SOIL COMPACTION AND TEXTURE EFFECT ON YIELD, VEGETATIVE GROWTH PARAMETERS AND QUALITY OF POTATO TUBERS (*SOLANUM TUBEROSUM L.)* IN SELECTED SITES IN LIMPOPO PROVINCE

BY

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DECLARATION

I, *Mufandilani Mvusuluso*, hereby declare that the dissertation for the master's degree at the University of Venda, hereby submitted by me, has not been submitted previously for a degree at or any other university, that it is my own work in design and in execution, and that all reference material contained therein has been duly acknowledged.

Signature [redacted]…………………. Date 24/06/2020…………………….

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CBD	Clay bulk density
DM	Dry matter
FSLBD	Fine sandy loam bulk density
LSBD	Loamy sand bulk density
MWD	Mean weight diameter of aggregates
NST	Number of tubers
OC	Organic carbon
PSI	Potato shape index
SG	Specific gravity
SLBD	Sandy loam bulk density
SPT	Size of potato tubers
TFI	Tuber shape index
PHT	Plant height

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DEDICATION

I dedicate this book to my brothers Vhuthu and Faresa Manthada and my little sister Zwivhuya Manthada. May this be an encouragement for you to work harder knowing that its possible. To my mother Elsie Mufandilani, thank you.

ABSTRACT

Compaction limits soil productivity especially plant growth. However, the effect of compaction in various South African soils on potato (*Solanum tuberosum* L.) tubers is not well understood. The purpose of this study was to investigate the effect of compaction in various soils on the number of stems, plant germination, number of tubers, plant vigour, plant height, biomass, size, shape, dry matter, fresh weight, specific gravity of potato tubers. It was hypothesized that soil compaction affects growth and quality of potato tubers. Soil samples were collected from four different potato farms and subjected to different levels of compaction, simulating field conditions. The experiment was conducted in a complete randomized design with a split plot treatment structure with three replications. Treatments were compacted, non-compacted soil and four different textures (loamy sand, sandy loam, clay and fine sandy). *Sifra* and *Fandago* potato cultivars were used to test response to the treatments. Potato tubers were harvested after 120 days. Analysis of variance was conducted using Minitab software version 17. The comparison of means was done using the Tukey method. It was generally found that size of tuber was decreased (>40%) by soil compaction for both cultivars. The shortest tuber size (46.1 mm) was obtained in the fine sandy loam soil. The clay soil produced the highest (21) specific gravity. Soil compaction slightly deformed some potato shapes but were not detected statistically. Fresh weight of tubers was decreased by 32% between the non-compacted and compacted soil. The highest plant vigour (3.4) was observed for loamy sand soil. Similarly, the tallest crop (38.2 cm) were observed in the sandy loam soil. Crop height was decreased by 38% at the compacted soil. It was apparent that Loamy sand and sandy loam soil seem to be suitable soil texture for potato production. Soil compaction had a negative impact, significantly producing small tubers, low yield, low specific gravity, crop height and number of potato tubers.

Key words: dry matter, potato shape, potato size, potato tubers, specific gravity.

CHAPTER ONE

1.0 Introduction

1.1 Background

Potato production has been increasing constantly over the past decade (Birch *et al*., 2012). Understanding potato crop and soil-environmental yield limiting factors at growers' management level is important to guide formulation of better management practices to increase yields (Gondwe *et al*., 2020). Potato farming systems generally use excess tillage and produce low levels of crop residue in the potato year, both of which are detrimental to soil quality (Carter and Sanderson, 2001). It is now grown in 149 countries due to increased demand for potato-based foods, potato products and the expanding uses of potato as a food and an industrial raw material (Birch *et al*., 2012). As potatoes are very well suited for human modern diet (Haase 2008), attention to its agronomy will hardly cease (Yakimenko and Naumova, 2018). Potatoes are produced in 16 regions in all nine provinces of South Africa. The regions have different climatic and soil conditions (Gericke, 2018). Producing quality potatoes is an ever-increasing challenge because it directly impacts human health (Gericke, 2018). It is an important staple food for most people. Potato production ranks fourth in the world after rice, wheat and maize (Fatemeh *et al*., 2017) in terms of total consumption. Almost 52% of the area under potato crop lies in the temperate region in Europe, 34% in Asia and 14% in Africa (Raja *et al.,* 2018). Its production in the developing world has increased in the last two decades, demonstrating its important contribution to food security (Acton, 2013). The current average farmers' yields are too low, less than t/ha for materials with a potential to achieve t/ha (Harahagazwe *et al*., 2018).

The need to increase agricultural production with less impact on the environment has renewed interest in assessing how soil use and management influence plant production

(Batey and Mckenzie, 2006). Soil compaction has increased in recent decades due to intensive farming practices such as short crop rotations and use of heavy machinery (Victor *et al*., 2016). Soil compaction is a major determinant of growth and mortality rates of plants (Hattori *et al.,* 2013). Many researchers agree that soil compaction leads to plant yield reduction. Underground plant parts such as tubers, roots and corms are the most vulnerable. The use of heavy field equipment is increasing gradually and causing soil compaction. Compacted soils contain few large pores, less total pore volume and consequently a greater density (DeJong-Hughes *et al.,* 2001), thus reducing growth and damaging tubers. Some studies have established that not only the roots, but also the tubers can be affected by high soil compaction and may physically restrict developing tubers reducing both yield and quality (Holmkvist, 2008). For example, the effects of soil compaction on potato (*Solanum tuberosum* L.) yield and quality were studied by (Stalham *et al*., 2007) and showed reduced number of tubers and increased incidence of deformed tubers.

Potato has a sparse, shallow root system, which makes it sensitive to soil compaction (Stalham *et al*., 2005). Consequently, soil compaction is a major cause of poor root growth and root system expansion (Bengough *et al*., 2006). Soil compaction limits penetration of roots into the soil and reduces rooting length. (Van Loon and Bouma, 1978; Hatley *et al*., 2005) showed increased second growth and deformed tubers when soil within the tuber zone was compacted. Soil compaction results in reduced porosity, especially of large pores, and increased bulk density (Victor *et al*, 2016).

1.2 Problem Statement

Soil compaction increases the strength properties of soils such as bulk density and shear strength and decreases porosity and may affect the quality of potato tubers. Potato quality determines its economic value. Potato production requires heavy equipment and massive machinery that can tramp down the soil, creating compaction. Due to this compaction caused by tramping down of the soil, potato tubers may develop physiological disorders, which affect the quality such as a change of shape, their usefulness and appearance. These physical qualities determine their degree of acceptance by consumers.

1.3 Justification of the Study

The tuber yield and quality attributes of potatoes are important parameters in grading, handling, processing and packaging systems. These attributes are important in the value chain of potato. However, the soils where potatoes are grown in South Africa are prone to compaction. There is little information about the effect of soil compaction on the tuber yield and quality traits of the crop. Therefore, this study will provide useful information for managing potato production in various soils that are prone to compaction. An improvement in the management of the production could produce economic benefits for the growers and end-users.

1.4 Aim and Objectives

1.4.1 AIM

The aim of the study was to improve potato yield, quality and vegetative growth parameters in various soils in Limpopo province.

1.4.2 Objectives

(1) The objective of the study was to determine the effect of compaction and texture on potato tuber yield in various soils.
(2) The objective of the study was to determine the effect of compaction and texture on the quality of potato tubers in various soils.
(3) The objective of the study was to determine the effect of compaction and soil texture on vegetative growth parameters in various soils.

1.5 Hypotheses

The study tested the following hypotheses:

(1) Soil compaction does not affect the yield of potato tubers in soils with different texture.
(2) Soil compaction does not affect the quality of potato tubers in soils with different texture.

