SOIL TEXTURE AND MINERALOGY INFLUENCE ON THE PRODUCTIVITY OF SELECTED TROPICAL LEGUMES

BY

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A dissertation submitted in partial fulfillment of the requirement for the degree of Master of Science in Agriculture (Soil Science) at the University of Venda

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ABSTRACT

Cowpea (*Vigna unguiculata*) and tepary bean (*Phaseolus acutifolius*) are essential legumes which provide food for many people in South Africa. However, the productivity of these major tropical legumes in Limpopo Province is low partly because of poor soil fertility and soil degradation. This study aimed to determine the productivity of tropical legumes (cowpea and tepary bean) in different soils in Limpopo Province. Two pot experiments were conducted at the University of Venda experimental farm. The experimental design was a Completely Randomized Design (CRD) arranged in a 2 × 4 factorial treatment structure replicated three times. The aim of the first experiment was to determine the effect of soil types on nodule dry weight (NDW), root dry weight (RDW) and above-ground biomass (ADB) of the legumes. Modified plastic pots (2.0 L) were used for planting the legumes. The second experiment was aimed at determining the effect of soil types on productivity variables including the number of branches per plant (NB), plant height (PHT), plant vigour (PV), number of pods per plant (NPP), number of seeds per pod (NSP), pod length (PL), pod weight per plant (PWT) and seed weight per plant (SWTP) of the two legume species. Similarly, 5.0 L plastic pots were filled with soil (4.5 kg) and used for sowing the seed of legumes. Soil type had highly significant ($P \leq 0.001$) effects on NDW, ADB and RDW of legume species. The highest NDW (0.2133 g), ADB (3.6767 g) and RDW (2.1067 g) of cowpea was observed on the Leptsols. There were no nodules in tepary bean. For tepary bean, the highest ADB (1.6933 g) was observed in Leptsols whereas, the highest RDW (0.7433 g) was observed in Luvisols. In the second experiment, the results showed highly significant ($P \leq 0.001$) effects of Luvisols, Leptsols, Ferralsols and Fluvisols on PHT, NB, NPP, PWT, SWTP and PV. However, soil type had no significant ($P > 0.05$) effects on PL and NSP. Leptsols was the most productive soil type for cowpea in all the measured parameters when compared to other soil types. The results in both experiments could be attributed due to variations in soil properties. It was concluded that Leptsols is the most productive soil for cowpea. However, field experiments are recommended to validate the results.

Keywords: *biomass; legume; nodule; pod; soil mineralogy; soil types.*

DEDICATION

I dedicate this work to my parents, Mr James Hlengani Mashaba and Mrs Rhulani Dorries Mashaba and my siblings Rito Sibusiso Mashaba, Yolonda Mashaba, Nkateko Mashaba and Hlamulo Mashaba.

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DECLARATION

I, Laster Themba Mashaba, student number: 11639842, hereby declare that this research project report for Master of Science in Agriculture (Soil Science) entitled “Soil Texture and Mineralogy Influence on Productivity of Selected Tropical Legumes” submitted to the Department of Soil Science, School of Agriculture, at the University of Venda has not been submitted previously for any degree at this or another university. It is original in design and in execution, and all reference material contained therein has been duly acknowledged.

Student: Mr. L.T. Mashaba

………… ………… ……… 04/10/2021………

Signature Date

As the supervisor / co-supervisor of the candidate, we agree with the submission of this dissertation.

Supervisor: Prof. I.I.C. Wakindiki

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LIST OF SYMBOLS

B =	Boron
Ca =	Calcium
Cu =	Copper
Fe =	Iron
$FeSO_4$ =	ferrous Sulphate
K =	Potassium
$K_2Cr_2O_7$ =	Potassium dichromate
Mg =	Magnesium
Mn =	Manganese
N =	Nitrogen
Na =	Sodium
NO_3-N =	Nitrate nitrogen
NO_4-N =	Ammonium nitrogen
P =	Phosphorus
S =	Sulfur
Zn =	Zinc
C =	Carbon

LIST OF ABBREVIATIONS

AAS =	Atomic absorption spectrometry
ANOVA =	Analysis of Variance
C.V. =	Coefficient of variation
CRD =	Completely randomized design
DAB =	Dry above ground biomass
DAP =	Days after planting
HCL =	Hallow cathode lamp
NB =	Number of branches
NDW =	Nodule dry weight
NPP =	Number of pods per plant
NSP =	Number of seed per pod
PHT =	Plant height
PL =	Pod length
POM =	Particulate organic matter
PV =	Plant vigour
PWP =	Pod weight per plant
RDW =	Root dry weight
SOC =	Soil organic Carbon
SOM =	Soil organic matter
SWP =	Seed weight per plant

1.0 CHAPTER ONE: INTRODUCTION

1.1 Background

Tropical legumes such as cowpea (*Vigna unguiculata*) and tepary bean (*Phaseolus acutifolius*) are regarded as essential legumes, which provide food for many people around the world in the tropical and subtropical regions. Cowpea is cultivated for edible leaves and seeds, whereas tepary bean is commonly cultivated for edible seed. According to Gwata et al. (2016), both tepary bean and cowpea grain provide affordable sources of protein for human consumption and are valuable for income generation for growers. Furthermore, legume seed provide valuable amount of carbohydrates and fibre, which play a vital role in human diet and animal feed (Sanchez-Chino et al., 2015). Cowpea seed contains 25% protein (Annor et al., 2010) whilst tepary bean grains contain about 24% protein (Bhardwaj and Hamama, 2005).

According to DAFF (2014), there are no records on the size of area under cowpea (*Vigna unguiculata*) production and the quantities produced in South Africa. However, the production of cowpea worldwide is 3 million tons on 12,5 ha of which, 64% of cowpea seeds harvested annually is produced in West and Central Africa (DAFF, 2014). According to Masunda and Goldsmith (2009), estimated that 3.3 million tons of cowpea grain were produced in 2000 of which, more than 8 million hectares are grown in West and Central Africa, where Nigeria was the largest producer with 4 million hectares followed by Niger.

Cowpea is well adapted to drought and performs well in hot, arid, and semi-arid areas (Dugje et al., 2009). Similarly, tepary bean is highly tolerant to heat and drought stress (Narina et al., 2015). Consequently, legumes can be cultivated in soils with deficiency in nitrogen because of their self-sufficient in nitrogen due to their ability to fix atmospheric nitrogen through symbiotic relationship with soil bacteria such as rhizobium

(Kanwarkamla, 2000). However, growers apply chemical fertilizers in the soil to increase productivity of legumes. However, the application of nitrogen fertilizer reduces the number of nodules whereas the application of phosphorus fertilizer increases the growth and yield of legumes (Abdul-Latif, 2013) and the number of nodules per plant (Amba et al., 2013).

Despite the significant effects of both cowpea and tepary bean on the fertility of soils, human consumption and animal feeds, their productivity is generally low particularly in degraded soils. Many soil factors such as soil type, farmer's practices, crop residues and mineral fertilizer management influence crop yield (Eugène et al., 2010). In addition, soil texture and chemical composition of soil remain major limitations to crop production in large scale in tropical regions of Africa (Eugène et al., 2010).

Nonetheless, soil fertility depends on the soil colloidal properties. Therefore, soil texture especially its clay content and mineralogy influence not only the soil fertility but the entire soil behavior (Brady and Weil, 2013). Therefore, soil texture could affect the productivity of grain legumes (Nyabyenda, 2005). Ibijbijen et al. (1996) reported that plant growth is affected by low phosphorus availability in many soils as a result of P fixation by Fe, Ca and Al, which leads to formation of inorganic phosphates that are insoluble in soil.

Soil factors such as soil mineralogy influence chemical and physical properties of soil due to the differences in surface area and charge of minerals (Wakindiki and Chinedu, 2016), which may, in return, affect the productivity of cowpea and tepary bean. For, example upland well-drained kaolinitic soils had higher soil organic content when compared to poorly drained low-land montmorrillonic vertisols in Mozambique (Wattel-Koekkoek and Buurman, 2004). Soil mineralogy also affects the aggregates stability of soil. Wakindiki and Ben Hur (2002) found that montmorillonic soil had lower aggregate stability than kaolinitic soil due to greater dispersivity of montmorillonite.

According to Eugène et al. (2010) reported that the plot with the highest percentage of sand (71.80%), the lowest percentage of clay (21.00%) and silt (7.20%) and with the highest amount of organic matter (10.26%), exchange potassium (0.36 g Kg-1), calcium (0.49 g Kg-1) and magnesium (0.46 g Kg-1) increased significantly the grow parameters of cowpea such as dry weight aerial parts, roots dry weight, number of flowering per plant and the flowering rate. Likewise, productivity of tropical legumes is associated with the physiochemical properties of various soil types.

1.2 Problem statement

Farmers in many parts of Limpopo province grow tropical legumes such as cowpea and tepary bean in different soil types. However, the productivity of these tropical legumes in Limpopo province are on the decline partly because of poor soil fertility and soil degradation. However, advances have been made on the nutritional requirements of these legumes but little evidence is available regarding the effect of soil types on their productivity. Therefore, low productivity affect growers by reducing their income. Farmers also fail to meet the food demand of the growing population because of the low productivity in their farms. Moreover, the productivity of both legumes in the various soil types has not been determined exhaustively. Therefore, there is a need to find out which soil type will result in higher productivity of each legumes.

1.3 Justification of the study

Determination of the productivity of selected tropical legumes in degraded soils in Limpopo province with deficiency in essential plant nutrients is necessary for identifying the soil types that provide optimum productivity of cowpea and tepary bean. Moreover, the project will also help the growers to increase their income by obtaining optimum productivity of legumes. In addition, growers will also be able to meet the food demand of the increasing population. Consequently, the project will also benefit researchers and growers by providing valuable information regarding the productivity of tropical legumes on different soil types.

