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Performance of selected cowpea (vigna unguiculata (l.) walp) varieties in different soil types in Singida District, Tanzania

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PERFORMANCE OF SELECTED COWPEA (*Vigna unguiculata* (L.) Walp) VARIETIES IN DIFFERENT SOIL TYPES IN SINGIDA DISTRICT, TANZANIA

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ABSTRACT

A participatory research was conducted in Singida District central Tanzania under Singida Nutrition and Agro ecological Project (SNAP), during the 2016/2017 cropping season to evaluate the performance of cowpea (*Vigna unguiculata*) varieties in different soil types. Four improved cowpea varieties; Tumaini, Fahari, Vuli-AR-I, Vuli-II and one local cowpea variety sourced from farmers in the study area were used. "Mother-baby trial" approach was used whereby a Randomized Complete Block Design (RCBD) experiment with three (3) replications was set in four different soil types; sandy loam, sandy clay, sandy clay loam and loamy sand as a mother trial. Twenty eight (28) farmers from three villages (Iddisimba, Merya and Msikii) were selected for the "baby trials". In the "mother trial" planting was done on 04th February 2017, with inter and intra-row spacing of 75 cm and 20 cm respectively for the bush type Tumaini, Fahari, and local varieties: while the determinate varieties Vuli-AR-I and Vuli-II were sown at spacing of 50 cm between rows and 20 cm within rows. The growth parameters were recorded in the 9th week after seedling emergences and yield parameters at harvest. The results showed significance difference ($P<0.05$) on growth parameters and yield parameters. Generally, the improved varieties performed better than the local variety in both mother and baby trials although yields were less in baby trial compared to mother trial. Vuli-AR-I performed better in all types of soil, Tumaini in sandy loam, Vuli-II and Vuli AR-I in sandy loam, sandy clay and sandy clay loam. In "baby trial" Tumaini in Iddisimba and Msikii village and Fahari variety in Merya village. The results therefore portray a differential performance of the varieties based on soil types and the study highlights the need for recommending these varieties based on the soil types.

DECLARATION

I, **Joseph Salvatory Kalonga** do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Mr. Joseph S. Kalonga

Name and signature of candidate **Date __________**

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CERTIFICATION

The undersigned certify that they have read the dissertation titled **“Performance of Selected Cowpea (*Vigna unguiculata* (L.) Walp) Varieties on Different Soil Types in Singida District, Tanzania”** and recommended for examination in fulfillment of the requirements for the degree of Masters of Life Science and Engineering of the nelson Mandela African Institution of Science and Technology

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Dr. Kelvin Mtei

Name and signature of Principal supervisor

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Dr. Ernest R. Mbega

Name and signature of Co-supervisor

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DEDICATION

I dedicate this piece of work to my beloved wife, Rachel Mathias Majinge, my mother Prisca George Siame and my son Germanico Joseph. Kalonga who was borne during my studies. Their inspiration and the encouragement from them were highly appreciated.

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LIST OF ABBRVIATIONS AND SYMBOLS

%	Percentage
a.s.l.	Above Sea Level
AC	Active Carbon
ANOVA	Analysis of Variance
BNF	Biological Nitrogen Fixation
Bp	Bacterial pustule
C	Carbon
CABMV	Cowpea Aphid Borne Mosaic Virus
CGIAR	Consultative Group for International Agricultural Research
CIAT	International Center for Tropical Agriculture
cm	Centimeters
CV%	Coefficient of Variation
DAICO	District Agricultural, Irrigation and Cooperative Officer
DPP	Directorate Plant Production
Fa	Fahari,
FAO	Food and Agriculture Organization
Fig	Figure
Fprob	Fixation Probabilty
g	gram
GenStat	General Statistics
ha	Hectare

IARI	Ilonga Agricultural Research Institute
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ITC	International Trade Centre
K	Potassium
kg	Kilogram
$Kgha^{-1}$	kilogram per hectare
LSD	Least Significant Differences
Lo	Local
LoamS	Loamy sand
Lt	Litres
m	Metre
MATI	Ministry of Agriculture Training Institute
N	Nitrogen
NM-AIST	Nelson Mandela African Institution of Science and Technology
P	Phosphorus
P	Probability
pH	Potential hydrogen
RCBD	Randomized Complete Block Design
SandyC	Sandy clay
SandyCL	Sandy clay loam
SandyL	Sandy loam
SNAP	Singida Nutrition and Agro ecological Project

SSA	Sub - Saharan Africa
t/ha	Ton per hactre
TN	Total Nitrogen
Tu	Tumaini
V2	Vuli – II
VR	Vuli-AR- I
Vuli - AR	Vuli Alectra Resistant
WCA	West and Central Africa
^{0}C	Degrees Celsius
mm	Millimeters
Wk	Week

CHAPTER ONE

INTRODUCTION

1.1 Background information

Cowpea (*Vigna unguiculata* (L.) Walp) is an important crop in semi-arid area of Sub-Saharan Africa (SSA) and is believed to have been used as a food crop since Neolithic times (Addo-quaye *et al*., 2011). Cowpea is grown extensively in 16 African countries, with the continent producing two-thirds of the world total production (Agyeman *et al*., 2014). It has been cited as an important source of food, livestock feed, income and forms a major component of agro ecological practices due to its ability to improve marginal lands through nitrogen fixation and as cover crop (Sanginga *et al*., 2003; Addo-quaye *et al*., 2011). It covers the soil surface by its dense green canopy thus conserve soil moisture, protect the soil against adverse weather conditions such as excessive direct sunshine, high rain drops which may lead to splash, soil wash and erosion (Sebetha *et al*., 2010). Cowpea can fix about 240 kg ha^{-1} of atmospheric nitrogen and make available about 60-70 kg ha^{-1} nitrogen for succeeding crops grown in rotation with it (Addo-quaye *et al*., 2011; Omae *et al*., 2014; Marinus, 2014).

Cowpea is cultivated around the world primarily for grains, but also as a vegetable (for leafy greens, green pods, fresh shelled green peas, and shelled dried peas), as cover crop and for fodder (Mekonnen *et al.,* 2016). In most African countries, cowpea is either grown as a sole crop or intercropped with various cereal crops, such as maize, millet, sorghum and other crops like pigeon peas, bananas and others (Abate *et al.*, 2011; Massawe *et al*., 2016). The crop is widely cultivated under rainfed conditions mainly in the savanna and transitional agro ecological zones (Langyintuo *et al*., 2003; Karanja *et al*., 2013). It is well adapted to the environmental condition with drought, high temperature and other abiotic condition than other crops (Powell *et al*., 1993). Cowpea is shade tolerant and compatible as an intercrop with cereal crops. The intercropping system helps to prevent buildup of disease incidence, insect pests and weeds (Chibarabada *et al*., 2017). Its variability of uses, nutritive content and storage qualities have made cowpea an integral part of the farming systems in Africa (Ronner *et al.*, 2013).

It is estimated that the annual world cowpea grown is 12.5 million ha, and the total grain production is 3 million tons although only a small proportion enters the international trade market (DPP, 2011). The leading producing regions in the world are West and Central Africa

(WCA), Africa producing 68% of the estimated 3 million tons of cowpea seed produced annually. Nigeria is the world’s leading cowpea producing country, followed by Brazil, United State of America, Asia and rest of the world (Gomez and Mjia, 2004). The average world yield of cowpea grain is quite low at less than 0.3 ton/ha and within Africa, average cowpea yields vary dramatically from 0.05 to 0.55 ton/ha as compared with potential yield of 1.0 to 1.5 ton/ha reported by researcher (Rusike *et al.,* 2013; Takim and Ii, 2010). Low cowpea yield is mostly contributed by the use of unimproved varieties and poor soil nutrition (Akibode and Maredia, 2011).

In Tanzania, cowpea is an important food and cash crop which is mostly grown by small holder farmers (Sebetha *et al.*, 2010). However, cowpea production in Tanzania is still low and does not meet the market demand due to increased demand of grain - legume proteins (Grafenauer *et al.*, 2008). The average yield is low averaging to 318 kg/ha (Mbwaga *et al.*, 2007). Factors for low yield include poor cultivars, drought, insect pests, diseases, parasites and weeds (Roberts *et al.*, 2009). Among these limiting factors, poor cultivars and pests have been cited as major constraints to cowpea production (Mbwaga *et al.*, 2011; Bisala *et al.*, 2014). However, small holder farmers keep on growing cowpea for other benefits such as soil erosion control, leaf vegetable and as a source of income. Some efforts have been made to improve cowpea production in all agro ecological zones of Tanzania through various means including the introduction of new improved varieties such as Vuli-AR-I, Vuli-II, Fahari and Tumaini which were used in this study.

Few studies have been done to evaluate the performance of cowpea varieties in different soil types of Tanzania. In selecting suitable varieties for different soil environments, it is important to understand the performance of these varieties in different soil types to allow for evaluation of suitable varieties under different soil types. This study, under Singida Nutrition and Agro ecological Project (SNAP) conducted a participatory research to evaluate performance of five varieties of cowpea in the predominant different soil types in rural Singida. Best performing varieties will be recommended to farmers in the study area Singida Rural for legumes diversification.

1.2 Problem statement and justification

Due to increasing population of people in Tanzania, the demand for protein is also increasing which lead to high price of animal proteins such as beef and fish. High price of animal protein in Tanzania lead to low-protein diet intake which result to poor growth of children due to malnutrition (Menon *et al.,* 2009). To overcome this problem, people are now shifting to affordable source of proteins such as cowpea. Currently, the demand for cowpea grains has increased while production is still low and does not meet the market demand (Williams *et al*., 2008). The average yield in small holder farmer is low, averaging to 318 kg/ha while the reported potential yield of cowpea is 1.0 to 1.5 ton/ha (Mbwaga *et al.*, 2007; Rusike *et al.,* 2013). Low yield of cowpea in Tanzania is caused by a number of limitations including poor cultivars, drought, insect pests, diseases, parasites and weeds (Roberts *et al.*, 2009); however, poor cultivars and pests but the major constrains (Mbwaga *et al*., 2011; Bisala *et al*., 2014).

To address the problem of low yield due to poor cultivars, improved varieties of cowpeas have been produced. However, information on their performance in the Tanzanian heterogeneous environment such as soil types and farmer's agronomic practices is scanty. For proper recommendation of the improved cowpea varieties, it is important to evaluate them in different soil types and farmer's agronomic practices. Therefore, this study aimed to assess the performance of cowpea varieties in different soil types in Singida Rural District.

1.3 Research objectives

1.3.1 Overall objective

This study was conducted in the framework of Singida Nutrition and Agro ecological Project (SNAP) initiated by Cornel University and implemented by Cornel University, Nelson Mandela African Institution of Science and Technology (NM-AIST), Action Aid and Ilonga Agricultural Research Institute (IARI). The project was established for the purpose of testing if a participatory; agro ecological peer farmer-led education intervention can be effective in improving legume production, food security, and infant and young child feeding practices in Singida District, Tanzania. Within SNAP then this study aimed to evaluate the performance of four (4) cowpea varieties on different soil types in Singida, Rural District

1.3.2 Specific objectives

i) To assess the growth and yield of selected varieties of cowpea in different soil types in Singida Rural District

ii) To determine yield of selected improved cowpea varieties under farmer's agronomic practices in Singida Rural District

1.4 Research questions

i) What are the effects of soil types on growth and yield of selected improved cowpea varieties in Singida Rural District?

ii) How does farmer's agronomic practices affect yield of selected improved cowpea varieties in Singida Rural District?