CHAPTER TWO

2.0 Literature Review

2.1 Potato Production in South Africa

South Africa is ranked 28th in the world in terms of total potato production. It contributes about 0.3 % to the global potato production. The share of potato in average annual diet of a global citizen is 33 kg on weight basis (FAO 2009). South Africa consume more than 90% of the total annual potato production (Harvest SA, 2017). Potato production in South Africa is growing due to increasing demand (FAO, 2008). It is one of South Africa's most affordable staple foods and is capable of being grown on less land and in harsher climates. Potatoes are used for a variety of purposes: as a fresh vegetable, as raw material for processing into food products or in different food ingredients, to manufacture starch and alcohol and as fodder for animals (Bhattarai and Swarnim, 2016). Potato production comprises table potatoes and seed potatoes with the former produced for consumption and the latter for regeneration (National agricultural marketing council, 2017). South Africa is among the five largest potato producers in Africa, annually producing approximately 42 tons per hectare (Potatoes South Africa, 2013). Potato has an annual production of 365 million tonnes, and ranks 4th in crop tonnage and 5th in crop value (FAO, 2015b; Haverkort and Struik, 2015). Potatoes are grown on approximately 50 000 ha and yield approximately 2 million tons per annum In South Africa (Potatoes South Africa, 2010), while the harvested area worldwide was 19.25 million ha with 376.83 million tons of potato produced in 2016 (FAO, 2016). However, during the last 10 years the farming sector has been facing a rapid decrease in world total harvested area and total production in potato crop (36.7% and 19.5%, respectively), which has been partially compensated by the increasing yields due to the introduction of new high yielding genotypes and improved farming practices (FAOSTAT,2020). Potatoes are produced from sixteen regions found in the Limpopo, Free State, Western Cape, Mpumalanga, KwaZulu-Natal and Eastern Cape (Fig. 1). Production of potatoes can be done under irrigation or on dry land. Potatoes under irrigation have increased by 35% since 1991 to

2005 and dry land production has decreased by 62% (National agricultural marketing council, 2017). In 2011, the South African potato industry contributed approximately 61% to the total gross value of vegetable production, 13% of horticultural products and 3% of total agricultural products (DAFF, 2012).

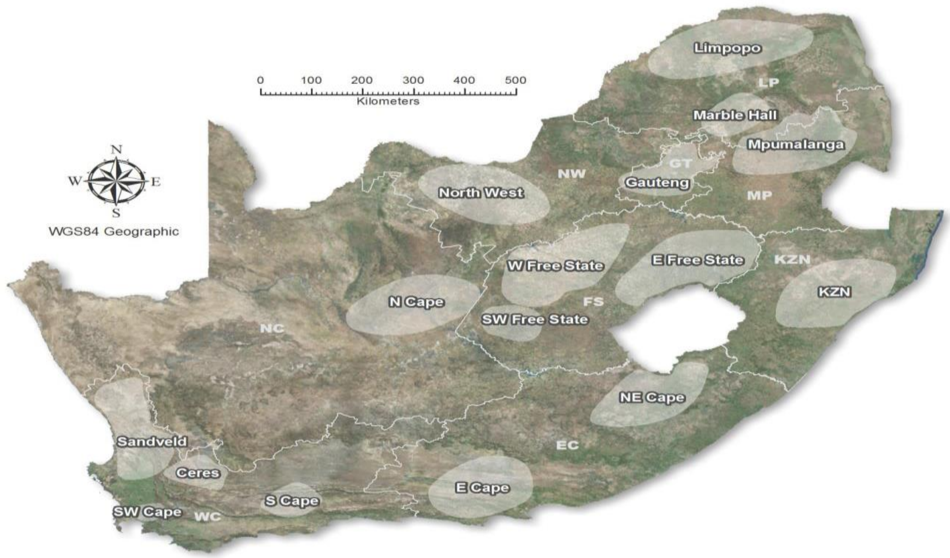

Figure 1: Potato productions regions in South Africa (Courtesy of Mr. L. van Zyl, TerraGIS, Cited by Van der Waals *et al*., 2016)

Producing quality potato tubers is of great interest to farmers and consumers. Potatoes are grown for different purpose, each with its own markets. Some of the significant features of potatoes are the average tuber size, tuber shape, dry matter and its variation. During production, tubers are exposed to an environment that has characteristic ratios of water, gas and solid compounds, different from those in the air, and are exposed to soil life that can affect their quality, usually in a negative way (Struik and Wiersema, 1999). In South Africa, potatoes are grown in any well drained, fertile sandy and sandy loamy soil, than in heavy compacted clay soil that keeps the roots from getting air and water they need.

2.2 Quality Attributes and Yield of Potato Tubers

Potato tuber quality can be defined as the sum of favorable characteristics of the tuber, which is a subjective and dynamic concept that depends on consumer's tradition lifestyles, food habits and the industrial process used (Richards *et al.,* 1997; Subia, 2013). Quality is one of the most important characteristics of potato and its quality is dependent on external and internal aspects of the tuber (Pandey and Sarkar, 2005; Pandey *et al*., 2009). The increase in human population is stimulating the increase in demand for good quality potato tubers and potato quality has become an important factor based on consumer demand (Abbas and Ranjan, 2015). Potato yields and tuber quality depend on a number of factors, such as soil and climatic conditions, agricultural techniques, biological and cultivar specifics regulated (Yakimenko and Naumova, 2018). The quality of crop yield is important for human diet with many health benefits, especially for technical crops like potato: such quality attributes as dry matter is usually of primary concern and often rather strictly regulated (Yakimenko and Naumova, 2018). It has been demonstrated that all these parameters are linked to the nutrient status of the tubers (Naumann *et al*.,2019). Some of the quality attributes desired for potatoes are tuber size, shape, dry matter and specific gravity. Post-harvest quality evaluation and sorting is required for potato in order to provide reliable and uniform quality to the marketplace. Like many other agricultural products, potato has non-uniform quality and non-uniform maturity at harvest. (Yu Chen *et al*., 2004). Consumers requirements concerning the quality of raw material and product as well as increasing competitiveness on the market encourages food producers to use better agricultural plant materials and improve their quality (Gancarz, 2012).

The dry matter (DM) content and specific gravity (SG) are used as determining factors for the processing quality of potato varieties. Consequently, potato varieties with a DM content of 20% or higher, and a specific gravity of 1.08 or higher are the most preferred for processed products (Kirkman, 2007). Tubers with a DM ≥ 20% are more susceptible to bruising. The DM content of potato tubers is an important parameter, which is often strongly correlated to the product value and the nutritious content (Glenn *et al*., 2016). Specific gravity of tubers is an important determinant of processing quality, it is an indicator of maturity (Hayes and Thrill, 2002). Specific gravity is directly proportional to the DM (Abong *et al*., 2009). Specific gravity has been used as a criterion of potato quality due to its positive correlation with the dry matter content of tubers and the rapidity with which it can be determined (Lulai and Orr, 1979; Abebe *et al*., 2012/2013). However, its effect is modified by cultural and environmental factors during the growing season (Killick and Simmonds, 1974; Abebe *et al*., 2012/2013). It gives a reflection of developmental maturity (Mehta *et al*., 2011).

Potato is a high biological value crop that gives an exceptional high yield with more nutritious content per unit area per unit time than any other major crops. (Miheretu, 2014). Tubers yielding tuber form index (TFI) ≥ 1.7 are generally desired in South Africa (Vorster, 2014). Farmers grow potatoes year-round and typically obtain average yields of 40–45 tons per ha (Franke *et al*., 2011).

For the fresh market, tubers need to be consistent in shape and size. Potato tubers are categorized as large, medium or small. Large tubers are ≥ 75 mm, between 55 and 75 mm are considered to be medium, and those ≤ 55 mm are small (Steyn *et al*., 2009). Tuber dimensions can be translated into the Tuber Form Index (TFI), reflecting the length and width of a potato (Ekin, 2013). Processing potatoes should be evenly shaped, of a standard size and quality from one end of the tuber to the other. Poor or irregular shape of tubers contributes to higher costs for the processing industry due to significant peeling losses (Yongsheng *et al*, 2018). Both yield and quality of potato tubers are influenced by various yield determining, limiting and reducing factors (Harverkort and Struik, 2015).