1.4 Aim and Objectives of the study

The aim of the study was to assess the effects of soil types on the productivity of tropical legumes. The specific objectives of the study were to determine:

(i) The effect of soil types on nodulation parameters (above-ground plant biomass, nodule, and root dry weight) among cowpea and tepary and

(ii) The effect of soil types on productivity variables among cowpea and tepary bean.

1.5 Hypotheses

The study tested the following hypotheses:

(i) The effect of soil types on nodulation parameters (above-ground plant biomass, nodule, and root dry weight) were similar among cowpea and tepary bean.

(ii) The effect of soil types on productivity variables were similar among cowpea and tepary bean.

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 Productivity of tropical legumes

A report by IITA (2009) revealed that, more than 5.4 million tons of dry cowpeas are produced worldwide, with Africa producing nearly 5.2 million. Nigeria, the largest producer and consumer, accounts for 61% of production in Africa and 58% worldwide. Moreover, with 2.1 million tones, Nigeria is the largest producer worldwide, followed by Niger with 65 0000 tones and Mali with 110 000 tones (IITA, 2003). However, 64% of the area under cowpea is grown in central and east Africa (Singh et al., 2011). Singh et. (2011) concluded that application of 60 kg P_2O_5 /ha could be recommended for higher yield of cowpea (1.4 t /ha) relative to 0 kg P_2O_5 /ha that yielded 1.0 t /ha.

The yield efficiency (the ratio of yield to crop water requirement) of soybean in Ultisol was higher under deficit irrigation of 30 % of available water deficit, whereas in Latosol the yield efficiency of soybean was high under full irrigation (Rosadi et al., 2007). However, under Sandy loam the highest grain yield of cowpea was obtained in variety IT99K-573-1-1 while application of phosphorus fertilizer at 30 kg/ha produced highest grain yield of cowpea (Mawo et al., 2016). In addition, cowpea variety IT99K-573-2-1 showed the highest value in all the yield parameters measured at phosphorus application rate of 40 kg/ha under Sandy loam (Nkaa et al., 2014). The average yields of dry beans under dryland conditions are 350 – 700 Ib/ac and yields with supplemental irrigation are 800 – 1500 Ib/ac (Wolf, 2018).

2.2 Soil texture influence on productivity of tropical legumes

A study that was conducted by Amir-Ahmadi et al. (2017) showed that Clay loam was not a suitable soil type for the cultivation of kidney bean, but the plant grew better in sandy loam and loam soil. Soil texture affects the soil structure, water holding capacity, susceptibility to erosion, organic matter content, cation exchange capacity (CEC), and pH buffering capacity, bulk density, and soil porosity (Hristov, 2013). Clay is rich in nutrients because of high surface area and charges which give it capacity to attract plants nutrients ions to its surface in forms which is available to plants. Consequently, soil properties which are attributed by soil texture play essential role on the growth and productivity of plants.

Soil texture affects the population of microorganisms in the soil which play essential role in the decomposition of plant residues and nutrients transformation which are required by plants. In the sandy loam and silty loam soils, the lowest level of bacterial populations was detected when compared to clay loam and silty clay loam soil (Hamarashid et al., 2010).

The results showed that the plot with the highest percentage of sand (71.80%), the lowest percentage of clay (21.00%) and silt (7.20%) and with the highest amount of organic matter (10.26%), exchange potassium (0.36 g/Kg), calcium (0.49 g/Kg) and magnesium (0.46 g/Kg) increased significantly ($P < 0.05$) the productivity and yield of cowpea (Eugene et al., 2010). However, sandy soil promotes vegetative growth of marama bean (*Tylosemaesculentum*) (Travlos and Karamanos, 2006). This is due to good aeration and drainage of sandy soil which is vital for tuber growth of marama bean. However, in the sandy clay loam the application of cattle manure led to an increment on shoot dry weight of soya bean (Mahmoodabadi, 2014). Consequently, there were significant differences in plant dry weight of cowpea (*Vignaunguiculata* L.) among the clay loam, sandy clay loam and sandy loam (Al-Saedi et al., 2016). In sandy loam total above ground dry matter, plant height, number of leaves, leaf area, and number of branches of cowpea were improved by application of phosphorus (Nkaa et al., 2014). Moreover, kidney beans grew better in sandy loam and loam sand when compared to clay loam (Amir-Ahmadi, 2017).

2.3 Soil minerology influence on productivity of tropical legumes

There is a dearth of information regarding the impact of soil mineralogy on the productivity of tropical legumes. However, mineralogy influences the physical and chemical and physical properties of soil which may affect plant growth. According to Brady and Weil (2013) soils dominated by 1:1 silicate clay displays less plasticity, stickiness, cohesion, shrinkage, and swelling and hold less amount of water, but with proper nutrients management it can be productive (Brady and Weil, 2013). Soils dominated by 2:1 silicate clay (montmorillonite) display high plasticity, cohesion, stickiness and hold high amount of water which may influence nutrients uptake by plants (Brady and Weil, 2013).

2.4 Growth vigour of tropical legumes

The shoot dry weight of cowpea was greater in soil amended with Tennery Sludge Compost (TSC) at 45 days after emergence than in unamended soil and the nodule dry weight increases with the increase of TSC application rates in sandy soil (Santos et al., 2011). Soybean grain yield was higher under rhizobium inoculation compared to inoculated treatments under brown moderately drained sandy loam (Lamptey et al., 2014). However, inorganic fertilizer and rhizobium inoculation showed a significant effect on the grain yield of tepary bean (Jiri et al., 2017).

2.5 Nitrogen fixation by tropical legumes

Nitrogen is one of the macro elements required by plants for optimum growth. However, there is abundance of nitrogen in the earth's atmosphere in the form of dinitrogen, which is relatively inert. Furthermore, we have three common forms of nitrogen fixation which include atmospheric, biological, and industrial nitrogen fixation. Therefore, for plants to be able to use this nitrogen it must be fixed into more biologically accessible forms. Consequently, biological nitrogen fixation is a process whereby atmospheric nitrogen gas is converted into ammonia and then to nitrogen containing organic compounds that can become available to plants (Ferreira de Araújo et al., 2008). All organisms form Amino acids, proteins, and other nitrogen containing compounds from Ammonia (Bano and Igbal, 2016).

The amount of atmospheric nitrogen fixed by legumes varies depending on the types of legume. According to Belane and Dakora (2010) the amount of nitrogen fixed by field grown cowpea was 49 – 178 kg N/ha in 2005 and 62- 198 kg N/ha in 2006 under Ferric Lixisols and Luvisols. The amount of nitrogen fixed by soybean ranged between 52.3 to 71 kg/ha under Loamy sand and the soybean N-derived from the atmosphere ranged between 42.51 and 49.89 percent (Abdul-Latif, 2013). Tepary bean also increases the nitrogen status of soil in tropical regions which correlates with the amount of atmospheric nitrogen fixed by the plant. The amount nitrogen fixed by pigeon pea was 85.7 kg N/ha in Chromic Luvisols as described by Njira et al. (2017).

There are many factors which affect Biological Nitrogen Fixation (BNF). These factors include phosphorus deficiency, excessive soil moisture, and deficiency of certain minerals, drought, soil acidity, excessive minerals, extreme temperature and light conditions and high temperature, which results in a failure of Biological Nitrogen Fixation (Bano and Igbal, 2016). The authors further explained that insects and nematodes also affect the nodules formation, development, and function, which in return will affect biological nitrogen fixation.

Nodulation is a symbiosis between plants and bacteria called rhizobia which leads to the formation of a lateral organ called a nodule where nitrogen fixation occurs (Guan, 2012). Therefore, plants which are widely known for formation of nodules in their roots are legumes such as cowpea, tepary bean, soyabean, groundnuts, Bambara groundnuts, field pea, chickpea, lentil, and dry bean. However, there are many soil factors which affect nodulation of legumes. According to Somasegaran (1994) nodule size and shape can differ from one plant species to another. Nodules can be classified into two groups in the form of active and inactive. Actively N-fixing nodules contain a pigmented protein called leghaemoglobin, which its presence results in a red coloration of the interior of nodules, indicating that the bacteria are alive and active (Somasegaran, 1994). Moreover, dead, inactive, and senescent nodules are usually greyish green or brown inside.

2.6 Grain quality of tropical legumes

The protein concentration of soybean was enhanced with increased phosphorus application rates, whereas the oil levels decreased with increased phosphorus application rates (Yin et al., 2016). Application of nitrogen fertilizer at the rate of 179 kg/ha on clay soil reduced the protein content of soybean by 1.05%, whereas the application of nitrogen fertilizer at 179 kg/ha increased the oil content of soybean by 0.7% under clay soil (Kaur et al., 2017). According to Bhardwaj and Hamama (2005) the seeds of tepary contained 1.8% oil as compared to literature value of 1.3%, 1.1%, and 1.1% for navy, kidney, and pinto beans. However, the seeds oil of tepary bean contained 33% saturated, 67% unsaturated, 24% monounsaturated, and 42% polyunsaturated fatty acids. Consequently, under sandy loam the protein content of cowpea (Pan 311) varied between 9.3 and 9.4 %, and between 9.9 and 12.3% for Red Caloona (cowpea) during both planting seasons (Sebetha, 2010).