1.5 Significance of the study

The proposed study contributes to better understanding of the effect and response of cowpea varieties under different soils types. This understanding provides a way forward to recommend the best performing varieties to small holder farmers in Singida District. These recommendations contribute to legumes diversification as one of the objectives of the project (SNAP) to improve crop yield and reduce household nutrition and food insecurity.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cowpea (*Vigna unguiculata* (L.) Walp) Classification and botanical characteristics

Cowpea belongs to class *Dicotyledonea*, order *Fabales*, family *Fabaceae*, subfamily *Faboideae*, tribe *Phaseoleae*, subtribe *Phaseolinae*, and genus *Vigna* (Line and Sharma, 2016). All cultivated cowpeas are grouped under the species *Vigna unguiculata*, which is subdivided into four cultivar groups (cv. gr.): *unguiculata* (the common cowpea), *biflora* (the catjang), *sesquipedalis* (the yard-long bean) and *textilis* (used for fibers) (Onasanya *et al*., 2015). Africa is the domesticated and origin of cowpea (Kouam *et al*., 2012).

Cultivated cowpea varieties are considered warm season crops that exhibit a wide range of growth habits and adapted to heat and drought conditions (Shanko *et al.,* 2016). It is an annual or perennial, erect to climbing herb and reaching heights of 15 - 80 cm with a strong tap root and many spreading lateral roots in the surface soil. Roots depth has been recorded at 22.5 cm depth 8 weeks after planting (Timko *et al*., 2007). They have different growth forms but mostly are erect, semi-erect, prostrate or climbing. The first pair of leaves is simple and opposite while the rest are arranged in an alternate pattern and are trifoliate (three leaflets) (Davis *et al.*, 1991). The leaves are usually dark green in colour (Etana *et al*., 2013). Cowpea leaves show considerable variation in size (6 –16 x 4 –11 cm) and shape (long, pointed to oval), depending on the variety. The leaf petiole is 5 cm to 25 cm long. The stems are striate, smooth or slightly hairy and sometimes tinged with purple (Timko *et al*., 2007).

Flowers are borne in alternate pairs, usually with only two or more flowers per complete flower head, including stems, stalks and flowers (Ahmed *et al*., 2011). They are conspicuous, self-pollinating, borne on short stalks like pedicels structures and the whorls of petals forming the inner envelopes of flowers may be white, dirty-yellow, pink, pale blue or purple in colour (Xaba, 2007). Flowers open early in the day and close at approximately midday. After blooming (opening once) they wilt and collapse (Timko *et al*., 2007). The stamens are diadelphous (9 forming a tube of filaments and 1 free). The ovary is straight with a bent style, which is hairy along the inner side and a globular, glandular stigma (Davis *et al*., 1991).

Fruits are dehiscent pods, which usually shatter when dry and vary in size, shape, color and texture. It is pendulous, mostly linear although curved and coiled (crescent-shaped) forms occur. The pod is green at early stage and when maturing it usually becomes yellow, light brown, pink or purple. The pod length may vary from 5.5 – 90 cm (Thulin, 1989).

Seeds vary considerably in size, shape and color. They are relatively large (2-12 mm long) and weigh 5-30 g/100 seeds. Seed shape is correlated with that of the pod (Singh *et al*., 1997). According to Sariah (2010), there are usually 10-20 seeds per pod. Seeds of cowpea cultivar vary considerably in color (such as brown, purple, white and speckled), shape (reniform or kidney shaped, ovoid, rhomboid etc.) and sizes ranging between 0.4 cm to 1.2 cm in length and 0.3cm to 1.0 cm in width. Weigh 5-30 g/100 seeds. Seed coat texture (testa) can be smooth, rough, wrinkle white, green, red, brown, black, speckled, blotched and hilum white surrounded by a dark ring (Timko *et al*., 2007).

2.2 Importance of cowpea to smallholder farmers in SSA

Cowpea plays an important role to smallholder farmers in SSA (Onasanya *et al*., 2015; Walp *et al*., 2016). Many parts of cowpea plant are used for food such as fresh leaves, immature pods and the grains. Cowpea contain a wide range of nutrients including; protein, carbohydrate, vitamins and minerals (Ikhlas and Sirelkhatim, 2014).

Cowpea has the ability to fix atmospheric nitrogen through its root nodules, and grows well in poor soils with more than 85% sand and with less than 0.2% organic matter and low levels of phosphorus (Lachyan and Dalvi, 2015). Many cowpea varieties can perform better or produce reasonable yield under dry conditions where other crop plants cannot perform. Cowpea varieties with deep rooting habit grow well under semi-arid conditions (Agyeman *et al.,* 2014). Cowpea plays a big role as a source of income to smallholder farmers especially women, through selling of leaves and grains (CGIAR, 2011). Cowpea is of major importance to smallholder farmers in SSA countries including Tanzania where animal protein is not easily available for the family.

2.2.1 Cowpea in smallholder farming systems

In farming systems, cowpea play a traditionally great importance for dry savannas of Africa because it requires relatively little water and nutrients especially Nitrogen, which is a big limiting resource in these areas (Singh *et al*., 1997). Areas along the coast which covers eastern and southern parts of Africa including countries like Somalia, Kenya, Tanzania and Mozambique (FAO, 2015). Cowpea is also important for the in-land dry savannas of Kenya, Tanzania (Central zone regions of Dodoma and Singida), Zambia and etc. It is normally grown alone as a sole crop in the coastal regions and as mixed crop with maize, pearl millet or sorghum in other regions (Kisetu *et al.*, 2014). Due to their different growth habit of indeterminate and semi determinate they are used as a cover crops hence suppress weeds and prevent the soil from soil erosion because they reduce splash of rain water (Ngalamu *et al.*, 2014). Crop residues after harvesting are incorporated into the soil to add organic matters which add nutrients in the soil. Organic matter in the soil creates good environment for beneficial microorganism in the soil (Singh *et al.*, 2011).

In Africa, more than 90% of cowpeas are produced as an intercrop with cereals such as maize, pearl millet or sorghum (Iderawumi *et al*., 2014). In eastern Africa, most of the farmers prefer to grow a dual purpose cowpea, where both leaves and grains are harvested for food. Leaves are harvested along the growing period and seeds are harvested at the end of the season when the crop is dry (Nai *et al*., 2012; Saidi *et al*., 2010). In Tanzania, cowpea plays a big role in the farming system whereby most of the farmers accompany maize or sorghum with cowpea (Kisetu *et al*., 2014). The grain legume which compete with cowpeas in grain production and consumption is common bean (*Phaseolus vulgaris*) but cowpea remains popular for the best tasty and leaf quality (ICRISAT, 2012). This is well known by farmers especially in Tanzania, but its utilization is still minimal (ITC, 2016). Lack or little information, research, resource and skills are some of the reasons for low adoption in integrating cowpea in the farming system. Keeping in view the economic benefits of cowpea, there is a need to promote it among the farming community.

2.2.2 Importance of cowpeas in the soil fertility management

Cowpea improves Nitrogen in the soil through the Biological Nitrogen Fixation (BNF) process, BNF is a unique feature of a legume in a farming system (Jessica *et al.*, 2014). Most legume such as cow pea are able to form a symbiosis with alpha- or beta-proteobacteria, collectively called rhizobia that use solar energy captured by the plant to break the bond in inert atmospheric di-nitrogen and form reactive N species, initially in the form of ammonium ($NH4^+$) (Baddeley *et al.*, 2014). Symbiotic relationship provide a relatively low-cost method of replacing nitrogen in the soil, enhancing soil fertility and boosting subsequent crop yields (Baddeley *et al.*, 2014; Saikia and Jain, 2016). The ability of cowpea to fix N in the soil are shown in Table 2. The variation exist on nitrogen fixation rate is due to environmental factors (temperature, nutrients level, pH and moisture level), Management practices and plant factors

(Schubert *et al.*, 1976; Hungria *et al.*, 2000; Mohammadi *et al.*, 2012). But also there is still little information on Nitrogen fixation rate on different soil types.

Cowpea is used as primary sources of food and fertilizer, or, secondarily, to enrich the soil, preserve moisture and prevent soil erosion (Bohlool *et al.*, 1992). Cowpeas improve soil organic matter content and water-absorbing capacity of the soil leading to improved yield to the subsequently crops (Shuaibu *et al.*, 2015). Since cow pea is rich in nitrogen its decomposition enhance availability of organic matter and biodiversity in the soil (USDA, 1998). This is ascertained by the fact that most other crop residues such as cereals contain much more carbon than nitrogen, while most biodiversity require both nitrogen and organic matter (Megan *et al.*, 2008; Reeves, 1997; USDA, 1998).

Cowpea as a legume have capacity to promote plant-soil-microbial activity on soils which can also result in regulating the soil pH to optimum levels for crop growth (Mugwe *et al.*, 2009; Butterly *et al.*, 2010). Cowpea provide an excellent break in a crop rotation (Makoi and Ndakidemi, 2016) that reduces the build-up of grassy weed problems, insects, and diseases (Tanner and Ababa, 2002; Khan *et al.*, 2007; Truscott *et al.*, 2009; Lupwayi *et al.*, 2011) .