2.3 Soil Compaction

Soil compaction is a serious concern in crop production areas of the world because of its deleterious effects on crops (Gelder *et al*., 2007). It occurs both in the topsoil and subsoil and results in reduced porosity, and increased bulk density (Guamen, 2016). Soil compaction occurs when soil particles are pressed together, reducing pore space between them, it changes pore space size and distribution (Keller *et al*., 2013). Soil compaction effects are long lasting or even permanent, particularly in soils with a low clay content (Håkansson and Lipiec, 2000; Lipiec *et al*., 2003). Soil compaction can be divided into two categories, surface horizon compaction and subsoil compaction (Olubanjo and Yessoufou, 2019). The effect of soil compaction has led to many debates, especially regarding the establishment of critical limits to plant growth (Moraes *et al*., 2014; De Jong van Lier and Gubiani, 2015). In potatoes, the operations which cause compaction involve ploughing, bed creation, stone gathering, planting, crop spraying and harvesting (Sarango, 2015). (Stalham *et al.,* 2005) point out that there has been a major change in the methods of cultivation for potatoes, which has increased the risk of creating poor soil conditions especially compaction. Tillage is often used as a solution to soil compaction, in the long-term, tillage may not be a good solution for compaction because it encourages decomposition of organic matter, breaks down soil aggregates and weakens soil structure (Chen and Weil, 2009; Brady and Weil, 2008).The severity of soil compaction depends on several factors including soil type (soil texture and structure), soil water content, machinery properties (weight, speed, and contact area of tire and soil surface), and farming practices (Chamen *et al*., 2003). Increased tractor power has allowed growers to cultivate in more marginal conditions and to greater depth but have increased the likelihood that the soil will be heavily compacted (Stalham *et al.,* 2007). Surface compaction may also occur as a result of heavy rain soon after cultivation depending on soil properties and is referred to as capping or slumping (Hatley *et al.,* 2005).

Compaction increases the strength properties of soils, namely bulk density and shear strength (Ahaneku *et al*., 2014). The extent of compacted soil is estimated worldwide at 68 million hectares of land from vehicular traffic alone (Flowers and Lal, 1998; Ahaneku *et al*., 2014). The main cause of soil compaction is intensive farming of crops and animals, including short crop rotations and use and intensification of heavy machinery under unfavorable soil conditions, in particular at high water content in the soil at the time the pressure is applied (Heesmans, 2007). Sandy soils, which often are used in potato production, seem to be especially susceptible to subsoil compaction (Miller and Martin, 1990; Westermann and Sojka, 1996; Holmkvist, 2008) and as it offers the least resistance to enlargement of the tubers. Loamy and sandy loam soils that are rich in organic matter, with good drainage and aeration, are the most suitable. Clay soils are avoided because they retain too much soil moisture and get hard when dry which tend to reduce yield and quality of tubers.

Compaction negatively alters soil structure and hydrology (i) by increasing bulk density, soil strength, water runoff, and erosion, (ii) by breaking down soil aggregates, and (iii) by decreasing porosity, aeration, and infiltration capacity (Bruenig, 1996; Hattori, 2013). (Kuht and Reintam, 2005) found that the bulk density of the compacted area increased by 0.16 - 0.26 $Kg.m^{-3}$, compared to the non-compacted area and the total porosity of the topsoil decreased by 37.1 - 51.7%. The result of the soil measurement demonstrated a strongly negative effect of wet soil compaction on soil characteristics and were in good correlation with the number of compactions carried out. It was concluded that changes in soil bulk density can have large effects on crop growth and yield in potatoes (Stalham *et al.,* 2007). (Stalham *et al*., 2007) revealed that in 16 experiments where potatoes were grown in artificially compacted soil, 13 showed a significant yield decrease owing to compaction.

2.4 Soil Texture

Soil texture refers to the relative proportion of sand, silt, and clay in a specific soil or horizon (layer) in the soil, because this determines how a soil feels. The three basic groups of texture classes are sands, clays and loams. The United State Department of Agriculture (USDA) soil textural triangle is used to break soil into 12 distinct classes according to their particle size distribution as shown in Figure 2. Loam soil consist of about 40% sand, 40% silt, 20% clay, while Clay soil has about 25% sand, 30% silt, 45% clay and Sandy contain about 90% sand, 2% clay and 8% silt (Moritsuka *et al.,* 2015). Texture is widely used for soil characterization and as root zone volume indicator (Oliver *et al*.,2013). Soil texture is a controlling factor of soil reaction, nutrient availability, water holding capacity, soil porosity, air water circulation and soil density (Chakraborty and Mistri, 2015). Soil texture is an important soil characteristic that drives crop production and field management (Goueguel *et al.,* 2019).

Loamy soils are all round soils and may be used to grow most crops, they have the advantage of clay soil in that they retain plant nutrients, yet they also have the drainage of sandy soils (Abdulazeez, 2017). Sandy textured soils are more fragile and looser, which facilitates the growth of the tubers. Sandy soil has a much lower water holding capacity than clay soil, thus clay soil retains water for plant growth (Owens and Rutledge, 2005). Fine-textured soils, which contain large quantities of clay, may pose severe problems for both agricultural, these soils generally have slow permeabilities and compact readily when wet, plant roots may be restricted (Martin *et al.,* 2017). Clay soil is potentially rich in nutrients but because of poor drainage these nutrients are often withheld from the plants (Abdulazeez, 2017).

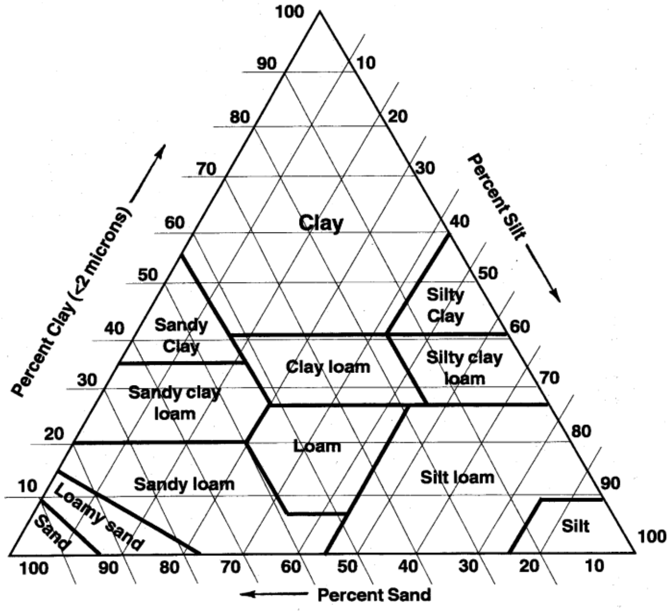

Figure 2: USDA soil texture triangle showing 12 soil texture classes (courtesy of plant and soil sciences eLibrary)

2.5 Effects of Soil Compaction on Quality of Potato Tubers

Potato production is becoming more and more specialized with the use of heavier farm machinery, with increased risk of soil compaction (Johansen *et al.,*2015). Soil compaction has a negative effect on potato crop production. However, there are few reports giving details of direct effects of compaction on tuber quality (Hatley *et al*., 2005). Soil compaction can reduce quality and physically restrict the development of tubers (Batey, 2009). In general, root and tuber development of potato plants grown in compacted soils are restrained and tuber yield and size decreases (Ozer and Oral, 1997). The highest mean for tuber number was obtained for control and it decreased by 46.1 and 47.5% in treatments with densities of 1.56 and 1.8 g/cm^3 respectively (Behbood *et al.,* 2012). In another study, compaction reduced the percentage of malformed potatoes from 11.0 % to 8.3% and from 11.8 to 8.8% respectively (Henriksen *et al*., 2007). Damage to potatoes as a result of subsoil compaction can be the result of compaction occurring in a previous crop, and/or when ploughing (Hatley *et al*., 2005). The highest mean for tuber number was obtained for control and it decreased by 46.1 and 47.5% in treatments with densities of 1.56 and 1.8 g/cm^3 respectively (Behbood *et al.,* 2012). Under wet condition with heavy harvesting trucks, Compaction increased malformed tubers and tuber damage during harvest (Hatley, 2005). Compaction also affects the dry matter of potatoes to a great extent. In terms of dry matter production per hectare, potatoes are among the most productive crops grown in the developing countries (Zelalem *et al.,*2009). The total dry matter of roots in the 0-30 cm soil layers was 0.0137 g·cm^{-3} for the 80% soil compaction and 90% compaction treatments (Glab, 2011). These compacted conditions are commonly observed on sandy loam soils having essentially a single grain structure. The most consistent conclusion of most reports is that soil compaction reduces tuber size and quality to a greater extent than it does to total yield. (Thornton *et al*., 2015).