3.0 CHAPTER THREE: MATERIALS AND METHODS

3.1 Study location

A pot experiment was conducted in a tunnel at the University of Venda experimental farm. The University of Venda is located 2 km west of Thohoyandou at Thulamela Municipality under Vhembe district in Limpopo province, South Africa. The site is at latitude 22° 58.08'S and longitude 30°26.4' E. The altitude of the area is 596 m above sea level and receives annual rainfall of approximately ±500 mm with average minimum and maximum temperature of 18°C and 31°C (Mzezewa and Van Ransburg, 2011).

3.2 Soils

Four soil types were used in the experiment. The soil types are presented as soil form according to the Soil Classification Working Group (1991). The equivalent soil types according to Food and Agricultural Organization (FAO) are presented in the brackets (WRB, 2016). The name of the soil types used in the study were obtained from the ARC-Institute for Soil, Climate and Water. The soil types are described as follows:

Glenrosa (Leptsols)

The Leptsols were collected at Ha-Davhana Village. The area is at latitude 23˚13'09''S and longitude 30˚27'25''E. The soil is characterized by Orthic A horizon overlying Lithocutanic B horizon. The soils have a very shallow profile depth and contain large amount of gravel.

Shortlands (Luvisols)

The Luvisols was collected at Mukula Village, which falls at a latitude of 22˚51’13” S and a longitude of 30˚34’44’’E. The Shortlands form consist of Orthic A horizon overlying the Red Structured B horizon. Luvisols are fertile and widely used for agriculture. They are also characterized by the translocations of clay sized mineral particles from the A to the B horizon.

Hutton (Ferralsols)

The Ferralsols was collected at University of Venda Experimental farm, which lies at the latitude, longitude and altitude stated at 3.1. The Hutton form consist of Orthic A horizon overlying Red Apedal B horizon. The soils are red and yellow in color, due to metal oxide such as Iron and Aluminum which dominate the soil. They have low soil fertility because of leaching of metal nutrients and require addition of lime and fertilizer if they must be used for agriculture.

Dundee (Fluvisols)

The Fluvisols was collected outside University of Venda at Tshamutore village which falls at a latitude of 22˚37’30” Sand a longitude of 30˚40’32” E. The Dundee form consist of Orthic A horizon overlying Stratified Alluvium. The soil displays stratified profile that reflect their depositional history. The soils are found in alluvial plains, rivers fans and valleys.

3.3 Soil sampling and preparation

The composite soil samples for experiment 1 and 2 were randomly collected from each farm at depth of 0 - 20 cm. Four samples, each 20,5 kg, were collected within a radius of 30 m from a representative profile from each site to avoid significant spatial variability of soil physical and chemical properties. The soil samples were air-dried, ground, and sieved using a 2 mm sieve before planting and analyzing for some selected chemical and physical properties using standard laboratory procedures.

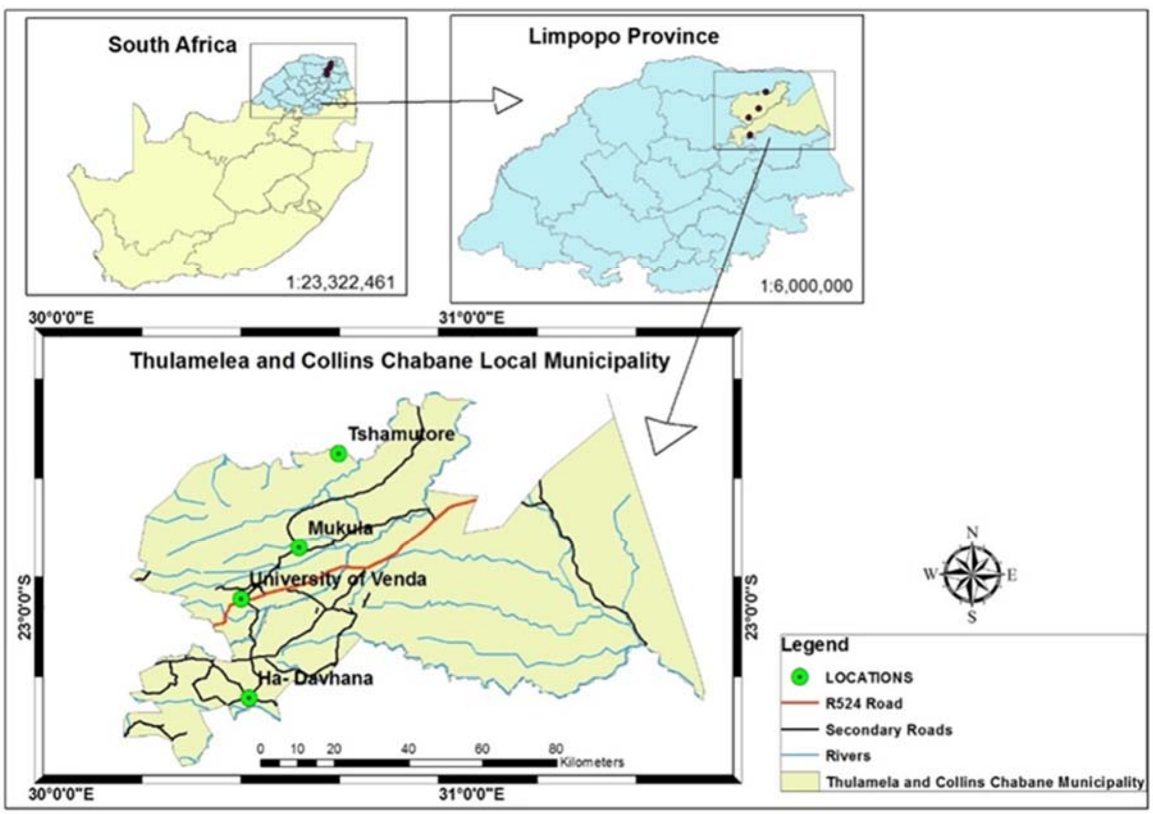

Figure 3.1: A map of soil sampling sites

Figure 3.2: Air-dried soil sample

3.4 Soil characterization

3.4.1 Soil texture

Soil particle size distribution was determined using the hydrometer method (Gee and Or, 2002). Hydrogen peroxide was used to oxidize organic matter, remove iron oxide, carbonates and soluble salts in the soil that bind the soil particles together. Sodium Hexametaphosphate was used for chemical dispersion.

3.4.2 Soil minerology

Soil mineralogy was determined by the Rietveld method for X-ray diffraction quantitative analysis (Zabala et al., 2007). Therefore, after milling, the samples were prepared using the back-loading method. Soil was analyzed with PANalyticalX'Pert PRO powder diffractometer with an X'celerator detector and variable divergence and fixed receiving slits with Fe-filtered Co-Kα radiation. The phases were identified using X'PertHigh Score Plus software. The relative phase amounts (weights %) was then estimated using the Rietveld method (Nciizah and Wakindiki, 2012).

3.4.3 Cation Exchange Capacity, Exchangeable Cations, Phosphorus, soil pH and Sulfur

Cation exchange capacity (CEC), exchangeable cations (Na^{2+}, Mg^{2+}, K^{+} and Ca^{2+}) and S were determined using the ammonium acetate extraction procedure (Peech, 1965). The soil sample was extracted using 1 M of ammonium acetate solution at pH 7. 00.

Nitrogen was determined using the Kjeldahl method (Bremmer and Mulvaney, 1982). The method involves digestion of sample in sulphuric acid with catalyst, which include anhydrous sodium sulfate and selenium tablet. Phosphorus was extracted using Bray 1

Method as described by Bray and Kurtz (1945). The absorbance of the compound was measured at 882 nm in spectrophotometer and it is directly proportional to the amount of phosphorus extracted from the soil. The soil pH was determined using pH meter in a 1:2,5 soil: water ratio as described by Peech (1965).

3.4.4 Determination of copper, iron, zinc, manganese, and boron

Copper (Cu), iron (Fe), zinc (Zn) and manganese (Mn) were determined using the Atomic Absorption Spectrometry as described by Helaluddin et al., (2016). The method measures the concentration of the element by passing light in specific wavelength emitted by a radiation source of a particular element through cloud of atoms from a sample. Consequently, atoms will absorb light from an energy source known as hollow cathode lamp. The reduction in the amount of light intensity reaching the detector is seen as a measure for the concentration of element in the original sample.

Boron was determined using the hot water extraction method as described by Gupta and Hettiarachchi (1993). The method involves the boiling of soil-water-charcoal or water-charcoal mixtures for 5 minutes on hot plate. The loss in weight due to boiling was made by adding deionized water and the mixture was filtered while still hot through a Whatman no.42 and it can also be filtered using equivalent type of filter paper.

3.4.5 Soil organic carbon

SOC was determined using Walkley-Black method as described by Rowell and Coetzee (2003). The titration was done using ferrous ammonium sulphate. The amount of SOC was calculated using the equation below.

From the equation:

$$2Cr_2O_7^{2-} + 3C + 16H^+ \rightarrow 4Cr^{3+} + 8H_2O + 3CO_2\uparrow$$

1 mL of 1 N Dichromate solution is equivalent to 3 mg of carbon.

Where the quality and normality of the acid/dichromate mixture used are as stated in the method, the percentage carbon is determined from the following:

Organic Carbon (%) = (0.003 g ×N ×10 mL (1- T/S) ×100)/ODW

= (3 (1- T/S)/ODW

Where

N = Normality of $K_2Cr_2O_7$ solution

T = Volume of $FeSO_4$ used in sample titration (mL)

S = Volume of $FeSO_4$ used in blank titration (mL)

ODW = Oven-dry sample weight (g)

3.5 Experimental setup

Two separate experiments were conducted in this study. The same soil types were used for both experiment #1 and experiment 2. However, only the quantity of soil used in each experiment were different. In experiment 1 the quantity of soil used from each site was 4.5 kg while in experiment 2 it was 15 kg. Moreover, about 1.0 kg of soil was used for analysis of soil properties from each site.

