diameter is not related to plant water status by a single-valued function but changes in stem diameter rather reflect changes in stem tissue hydration. The dynamics of stem diameter changes are generally explained by the cohesion-tension theory of the xylem and pressure-flow model of the phloem while changes within the xylem and phloem thus create reversible and irreversible (growth) changes in the stem diameter (CHAN, 2012). Water concentration in the pots was kept at field capacity throughout this present experiment. This present study showed that application of 100 kg N/ha fertiliser increased the stem of *Solanum nigrum*. Although diurnal diameter readings were not investigated, a positive growth was evident.

Moisture

Treatment means differed significantly ($p < 0.05$) and were consistently high throughout the experiment ranging between 75.16 and 92.08 % in the 7th and 3rd week respectively (Tab. 5). The means for the duration of the trial were highest in T5 followed by T2 and least

Tab. 4: Effect of organic and inorganic fertilisers on stem diameter (mm) of *Solanum nigrum* L. cultivated in the greenhouse.

	Plant age (Weeks after transplanting)							
	0	3	4	5	6	7	8	9
T1	1.27±0.14	4.49±0.50^{a}	4.76±0.12^{a}	4.85±0.27^{a}	4.96±0.45^{a}	5.00±0.27^{a}	5.20±0.22^{a}	5.80±0.41^{a}
T2	1.27±0.14	5.59±0.34^{b}	6.12±0.54^{b}	6.38±0.45^{b}	6.69±0.14^{b}	6.86±0.51^{b}	6.95±0.72^{b}	7.35±0.06^{d}
T3	1.27±0.14	4.50±0.12^{a}	4.64±0.18^{a}	4.75±0.13^{a}	4.82±0.22^{a}	5.18±0.08^{a}	5.24±0.52^{a}	5.29±0.13^{c}
T4	1.27±0.14	5.20±0.35^{b}	5.49±0.18^{c}	5.53±0.26^{c}	6.23±0.36^{b}	6.41±0.26^{b}	6.51±0.24^{b}	6.89±0.31^{b}
T5	1.27±0.14	4.92±0.29^{ab}	5.11±0.60^{ac}	5.51±0.24^{c}	6.67±0.39^{b}	6.74±0.36^{b}	6.91±0.15^{b}	7.19±0.34^{b}

0 represents data collected at the time of transplanting
Values shown are mean ± SD
Means with different letters down the same column represent significant differences at $p < 0.05$.

in T1. Statistical analysis showed an interaction between plant age and the fertiliser treatment on moisture content. Regression analysis with moisture content as the dependable variable and time (plant age) as the regressor showed a coefficient of determination (R^2) of 31 % indicating that plant age had a minimal effect on moisture content.

The results of the current study are comparable with those of AKUBUGWO et al. (2007) who reported moisture content of 84.70 % in *Solanum nigrum* leaves. Results reported by ASIBEY-BERKO and TAYIE (1999) are also similar to the current study. These authors reported a range between 79.6 and 91.6 % in various wild vegetables including 80.4 % in *Solanum nigrum*. HUSSAIN et al. (2010) reported a range between 85.74 and 94.42 % in a variety of wild vegetables including some *Solanum* species (92.60 %) and these results are not very different from the current study. Water constitutes about 80-95 % of the mass of a growing plant and thus plays a crucial role in the life of the plant. Plants need water to maintain cell turgor pressure which is essential for physiological processes such as cell enlargement, gas exchange in the leaves, transport in the phloem and various transport processes across membranes (DAINTY, 1976). Furthermore, turgor pressure also contributes to the rigidity and mechanical stability of non lignified plant tissues. The high water content of *Solanum nigrum* leaves in this trial is not only a good indicator of the good quality and health status of the plant but also an indicator of its favourable nutritional status. Reports have suggested that water containing foods provide about 25 % of the average water need in humans (SHARP, 2007). *Solanum nigrum* leaves would therefore be a good supplier of water to humans. All the treatments in this study generally indicated sufficient water in the leaves but 50 kg N/ha + 4.07 t manure/ha recorded the highest average water content for the trial.