2.6 Effects of Soil Compaction on Yield of Potato Tubers

The detrimental effects of soil compaction on the growth and yield of crops cannot be overlooked (Chukwuka *et al.,* 2018). Soil compaction can influence yield by decreasing the quality, weight and size of tubers (Iler and Stevenson, 1991; Edrris *et al*., 2020). Compaction can limit vertical root growth, water and nutrient uptake, and air and water infiltration, resulting in substantial yield reductions (Ekelof *et al.,* 2015). The subsoil compaction directly affects potato root growth due to mechanical resistance to penetration (Stalham *et al.,* 2007). Compaction is an important physical limiting factor for the root growth and plant emergence and is one of the major causes of reduced crop yield worldwide (Tekin, 2008). Yield reductions of up to 37%, caused by compaction, have been recorded experimentally (Hatley *et al.,* 2005). Yield was highest (3.09 kg/plant) in the treatment where the soil was not compacted (1.11 g/cm^{-3}) in the tuber compartment, and lowest (1.60 kg/plant) in the treatment having the highest compaction level (1.6 g/cm^{-3}) (Ferguson and Gumbs, 1976). The decrease in yield with increase in soil compaction in the root and tuber compartments was therefore due mainly to a decrease in tuber size (Ferguson and Gumbs, 1976) Comparison of means showed that potato yield was 6.32 kg/m^2 for control treatment which was significantly more than those treatments with higher bulk densities 1.56 and 1.8 g/cm^3 that produced a yield of 5.87 and 5.13 kg/m^2, respectively (Behbood *et al.,* 2012). The tuber yield of control was respectively 7 and 19% higher than those of treatments with densities of 1.56 and 1.8 g/cm^3 (Behbood *et al.,* 2012). Soil compaction produced losses in tuber marketable yield of 20%-30% in many productions (Thornton *et al.,* 2015). Potatoes have a global yield of $19 Mgha^{-1}$ (FAO, 2015b). The mean potato yield was greatest from the medium compaction (10 cm depth) (39.1 Mg ha^{-1}), but not significantly more than from the deep compaction (30 cm depth), 2% less (38.2 Mg ha^{-1}) or than from the shallow compaction (0 cm depth), 7% less (36.2 Mg ha^{-1}), (Rees et al., 2015). Studies applying artificial compaction have shown that compaction can decrease potato yield by up to 72% (Ekelöf *et al*., 2014). The yield reduction reported in different studies is on average 18 t ha^{-1}, but maximum reductions of 25–38 t ha^{-1} have been observed (Timm and Flocker 1966; Van Loon *et al*, 1985; Stalham *et al,* 1997/2005; Ekelöf *et al*., 2014).

2.7 Effects of Soil Compaction on vegetative growth parameters

Soil compaction is one of the major physical factors that affects plant growth. Generally, soil compaction leads to negative growth conditions for crops due to high mechanical impedance for roots, decrease in soil aeration, and decrease in water storage (Da Silva and Kay, 1996; Marinello *et al.,* 2017). A very low soil compaction around potato tubers at the planting time could delay crop emergence (Edrris, 2020). Although soil compaction in the field may benefit or inhibit the growth of plants, the harmful effects are much more common (Kozlowski, 1999). There is insufficient information about the effect of soil compaction on vegetative growth parameters of a potato crop. The effects of compaction on leaf growth leads to significant reductions in number of tubers 695-591(Stalham *et al,* 2005). Soil compaction restricts nutrients uptake by crops thus delaying plant growth and consequently lead to yield loss. Compaction at 0.1 m delayed emergence slightly, reduced the length of the mainstem, reduced initial rate of leaf appearance, leaf length and rooting depth compared with uncompacted soil and deeper compaction at 0.4 m (Stalham *et al*, 2007).

2.8 Effects of Soil Texture on Yield of Potato Tubers

Soil texture and its characteristics can play an important role in potato production (Hamed *et al.,* 2017). Soil texture components (sand, silt and clay) had a stronger impact on potato yield (Redtflla *et al.,* 2012). Crop yields may drop by average rates ranging from 15% in maize across soil textural groups (Duiker and Curran, 2004; Wolkowski and Lowery, 2008) to 34% in potato grown in coarse-textured soils (Stalham *et al.*, 2005; Wolkowski and Lowery, 2008). Potato crops grown sequentially in coarse-textured soils may therefore suffer considerably from soil compaction (Xu *et al*., 2017). Tuber yield on clay soil was almost 30% lower than on loam soil (karam *et al.,*1998). The tuber yield of the potato plant grown in the clayey soil was higher than the plants grown in sandy soil (martins *et al.,* 2018). Compared to clay, the yield of cultivars on the loam was higher

(0.9-4.6 t/ha) (Zeiruk *et al.,* 2007). Loamy sand soil is the suitable soil for potato production because plants can take up sufficient amount of nutrients, which potentially lead to higher yield (Ahmaadi *et al.,* 2011).

2.9 Effects of Soil Texture on Quality of Potato Tubers

It is known that quality of potatoes depends on the growth condition of soil (Zeiruk *et al.,* 2007). Sandy textured soils are more fragile and looser, which facilitates the growth of the tubers, thus lead to bigger tubers sizes (Martins *et al*., 2018). The fraction of tuber diameter which was 40-80 mm was higher at the loam soil (Zeiruk *et al*., 2007). Tuber specific gravity was not affected to a large degree by loam and sand soil (Martin *et al*, 1983). The plants grown in the sandy loam soil produced tubers with significantly highest fresh 25.12 g and dry 2.71g matter and highest length 13.5 cm and diameter 2.82 cm among all soil types (Travlos and Karamanos, 2006). Very fine sandis not good as it becomes very compacted and limits tuber development (Mbiri *et al.,*2015).

2.10 Effects of Soil Texture on vegetative growth parameters

Well drained and rich loam soils seem ideal for vegetative production and root growth (Abdulazeez, 2017). The fine sandy loam and sandy loam soils produced the tallest plants 6.4 cm at harvest (Moore and Lawrence, 2013). Vegetative and tuber growth and production of the plants grown in the clay and the clay loam soil were significantly restricted and therefore these soils need to be avoided. The maximum number of stems 7.0 stem/plant on the clay and 6.2 stem/plant on the loam, the maximum height of plant was registered for loam soil (Zeiruk *et al*., 2007). Generally, root growth is lower in soils of courser texture (sandy) than of finer texture (clay) due to lower fertility, lower unsaturated hydraulic conducting, and lower water storage capacity (Luo and Zhou, 2006). Plant growth is controlled by the size of soil particle through controlling of nutrition availability and root growth (Mistri and Chakraborty, 2015).

CHAPTER THREE

3.0 Materials and Methods

3.1 Study Site

3.1.1 Location

Soils for pot experiment were collected from four different areas namely Tshivhilidulu village, Ha Davhana, Universlity of Venda and Mangaya village in Makhado and Thulamela municipality (Figure 2). The study was conducted at the University of Venda experimental tunnel (Figure 3) located at latitude of 22˚58'48.2"S and a longitude of 30˚26'14.4''E, which is located in Thohoyandou, 70 km east of Louis Trichardt in Limpopo Province of South Africa.