3.5.1 Experiment 1: Evaluation of the effect of soil types on above-ground plant biomass, nodule, and root dry weight among two selected tropical legumes

This component of the study was conducted as a separate experiment partly because of the necessity for the destructive evaluation method of the root nodulation parameters as described below. Similar previous studies used the destructive evaluation method successfully (Purcell et al., 1997; Ikeda, 1999; Gwata et al., 2004).

3.5.1.1 Planting and data collection

A 4.5 kg sample of the sieved soil was divided into 3 portions of 1.5 kg each and filled into plastic pots (approximately 1.5 L) (Fig. 3.3). Each plastic pot was formed and modified by removing the top 15.0 cm of 2.0 L plastic bottle and perforating the base (to create equidistantly positioned four x 5.0 mm holes for aeration). Therefore, the resulting volume ($V = \pi r^2 h$) of each modified plastic pot was approximately 1.57 L. two seeds of each legume were planted per plastic pot filled with soil (1.25 kg). Irrigation and weeding were done manually when necessary.

The three nodulation parameters namely the above ground dry biomass (ADB), nodule dry weight (NDW) and root dry weight (RDW), were evaluated at 49 days after planting (DAP). Prior to harvesting the nodules, the plants were watered up to saturation point followed by careful uprooting and washing the roots gently with tap water. The nodules were harvested from each plant into labeled brown paper bags and oven dried at 65 °C for 48 hours and allowed to cool down before weighing on a scale with a 0.001 g sensitivity to obtain the NDW. The NDW was used as one of the indicators for nitrogen fixation capacity as described by Sinclair (1991).

The ADB was obtained firstly by harvesting the fresh above-ground biomass (stem, braches and leaves) per individual plant (into a labelled brown paper bag) followed by oven-drying at 65 °C for 48 hours prior to weighing. Similarly, the roots per plant were excised and collected into a labelled brown paper bag prior to drying in an oven at 65 °C for 48 hours and weighed thereafter to obtain the RDW.

3.5.1.2 Experimental design and data analysis

The experimental design was a completely randomized design (CRD) arranged in a 2 x 4 factorial experiment replicated three times. The data sets of each parameter was subjected to Analysis of Variance (ANOVA) in Statistix 10.0. The significant differences between soil types and legumes were compared using Tukey’s test at probability level of 0.05.

Figure 3.3: Evaluation of root nodulation parameters of tepary bean and cowpea plants in different soil types using modified plastic pots.

3.5.2 Experiment 2: Evaluation of the effect of soil types on the productivity variables among two selected tropical legumes

3.5.2.1 Planting and data collection

Each of the sieved 15.0 kg soil sample was divided into 3 portions of 5.0 kg each of which 4.5 kg was used subsequently for filling 5.0 L pots (Fig. 3.4). Phosphorus was applied as Super Phosphate to the pots at planting at the rate of 40 kg P_2O_5 / ha. Five seeds of each legume were planted on each pot and subsequently thinned down to two plants per pot. The irrigation and weeding were done manually when necessary.

The plant height (PHT) was measured at maturity (using a measuring tape), starting from the ground level of the apex of each plant. The average PHT for each pot was calculated. Plant vigour (PV) was recorded at 16 DAP (days after planting). Plant vigour were observed based and ranged according to the following scale: 1 = poor, 2 = slightly poor, 3 = moderately, 4 = good, 5 = very good. The number of branches per plant (NB) were counted at maturity and the average NB for each pot was calculated. Similarly, the number of pods per plant (NPP) was determined by manually counting the pod load on each plant at maturity. From each plant, at least two pods were randomly selected and air-dried to constant weight prior to weighing in order to determine the pod weight per plant (PWT). Similarly, the pod length (PL) and number of seeds per pod (NSP) were measured (with a ruler) and counted, respectively. Finally, all the pods from each plant were shelled and the seed bulked before weighing to determine the seed weight per plant (SWTP).

3.5.2.2 Experimental design and data analysis

The experimental design was 2 x 4 factorial experiment arranged in a CRD replicated three times. Similarly, the data sets of each variable were subjected to ANOVA in Statistix 10.0, followed by mean separation using Tukey's test at the 5.0% probability level.

Figure 3.4: Evaluation of productivity attributes of tepary bean and cowpea plants in different soil types using 5.0 L pots.

4.0 CHAPTER FOUR: RESULTS

4.1 Soil properties

The textural analysis showed four textural classes, which included clay (Ferralsols), loamy sand (Leptsols), loam (Luvisols) and sand (Fluvisols). The available phosphorus ranged between 2.00 and 8.00 mg/kg with the highest in Glenrosa (Table 4.1). The Ferralsols contained the highest proportion of clay (50.00%) than all the other soil types while both the Leptsols and Fluvisols contained >80.00% sand. In addition, Fluvisols contained the least proportion of silt (2.00%) (Table 4.1). Quartz was the dominant mineral ranging from 22.70 % to 98.35 %. Both actinolite and talc were absent from Ferralsols, Luvisols and Fluvisols (Table 4.2). However, smectite was present only in the Luvisols. In contrast, Fluvisols contained only hematite, kaolinite, and quartz (Table 4.2). On the other hand, microline (24.00%) was markedly present in Leptsols but absent from both Ferralsols and Fluvisols.

Table 4.1: Physiochemical properties of four different soil types that were used in the study.

Chemical properties	**Ferralsols**	**Leptsols**	**Luvisols**	**Fluvisols**
pH (water)	6.18	6.29	5.52	4.55
P Bray 1 (mg/kg)	3.50	8.00	2.00	3.50
Na (mg/kg)	2004.50	38.50	45.00	24.00
K (mg/kg)	73.50	106.50	70.50	23.50
Ca (mg/kg)	1024.50	497.00	1932.00	339.00
Mg (mg/kg)	255.50	181.50	495.00	89.50
CEC (Cmol /kg soil)	16.15	4.40	14.10	3.15
S (mg/kg)	27.94	4.03	17.00	5.64
Cu (mg/kg)	9.63	1.11	8.88	0.29
Fe (mg/kg)	5.48	2.18	6.12	8.51
Mn (mg/kg)	95.81	16.26	54.29	1.55
Zn (mg/kg)	2.05	1.74	1.68	0.24
B (water)	0.06	0.15	0.19	0.08
C (mg/kg)	0.85	0.45	1.10	0.45
NO_3-N (mg/kg)	36.72	12.30	15.06	13.32
NH_4-N (mg/kg)	25.30	22.32	33.17	26.02
Physical properties				
Clay%	50.00	8.00	24.00	6.00
Sand%	27.00	81.50	37.00	92.00
Silt%	23.00	10.50	39.00	2.00
Textural class	Clay	Loamy Sand	Loam	Sand

Table 4.2: Clay mineralogy content of four different soil types that were used in the study.

	Soil mineralogy (%)								
Soil types	Q	H	A	K	Mi	P	Ac	T	S
Ferralsols	22.70	8.15	1.35	67.75	0.00	0.00	0.00	0.00	0.00
Leptsols	40.80	0.00	0.00	0.00	24.00	31.50	3.40	0.25	0.00
Luvisols	25.85	3.35	1.10	65.30	0.10	0.55	0.00	0.00	3.80
Fluvisols	98.35	0.35	0.00	1.35	0.00	0.00	0.00	0.00	0.00

A= anatase, Ac = actinolite, H = aematite, K = kaolinite, Mi = microline, P = plagioclase, Q = quartz, S = smectite, T= talc

4.2 The effect of soil type and legume species on nodulation parameters

A variable number of root nodules developed on most of the plants (Fig. 4.1a). However, the leaves of tepary bean plants were mainly chlorotic indicating either the absence of root nodules or presence of ineffective nodules and hence no nitrogen fixation (Fig.4.1 (b)).

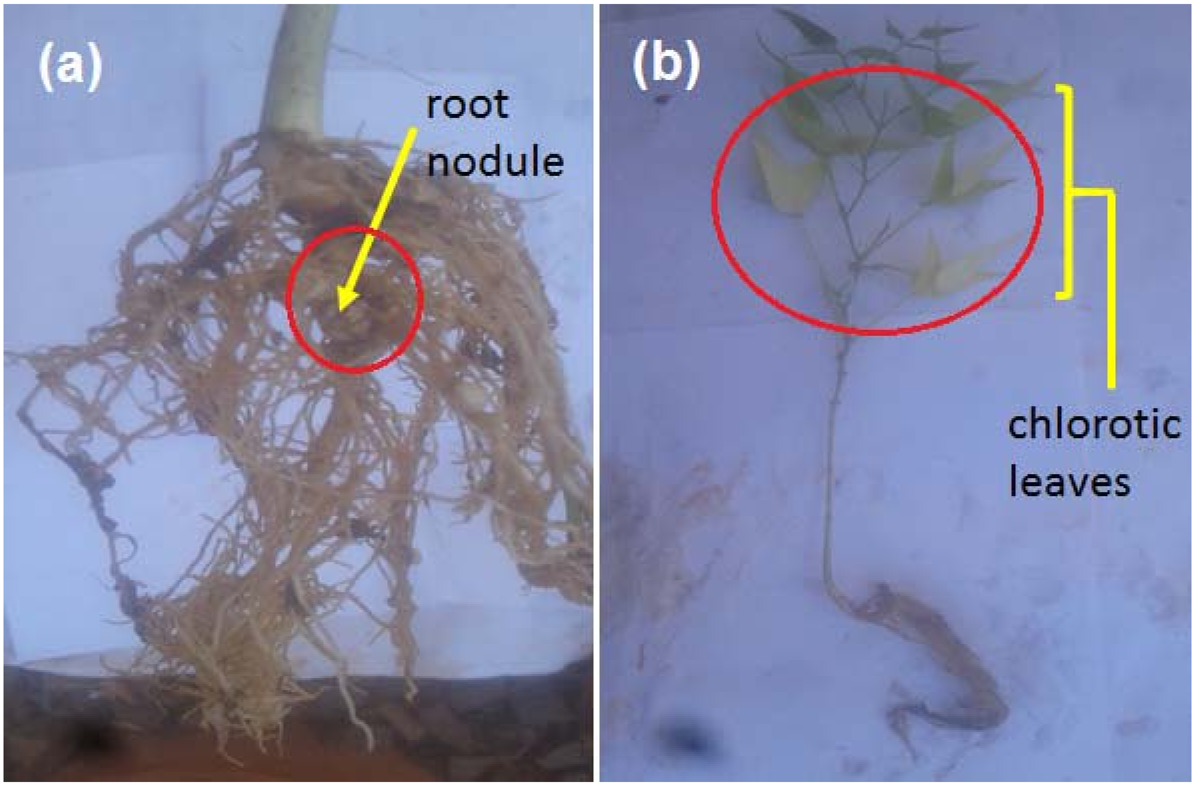

Figure 4.1: (a) A nodulated cowpea root crown and (b) chlorotic leaves on a tepary bean plant.