Root: shoot ratio

The root: shoot ratio decreased exponentially between the time of transplanting and the 3rd week and began to vary there after (Tab. 6). There were significant differences ($p < 0.05$) in treatment means except in the 4th and 5th week and ranged between 0.08 and 0.28 in the 3rd week and time of planting respectively. The means for the duration of the trial were highest at T3 and least at T2 and T5. Statistical analysis showed an interaction between plant age and the fertiliser treatment on the root: shoot ratio. Regression analysis with the root to shoot ratio as the dependable variable and time (plant age) as the regressor showed a coefficient of determination (R^2) of 23.3 % indicating that plant age had a minimal effect on the root to shoot ratio.

In a study conducted on the field (BVENURA and AFOLAYAN, 2013), the root: shoot ratio of *Solanum nigrum* was found between 0.05 and 0.28 and this is not very different from the current glasshouse trial. In related species, NAHAR and GRETZMACHER (2011) as well as MUTHONI and MUSYIMI (2009) reported that root: shoot ratio of some tomato cultivars and African nightshades respectively increased in response to water stress conditions. In general, most trees have a root: shoot ratio between 0.17 and 0.20 (HARRIS, 1992). In the current study, the ratio conceivably increased in response to nutrient stress since soil moisture was kept at field capacity throughout the trial period. Nutrient depletion in the control presumably led to a high root: shoot ratio while a good supply in the other treatments lowered the ratio. Reduced nutrient supply increases the root: shoot ratio thereby compensating for loss in root foraging capacities (DIXON, 2006). The relatively low root: shoot ratio values reported in the present study are a good indicator of the favourable conditions (nutrient and water supply) the plant was subjected to

Tab. 5: Effect of organic and inorganic fertilisers on moisture content (%) of *Solanum nigrum* L. leaves cultivated in the greenhouse.

	Plant age (Weeks after transplanting)							
	0	3	4	5	6	7	8	9
T1	88.52±0.34	98.25±0.05^a	82.62±0.96^a	78.75±0.13^a	79.02±0.04^a	75.16±0.07^a	80.05±0.04^a	80.32±0.02^a
T2	88.52±0.34	92.08±0.04^b	86.78±0.09^b	83.20±0.18^b	85.34±0.09^b	86.10±0.10^b	86.36±0.11^b	86.75±0.02^b
T3	88.52±0.34	90.50±0.45^c	83.47±0.23^a	80.32±0.03^c	80.89±0.09^c	83.54±0.04^c	83.95±0.02^c	85.55±0.04^c
T4	88.52±0.34	91.29±0.90^d	86.32±2.70^b	81.85±0.12^d	85.10±0.13^b	86.54±0.04^b	86.72±0.04^b	87.39±0.09^d
T5	88.52±0.34	89.55±0.09^e	88.07±0.06^b	85.75±0.11^e	85.09±0.03^b	86.55±0.09^b	86.62±0.09^b	86.47±0.06^b

0 represents data collected at the time of transplanting
Values shown are mean ± SD
Means with different letters down the same column represent significant differences at $p < 0.05$.

Tab. 6: Effect of organic and inorganic fertilisers on Root: shoot ratio of *Solanum nigrum* L. leaves cultivated in the greenhouse.

	Plant age (Weeks after transplanting)							
	0	3	4	5	6	7	8	9
T1	0.28±0.01	0.19±0.04^a	0.12±0.01	0.17±0.03	0.22±0.02^a	0.22±0.02^a	0.22±0.01^a	0.25±0.05^a
T2	0.28±0.01	0.08±0.02^b	0.11±0.02	0.13±0.02	0.12±0.02^b	0.15±0.02^b	0.11±0.02^b	0.12±0.02^b
T3	0.28±0.01	0.16±0.02^a	0.15±0.02	0.20±0.03	0.19±0.03^a	0.21±0.01^a	0.19±0.02^a	0.21±0.02^a
T4	0.28±0.01	0.12±0.02^b	0.12±0.04	0.17±0.03	0.18±0.02^a	0.16±0.02^b	0.12±0.04^b	0.14±0.02^b
T5	0.28±0.01	0.09±0.01^b	0.10±0.05	0.16±0.03	0.14±0.02^{ab}	0.13±0.02^b	0.12±0.04^b	0.12±0.02^b

0 represents data collected at the time of transplanting
Values shown are mean ± SD
Means with different letters down the same column represent significant differences at $p < 0.05$.

during its growth. Furthermore, a reduction in the root: shoot ratio is almost always in response to more favourable growing conditions while an increase on the other hand indicates growth of a plant in less favourable conditions (HARRIS, 1992). In the present study, the lowest ratio was recorded in 100 kg N/ha amended soil.