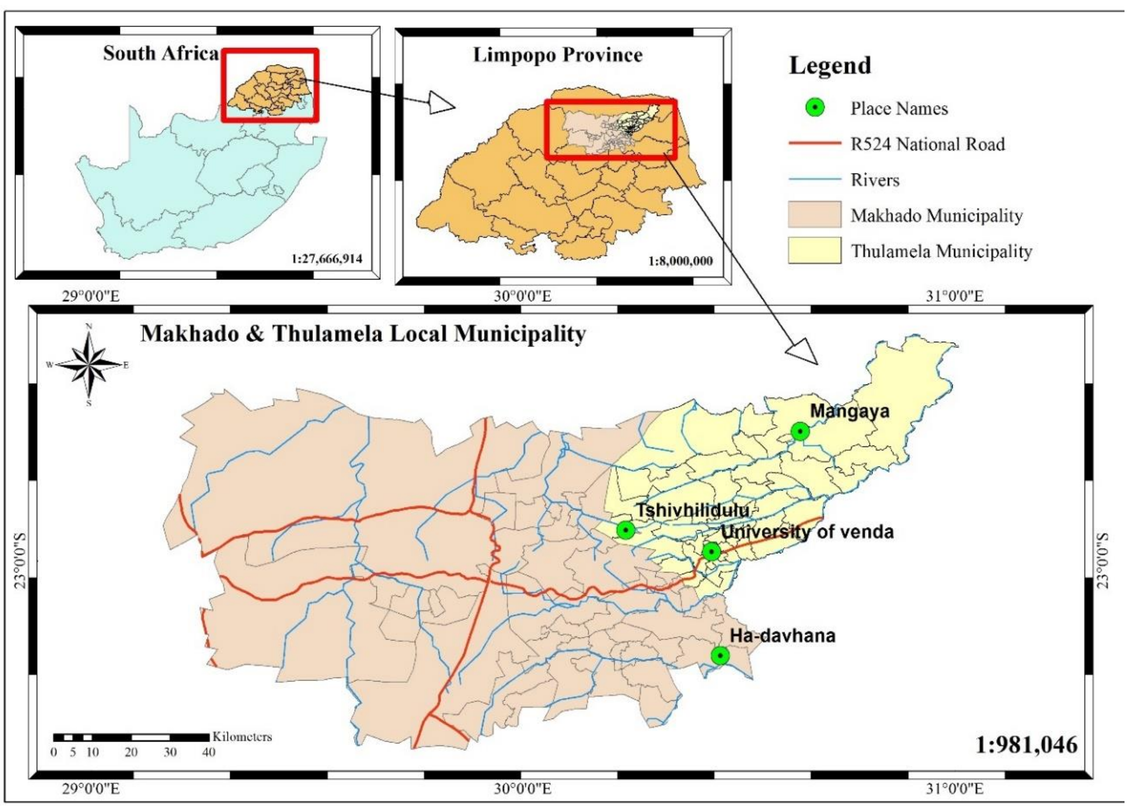

Figure 3: The soil for pot experiment was collected from four sites in Limpopo Province.

Figure 4: Potato plants in a tunnel at University of Venda experimental farm

3.2 Soils

Soils were collected from the depth of 0 – 0.4 m topsoil using a spade from four different areas in South Africa, Limpopo provinces. The soils were obtained from the following areas.

(1) Nzhelele, Tshivhilidulu, which falls at a latitude of 22˚55'44.4''S and a longitude of 30˚14'20.9''E, at an altitude of 2.82 Km. The soil found there is Loamy sand with a Bloemdal soil form.

(2) Ha-Davhana, which falls at a latitude of 23˚13'09.4''S and a longitude of 30˚27'26.4''E, at an altitude of 2.82 Km. The soil found there is Sandy loam with Glenrosa soil form.

(3) University of Venda, experimental farm which falls at a latitude of 22˚58'44.8''S and a longitude of 30˚26'13.0''E, at an altitude of 2.56 Km. The soils found there is Clay with Hutton soil form.

(4) Mangaya village which falls at a latitude of 22˚42'01.1''S and a longitude of 30˚31'33.0''E. at an altitude of 2.53 Km. The soils found there is Fine sandy loam with Avalon soil form.

3.3 Experimental Design and Data Analysis

The experiment was set up in a Randomized Complete Design. Two potato cultivars were grown. Un-compacted, compacted and Four soils constituted the treatments in split plot arrangement. The treatments were replicated three times. Potato tubers were harvested, thoroughly washed and air dried before measurements. The effect of soil compaction on the yield and quality of tubers as well as the vegetative growth parameters was examined by analysis of variance (ANOVA) using Minitab version 17.1. Where significant difference was observed, Tukey's multiple comparison test was used to compare the treatments means at $P < 0.05$ (Steel et al., 1997).

3.4 Potato Parameters

The following tuber yield attributes were measured:

(i) Fresh weight of tubers - The fresh weight of tubers was weighed per pot using a high precision balance immediately after harvest.
(ii) Number of tubers - The number of tubers per pot was counted after harvest.
(iii) Size of tubers - The size of each tuber was determined by measuring its diameter along the principal axes using a Vernier caliper having an accuracy of 0.02 mm. The following tuber size categories were used. Large ≥ 75 mm, medium 55 to 75 mm and small ≤ 55 mm (Ekin, 2013).

The following tuber quality attributes were measured:

(i) Shape of tubers - The shape of potato tuber was determined by measuring the length and width of the tuber using a Vernier caliper having an accuracy of 0.02 mm. The potato shape index was used to classify tuber shape as round < 1.09), short-oval 1.10-

1.29, oval 1.30-1.49, long-oval 1.50-1.69 and long ≥ 1.70) (Ekin, 2013). Potato shape index was then calculated using the following equation.

$$\text{Potato Shape Index} = \frac{\text{Length of Potato Tuber (mm)}}{\text{Width of Potato Tuber (mm)}} \qquad [1]$$

(ii) Dry matter of tubers - Whole tubers were cut into small slices, 1-2 mm, and mixed thoroughly to measure the Dry matter. Dry matter was then determined by drying the slices at 80°C until constant dry weight was obtained in a forced air oven. The dry matter was calculated using Equation 1 (Namo and Babalola., 2016).

$$\text{Dry matter(\%)} = \frac{\text{Dry mass (g)}}{\text{Fresh mass (g)}} \times 100 \qquad [2]$$

(iii) Specific gravity of tubers – Specific gravity was determined using weight in air and weight in water method (Steyn *et al.,* 2009). The specific gravity was computed using Equation

$$\text{Specific gravity} = \frac{\text{weight of tuber in air}}{\text{weight of tuber in air} - \text{weight of tuber in water}} \qquad [3]$$

The following vegetative growth parameters were measured.

(i) Number of stems – The number of stems were counted manually for each pot after 14 days and then recorded

(ii) Plant germination – Plant germination was measured after 14 days of planting. It was measured using scores of 1 – 5, where 1 = poor, 2 = slightly, 3 = moderate, 4 = very good.

(iii) Plant vigour – Plant vigour was measured after 21 days of planting. It was measured using scores of 1 – 5, where 1 = poor, 2 = slightly, 3 = moderate, 4 = very good.

(iv) Plant height – The PHT was measured from the base of the stem to the apex of the main shoot.

(v) Biomass- The whole fresh plant weight was measured immediately after cutting the plants and then dried in the oven at 80^0c until constant weight to obtain the biomass.