There were highly significant (P≤0.001) differences due to soil types on all the three nodulation parameters (NDW, ADB and RDW) among the legume species (Table 4.3). A similar pattern on the same attributes was observed on legume species (LS), soil type (ST) as well as the ST x LS interaction (Table 4.3). The heaviest nodules (0.11 g) and roots (1.36 g) were observed for the Leptsols (Table 4.4). In comparison with the Luvisols, the Leptsols produced more than two-fold ADB (Table 4.4).

Table 4.3: Mean squares for three nodulation parameters of two legume species that were raised in distinct soil types

Source	df	NDW (g)	ADB (g)	RDW (g)
Replicate	2	0.00158	0.52613	0.03355
Soil Type (ST)	3	0.01279***	6.34409***	1.04187***
Legume Species (LS)	1	0.03527***	4.0755***	2.34375***
ST x LS	3	0.01279***	1.08267***	0.53792***

*** = significant at the 0.001 probability levels.

NDW = nodule dry weight; ADB = above-ground dry biomass; RDW = root dry weight.

Table 4.4: The main effect of soil types on three nodulation parameters of two legume species that were raised in distinct soil types

Soil type	Nodulation parameter		
	NDW (g)	ADB (g)	RDW (g)
Leptsols	0.12 a	2.68 a	1.36 a
Luvisols	0.02 b	0.94 b	0.96 ab
Fluvisols	0.02 b	0.42 c	0.39 c
Ferralsols	0.01 b	0.66 bc	0.84 bc
Grand Mean	0.04	1.18	0.84
C.V.	75.66	21.34	32.01

Means followed by the same letter in a column are not significantly different (P≤ 0.05) (Tukey's test).

NDW = nodule dry weight; ADB = above-ground dry biomass; RDW = root dry weight

C.V. = coefficient of variation

Overall, cowpea produced more ADB irrespective of the soil type in comparison with tepary bean (Fig. 4.2). For each of the two legumes, the Leptsols and the Fluvisols produced the highest and lowest ADB, respectively (Fig. 4.2). In addition, cowpea produced relatively more root weight than tepary bean in all the soil types that were used in the study (Fig. 4.3). The lightest roots for both legumes were observed in Fluvisols.

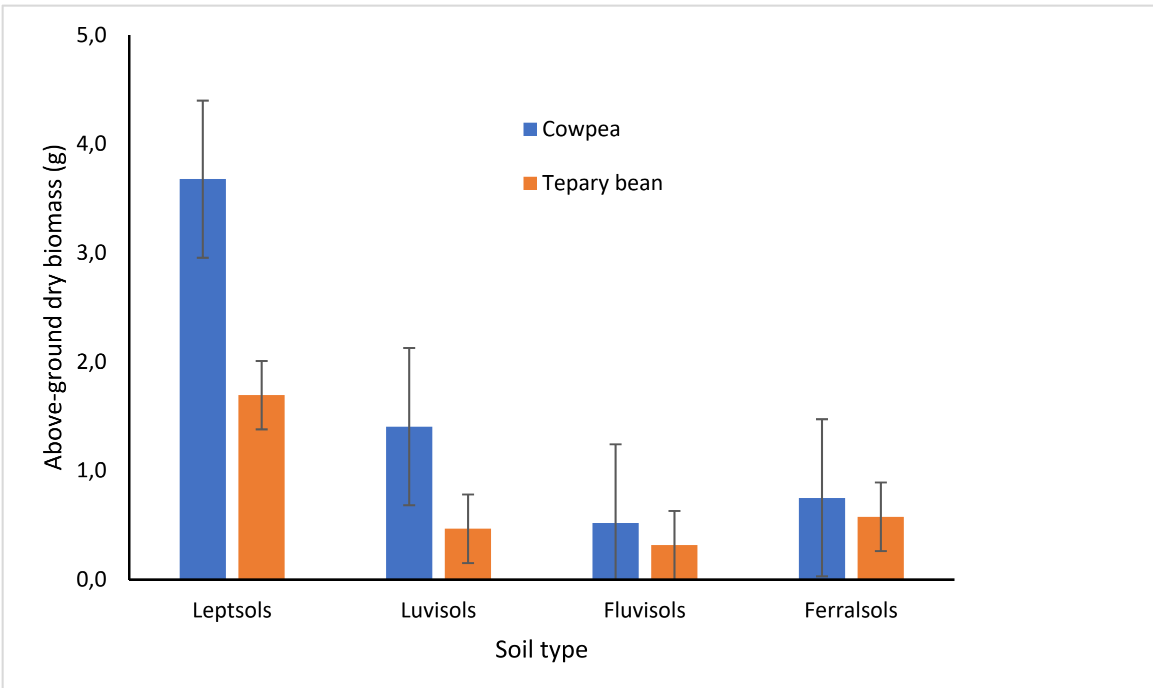

Figure 4.2: Above-ground dry biomass of two tropical legumes that were raised under different soil types

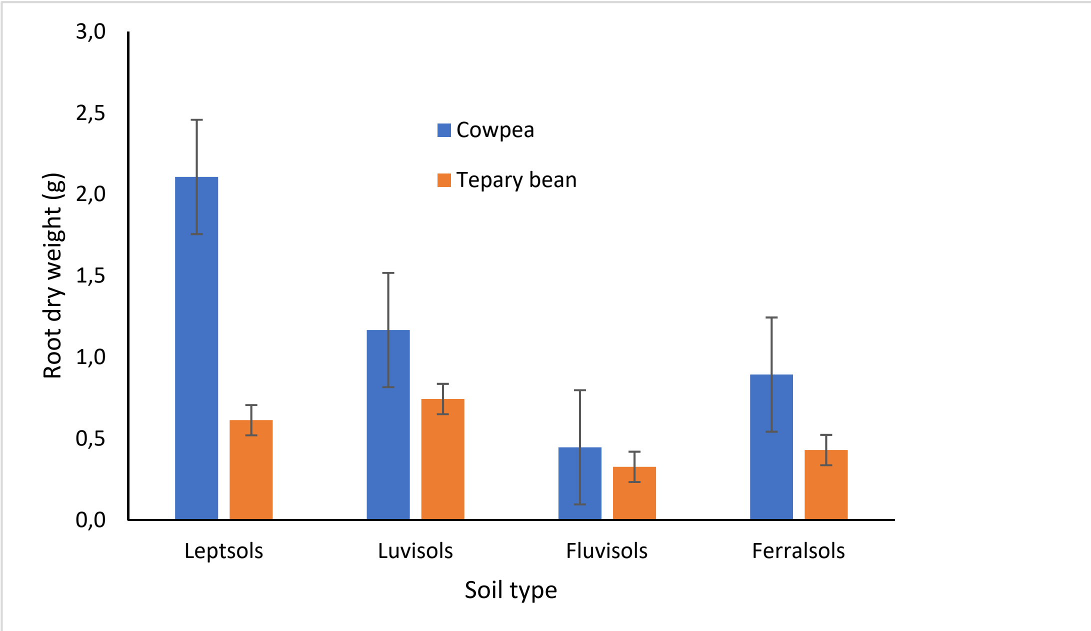

Figure 4.3: The effect of soil type on root dry weight of cowpea and tepary bean plants

4.3 The effect of soil types and legume species on productivity variables

Soil type had highly significant ($P \leq 0.001$) effects on all the productivity variables except PL and NSP (Table 4.5). In contrast, the legume species significantly ($P \leq 0.001$) influenced both the length of pods as well as the quantity of seeds that were developed in a pod (Table 4.5). The interaction between ST x LS was highly significant ($P \leq 0.001$) on some of the variables including PHT but not on NB, PL and NSP. The tallest plants (29.17 cm) were observed in the Leptsols (Table 4.6). On average, the legumes produced pods that were about 8.0 cm long and containing about 5 seeds each, irrespective of the soil type. In addition, the Leptsols produced eight-fold more SWTP than the Fluvisols (Table 4.6).

Table 4.5: Mean squares for productivity variables among legumes that were raised in distinct soil types

Source	df	PHT	NB	NPP	PL	PWT	SWTP	PV	NSP
Replicate	2	3.4579	0.6979	1.1667	0.0440	0.2258	0.1095	0.51042	1.0500
Soil type (ST)	3	92.2326***	14.8160***	29.4861***	10.5630	25.6584***	13.6321***	2.03819***	7.6700
Legume species (LS)	1	0.0338	0.2604	15.0417	312.1210***	44.7993***	19.7835***	0.09375	115.5740***
ST x LS	3	68.6415***	1.3438	28.4861***	7.0150	23.5354***	12.7424***	0.62153*	8.318

*, *** = significant at the 0.05 and 0.001 probability levels, respectively.