Table 1: Nitrogen fixation rates of cowpea

Biological nitrogen fixation rate (Kg/ha)	References
35	One Acre Fund (2014)
61 - 155	Baijukya *et al.* (2013)
30 - 125	Ennin *et al.* (2004)
30	Martins *et al.* (2015)
42.68	Yabuku *et al.* (2010)
120	CIAT-TSBF (2010)
28	Chikowo *et al. (*2004)
47	Rowe and Giller (2003)
73–354	Silva and Uchida (2000)

2.2.3 Cowpea in food security and nutrition

“Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (FAO, 2006). Cow pea is consumed in many forms such as seedling and young leaves. As seedling cowpea can be prepared in various dishes or in association with cereals, fresh green leaves can be eaten as salad (Burstin *et al.*, 2009). Cowpea has low fat content which serve as alternative to red meat (Swinburn *et al.*, 2004; Duranti, 2006). It has plenty fibers which may help to control appetite by keeping one feeling fuller for longer (Naim *et al.*, 2012; Egbe *et al.*, 2013). This makes cowpea is a good supplement for cereal and root-and-tuber-based diets in many people of SSA's communities. The grains and pods are the ones which give the good economic value to this crop (El-Shaieny *et al.,* 2015). Crop residues provide good fodder that significantly supports the livestock production especially that of dry savannas of West and Central Africa (Asio *et al.*, 2005). Multiple uses as food and fodder have resulted in a potential of cowpea in ensuring food security in many parts of the world. Nutritional values of cowpea are shown in the table below;

Table 2: Nutritional value of cowpea

Nutrient	**Seeds %**	**Hay %**	**Leaves %**
Carbohydrates	56 - 66	-	8
Protein	22 - 24	-	4.7
Water	11	18	85
Crude fibre	5.9 – 7.3	9.6	2
Ash	3.4 – 3.9	23.3	-
Fat	1.3 – 1.5	11.3	0.3
Phosphorus	0.146	2.6	0.063
Calcium	0.104 – 0.076	-	0.256
Iron	0.005	-	0.005

Source (Ntombela and Thembinkosi, 2012)

2.3 Agronomic requirements of cowpea

Cowpea is adapted to different soil types, and reported to grow well in sandy soils where root growth is not restricted (Goenaga *et al.*, 2013). It can perform under low soil fertility acid soils but it is less tolerant to cold soils (Wendt *et al.*, 2004). Well drained soil with pH range between 5.6 to 6.0 is favorable for cowpea but do not grow well in water logging conditions that commonly occur on heavy clay soils (Roberts *et al.*, 2009). Cowpea is a higher drought-tolerant crop than many other crops (Amede and Kirkby, 2001). The crop requires optimum rainfall conditions range from 400 to 700 mm per annum (Gogile *et al.,* 2013). The temperature for germination is 8.5 °C and for vegetative growth is 20 °C. The optimum or recommended temperature for growth and development is around 30 °C. Varieties differ in their response to day length, some being insensitive and flowering within 30 days. The time of flowering of photosensitive varieties is dependent on time and location of sowing and may be more than 100 days. Even in early flowering varieties, the flowering period can be extended by warm and moist conditions, leading to asynchronous maturity (Aderibigbe *et al*., 2014).

2.4 Cowpea production

It is estimated that 14.5 million hectares of land in the world are planted with cowpea each year (Abate *et al*., 2011). Global production of dried cowpeas in 2010 was 5.5 million metric tons dominated by Africa which was responsible for 94% (CGIAR, 2011). Nigeria is the largest producer and consumer of cowpea, producing 2.2 million metric tons of dried grain in 2010. Niger is the second largest producer, followed by Burkina Faso, Myanmar, Cameroon, and Mali and Tanzania is the 7th (Gomez and Mjia, 2004). An estimated 38 million households (194 million people) grow cowpea in sub-Saharan Africa, but productivity has not seen sustained growth over the last two decades total area, yield, and production grew by 4.3%, 1.5%, and 5.8%, respectively (Abate *et al*., 2011; Ronner and Giller, 2013). In Tanzania, the land area under cowpea cultivation is 158,000 ha but yield is as low as 0.4 t ha^{-1} (Kisetu *et al*., 2014). Although area under production of other legumes has been increasing annually than yields from 1985 to 2007, the area under cowpea showed a small decrease of 0.4% (Mbwaga *et al*., 2007). Efforts on cowpea production would held 850 million people in the world with high incidence of food insecurity and under nourishment in sub-Saharan Africa (FAO, 2015b).

Table 3: Ranking of cowpea production in the developing countries for the year 2006 - 2008

	Countries	Average area harvested (million ha)	Percent share in area harvested	Cumul.Percent share	Average production (million tons)	Average Yield (tons/ha)
1	Niger	4.76	41.80	41.80	1.10	0.23
2	Nigeria	4.40	38.63	80.43	2.92	0.66
3	Burkina Faso	0.70	6.17	86.60	0.33	0.47
4	Mali	0.25	2.16	88.75	0.07	0.29
5	Senegal	0.21	1.86	90.61	0.08	0.38
6	Myanmar	0.15	1.33	91.95	0.15	0.98
7	Tanzania	0.15	1.32	93.27	0.06	0.38
8	Kenya	0.15	1.29	94.56	0.07	0.50
9	Dem. Rep of the Congo	0.12	1.02	95.57	0.06	0.48
10	Sudan	0.11	0.96	96.54	0.03	0.31
11	Cameroon	0.11	0.92	97.46	0.10	0.98
12	Malawi	0.08	0.70	98.16	0.05	0.69
13	Uganda	0.07	0.64	98.80	0.08	1.04
14	Haiti	0.04	0.37	99.17	0.03	0.70
15	Mauritania	0.02	0.20	99.37	0.01	0.35

Source: Akibode and Maredia, 2011

2.5 Legume Diversification in Soil Fertility Management and Food Security for Resource Poor Farmers in Sub Saharan Africa

2.5.1 Introduction

Soil fertility refers to the ability of soil to provide plant with essential plant nutrients in adequate amounts and proportions for plant growth and reproduction, to sustain high quality and consistent crop yields (Watson *et al.,* 2002). Low soil fertility and degraded, low soil carbon status can results in poor crop production. This in turn will lead to food insecurity, particularly among smallholder farmers who depend largely on their own agriculture production for food and income (Tully *et al.,* 2015). It is clear that “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (FAO, 2006). To achieve this, fertile soils are crucial for rising sufficient crops; yet, soil fertility status may be on the decline and causing major problems for sustainable production in Africa (Chukwuka, 2009).

Soils in Africa are typically highly variable in fertility, and in the way they respond to inputs (Omotayo and Chukwuka, 2009). Most soil resources in Africa have low nutrient levels with a high propensity towards nutrient loss due to their fragile nature (Silva and Uchida, 2000); although not all, as some are volcanic in nature and thus less nutrient depleted. Highly cultivated soils in the tropics have been observed to suffer from multiple nutrient deficiencies and nutrient imbalances (Kinsey, 2012). Nearly 40% of soils in SSA are low in nutrients reserves (<10% weatherable minerals), 25% suffer from aluminum toxicity, and 18% have a high leaching potential (low buffering capacity) (Tully *et al*., 2015). In the 2002─2004 cropping season, about 85% of African farmland (185 million hectares) had nutrient removal rates of more than 30 kg/ha of nutrients yearly, and 40% had rates greater than 60 kg/ha yearly (Henao *et al*., 2006). In addition, fertilizer applications across Africa are highly variable and nil in many instances, due to lack of knowledge, poor profitability, cash and credit constraints, and unavailability of fertilizers in many locations (Shiningayamwe, 2012). Fertilizer rates are very low in some east Africa countries, close to zero across much of Uganda for example, and higher in parts of Central Africa, in the range of 30 to 40 kilograms (kg) of nitrogen, phosphorus, and potassium (NPK)/ha yearly (Malingreau *et al*., 2012). Government subsidies has promoted use of fertilizer in some instances, such as in Malawi and some regions of Tanzania – yet soil degradation is becoming of increased concern in recent years due to such factors as limited soil cover and poor nitrogen-fixation as well as physical soil degradation, soil erosion and leaching (Jonas*et al.,* 2011).

In efforts to address the problem, farmers apply different methods such as application of inorganic fertilizers, animal manure, recycling of crop residues and shifting cultivation (Henao *et al.,* 2006; Omondi *et al*., 2014). However, most of these methods are no longer sustainable due to increasing pressure on land resources as a result of increasing human population (Druilhe and Barreiro-hurlé, 2012; Baijukya, 2004; Shuaibu *et al.,* 2015). In addition, use of some of those methods e.g. inorganic fertilizers by resource poor farmers is constrained by profound lack of knowledge of application, high fertilizer cost, unavailability, access and drought (Cagley and Gugerty, 2009; Njira *et al.,* 2012; IFDC, 2012; Williams *et al.,* 2014; Cedric and Nelson, 2014). Use of inorganic fertilizers also has been reported to have effect on water resources, soil fauna and soil health (Jonas *et al.,* 2011; Schröder, 2014).

To address the challenges of fertilizer needs to small scale farmers, several approaches such as integrating legumes in the farming systems (FSs) and legume diversification are now being advocated for soil fertility management worldwide (Eriksen *et al.,* 2010; Shiningayamwe, 2012; Waddington, 2002). There is sufficient evidence that legumes harbor rhizobia bacteria which can fix atmospheric nitrogen (N) and convert it to a form that can be used by plants

(Lindström, 1999). The fixed N can reduce or supplement for the N fertilizer requirement of the main field crop in rotation, in so, making it an attractive and affordable source of N for resource-poor farmers (Toomsan *et al.*, 2004). Legume diversification is a practice of growing more than one legume crop within one unit area to increase financial and biological stability of the farm (Johnston *et al*., 2001). Much that these strategies are used in sustainable soil fertility management, limited literature is available on their application in Africa. Therefore, this review article aims at highlighting the potentiality of legume diversification in soil fertility management and food security for resource poor farmers in Sub Saharan Africa.

2.5.2 Legumes diversification in SSA

Legumes are important components of various farming systems in SSA, and farmers acknowledge the positive contributions of legumes in improving soil fertility and food security (Amede, 2003). Farmers grow legumes either as a sole crop, by crop rotation, mixed farming or intercropping with cereals (Massawe *et al*., 2016). There are about 30 species of economically important legumes grown in the SSA (Baldev*et al*., 1988; Raemaekers, 2001; Gowda*et al*., 2007). Among the major ones are common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), chickpea (*Cicer arietinum*), groundnut (*Arachis hypogaea*), pigeonpea (*Cajanus cajan*), and soybean (*Glycine max*). Others that are important in one or other regions of the tropics include faba bean (*Vicia faba*), lentil (*Lens culinaris*), field pea (*Pisum sativum*), Bambara groundnut (*Vigna subterranea*), hyacinth bean (*Lablab purpurea* – also known as Dolichos lablab), Kerting's groundnut (*Macrotyloma geocarpum*), lima bean (*Phaseolus lunatus*), yam bean (*Sphenostylis stenocarpa*), mung bean or green gram (*Vigna radiata*), black gram or black bean (*Vigna mungo*), moth bean (*Vigna aconitifolia*), rice bean (*Vigna umbellata*), and horse gram (*Macrotyloma uniflorum*) (Abate *et al*., 2011). Of these, cowpea (*Vigna unguiculata* L.) and common bean (*Phaseolus vulgaris* L.) are the most widely grown in SSA (Ronner *et al*., 2013; Goenaga *et al*., 2013).

2.5.3 Integrating legumes in farming systems

Integrating legumes in farming systems is among the strategies used by smallholder farmers for crop diversifying and effective utilization of the land in SSA (Matusso *et al*., 2012). Intercropping is extensively practiced by smallholder farmers in SSA and commonly practiced in tropical parts of the world compared with other cropping systems (Amede, 2003; Massawe *et al*., 2016). It is estimated that 80% of the legumes grown in SSA are intercropped with cereals (Abate *et al*., 2011; Nyasasi and Kisetu, 2014). Variations exist in cereal-legumes plant species used in intercropping across regions in SSA and the system commonly involves cereal being considered as the main crop *(*Massawe *et al*., 2016). Cereals are, in most cases, the main food source hence more efforts are made to increase their yield than that of the legumes (Ronner *et al*., 2013). Cowpea occupies the largest proportion (43%) of all grown legumes in SSA, followed by groundnut (34%), common bean (19%), soybean (<5%), pigeonpea (<2%), and chickpea (<2%) (Abate *et al*., 2011). Legumes are also grown in association with other legumes in what is known as doubled-up legume technology (legume-legume intercrop) whereby pigeonpea are intercropped with other legumes such as cowpea, groundnuts, soybean etc, a cropping system that is more practiced by some farmers in Malawi (Oliver *et al*., 2013). Although intercropping has been used by smallholder farmers in SSA for thousands of years and is widespread in many parts of the world, it is still poorly understood from an agronomic perspective (Njoku and Muoneke, 2008). More research is needed to better understand how intercrops (legumes-cereal or legume-legume) function and to develop intercropping systems that are compatible with current traditional farming system.