3.5 Soil Compaction

Bulk density was determined using the core method (Blake and Hartge, 1986. Weight(g) of empty cores were recorded using a balance and the height of the cores were measured using a tape measure in cm and then marked with a marker. The cores were pressed down using an auger in the planting pot and then removed and closed immediately with a lid to avoid loss of moisture. Then all the cores were taken to the lab and measured using a high precision balance and the core were dried in the in oven at 105 ^{0}c for 24 hours. The oven dried sample weight was determined and then recorded. Bulk density was the calculated using Equation 4

$$\text{Bulk density} = \frac{\text{weight of ovem dried soil in grams,Kg}}{\text{volume of soil in core sampler,M}^3} \qquad (4)$$

3.6 Soil Texture

Particle size distribution was measured using the hydrometer method (Bouyoucos, 1962). 50 grams of air-dry soil that had been passed through a 2 mm sieve was weighed and transferred into metal dispersing cup. 20 mL of 2.5 N sodium hexametaphosphate, $(NaPO_3)_6$ was added, the dispersing cup was filled with deionized water and was let to stand for 10 minutes. The dispersing cup was carefully attached to the mixer and allowed to stir for 5 minutes. The dispersed sample was quantitatively transferred from the dispersing cup into a sedimentation cylinder. The cylinder was filled with deionized water to the 1000 mL mark. The hydrometer used was calibrated by placing it in a sedimentation cylinder that contains 20 mL 2.5 N sodium hexametaphosphate and 980 mL deionized water. A rubber stopper was placed in the end of the cylinder and agitated vigorously by turning end to end. When all the soil material was resuspended, the cylinder was set down and the exact time was recorded. The hydrometer was then inserted into the suspension immediately. 40 seconds after the cylinder was set down, the hydrometer reading was then recorded. The 40-second reading gave the amount of silt and clay still suspended after the sand particles have settled. The temperature of the suspension after both hydrometer readings (40 seconds and 2 hours) was Measured and recorded. At the end of the 2-hour settling period the hydrometer was carefully placed into the suspension and the reading was recorded.

The percent sand, silt and clay were calculated using the following equation 5, 6, 7 and 8.

Sand = oven dry weight of soil. - corrected 40 sec. reading. (5).

Silt + clay = corrected 40 sec. reading.

Clay = corrected 2 h. reading.

Silt = corrected 40 sec reading - corrected 2 hr. reading.

$$\% \text{ sand} = \frac{\text{grams sand}}{\text{oven}-\text{dry weight}} \times 100 \quad (6).$$

$$\% \text{ silt} = \frac{\text{grams silt}}{\text{oven dry weight}} \times 100 \quad (7).$$

$$\% \text{ clay} = \frac{\text{grams clay}}{\text{oven dry weight}} \times 100 \quad (8)$$

The textural triangle was used to determine the texture of the soil samples.

3.7 Soil pH (H_2O)

The pH meter was calibrated with buffer 4.0 and buffer 7.0. 10 g dried soil was placed in a glass beaker. 25 cm^3 de-ionised water was then added. The contents were then stirred rapidly for 5 seconds with a glass rod and left to rest. It was then stirred again after 50 minutes and allowed to stand for 10 minutes. The pH was the determined after 30 seconds with the electrode positioned in the soil sample.

3.8 Aggregate Stability

Aggregate stability was determined according to the method developed by Kemper and Rosenau, (1986). It was determined using the wet sieving apparatus. 4.0 g of 2 mm air dried aggregates was weighed into the sieves. The aggregates were pre-moistened for 5-10 minutes before submerging them. The sieves were placed into the sieve holder. The weighed and numbered cans were placed in the apparatus. The sieve holder was placed on the build in stop. Enough distilled water was placed into the cans to cover the soil. The sieve holder was placed in the working position by putting the sieve holder in the second hole on the shaft. The motto was started by putting the main switch into 3 minutes position, it was then allowed to raise and lower the sieve-holder for 3 minutes. The sieve holder was raised out of the water and placed in the leak out position. The cans were then replaced with another set of weighed number of cans. The cans were filled with a dispersing solution (2g NaOH/L). The sieve holder was then placed in a working position. The motto was started by putting the main switch into continue and continued to sieve until sand particles are left on the sieve. The sieve holder was raised out of the water and placed in the leak out position. Both sets of cans were placed in a convection oven at 1100c. the weight of the materials in each can was then determined by weighing the can, plus contents and subtracting the weight of the can. 0.2g was subtracted from the weight of contents in the cans with the dispersing solution to obtain the soil weight.

3.9 Organic Carbon

Organic Carbon was determined according to Walkley and Black method as described by (Nelson and Sommers, 1982). The iron (II) ammonium sulphate solution was standardized against 10 cm^3 0.167 mol dm^{-3} $K^2Cr^2O^7$. The soil was grinded to pass a 0.35 mm sieve using a porcelain mortar and pestle. 1g of airdried soil was transferred to a 500 cm^3 Erlenmeyer flask. 10 cm^3 $K^2Cr^2O^7$ solution by pipette to the soil sample. The flask was swirled to disperse the soil in the solution. 20 cm^3 concentrated sulphuric acid was rapidly added directing the steam into the solution until soil and reagent are mixed. The swirling was then done more vigorously for 1 minute. The flask was allowed to cool for 30 minutes. 150 cm^3 de-ionised water and 10 cm^3 concentrated ortho-phosphoric acid. 1 cm^3 Barium diphenylamine sulphonate indicator was then added. Excess dichromate was titrated with iron (II) ammonium sulphate solution. As the end point approached, the solution colour changed to a dark violet brown. Iron (II) ammonium sulphate solution was added drop by drop until the solution changed to green.

Using a recovery factor f = 1.3, carbon content was calculated according to Equation 9 and 10.

$$\text{concentration of Fe(NH4)2(SO4)2 mol/dm}^3 = \frac{10\ \text{cm}^3\ \text{K2Cr2O7 x 0.167 x 0.3 x f}}{\text{cm}^3\text{Fe(NH4)2(SO4)2}} \qquad (9)$$

$$\text{Organic C \%} = \frac{[\text{cm}^3\text{Fe(NH4)2(SO4)2 blank} - \text{cm}^3\text{Fe(NH4)2(SO4)2 sample}]\ \text{x M x 0.3 x f}}{\text{soil mass (g)}} \qquad (10)$$

Where M = Concentration of the Fe(NH4)2(SO4)2 in mol dm^{-3}

3.10 Porosity

Soil were collected for bulk density and the used to determine porosity where, Bulk density was determined using the core method (Blake and Hartge, 1986. Weight(g) of empty cores were recorded using a balance and the height of the cores were measured using a tape measure in cm and then marked with a marker. The cores were pressed down using an auger in the planting pot and then removed and closed immediately with a lid to avoid loss of moisture. Then all the cores were taken to the lab and measured using a high precision balance and the core were dried in the in oven at 105 ^{0}c for 24 hours. The oven dried sample weight was determined and then recorded. Bulk density was the calculated using Equation 11.

$$\text{Bulk density} = \frac{\text{weight of ovem dried soil in grams,Kg}}{\text{volume of soil in core sampler,M}^3} \quad (11)$$

Porosity was then calculated from bulk density results using Equation 12.

$$\text{porosity}(\%) = 1 - \frac{\text{bulk density (KgM)}}{\text{volume of soil in core sampler (M}^3\text{)}} \times 100 \quad (12).$$

CHAPTER FOUR

4.0 RESULTS

4.1 Physico-Chemical Properties of the Soils

The physico-chemical composition of the soils used in this experiment is shown in Table 1. The soil texture was loamy sand, sandy loam, clay and fine sandy. The soils were slightly acidic with pH ranging from 6.1 - 6.8. Univen clay soil had the highest organic carbon than the rest of the soils.