NB= number of branches; PHT= plant height; PV= plant vigour; NPP= number of pod per plant; NSP= number of seeds per pod; PL= pod length; PWT= pod weight per plant; SWTP= seed weight per plant.

Table 4.6: The main effects of soil type on productivity variables among two legumes that were raised in distinct soil types

Soil Type	Vegetative Traits							
	PHT (cm)	NB	NPP	PL (cm)	PWT (g)	SWTP (g)	PV	NSP
Leptsols	29.17 a	4.75 a	7.00 a	9.68a	5.28 a	3.78 a	4.75 a	5.22 a
Ferralsols	28.97 a	4.17 a	5.17 ab	9.16 a	2.30 b	1.47 b	4.08 b	6.08 a
Luvisols	24.54 b	2.25 b	2.83 b	7.50 a	1.08 b	0.74 b	3.92 bc	3.78 a
Fluvisols	20.99 c	1.42 b	2.17 b	6.89 a	0.73 b	0.46 b	3.33 c	3.80 a
Grand mean	25.92	3.14	4.29	8.31	2.35	1.61	4.02	4.72
C.V.	5.37	23.43	48.90	25.70	59.92	62.27	9.74	36.00

Means followed by the same letter in a column are not significantly different (P≤ 0.05) (Tukey’s Test).

NB= number of branches; PHT= plant height; PV= plant vigour; NPP= number of pod per plant; NSP= number of seeds per pod; PL= pod length; PWT= pod weight per plant; SWTP= seed weight per plant.

C.V. = coefficient variation.

In Luvisols, tepary bean produced significantly taller plants than cowpea (Fig. 4.4). However, there were no significant differences in PHT between the two legumes in both Fluvisols and Ferralsols. The PHT for cowpea was similar under Luvisols and Fluvisols (Fig. 4.4). However, the vigor of individual plants among the legume species varied markedly across the different soil types (Fig. 4.5). The most vigorous and least vigorous plants were observed for the Leptsols and Fluvisols, respectively. For both legumes, branching was markedly depressed in both the Luvisols and Fluvisols (Fig. 4.7). On average, cowpea produced <50% fewer branches in both of these soils in comparison the pattern of branching that was observed for both Leptsols and Ferralsols.

In Leptsols, cowpea displayed a superior pod load per plant but the remainder of the soils produced similar NPP between the two legumes (Fig. 4.8). A similar pattern was observed for both the PWTP (Fig. 4.9) and SWTP (Fig. 10).

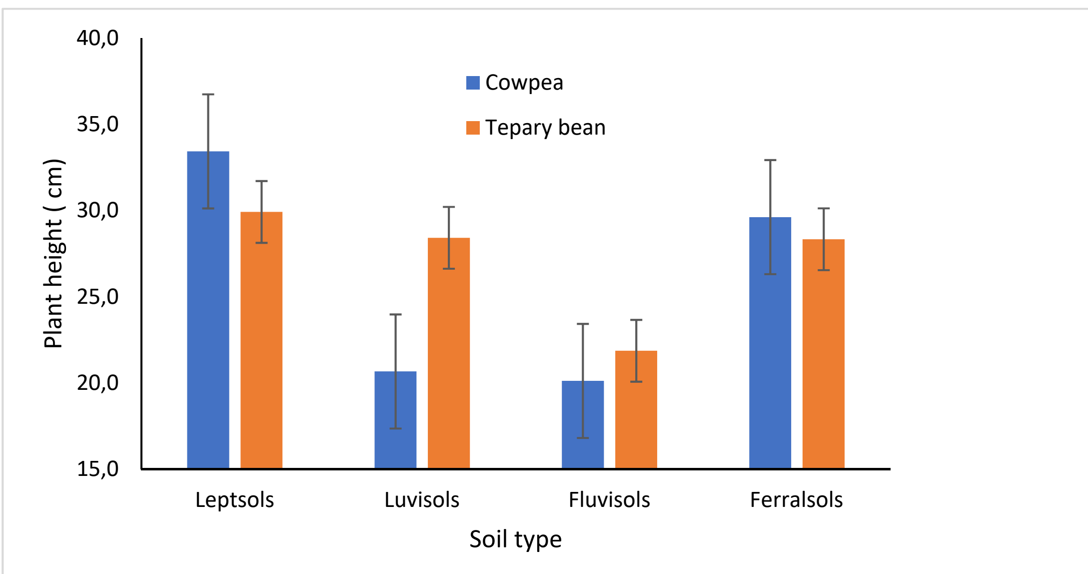

Figure 4.4: Effect of soil types on plant height of cowpea and tepary bean plants

Figure 4.5: Variation in plant vigour in legume plants which were raised in distinct soils types. (D/C = Leptsols; S2 = Luvisols; U = Ferralsols; S1 = Fluvisols)

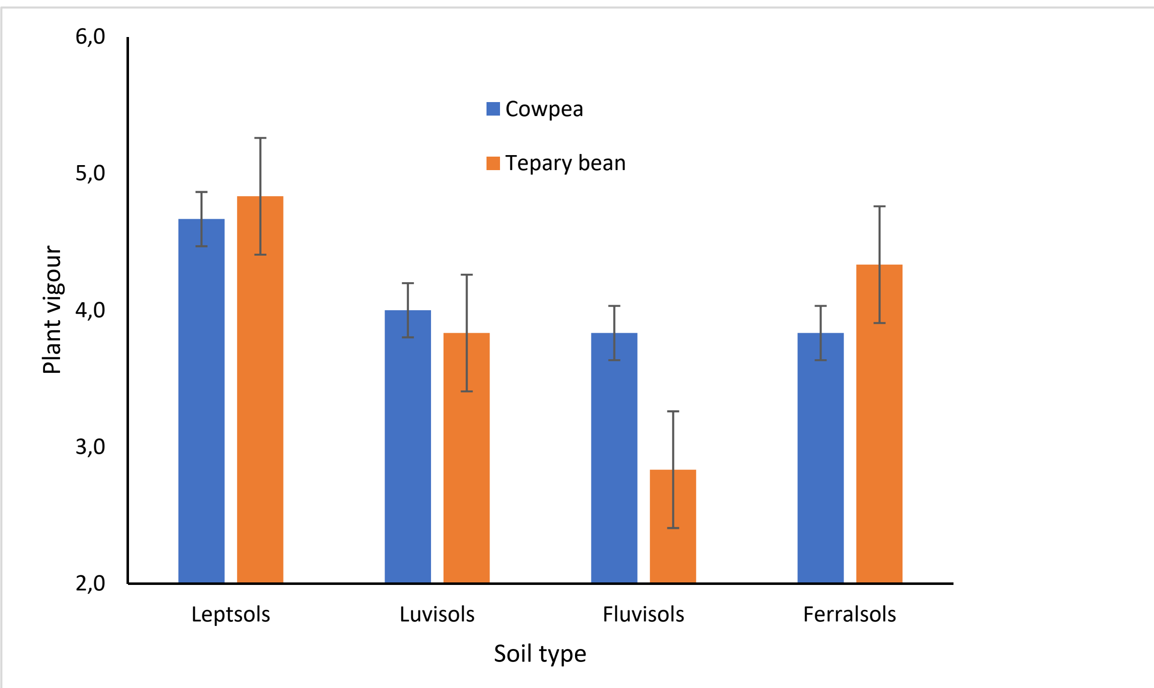

Figure 4.6: Effect of soil types on the plant vigour of cowpea and tepary bean

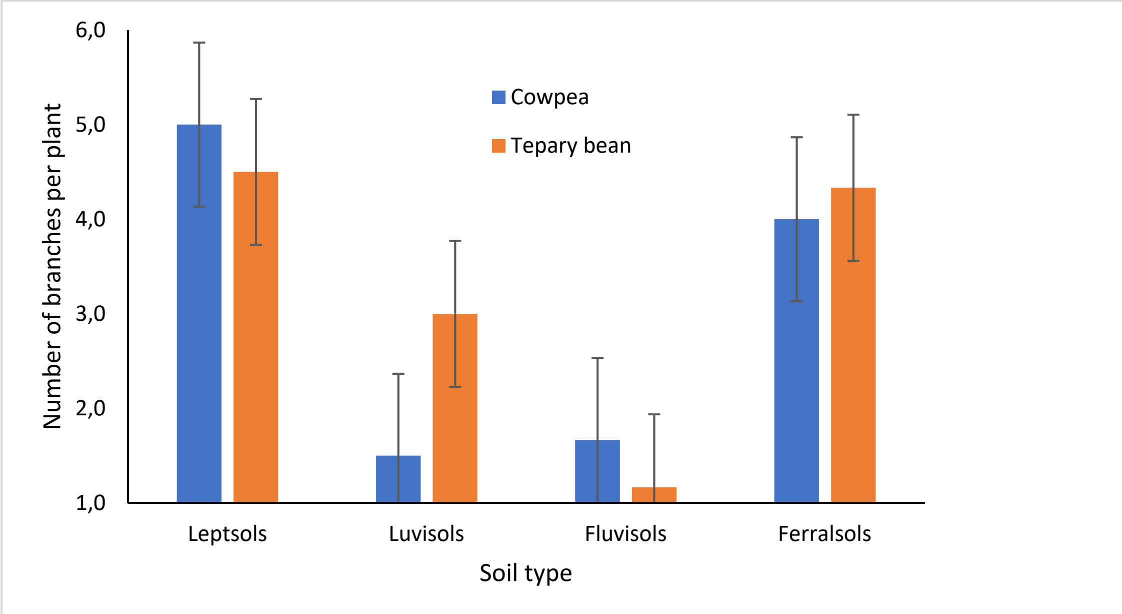

Figure 4.7: Effect of soil types on the number of branches of cowpea and tepary bean plants.