2.5.4 Nitrogen fixation in legumes improves soil fertility

Legumes improve soil fertility through symbiosis relationship between legumes and rhizobia bacteria called Biological Nitrogen Fixation (BNF) (Zahran, 1999). The terms *Rhizobium* or rhizobia are used collectively for the genera *Rhizobium, Bradyrhizobium, Sinorhizobium, Mesorhizobium, Allorhizobium,* and *Azorhizobium,* unless specified otherwise (Haque and Lupwayi, 2017). BNF is the process whereby a number of species of bacteria use the enzyme nitrogenase to convert atmospheric N_2 into ammonia (NH_3), a form of nitrogen (N) that can then be incorporated into organic components, e.g. protein and nucleic acids, of the bacteria and associated plants (Jessica *et al*., 2014). Interactions between rhizobia and legume roots result in formation of root nodules, in which rhizobia use energy from the host plant to transform atmospheric N_2 into plant available forms of nitrogen (Massawe *et al*., 2017). The amount of N_2 fixed by a legume crop varies widely because it depends on the legume genotype, rhizobium strain and the soil environment (Lupwayi *et al*., 2011). Legumes can supply up to 90% of their own N hence they do not require addition N *(*Bohlool *et al*., 1992; Stagnari *et al*., 2017). Through BFN, legumes provide a relatively low-cost method of replacing nitrogen in the soil, enhancing soil fertility and boosting subsequent crop yields (Baddeley *et al.,* 2014; Saikia and Jain, 2007). There exist different rhizobia strains which are specific to some legumes (Andrews and Andrews, 2017; Oono *et al*., 2009). Due, to this legumes have different N fixation rates capacities (Danso and Eskew, 1998; Nglade and Illen, 2015). The table below indicates some common legumes and their N fixation rates capabilities. Having two or more legumes intercrop will double soil fertility benefits as both crops contribute fertility to the soil through N fixation (Regis *et al.*, 2016).

Table 4: N fixation rates (kg ha^{-1} $crop^{-1}$) by some common legumes grown in SSA

Legume	**N. fixation rate (Kg/ha)**	**References**
Vigna unguiculata (cowpea)	35	One Acre Fund (2014)
	61 – 155	Baijukya *et al.* (2013)
	30 – 125	Ennin *et al.* (2004)
	30	Martins *et al.* (2015)
	42.68	Yabuku *et al.* (2010)
	120	Woomer (2010)
	28	Chikowo *et al.* (2004)
	47	Rowe and Giller (2003)
	73–354	Silva and Uchida (2000)
Phaseolus vulgaris (common bean)	16 – 27	Argaw and Tsigie (2017)
	35	Devi *et al.* (2013)
	25-45	Miyamoto *et al.* (2008)
	35	Woomer (2010)
	125	Woomer (2010)
	40–70	Silva and Uchida (2000)
Glycine max (soybean)	200	One Acre Fund (2014)
	138 - 156	Baijukya *et al.* (2013)
	45-130	Miyamoto *et al.* (2008)
	60 – 240	Ennin *et al.* (2004)
	70	Chianu *et al.* (2011)
	60–168	Silva and Uchida (2000)
	165	Gibson *et al.* (1982)
Arachis hypogaea (Groundnut)	76	Egbutah and Obasi (2016)
	150	One Acre Fund (2014)
	47 – 52	Baijukya *et al.* (2013)
	27.19	Yabuku *et al.* (2010)
	160	Bationo *et al.* (2007)
	50 – 150	Ennin *et al.* (2004)
	25-56	Gibson *et al.* (1982)
	26	Montanez (2000)
Cajanus cajan (pigeonpea)	30 -100	Mhango *et al.* (2016)
	40	Bationo *et al.* (2007)
	97	Chikowo *et al.* (2004)
	39	Rowe and Giller (2003)
	8 – 82	Mapfumo *et al.* (2000)
	168–280	Silva and Uchida (2000)
	44	Mendonça *et al.* (2017)
*Lab labpurpurea (*hyacinth bean*)*	130-220	Miyamoto *et al.* (2008)

	140	Haque and Lupwayi (2017)
	89	Sanginga (2003)
	15 – 210	Zahran (2001)
	270	Rochester *et al.* (2000)
Vigna subterranea (bambara nut)	55	Egbutah and Obasi (2016)
	28	Egbe *et al.* (2013)
	32 – 81	Mukhtar*et al.* (2016)
	32.53	Yabuku *et al.* (2010)
	10 – 62	Ncube *et al.* (2009)
	52	Rowe and Giller (2003)

The ability of legumes to fix N_2 allows farmers to grow them with minimal inputs of N fertilizer (Gary *et al*., 2014). Non-legume crops grown in association or in rotation with them usually have reduced fertilizer N requirement ("Nitrogen Cycling"), which has both economic and environmental benefits (Lupwayi *et al*., 2011). There is a need for more definitive studies on the nutritional factors limiting N fixation in legumes in general, and in those legumes that have a potential in farming systems in SSA (Haque and Jutzi, 1984).

2.5.5 Incorporation of legumes crop residues in the soil (Organic materials)

Legumes improve soil fertility through their decomposed residues (Singh *et al*., 2011). Application of organic materials is one of the strategy used by farmers in SSA for soil fertility management (Omotayo and Chukwuka, 2009). Organic matter includes any plant or animal material that returns to the soil and goes through the decomposition process (FAO, 2005). Organic materials contribute directly to the deposition of soil organic matter (SOM) and is important in improving the physical, chemical and biological composition of the soil (Moyin-jesu, 2015; Silva and Uchida, 2000). Most soils in SSA contain 2 - 10 percent organic matter (Omotayo and Chukwuka, 2009) and they are plant tissue such as crop residues, leguminous, cover crops, green manures, mulches and household wastes (Vanlauwe *et al*., 2015). Plant residues contain 60–90 percent moisture, the remaining dry matter consists of carbon (C), oxygen, hydrogen (H) and small amounts of sulphur (S), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) (FAO, 2005). At maturity 30–40% of the N in legume crops is in the seeds, which are typically 25–30% protein (Chukwuka, 2009). When this grain is harvested, much of the N that has been fixed will be exported off of the property and the rest in the stem and other part which when incorporated in the soil it release nutrients (Lindemann *et al*., 2007; Tully *et al*., 2015). Although present in small amounts, these nutrients are very important from the viewpoint of soil fertility management. The effects of applied materials vary with cropping systems, soil types, organic material management and environmental factors; however, the information on their interaction is scarce (Mugwe *et al*., 2009). Legumes crop residues contains different amount of nutrients, hence legumes diversification allow double or multiple soil fertility contribution in the soil (Njira *et al*., 2012). Organic matter contributed by legumes residues in the soil provide essential nutrients to plant as a result crop yield is increasing hence food security is assured to resource poor farmers (Tittonell, 2015). Little knowledge on multiple legume residues benefits on soil fertility improvement to SSA's smallholder farmers. More research should be done on the farming systems which will have high or better contribution of legumes crop residues on soil fertility improvement in different soil types in order to suggest the best legumes crop residue incorporation system which gives high returns to farmers.

2.5.6 Grain legumes – root systems and soil health

Most of the legumes have well-developed taproots reaching 6 to 8 feet deep and half inch in diameter which go deeper into the soil which help them to recycle crop nutrients that are deeper into the soil. This result into effective use of applied fertilizers and reduces leaching of nutrients especially nitrate-nitrogen for the shallower-rooted crops (Sharifai, 1985). Moreover, nitrogen rich legume residues encourage earthworms and the burrows they create with the root channels and earthworm burrows increase soil porosity, promoting air movement and water percolation deep into the soil (Truscott *et al.*, 2009).

Through their effects on soil biology, legume crops also improve soil structure by enhancing the formation and maintenance of soil aggregates (Schröder, 2014). Soil structure improvements are attributed to increases in more stable soil aggregates (Stein-bachinger *et al*., 2015). The protein, glomalin, symbiotically along the roots of legumes and other plants, serves as "glue" that binds soil together into stable aggregates. This aggregate stability increases pore space and tilth, reducing both soil erodibility and crusting i.e. reduces soil erosion, protects soil organic C from microbial breakdown, and increases water infiltration and air circulation (Tanner and Ababa, 2002). Lupwayi *et al*. (2011) has reported order of crops in maintaining soil structure: lupin (*Lupinus angustifolius* L.) > lentil (*Lens culinaris*) > canola (*Brassica napus*) > pea (*Pisum sativum*) > linseed (*Linum usitatissimum* L.) > barley (*Hordeum vulgare*). Probably these results will be the same in SSA. In Nigeria, Obi (1999) observed the following order of legume and grass cover crops in cumulative water infiltration in a degraded soil: legumes (*Stylosanthes gracilis* L. and *Pueraria phaseoloides* L.) > grasses (*Panicum maximum* L., *Pennisetum polystachion* L., *Cynodon plectostachion* L., and *Axonopus compressus* L.) > bare soil. The order of soil organic C contents was similar, and the differences were related to soil structure. Therefore, the forage legumes had greater restorative effects of the soil than grasses and bare soil. These are some of the benefits of legumes, but unfortunately, they are often omitted because of difficulty in quantifying them. More research should be focused on influence of grain legumes on nutrients recycling and soil structure improvement.

2.5.7 Legumes diversification reduce risk of crop failure to smallholder farmers

Legume diversification is a practice of growing more than one legume crop in any year to increase biological stability of the farm, food security and financial status (Johnston *et al.*, 2001). There are highly diverse species of grain legumes which are indigenous to various parts of the world (Katunga *et al*., 2014). Soil fertility status and food security of smallholder communities are hindered by the reduction in legume species utilized in agricultural ecosystems (Small and Raizada, 2017). The potential for crop failure is worsened by the reliance on a few crop species (Koenen *et al*., 2013). Plant species vary in their vulnerabilities and resistances to harsh condition such as environmental stress including heat, cold, drought, floods, pests, and disease. Due to this reliance on a few legumes crop species is a risk to farmers (Sundström *et al*., 2014). Farming system relies on monoculture increases exposure of crops to pests, diseases, and environmental stress (Kim, 2005). Total crop yields are stabilized by the capacity for each individual crop species to adapt and be productive in different conditions, and hence, legumes diversification is an asset to farmers in adapting environmental changes (Rosegrant *et al.*, 2008). The consequence of reduced legumes crop species can be immense for smallholder farmers whose livelihood depends on their crop yield. For example, due to unpredictable rainfall in sub-Saharan Africa, it has been experienced rainfall delayed by up to a month, thus reducing the growing season (Lobell and Gourdji, 2012). The unpredictable onset of the rain challenges farmers to utilize crops that will be productive in growing seasons of varying durations. When the growing season is delayed, the utilization of short maturing, drought-tolerant crops like cowpea and common bean, and short-duration varieties, is an important adaptive strategy for small holder farming system (Ebert, 2014).