Leaf area

Leaf area increased until the 7th week in all the treatments and started to decrease (Tab. 7). The treatment means were significantly different ($p < 0.05$) and ranged between 2.44 cm^2 from the time of transplanting and 92.98 cm^2 in T5. The means for the trial period were highest in T5 (90.6 cm^2) and lowest in the control (48.8 cm^2). Statistical analysis showed an interaction between plant age and the fertiliser treatment on leaf area. Regression analysis with leaf area as the dependable variable and time (plant age) as the regressor showed a coefficient of determination (R^2) of 72 % indicating that plant age had a significant effect on leaf area. Flowering commenced in the 4th week and berries were first noted in the 5th week. Ripening was first observed in the 7th week and on the 9th week, all the berries on all the plants were mature and ripe.

The results of the present study are within the range reported by MUTHONI and MUSYIMI (2009). These authors reported LA of 77.42 cm^2 in *Solanum scabrum* MILL plants that were not subjected to water stress after 35 days (about 7 weeks). In the current study, after 7 weeks, the LA ranged between 53.55 and 92.98 cm^2. LA estimation is critical in plant nutrition, plant-soil-water relations, plant protection measures, plant competition, respiration, light reflectance as well as heat transfer, hence it is an important parameter in understanding water and nutrient use, photosynthesis, light interception and more importantly crop growth and yield potential (MOHSENIN, 1986; SMART 1974; WILLIAMS, 1987). Leaf morphogenesis usually includes three phases, which are an early phase of increasing photosynthetic rates and the leaf is actively expanding at this time, followed by a mature phase where such rates peak and lastly senescence where they decline (AGÜERA et al., 2012). During the early phase of growth, the leaf acts a sink, receiving nutrients, however, when it reaches its full photosynthetic capacity, it becomes the main source organ of the plant (HÖRTENSTEINER and FELLER, 2002). Senescence involves a shift from nutrient assimilation to nutrient remobilisation and recycling (GUIBOILEAU et al., 2010). In the present study application of 50 kg N/ha + 4.07 t manure/ha significantly increased LA as compared to other treatments up to the 7th week when the fruits started ripening. During the 8th and 9th week, we assume that nutrients such as N were at this time being remobilised and recycled and this led to a decline in LA. This study indicates that the plant went through all the growth phases successfully and 50 kg N/ha + 4.07 t manure/ha was the best treatment.

Chlorophyll

Treatment means were significantly different ($p < 0.05$) from the 4th week to the 6th week and ranged between 23.11 at the time of transplanting and 49.49 SPAD values in T2 (Tab. 8). The means for the duration of the trial were highest at T4 followed by T2 and least at T1. Statistical analysis showed an interaction between plant age and the fertiliser treatment on chlorophyll content. Regression analysis with chlorophyll content as the dependable variable and time (plant age) as the regressor showed a coefficient of determination (R^2) of 34.6 % indicating that plant age had a minimal effect on chlorophyll content.

Comparing the present results with similar studies conducted elsewhere, the current values are in agreement with those reported by PREHL (2010). These authors reported between 30 and 40 SPAD units in young *Solanum nigrum* plant leaves. MASINDE et al. (2009) reported higher values than the present study (between 40 and 70 SPAD units in *Solanum villosum*). In a trial conducted on the field, BVENURA and AFOLAYAN (2013) reported higher values between 23.11 and 60.34 SPAD units in *Solanum nigrum*. Different destructive and non-destructive methods of chlorophyll determination give different results. To measure the relative chlorophyll concentration in the leaves, the spectrophotometer used in this study (SPAD 502 PLUS) measures the absorbance of the leaf in two wavelengths (400-500 nm and 600-700 nm) (SPAD-502 PLUS MANUAL, 2009). Therefore, an increase in values generally indicates an increase in chlorophyll content. Various authors agree that high chlorophyll values in plant cells are an indication of high N and therefore a good nutrient status of the plant. An experiment conducted to determine N status of the leaves in the treatments revealed a trend almost similar to the chlorophyll content. The average values of N were 3.08 % (T2), 5.69 % (T2), 3.45 % (T3), 4.93 % (T4) and 5.32 % (T5) while 100 kg N/ha (T2) produced the best N content compared to other treatments and this is comparable to the chlorophyll concentration. The control recorded the lowest values indicating in both chlorophyll and N readings. High chlorophyll values and N content recorded in this study are an indication of the good health status of the plant. The highest mean value for the trial period recorded was as a result of the application of 100 kg N/ha + 8.13t manure/ha.