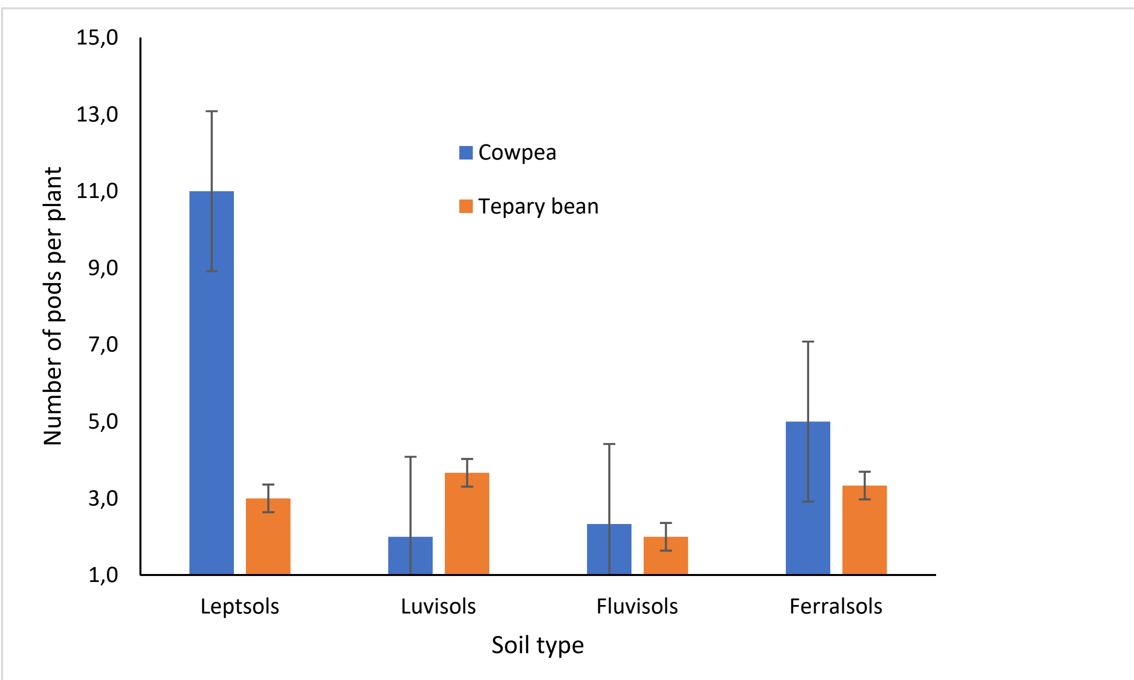

Figure 4.8: Effect of soil types on the number of pods per plant in cowpea and tepary bean plants

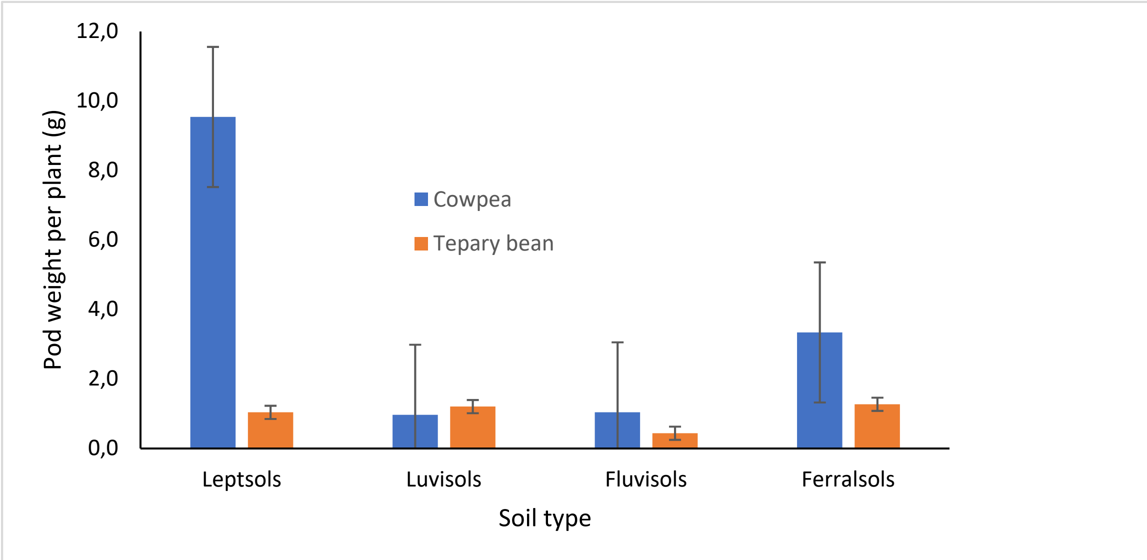

Figure 4.9: Effect of soil types on pod weight per plant in cowpea and tepary bean plants

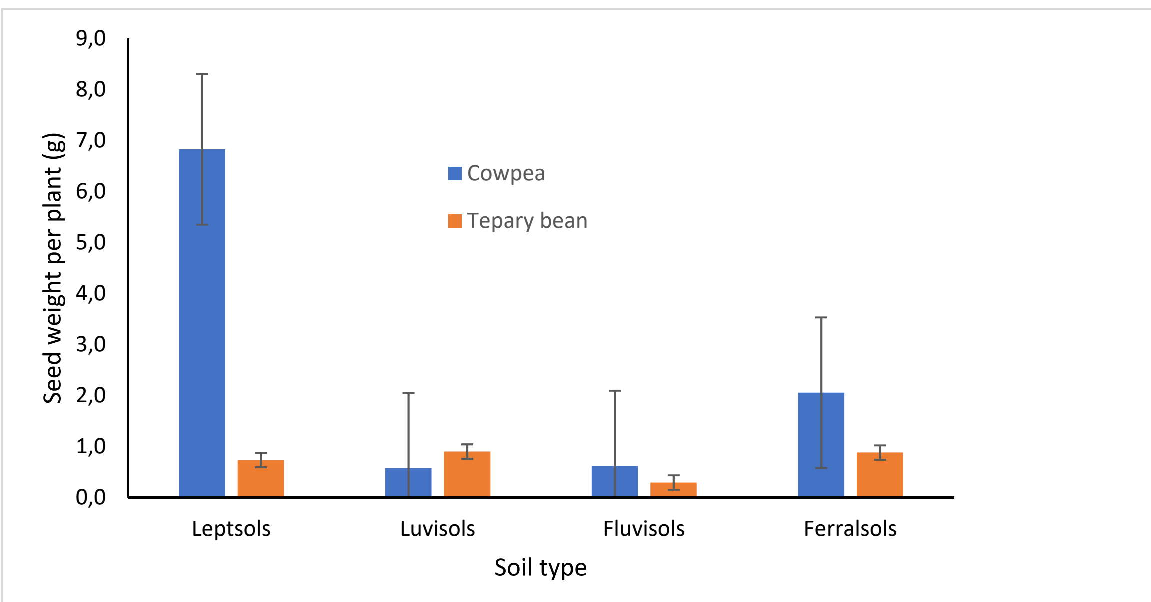

Figure 4.10: Effect of soil types on seed weight per plant in cowpea and tepary bean plants

5.0 CHAPTER FIVE: DISCUSSION

The results of this study showed that the various soil types had different influences on the productivity of the selected tropical legumes. The results of the soil analysis indicated variation in both their textural and mineralogical profiles, which likely explain, at least in part, the observed variations in their influences on legume productivity as measured by both nodulation parameters and productivity variables.

5.1 Soil properties

The variation in soil pH (ranging between 4.55 – 6.29) that was reported in this study could partly explain the differences in the nodulation patterns from one soil type to the other. This observation was in agreement with the results of a similar study that was conducted on cowpea under different soil pH levels and found that growth parameters were at their optimum within the pH range of 6.6 to 7.6 (Joe and Allen, 1980). Similar findings were reported in other studies involving legumes (Alva et al., 1990; Lin et al., 2012; Bekere et al., 2013).

In this study, the soil textural classes ranged from clay to sand. Soil texture can be among the factors, which influence nodule formation. Moreover, soil texture affects soil aeration, soil moisture, soil temperature, water infiltration and soil porosity. In addition, sufficiency in the level of all plant essential elements also supports optimum plant growth. According to Ndema et al. (2010), RDW in cowpea increased significantly from 293 to 454 mg in plot with highest percentage of sand (71.80%), the lowest percentage of clay (21.00%), high organic matter (10.26%), exchange potassium (0.36 g/kg), calcium (0.49 g/kg) and magnesium (0.46 g/kg).

Soil mineralogy affects the soil physiochemical properties of soil, which may affect plant vigour of the plant. soil physical properties determine the ease of root penetration, water availability and the ease of water absorption by plants, the amount of oxygen and other gases in the soil, lateral and vertical movement of water through the soil, and nutrient cycling (Kome et al., 2019). One of the two important properties of clay minerals capable of influencing soil fertility are chemical property and physical property (Kome et al., 2019). However, chemical property considered is the cation exchange capacity and the physical property considered is the surface area.