2.5.8 Legume diversification in food security and nutrition

Legumes can survive under hot, dry and area with little N, the area where other crop such as cereals cannot perform better (Koenen *et al*., 2013). They have aggressive taproots reaching 6 to 8 feet deep and a half inch in diameter that open water pathways deep into the soil (Sharifai, 1985). This increase the surface area for biodiversity-plant root zone interaction, for instance earthworms can burrow the soil and provide access of roots to nutrients and air for root respiration. Also facilitates activities of soil flora and fauna lending to a greater stability of the soil's total life (Truscott *et al.,* 2009; FAO, 2009; Michael, 2010; Cong *et al.,* 2014; UNEP, 2008; Williams *et al.,* 2014). These help legumes to survive on the environment where other crops cannot survive and give out a reasonable yield which helps smallholder farmers to get enough food in each year (Chibarabada *et al*., 2017). Legumes provide an excellent break in a crop rotation that reduces the build-up of grassy weed problems, insects, and diseases as a result reduces the loss which can be caused by pest and increase crop yield (Khan *et al.,* 2007; Truscott *et al.*, 2009; Lupwayi *et al.*, 2011; Tanner and Ababa, 2002). Due to these unique features, integrating legumes in the existing system can reduce the risk of crop failure and insuring food security to Small Holder Farmers (SHF) in SSA (Kerr *et al*., 2007). The ability to survive under different harsh environment differ from one legume to another and within species one variety to another (Staniak and Księżak, 2014). Having a diverse of legumes will widen or multiply a chance for utilizing the benefits brought by legumes due to their different capability to survive in different environment (Abate and Orr, 1981). Diverse foods outputs are obtained through multiple cropping, thus providing a chance of choice for using food commodities in smallholders farmers (Stagnari *et al*., 2017).

Grain legumes are an essential source of protein, Carbohydrates, vitamins and micronutrients thus, a valuable component to attain nutritional security (Ebert, 2014). Legumes are consumed mainly in association with cereals with legumes constituting the main component of traditional dishes (Gepts, 2004). Some legumes provide food during its all stage of growth, they are consumed in many forms: seedling and young leaves are eaten in salads, fresh immature pods and seeds provide a green vegetable, and dry seeds are cooked in various dishes (Burstin *et al.*, 2011). Grain legumes contain a wide range of nutrients, including low glycaemic index (GI), high content of fibers, antioxidants, vitamins especially the B-group and minerals such as iron, calcium, phosphorus, zinc and magnesium (Messina, 1999; Mugendi and Njagi, 2010; Oboh, Osagie *et al*., 2010). Low GI in legumes mean that they can release glucose into the bloodstream less rapidly making them preferred by people with diabetes and those who wish to reduce their body weights as well as for the community in general (Duranti, 2006; Williams *et al.,* 2008; Rovner *et al.,* 2009). Except soybeans, legumes contain low fat and large amount of fibers which may help control appetite by keeping one feeling fuller for longer. Legumes contain different nutritional value depending on the species (Table 2) hence having a diverse of legumes will provide an opportunity for smallholder farmers to benefit from different nutritional requirement from these legumes (Rivas-Vega *et al.,* 2006). Current trends suggest that there is an increasing gap between human population and protein supply (Chibarabada *et al*., 2017). Legumes which are cheapest source of proteins still not widely used in the diet because of few diversity (Chibarabada *et al*., 2017). Legumes diversifications are potential strategies for making legumes available and increase protein supply to communities in SSA.

Table 5: Nutritional value for some common grown grain legumes in 100 gram

Legume crop	Carbohydrates	Proteins	Dietary fibre	Fat	Calcium	Iron
Cowpea	7	16	28	0	2	13
Pigeon pea	21	44	60	2	13	28
Common beans	21	42	64	1	15	28
Soybean	10	72	36	30	27	87
Groundnuts	5	52	36	75	10	25
Lablab	7	16	-	0	4	25
Bambaranuts	66	20	6	6	2	12
Chick pea	20	38	68	9	10	34
Green gram	21	48	64	1	13	37

Source: Modified from United States Department of Agriculture (USDA)

2.5.9 Other benefits of Legumes to smallholder farmers in SSA

Resource poor farmers in developing countries both consume and sell legumes thus getting profit in terms of nutrition and income (Chibarabada *et al*., 2017). Legumes diversification allows smallholder farmers to get multiple crops from same cropped land, while act as risk management system in case of failure for one of the companion crops (Smith *et al*., 2016; Smýkal *et al*., 2017). Due to this surplus legumes produced by farmers are sold as a raw materials and become a direct source of income to farmers and create employment to the processing industries (Kerr *et al.*, 2007). Legumes produces high value grains with 2- 3 times higher price than cereals and oil crops, example fresh pods, peas and leaves attract highest prices in urban and export markets (Ebert, 2014). Legume diversification provide a wide ranges of food products which are processed locally from row materials creating remunerative employment, especially for rural women (CGIAR, 2016). Legume is processing into products such as soymilk, soy cheese and cowpea cake which are sold and become common income generating activities (ITC, 2016). This food processing activity plays a vital role in the survival and sustenance of their household and in meeting domestic financial obligations (Chibarabada *et al*., 2017). However, these products are usually prepared under poor sanitary conditions, processors need to be trained on improved processing methods and food safety practices (Subuola *et al*., 2012). Income obtained is used to buy other important food crops such as cereals (Banjarnahor *et al.*, 2015). Legumes diversification is also important from marketing point of view, as getting more than one crop simultaneously, even if the selling price of one crop is less in the market, the other will be there to compensate (Preissel *et al*., 2015). This information is well known to farmers especially in SSA, but its utilization is still minimal (ITC, 2016). Lack or little information, research, resource and skills are some of the reasons for low adoption of legume diversification. Keeping in view the economic benefits of legumes diversification, there is a need to promote it among the farming community.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study site

The study was conducted in Singida District, Tanzania which lies between longitudes 33^0 27’ 35’’ and 35^0 26’ east of Greenwich and latitude 3^0 52’ and 7^0 34’ of the equator. The region forms part of the semi-arid central zone of Tanzania, which experiences low rainfall and short rainy seasons that are often erratic, with fairly widespread drought in one year out of four (Singida Region Commissioner’s Office, 1997). Rainfall varies from 550 mm to 650 mm annually, very variable and unreliable. The soil is acidic grayish-brown sand which lack cracking clays in valleys and depressions. The zone has considerable soil erosion (Singida Region Commissioner’s Office, 1997).

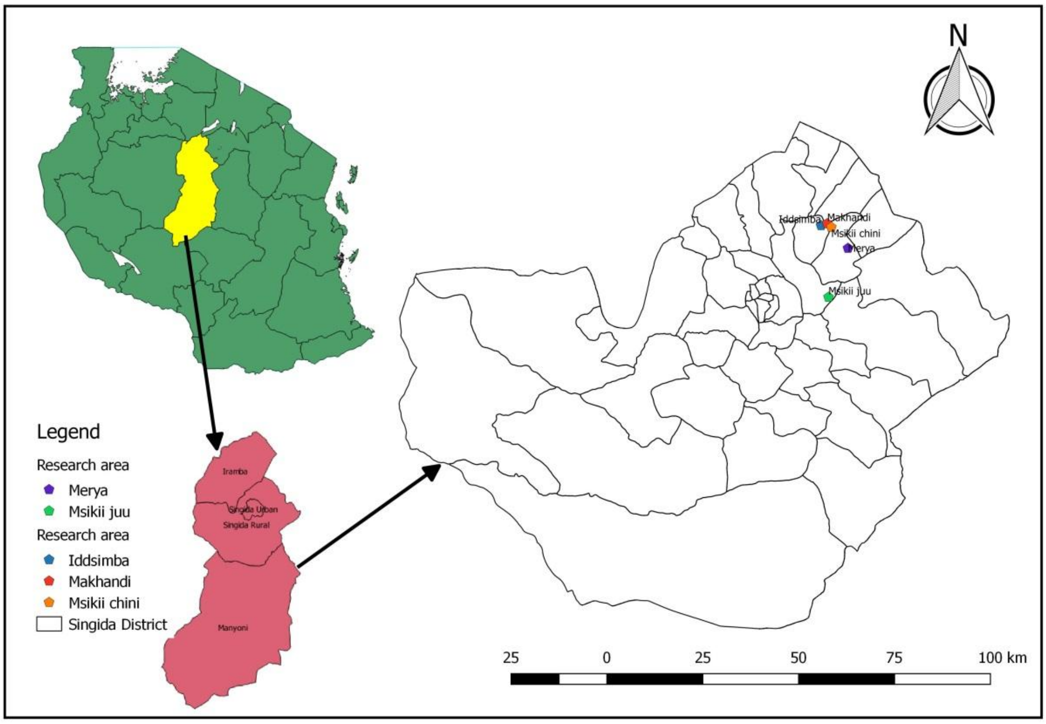

Figure 1: Map of Tanzania, Singida Region and Singida District indicating the study sites

3.2 Materials

A total of five cowpea varieties were used in this study that includes four improved cowpea varieties from Ilonga Agricultural Research Institute (IARI) namely: Tumaini, Fahari, Vuli – AR and Vuli-2; and one local variety from the study area. The selection considered the following factors: (a) some varieties are resistant to *Alectra*; (b) Determinate and indeterminate growing types to enhance heterogeneity in mixtures; (c) early and medium maturity varieties (d) local variety from the study area as a control for comparison purposes as detailed in the table below

Table 6: Characteristics of selected cowpea varieties

Variety/ General Characteristics	**Tumaini**	**Fahari**	**Vuli - AR**	**Vuli-2**
Maturity	Medium	Medium to late	Early	Early
Growth habit	Spreading type	Spreading type	Determinate to semi spreading type	Determinate to semi spreading type
Flower colour	Purple	Purple	Purple	Purple
Seed colour and shape	Cream and round	Buff and round	Red and round	Broken white and round
Mean sea level (m)	0 – 1500	0 – 1500	0 – 1500	0 – 1500
Days to maturity	70 – 75	75 – 90	55 – 65	65 – 70
Grain yield under optimum management	3 t/ha	3 t/ha	2 t/ha	3.5 t/ha
Resistance to diseases	Cowpea Aphid borne Mosaic virus CABMV, Bacterial pustule Bp, and bacterial blight	Cowpea Aphid borne Mosaic virus CABMV, Bacterial pustule Bp, and bacterial blight	Alectra, cowpea Aphid borne Mosaic virus CABMV, Bacterial pustule Bp, and bacterial blight	Cowpea Aphid borne Mosaic virus CABMV, Bacterial pustule Bp, and bacterial blight

Source: Cowpea Varieties, Ilonga Agricultural Research Institute (2014)

3.3 Methodology

3.3.1 Site selection

Initially, discussions were held with District Agricultural, Irrigation and Cooperative Officer (DAICO) office on the general overview on agriculture in Singida District including types of crops grown, types of soil available, legumes diversification and crop distribution in villages selected by SNAP. Another discussion was held with members of SNAP farmers groups from ten villages together with agricultural extension officers were held in the villages in their farms to gather information on their knowledge about legumes and production systems. Also, information about common cultural practices and associated constraints were gathered as well as farmer's experiences with agro ecological based on soil types, soil colour, agricultural practices and rainfall. Soil types were categorized using different characteristics such as soil texture and major nutrients availability. Since the research aim to test cowpeas varieties in different soil types the main criteria for site selection were first the soil type. The second criterion was the availability of land from a willing farmers who was the mentor farmer in a respective village, and who was in the research. Mentor farmers are leaders of a group of 30 farmers who receive training, share experiences, lessons and disseminate findings to his/her members in the group. Two pieces of land, one from female mentor farmer and another from male mentor farmer were selected from three villages which are Msiki (Eastern Singida), Makhandi village (Northern, Singida), Merya (North-East, Singida) and Iddisimba (Northern Singida).