Table 1: Physiochemical properties of the soils used in the experiment

	Sampling site			
Characteristic	Tshivhilidulu	Ha-Davhana	Univen	Mangaya
pH (H_2O)	6.6	6.1	6.5	6.8
O C (%)	0.54	0.45	1.6	0.24
Sand (%)	84	76	26	54
Clay (%)	12	14	52	15
Silt (%)	4	10	22	31
Textural class	Loamy sand	Sandy loam	Clay	Fine sandy loam
MWD (mm)	0.56	0.29	0.50	0.26

OC = Organic carbon, MWD = Mean weight diameter of aggregates

4.2 Effects Soil Compaction and soil texture on Yield of Potato Tubers.

Soil texture has a significant effect on the number of tubers (Table 2). Clay and fine sandy loam produced the highest and the same mean for number of tubers (9). The was a >50% increase in number of potato tubers to the compacted soil (Table 2). bulk density and soil texture showed a highly significant difference (p<0.01) for size of tubers (Table 2). There was a >40% decrease in tuber size for both cultivars in the compacted soils (Table 2). The longest tubers (55.8 mm) were found in the loamy sandy soil while the shortest tubers (46.1 mm) were observed in the fine sandy loamy. Similarly, the highest tuber fresh weight (387.9 g/pot) was produced in loamy sand and the smallest tuber fresh weight (256.9 g/pot) was produced in the fine sandy loam. The effect of bulk density showed a significant difference (p<0.01) for fresh weight in both cultivars. Non compaction soil increased fresh weight by >60% (Table 2). There was a greater than >30% decrease in the fresh weight of potato tubers due to soil compaction.

Table 2: Effect of compaction and soil texture on potato tuber yield.

TREATMENT	NT	SPT (mm)	FW (g/pot)
Soil texture			
Loamy Sand	8.0ab	55.8a	387.9a
Sandy Loam	5.2b	51.9ab	275.3b
Clay	9.0a	50.3b	305.7ab
Fine Sandy Loam	9.4a	46.1c	256.9b
Bulk density			
Uncompacted	8.0a	57.3a	392.4a
Compacted	7.9a	44.8b	220.6b
P-value			
soil texture	**	**	**
density	Ns	**	**
STxBD	Ns	Ns	ns

** = significant at p<0.01, * = significant at p<0.05, ns= not-significant, NT= number of tubers, SPT = size of potato tubers, FW = fresh weight, ST = soil texture, BD = bulk density.

4.3 Compaction and Texture Effects on the Quality of Potato Tubers

There was no significance difference observed for potato shape index (PSI) for both bulk density and soil texture (Table 3). The tubers produced had a short-oval, oval and long-oval shape. Soil compaction and soil texture had a significance effects ($p<0.05$) on specific gravity of potato tubers (Table 3). Specific gravity was higher (19.9) in the uncompacted treatment and lower (15.6) in the compacted treatment. Compaction decreased the specific gravity by more than 40% (Table 3). The highest specific gravity (21) was found in the Clay and the lowest (14) was found in the Sandy loam soil (Table 3). The interaction between soil texture and bulk did not affect potato shape index, specific gravity and dry matter (Table 3). Soil compaction did not affect the dry matter of the tubers (Table 3).

Table 3: Effect of compaction and soil texture on potato tuber quality evaluated in a tunnel at University of Venda

TREATMENT	PSI (mm)	SG	DM (%)
Soil texture			
Loamy Sand	1.3a	16.9ab	13.9a
Sandy Loam	1.3a	14.0b	21.0a
Clay	1.3a	21.0a	18.9a
Fine Sandy Loam	1.3a	19.1b	17.8a
Bulk density			
Uncompacted	1.3a	15.6b	16.4a
Compacted	1.3a	19.9a	18.9a
P-value			
soil texture	Ns	*	ns
Bulk density	Ns	*	ns
STXBD	Ns	Ns	ns

** = significant at $p<0.01$, * = significant at $p<0.05$, ns = not-significant, PSI = potato shape index, SG = specific gravity, DM = dry matter, ST = soil texture, BD = bulk density

4.4 Compaction and Texture Effects on the vegetative growth parameters of Potato Tubers

Soil texture did not affect the number of stems (NST), plant germination (PG), height, biomass (BM), but had a significant effect ($p<0.05$) on plant vigour (Table 4). Although there was not much difference in plant vigour, loamy sand had the highest (3.4) plant vigour whilst sandy loam soil had the lowest (2.4) (Table 4). Sandy loam and loam sand soil had the tallest plant (38.2 and 35 cm) respectively. Compaction significantly affected ($p<0.01$) for NST, PV, height of potato crop. Surprisingly, the highest number of stems was found in the compacted soil (4.4/ pot) than in the uncompacted soil (3.3/pot), while the highest PV (4.2) and plant height (41.9 cm) was found in the uncompacted soil. There was a greater than >60% increase in the height of potato crop of uncompacted soil.

Table 4: Effect of compaction and soil texture on potato vegetative growth parameters

Treatments	**NST**	**PG (after 14 d)**	**PV (after 21 d)**	**PHT (cm)**	**BM (g/plant)**
Soil texture					
Loamy Sand	4.2a	3.3a	3.4a	35.0a	9.3a
Sandy Loam	3.9a	3.4a	2.4b	38.2a	9.7a
Clay	3.5a	3.0a	3.3ab	30.1a	8.9a
Fine Sandy Loam	3.8a	3.1a	3.2a	32.8a	11.1a
Bulk Density					
Uncompacted	3.3b	3.2a	4.2a	41.9b	10.0a
Compacted	4.4a	3.2a	2.0b	26.1a	9.5a
P-value					
Soil texture	Ns	ns	*	ns	ns
Bulk Density	**	ns	**	**	ns
BDXST	Ns	ns	Ns	ns	ns

** = significant at $p<0.01$, * = significant at $p<0.05$, ns= not-significant, NST= number of stems, PG= plant germination, PV= plant vigour, PHT = plant height, BM= biomass, BD= bulk density, ST= soil texture.

Figure 5 shows a picture of some deformed tubers with a pointy end shape that were harvested from a compacted treatment in the experiment.