Phosphorus is a major constraint for nodule formation in many tropical soils. Leptsols showed the highest available phosphorus (8.00 mg/kg) when compared to Luvisols (2.00 mg/kg), Fluvisols (3.50 mg/kg) and Ferralsols soil (3.50 mg/kg). Phosphorus had a significant effect ($P<0.005$) on number of nodules and nodule weight in cowpea varieties (Nkaa et al., 2014). The highest available P could have influenced the formation and development of nodules in the soils. Singleton et al. (1985) reported that deficiency of phosphorus in legumes affects the development of effective nodules and the nodule leghemoglobin. In addition, Nkaa et al. (2014) reported that phosphorus is essential to cowpea yield as it initiates nodule formation and stimulates growth as well as influence the efficiency of the rhizobium legume symbiosis. The effectiveness and dry weight of nodules in all cowpea varieties were directly proportional to P fertilizer application in slightly acid sandy loams soil (Karikari et al., 2015). Moreover, application of phosphorus at 26.4kg P/ha significantly ($P \leq 0.05$) produced higher number of nodules throughout the study period than the other levels used (Amba et al., 2013). However, there were no nodules found in all soil types for tepary bean. Probably this was due to the use of tap water to wash away the soil (especially with high clay content) from the roots that could have contributed to the inadvertent removal of nodules on tepary bean without noticing.

Soil mineralogy affects the soil properties including soil fertility. However, despite the dominant effect of soil mineralogy on soil dispersivity, soil aggregate, soil erosion, soil crusting, soil sealing and soil aeration, there is a dearth of information regarding the effect of mineralogy on nodule dry weight. Soil mineralogy affects the soil properties, which are associated with formation of nodules in legumes. The soils that were used in this study were dominated by primary minerals, especially quartz. Leptsols had the highest percentage of quartz (40.80%) when compared to Ferralsols (22.70 %) and Luvisols (25.85%). However, Fluvisols (98.85%) had the greatest percentage of quartz when compared to all soil types. According to Wakindiki and Chinedu (2016) soil mineralogy influences chemical and physical properties of soil due to the differences in surface area and charge of minerals, thus affect the nodule dry weight, roots dry weight and dry above ground biomass of legumes.

5.2 Nodulation parameters

The soil types also influenced the nodulation parameters in the legumes. For instance, a, 2:1 clay is more dispersive than 1:1 clay (Lado et al., 2007). According to Buhman et al. (2006), the specific surface area of quartz promotes rapid soil organic matter mineralization resulting in poor aggregate stability. In addition, when there is poor aggregate stability, soil particles easily break away from each other when water enters an aggregate with low stability. These soil particles fill surface pore spaces which leads to hardening hence difficult for the roots to grow and absorb nutrients from the soil, thus negatively affecting the root growth and above ground biomass.

The variable number of root nodules that was observed between the soils and between the legumes could be attributed most probably to differences in rhizobial populations in the soils and preferential associations between host genomic backgrounds and symbiotic genotypes (Laguerre et al., 2003). The populations of soil rhizobia can vary widely (Wakelin et al., 2018; Mendes and Bottomley, 1998). However, determination of the rhizobial populations in the four soil types was not done in this study since it was outside the specific objectives of the study but could be considered in future in order to compliment the soil analysis. In addition, the yellowing of leaves (chlorosis) that was observed in tepary bean could have been due to the absence of effective nodules that could fix nitrogen resulting in green leaves (Gwata et al., 2005).

5.3 Productivity variables

Many productivity variables were influenced by soil types as presented above in the results section. For instance, clay minerals affect soil fertility through their physical and chemical properties by controlling the supply and availability of nutrients, sequestration and stabilization of organic matter, controlling soil physical properties through the formation of microaggregates, influencing soil acidity, and controlling soil microbial population and activity (Kome et al., 2019). In a study, conducted by Sudharani et al. (2020) reported that the application of phosphorus increased the NBP in cowpea, which could be attributed partly to the metabolic role of P in promoting the reproductive growth of the crop (Rafat and Sharifi, 2015). On the other hand, plant vigour is also influenced by the availability of nutrients and the ability of plant to absorb the essential nutrients from the soil (Pahla et al., 2014).

A variation in both PHT and PL was also observed in this study due to soil type. This was in agreement with a previous study involving French bean and silt loam soil (Ali et al., 2015). However, the pod length did not necessarily translate into a high number of seed inside the pod. This is because in the experiment some pods were long but had few seed inside due to the failure of seed to be formed in the pod, thus effectively diminishing the productivity of the respective legume. The variation in PHT was also reported in a similar study (Mashaba et al., 2020) (Appendix I). According to Karathanasis (1985) the effect of the mineralogical composition of the soil on soil productivity is that it affects chemical reactions that regulate the availability and uptake of nutrients and affects physical properties that control the balance of soil moisture and soil physical conditions. Consequently, the performance of the plant and, thus, the number of seeds per pod of the legume species would also be affected.

6.0 CHAPTER SIX: CONCLUSIONS AND RECOMANDATIONS

The results of this study showed some new insights into the impact of soil types (originating from Limpopo Province) on the productivity of tropical legumes in the area. The Leptsols outperformed the other soil types in terms of the nodulation parameters (nodule dry weights and above ground biomass) but Luvisols favored mostly the root dry weight of the legumes. The root nodulation was generally poor in tepary bean in comparison with cowpea. The observed variations among the soils were attributed partly to the differences in the soil properties particularly the texture and minerology profiles. The two legumes also showed differential response to the soils with cowpea outperforming tepary bean, particularly in nodulation. The Leptsols was also the most productive soil type for cowpea in all the parameters that were measured.

These findings suggested that there will be merit in evaluating a larger number of soil types as well as tropical legumes especially on a field basis in order to identify the optimum soil conditions x legume combinations that can be recommended to growers in the area. It is recommended that field experiments should be conducted in all sites where soils were collected in order to validate the findings and recommend the most productive soil types to the growers of legumes species. Alternatively, agronomic interventions aimed at improving the soils, for instance, addition of chemical fertilizers or incorporation of crop residues into soil in order to increase organic matter content, could be useful for optimizing the productivity of the two legumes. Liming could also be useful as it can increase the soil biological activity (to improve mineralization of organic matter). Although, based on the results at hand Leptsols can be recommended for cowpea production, there will be merit in future to evaluate more tropical legumes as well as more varieties from each species in the different soils. This is because of the deferential response of varieties to edaphic conditions as well as other biotic (for example pests and diseases) and abiotic (for example soil temperature) factors that could influence the productivity of the selected legumes significantly. In other words, more detailed studies that will take into account such factors in the area could be more informative and useful to the legume farmers and end-users in the legume value chain.

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Appendix I

Mashaba et al., (2020). Impact of soil types on tepary bean (*Phaseolus acutifolius*) productivity. Combined Congress. BAS – Fund. Sust. Agric.; January 20-23, 2020; UFS, S. Africa. pp 203.

IMPACT OF SOIL TYPES ON TEPARY BEAN (PHASEOLUS ACUTIFOLIUS) PRODUCTIVITY

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INTRODUCTION

- Tepary bean (*Phaseolus acutifolius*) is a food legume, which is cultivated in Limpopo Province.
- The grain of tepary bean is rich in carbohydrates, fibre, and protein[1].
- The productivity of the various soil types that are prevalent on smallholder farms for the crop in the area has not been determined exhaustively.
- Therefore, the objective of this study was to determine the productivity of tepary bean using distinct local soil types that are prevalent in the production area.

MATERIALS AND METHODS

- A pot experiment was conducted at Thohoyandou (22°35'S;30°15'E) using four soil types namely Hutton (Ferralsols), Glenrosa (Leptsols), Shortlands (Luvisols) and Dundee (Fluvisols).
- Soil samples were collected at a depth of 0 – 30 cm from each of four different farms located in Vhembe District (Limpopo Province), sieved and filled into 5.0L pots prior to planting.
- Two seeds of tepary bean were planted per pot and subsequently thinned down to one.
- Soil organic carbon was measured using the Walkley Black Method and soil pH was measured in water.
- A randomized complete block design with three replications was used in the study.
- Key crop productivity variables including plant height (PHT), number of pods per plant (NPP), number of primary branches per plant (NPB) and number of seeds per pod (NSP) were measured at maturity.
- The data sets were subjected to the analysis of variance using Statistix 10.0.

RESULTS AND DISCUSSION

- The results showed that there were significant ($P<0.05$) differences between the soil types in terms of both organic carbon (OC) and pH.
- There were highly significant ($P<0.01$) differences among the soil types for each of the productivity variables except for NPP.
- The tallest plants (Fig. 1) and the highest NSP (4.42) were observed for Glenrosa soil while Hutton produced the lowest NPP (7.0) (Fig. 2).
- The productivity variables of the crop were influenced largely by the variation in the soil OC and pH.
- Glenrosa showed the highest pH (6.75), followed by Shortlands (6.26), Hutton (5.88) and Dundee (5.79).
- However, Dundee attained the highest OC (1.08%).
- Likely, OC influenced both early nutrient supply and water retention capacity[2].

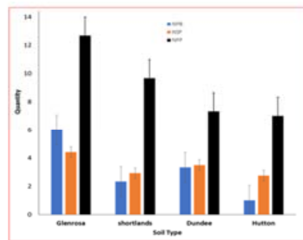

Fig. 1 Distribution of pod characteristics per soil type. (NPP = number of pods per plant; NSP = number of seeds per plant; NPB = number of pods per branch).

Fig. 2 Variation in tepary bean plant height across the soil types.

CONCLUSION AND RECOMENDATION

- The results suggested that at the pH values in the study, Glenrosa was the most productive soil for tepary bean in the area.
- More soil characteristics such as structure should be included in future similar studies.
- In order to improve the productivity, liming is recommended for the area since tepary bean favors slightly alkaline soil conditions.

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