3.3.2 Experimental Design

The study was conducted on the basis of researcher-farmer participatory experiment through the "mother-baby" approach (Bellon and Reeves, 2012). Mother trials were managed by mentor farmers and researcher and the baby trials were managed by farmers alone under their cultural agronomic practices.

The "mother trial" were laid out in a Randomized Complete Block Design (RCBD) with three replications. A total of five cowpea varieties Tumaini, Fahari, Vuli-AR-I, Vuli-II and one local variety were selected and planted in three different soil types; sandy loam (Iddisimba village, Northern Singida), sandy clay (Makhandi village, Northern Singida), sandy clay loam (Merya village, North-East Singida) and loamy sand (Msikii village, Eastern Singida) found in the study area. One experimental plot was established in each village, making a total of four (4) experimental plots. Planting was done on 4th of February 2017 in the plots of 4.5 m by 4 m with spacing 75×20cm (66 666 plants ha^{-1}) for Tumaini, Fahari, and local which are Spreading type variety while Vuli-AR-I and Vuli-II which are determinate to semi spreading types were planted at 50×20 cm (100 000 plants ha^{-1}). Land preparation was done by hand hoe and no fertilizer was applied to the lot.

The “baby trial” represented a farmer managed trial which involved twenty eight (28) farmers from three villages; nine farmers from Iddsimba (Northern Singida), nine at Merya (North-East Singida) and ten at Msikii 10 (Eastern Singida). Farmers were given 250 g of one selected improved variety of cowpea and one local variety were given to 28 farmers and planted to their farms under their own agronomic practices such as planting date, weeding, pest control methods, etc. Farmers were required to record all the cultural and agronomic practices such as planting date, weeding, insect pests and diseases control and harvesting from panting to harvest

3.4 Experimental management

3.4.1 Land preparation

The fields were cleaned by removing existing vegetation. Ploughing was done using oxen whereas harrowing was done by using a hand hoe, which was followed by experimental layout. After experimental lay out the cowpea varieties were randomly allocated to all plots. For improved varieties, two seeds were planted per hole while for local variety; three seeds were planted per hole. Thinning of seedlings to leave one plant per hill was done after emergence.

3.4.2 Weeding

Weeding was done to control weeds and to improve soil physical conditions. Weeding was done in week three (3) and six (6) after plating by cutting and removal by hand hoeing, hand pulling and tillage. Manual weed control is the most common method used by farmers in cowpea production.

3.4.3 Insects pests control

Pest control was done through cultural practices comonly used by famers in Singida villages. Soap and pepper were mixed and diluted in water in the ratio of five (5) fresh pepper and one (1) table spoon of powder soap in one litter (1L) of water. This mixture was applied after every two weeks until flowering set as recommended by Pipoly and Granson (2012).

3.5 Data collection

3.5.1 Soil Sampling and Analysis

Soil samples were collected before planting from each experimental plot in the three villages. Five (5) composite samples were collected randomly form each experimental plot at a depth of 0 to 15 cm with the aid of soil auger. At each site, soils from six (6) auger borings were mixed to form one composite sample of 500g from each point. The samples were crushed to pass through a 2 mm sieve. Sub-samples for total N and organic C (labile fraction of soil C) analysis were further pulverized to a fine powder (< 0.5 mm). Soil pH were determined in a 1:2.5 soil: water suspension (Strosser, 2010). Organic C determined by chromic acid digestion and spectrophotometric analysis. Total N was determined from a wet acid digest and ammonia electrode analysis (Esfahani *et al.*, 2009). Potassium (K) and available total phosphorus (P) were extracted using the Mehlich-3 procedure. Potassium was determined by atomic absorption spectrophotometry and total P by using the malachite green procedure. This is the modification of the method used by Wendt *et al.* (2004).

3.5.2 Cowpea growth and yield parameter from mother trial

Weight of fresh and dry plant samples, plant height, number of pods and number of branches were measured following the standard protocol (Agyeman *et al.*, 2014). Middle plants from four middle lines were sampled for taking all the required data. In all experimental plots plant samples were taken, carefully washed to remove attached soil and then placed in an envelope and labeled before taken to the laboratory for dry matter analysis. Fresh weight, root length and dry matter were recorded. Plant samples were placed in an oven maintained at 80^oC for 48 hours and then removed and weighed. After maturity another four plant samples from each experimental plots harvested to determine seed yield in kg per plant, 100 grains weight, number of pods per plant and grains per pod. This is a modification of the method used by (Agyeman *et al.*, 2014).

3.5.3 Yield data from the baby trials

Plants were harvested from 2 ridges (rows) of 1 m length at 3 positions along a diagonal transect, by leaving at least 4 ridges at the edges of the fields to avoid edge effects as shown in Fig. 2 bellow. The three net-plots on a diagonal took care of in-field heterogeneity. Plant population was estimated by counting all plants for the 2 ridges of 1 m length for each of the 3 harvested plots. Due to the fact that farmers use different ridge spacing, ridge spacing was recorded accurately for computing area by measuring crest to crest distance as this was the easiest approach. Ridge distance was measured at two locations per harvest area. This is a modification from Snapp *et al.* (2002).

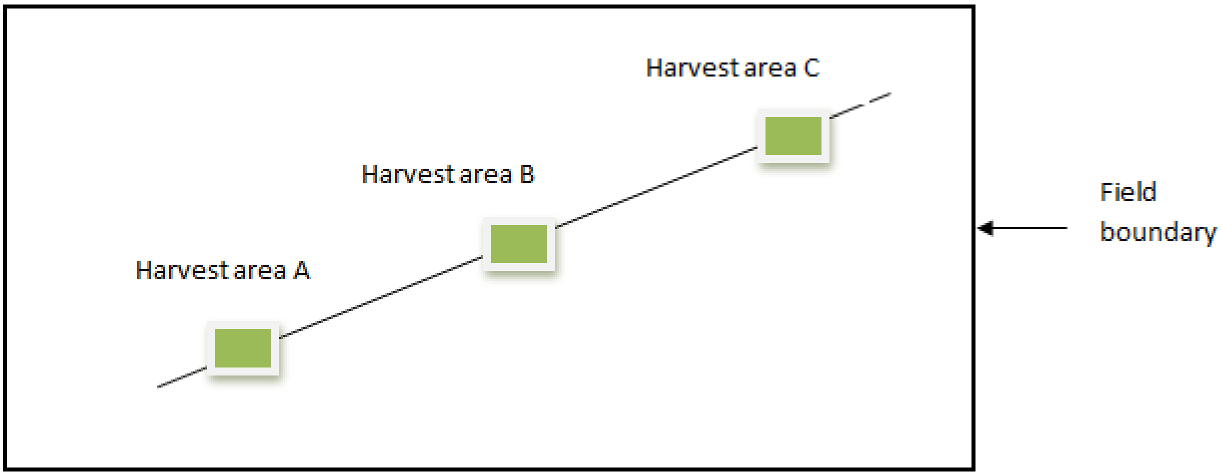

Figure 2: Sampling station in baby trials in one particular field

3.5.4 Data analysis

All data generated were subjected toanalysis of variance (ANOVA) using the GenStat discovery 2011 software. Treatments were tested at 5% level of significance and all probability less than 0.05 are significant ($p \leq 0.05$). The difference between treatments means was separated using Duncan Multiple Range test.

CHAPTER FOUR

RESULTS AND DISCUSSION

The study assessed performance of five (5) selected cowpea varieties on different soil types. The result showed that varieties performed differently on growth and yield parameters (Number of leaves, height of plants, fresh weight of plants, dry matter weight of plants, number of branches, number of pods per plant, number of grains per pods, weight of 100 grins, yield per plant) of cowpeas varieties in all soil types.

4.1 Soil analysis

Table 7: Characteristics of the soils from experiment sites

	Particle size								
Experimental site	**Sand %**	**Silt %**	**Clay %**	**Textural class**	**Active carbon (mg Kg^{-1})**	**T N %**	**A P (mg Kg^{-1})**	**K %**	**pH**
Iddisimba	54.75	32.97	9.37	Sandy loam	159.55	0.05	5.73	1.30	6.96
Makhandi	45.78	15.85	37.23	Sandy clay	327.34	0.05	7.7	0.14	6.18
Msikii	57.81	14.65	27.45	Sandy Clay loam	72.52	0.06	10.0	0.35	5.94
Merya	81.36	7.98	9.54	Loamy sand	354.64	0.07	8.7	0.21	6.72

TN: Total Nitrogen, **AP**: available phosphorus and **K**: potassium

The soil analysis results showed that soils pH was weak acid to neutral (5.94 – 6.96) which is the ideal range for satisfactory for cowpea, had inadequate amount of organic matter and nitrogen. K and available P were within the recommended standard except in Iddisimba village (Northern Singida) where available P was observed to be low, recommended range is 20 – 40 mg Kg^{-1}. All soil types had more than fifty percent sandy except for the Makhandi site soil. Interpretations of the analysed soil based on the rating suggested by Landon (1991).

4.2 Growth and yield of different cowpea varieties in different soil types

This study assessed performance of five (5) selected cowpea varieties in different soil types. The results showed that there are significant differences on growth and yield parameters i.e. number of leaves, height of plants, fresh weight of plants, dry matter weight of plants, number of branches, number of pods per plant, number of grains per pods, weight of 100 grins, yield per plant of different cowpeas varieties in all soil types at 5% level of significance.