From this study, it can be concluded that different fertiliser dosages had different effects on the growth of *Solanum nigrum*. These results further indicate that the application of fertilisers in *Solanum nigrum* cultivation indeed improves the yield and quality of the plant while physical growth is also enhanced. More specifically, the application of 100 kg N/ha significantly boosted the total number of leaves, stem diameter and root: shoot ratio. On the other hand 100 kg N/ha + 8.13 t manure/ha significantly increased chlorophyll content and 50 kg N/ha + 4.07 t manure/ha significantly boosted moisture content, plant height and leaf area. However, the application of organic

Tab. 7: Effect of organic and inorganic fertilisers on leaf area (cm^2) of *Solanum nigrum* L. leaves cultivated in the greenhouse.

	Plant age (Weeks after transplanting)							
	0	3	4	5	6	7	8	9
T1	2.44±0.33	30.74±7.32^a	36.85±5.80^a	40.79±2.92^a	51.79±6.57^a	53.55±5.67^a	39.35±3.88^a	37.43±5.66^a
T2	2.44±0.33	62.26±8.79^b	62.73±8.36^b	68.53±8.04^b	70.61±3.45^b	78.83±13.89^b	70.52±4.88^b	68.22±9.88^b
T3	2.44±0.33	28.51±14.45^a	49.24±21.15^{ab}	50.34±18.52^{ab}	54.91±6.42^{ab}	56.85±8.72^a	45.29±8.01^a	41.50±21.26^a
T4	2.44±0.33	43.88±1.33^a	54.13±5.82^{ab}	59.77±5.05^b	62.30±11.49^{ab}	71.90±8.61^b	64.31±6.17^b	62.68±4.17^b
T5	2.44±0.33	64.54±10.70^b	65.22±10.93^b	66.24±7.52^b	73.71±14.32^b	92.98±7.93^b	90.02±25.33^b	88.48±10.90^c

0 represents data collected at the time of transplanting
Values shown are mean ± SD
Means with different letters down the same column represent significant differences at $p < 0.05$.

Tab. 8: Effect of organic and inorganic fertilisers chlorophyll content (SPAD units) of *Solanum nigrum* L. leaves cultivated in the greenhouse.

	Plant age (Weeks after transplanting)							
	0	3	4	5	6	7	8	9
T1	23.11±2.28	39.74±0.15	38.01±1.06^{ab}	39.78±3.68^{a}	38.28±3.86^{a}	32.82±3.49^{a}	24.02±1.80^{a}	23.24±1.74^{a}
T2	23.11±2.28	39.35±1.55	41.93±3.15^{a}	47.91±1.07^{b}	46.16±1.87^{ab}	37.22±3.11^{ab}	44.15±3.07^{b}	49.49±2.06^{b}
T3	23.11±2.28	39.17±2.42	35.55±0.87^{b}	36.87±0.65^{a}	38.44±3.14^{a}	38.04±1.53^{ab}	32.18±4.06^{c}	25.49±2.22^{a}
T4	23.11±2.28	38.84±3.19	40.36±0.88^{a}	48.44±2.57^{b}	47.82±2.84^{b}	40.58±5.42^{b}	40.09±4.87^{bc}	47.25±0.60^{b}
T5	23.11±2.28	36.54±1.52	40.58±0.55^{a}	45.69±2.69^{b}	40.28±1.00^{a}	43.21±1.56^{b}	41.98±1.22^{b}	46.38±3.71^{b}

0 represents data collected at the time of transplanting
Values shown are mean ± SD
Means with different letters down the same column represent significant differences at $p < 0.05$.

manure alone did not positively affect the growth of the plant. The favourable results obtained from mixing organic and inorganic fertilisers are a good indicator to poor small scale resource farmers who may not be able to purchase large amounts of fertilisers required from local dealers. Some of these farmers rear livestock in their back yards therefore making organic fertilisers readily available to them. The slow growth recorded in the control may be attributed to nutrient stress.

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