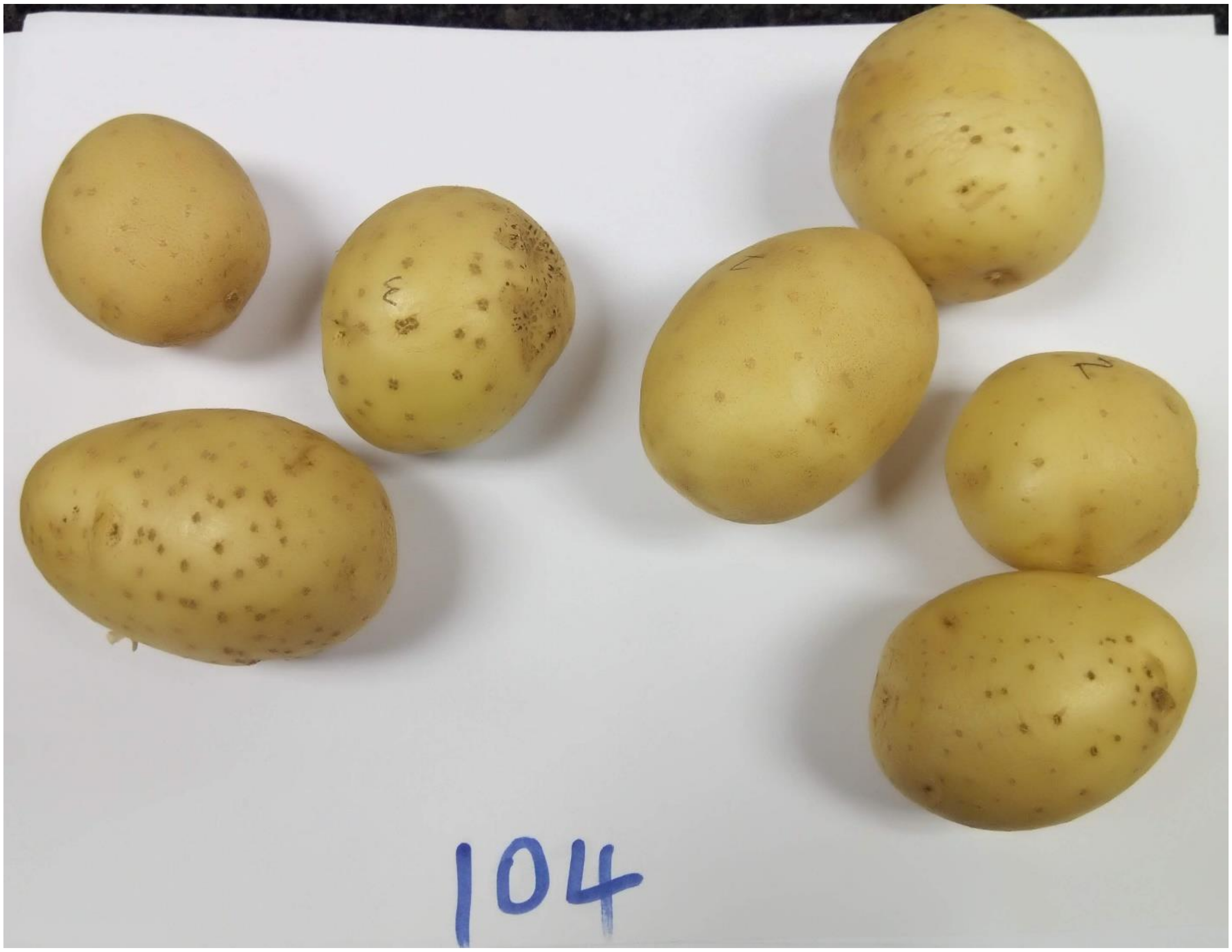

Figure 6 shows a picture of some potatoes that were harvested from a non-compacted treatment in the experiment.

CHAPTER 5

5.0 DISCUSSION

5.1 Effect of Compaction and Soil Texture on Yield of Potato Tubers

In the loamy sand soil of this study, fresh weight was reduced by >30% by compaction (Table 2). Whereas, in an experiment in which compaction treatments were applied, (van Loon and Bouma, 1978., hatley *et al.,*2005), yield was reduced to about 63% of the control by subsoil compaction. Crop yields can be reduced by soil compaction due to increased resistance to root growth and decrease in water and nutrient use efficiencies (Ishaq, 2001). In the same study by Ishaq, 2001, tuber fresh weight was reduced by compaction 51% to 71% over the two-year study. Fine sandy loam produced the lowest tuber fresh weight (256.9 g/pot) as compared to the other soils in the experiment (Table 2). This is in agreement with Hatley, (2005) who stated that some soil types are more susceptible to harmful compaction; especially fine sandy loams. On a sandy soil with differing compaction treatments, yields in a severely compacted treatment were 54-94% of those in a non-compacted treatment (hatley *et al*.,2005; Van Oijen *et al*., 1995). Clay soil showed a 24% reduction in tuber yield in this experiment. Tuber fresh weight of potatoes is significantly reduced on heavy clay soils, perhaps due to the bad drainage and the low total porosity (high bulk density) of these soils (Howeler *et al*., 1993; Travlos and Karamanos, 2006). Potato production is high in porous, non-compacted soils that ensure optimum water, nutrient and oxygen supply (Travlos *et al*.,2009). This agrees with (Ishaq *et al*., 2000) who showed that compaction increased soil bulk density by 16% and decreased total porosity from 0.37 to 0.27 m^3 m^{-3} and air-filled porosity from 0.16 to 0.06 m^3 m^{-3}.

5.2 Effect of Compaction and Soil Texture on the Quality Potato Tubers.

The results of this study indicated that soil compaction reduced the quality of potato tubers and yield vegetative growth parameters of potato crop (Table 2). There are few reports giving details of direct effects of compaction on tuber quality (hatley et al.,2005). In each soil, compaction did not affect the number of tubers, but it showed a significance effect on the number of tubers between the soils (Table 2). Compaction reduced number of tubers >10 mm, total and graded yields (Stalham *et al*., 2007). The largest tuber number (9) was found for the clay and fine sandy loam of this experiment. This is in agreement with Hickey, 1977 who stated that plants growing in the fine sand and clay loam showed a marked increase in tuber number (8.7, 5). This may have been due to the great porosity and water retention of fine sand and clay loam soil.

A difference in the size of the tuber caused by soil compaction was very noticeable. The tubers produced were small and medium sized. Loamy sand soil produced the longest tubers (Table 2). This length may be due to the excellent pore size of loamy sand which allows for easy growth of tubers and is not easily compacted. Similarly, sandy loam soils also produced longer tubers. Sandy soils tend to have a much larger pore spaces because the sand grains are more irregular in shape and do not compact as readily (Vittum, 2009). The course textured, sandy soils are preferred because tuber quality is better, perhaps because this sensitivity to texture results from differences in aeration (Cary, 1985). The size of tubers was reduced significantly by compaction (Table 2) probably because when the soil is compacted, the size of pores is reduced while squashing the tubers to the point where tubers cannot grow to their normal size.

Statistically, there were no significant differences in potato shape index of tubers for both bulk density and soil texture (Table 3). Some tubers though very small had some pointy end shape to show deformities (Figure 5). Tubers from the compacted compartments also had a slightly greater number of points or toes (Ferguson and Gumbs, 2014). Short-oval, oval, long-oval shape of potato tubers were obtained from this experiment. Specific gravity was reduced as a results of soil compaction. Loamy sand and fine sandy loam produced the highest specific gravity. Specific gravity result in higher crisp yield and lower oil percentage, which are advantageous to the processing industry (Kumar *et al.,* 2007). The higher the dry matter content the higher the specific gravity of tubers. Loamy sand produced significantly higher fresh tuber yield than coarse sand and sandy loam soils and the same tendency was found for dry matter yield (Ahmadi *et al.,*2010). In this experiment, dry matter was not affected by soil compaction and soil texture.

5.3 Effect of Compaction and Soil Texture on the vegetative growth parameters of Potato Crop.

The result of this study showed that the effect of soil texture on plant vigour was noticeable and as well as the effect of compaction on number of stems, plant vigour and height of potato crop. The effect could probably be due to compaction that reduces the porosity of soils needed for movement of water and air, thus making it difficult for tubers to expand and grow, restrict roots from accessing necessary nutrients and water which indirectly affect germination, and plant vigour consequently decreasing yield. Soil texture affects the ability of soil to hold nutrients and water, thus loamy sandy and sandy loam hold less water and nutrients which may restrict the vegetative growth parameters from growing well indirectly affecting the yield and quality of potato tubers.

6.0 CONCLUSION AND RECOMMENDATION

This study investigated the effect of compaction on the quality of potato tubers of potatoes. The results show that compaction significantly affect size of tubers, specific gravity, yield, number of tubers. This was in agreement with several other previous studies involving effect of compaction on potatoes. Loamy sand and sandy loam produced better tubers than clay and fine sandy loam although the difference was not that high. This is because they have good drainage and aeration. Clay soil can be used to grow potatoes, but it will need a lot of management since it becomes very sticky and difficult to harvest when compacted. In this experiment, Fine sandy loam did not perform well in terms of productivity as compared to the other soils. The interaction between bulk density and soil texture only significantly affected size and specific gravity of the tubers.

The results of this study clearly show that different soil texture and compaction usually correspond to their potential production capacity such as porosity, organic matter, water holding capacity and aggregate stability. It is important to choose the soil that are less prone to compaction and will produce better vegetative growth thus, producing better potato yields and quality. Soil compaction significantly reduced the quality and yield of tubers. It is important to find solution on how we can prevent compaction. This shows that proper management of soils is necessary in potato production to reduce soil compaction for higher productivity. Further experiment needs to be done in the field in order to attain more practical results to make conclusive recommendations especially for compaction.

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APPENDICES

APPENDIX 1

The results were presented at the combine conference

Mufandilani M, Gwata Et, Wakindiki IIC. 2020. Effect of soil texture and compaction on potato (*solanum tuberosum*) tuber yield attributes. Poster session presented at the combined congress, 20-23 Jan, University of the Free State, Bloemfontein, South Africa. pp. 207.