4.2.1 Number of leaves

The results for number of leaves of different cowpea varieties on different soil types are shown in Tables 8, 9, 10 and 11. Varieties had significant differences ($p < 0.05$) on the number of leaves in all soil types except in loam sand soils. Local variety had significantly higher mean number of leaves in all types of soil than other varieties except for sandy clay where Fahari showed a higher number of leaves followed by local varieties. Tumaini had low mean number of leaves in sandy loam, sandy clay and sandy clay loam except in loamy sand soils where Fahari had similar number of leaves with other varieties (Fig. 3). The higher number of leaves per plant in local variety may be attributed to higher nutrient absorbing capacity and root system. This is in agreement with the findings by Sebetha *et al*. (2010) who reported that, the longer season cowpea cultivars have higher fresh and dry matter at the mid vegetative growth stage.

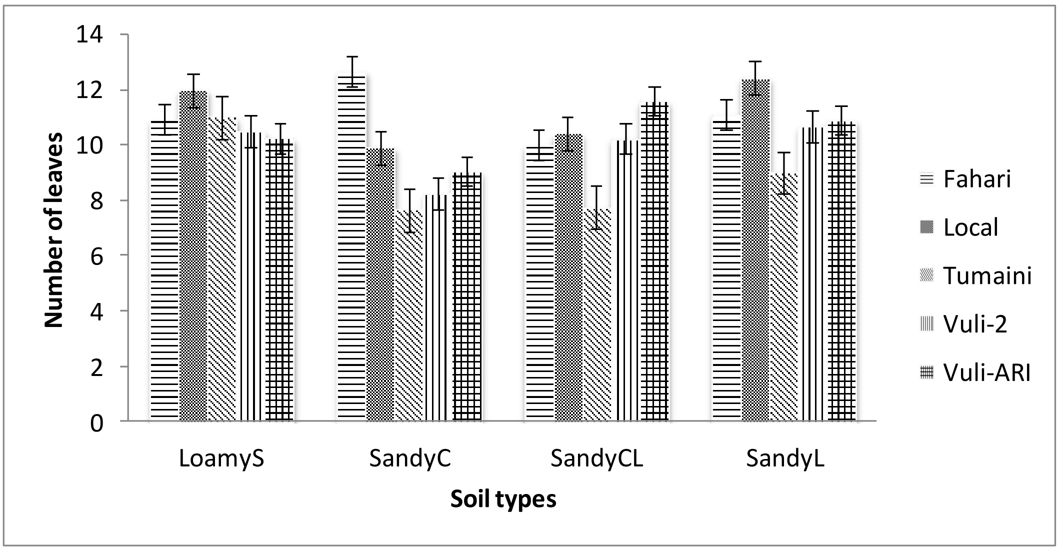

Figure 3: Number of leaves for different cowpea varieties on different soil types. **NB:** Loam S = Loamy sand, SandyC = Sandy clay, SandyCL = Sandy clay loam and SandyL = Sandy loam

4.2.2 Plant height

The plant height of five varieties of cowpea grown in different soil types are shown in Tables 8, 9, 10 and 11. Results showed that there is no significant differences on plant height in three soil types; sandy loam, loamy sand and sandy clay except in sandy clay loam where significant differences ($p \leq 0.05$) on plant height recorded in week 9 after planting was observed (Fig. 4). In sandy loam soil varieties had similar heights although variation among varieties existed. Vuli-II had 43 cm which was taller than other varieties, Tumaini (31.82 cm) and Vuli-AR-I (31.88 cm) was shortest varieties in this soil type (Table 8). In sandy clay soil Fahari (34.16 cm) was the tallest variety in this soil type and local (29.92 cm) was the shortest variety (Table 9).

In sandy clay loam soil, local (48.75 cm) and Fahari (48.25 cm) varieties were the tallest varieties compared with other varieties (Table 10). In loamy sand soil; Tumaini (55.18 cm) was the tallest varieties in this soil type than other varieties and local (39.21 cm) variety was the shortest varieties (Table 11). Generally, the tallest variety was observed in sandy loam which was Tumaini and the shortest variety was observed in sandy clay for the local variety. The observed variation in heights among cowpea varieties may be due to their growth habit for instance, Vuli-AR-I and Vuli-II are determinate to semi spreading type while Fahari and Tumaini are spreading type (Fig. 6). This argument is consistent with the finding of Addo-quaye *et al*. (2011) who investigated the performance of cowpea varieties in different agro ecological zones in Ghana and reported variation in height between determinate and indeterminate.

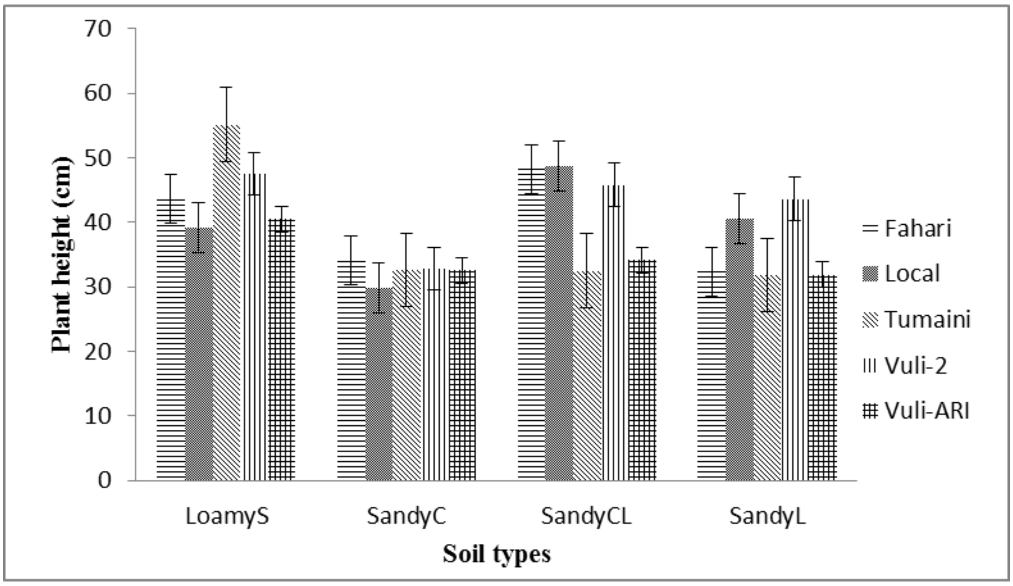

Figure 4: Plant height for different cowpea varieties in different soil types.
NB: LoamyS = Loamy sand, SandyCL = Sandy clay loam and SandyL = Sandy loam

4.2.3 Fresh weight and dry biomass

The results of the fresh weight and dry weight of different cowpea varieties under different soil types are shown in Tables 8, 9, 10 and 11. Cowpea varieties had significant differences ($p < 0.001$) on fresh and dry weight of the cowpea plants in all soil types in week 9 after plating. In sandy loam soil Vuli-II variety (165.70 g) had the heavier plant fresh biomass weight than all other varieties, and Local variety (49.6 g) was the lightest (Table 8). In sandy clay soil local variety (134.31 g) was heavier than other varieties and Tumaini variety (64.92 g) was the lightest varieties in this soil type (Table 9). In sandy clay loam vuli-II variety (168 g) was the heaviest variety and local variety (70.2 g) was the lightest (Table 10). In loamy sand local variety (253.0 g) had the heaviest fresh plant biomass than all other varieties while Tumaini (169.6 g) and Vuli-II variety (149.4 g) had the lightest fresh plant biomass (Table 11).

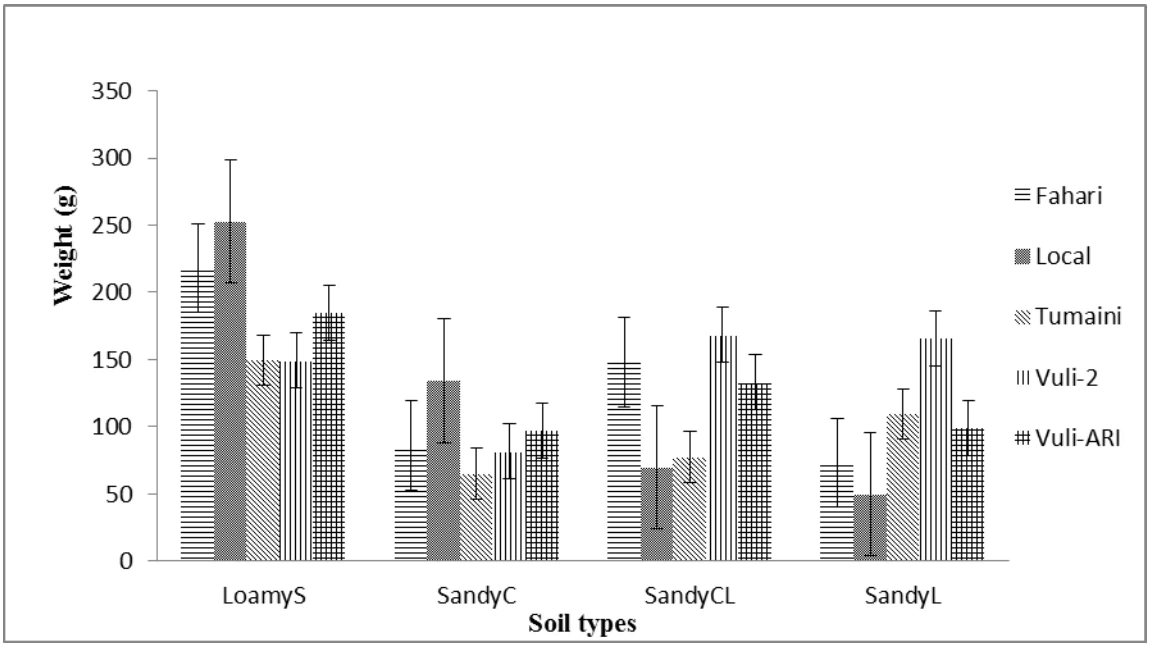

Figure 5: Plant biomass for different cowpea varieties in different soil types.
NB: LoamyS = Loamy sand, SandyC = Sandy clay, SandyCL = Sandy clay loam and SandyL = Sandy loam

In this study, it was observed that cowpea varieties exhibited highly significant differences ($p < 0.001$ level of probability) on the dry matter weight of the plant biomass taken in week 9 after planting in all types of the soil (Tables 8, 9, 10 and 11). In sandy loam soil Vuli-II variety (22.15 g) had the heaviest plant dry biomass than all other varieties, and Local variety (9.74 g) was the lightest (Table 8). In sandy clay soil local variety (21.82 g) was heavier than other varieties and the lightest variety was recorded in Tumaini (14.44 g) (Table 9). In sandy clay loam Tumaini variety (23.18 g) had the heaviest dry plant biomass weight and Fahari variety (13.28 g) was the lightest (Table 10). In loamy sand local variety (35.98g) and Fahari (35.53 g) was heavier than all other varieties and Tumaini (23.43 g) was the lightest (Table 11). Generally the heaviest fresh and dry biomasses weight was observed in sand loamy soil for local variety and the lightest fresh and dry matter weight was observed in sandy loam for local variety (Fig. 5 and Fig. 6). The observed variation in each variety may be due to their individual ability to absorb water and nutrients in different soils which is a genetic characteristic, but also nutrients availability in the soil. The results from this study confirms with the findings of Agbogidi and Egho (2012) who reported that plants respond differently to environmental factors depending on their genetic makeup and their adaptation capability. These results were consistent with the findings of Agyeman *et al*. (2014) which suggest that varietal differences might be due to the ability of cowpea to survive under extreme conditions. This was achieved by slowing growth and reducing transpiration, in extreme environmental conditions during vegetative stage providing diminution of the growth in most crop leaves and stems.

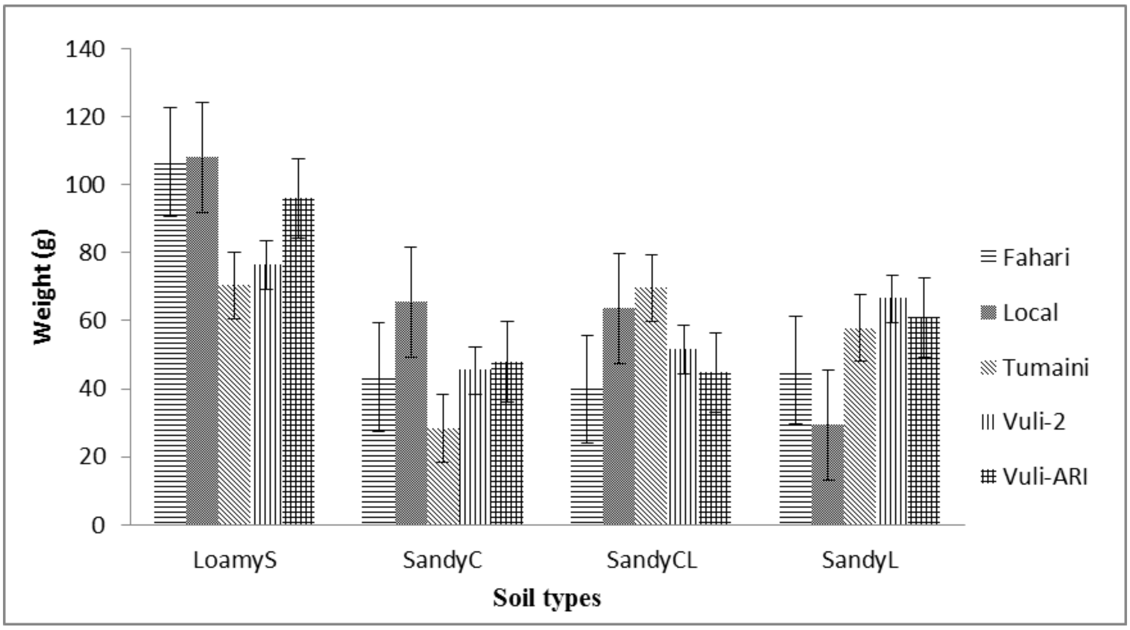

Figure 6: Weight of plant dry biomass for different cowpea varieties in different soil types.
NB: LoamS = Loamy sand, SandyC = Sandy clay, SandyCL = Sandy clay loam and SandyL = Sandy loam

4.2.4 Number of branches

Results of the number of branches in cowpeas varieties grown in different soil types are shown in (Tables 8, 9, 10 and 11). Cowpea varieties had high significant differences ($p < 0.001$) on number of branches for plant samples taken in week 9 after planting in all soil types. In sandy loam the largest number of branches was observed in Vuli-II (4.92) and the lowest number was observed in local variety (2.75) (Table 8). In sandy clay soil; local variety (5.50) had the largest number of branches than other varieties and Tumaini variety (2.43) had the lowest number of branches (Table 9). In sandy clay loam soil; Tumaini variety (6.70) had the largest number of branches compared with other varieties in this soil type and local variety had the lowest number (4.0) of branches (Table 10). In loamy sand soil; the largest number of branches was observed in Fahari (5.42) and local variety (5.25) while the lowest number was observed in local variety (3.70) (Table 11). Generally, the largest number of branches was observed in sandy clay loam for Tumaini variety (6.70) and the lowest average number of branches was observed in sandy loam for local variety (2.75) (Fig. 7). Variation observed in the number of branches among varieties in different soil types may be due to the growth habit related to genetic makeup whereby some varieties such as Vuli-AR-I and Vuli-II are determinate to semi spreading and Fahari and Tumaini are spreading type. Tumaini varieties may be preferred by farmers who grow cowpea for grains and leaves harvest. This finding is also supported by Addo-quaye *et al*. (2011) who carried out an experiment to investigate performance of cowpea varieties in different agro ecological zones in Ghana. The two varieties with the highest number of branches were among the good performing varieties. This finding is also in agreement with work reported by other researchers that there is a relationship between the number of branches and grain yield in cowpea. Kamai *et al*. (2014) obtained the same results and explained the significance that the numbers of branches per plant to be most important character in cowpea yield.

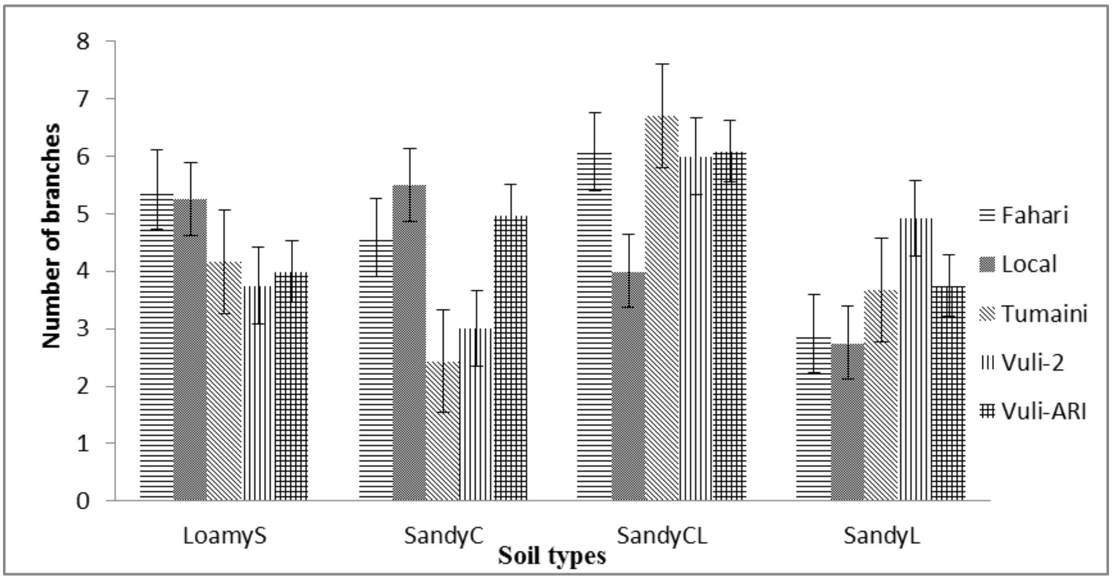

Figure 7: Number of branches for different cowpea varieties in different soil types.
NB: LoamyS = Loamy sand, SandyC = Sandy clay, SandyCL = Sandy clay loam and SandyL = Sandy loam

4.2.5 Days to 50% flowering

The mean number of days to 50% flowering of the selected varieties studied is presented in Tables 8, 9, 10 and 11. Cowpea varieties had highly significant differences ($p < 0.001$) on number of days to 50% flowering in all soil types. Local varieties attained 50% flowering later than other varieties in all soil types which ranged from 106.67 to 102.67 days from planting. The earliest variety to attain 50% flowering was Vuli-AR-I which ranged between 57.67 to 58.67 days from planting in all soil types (Fig. 8). This indicates that the variation in days to flowering may be due to genetic composition for each variety and not the influence of soil types. Similar results were reported by Olayiwola and Soremi (2017) on variation in number of days to 50% flowering among varieties in 4 different locations in Nigeria and the majority took 39 to 44 days. Many studies have reported additive gene to be responsible for genetic variation for early flowering (Cobbinah and Asante, 2011). This was found to be contradicting with the study by Singh *et al.* (1997), which reported the action of non- additive genes and interactions between genotype and environment to be important in early flowering. High yielding varieties require short flowering periods to channel energy into pod and seed development. For any early maturing variety this phenomena results into earlier sets of flowers, hence earlier maturity (Njoku and Muoneke, 2008).

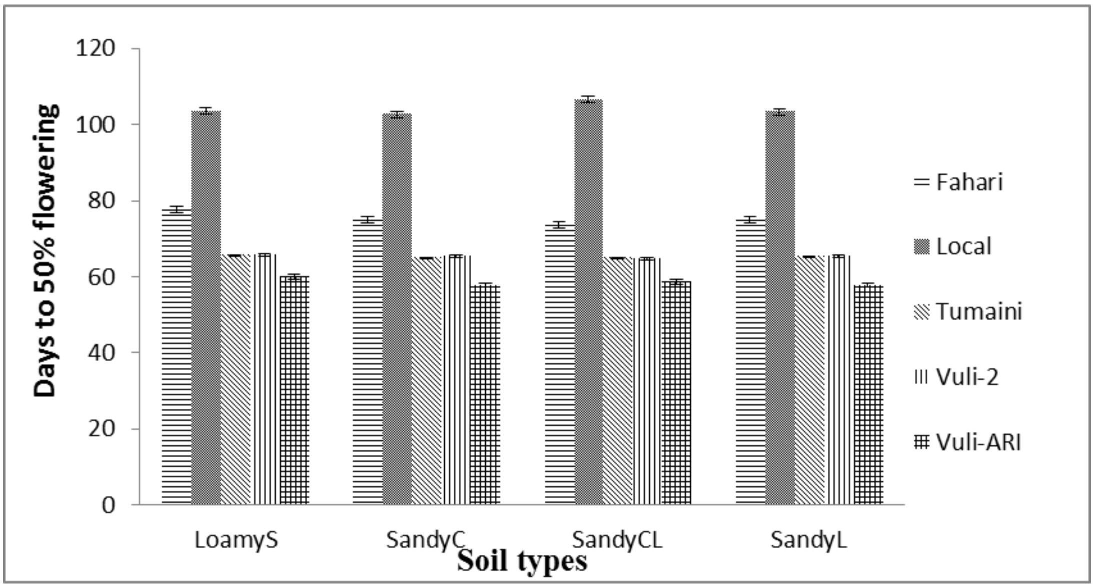

Figure 8: Days to 50% maturity for different cowpea varieties in different soil types. **NB**: LaomyS = Loamy sand, SandyC = Sandy clay, SandyCL = Sandy clay loam and SandyL = Sandy loam

Table 8: Growth parameters of different cowpea varieties in sandy loam soil in Iddisimba village (Northern, Singida).

Textural class	**Variety**	**No of Leaves Wk 9**	**Plant height Wk 9**	**Fresh weight (g) Wk 9**	**Dry weight (g) Wk 9**	**50% Flowering**	**Branches Wk 9**
Sandy loam	Fahari	11.11 b	32.38a	73.25bc	15.16ab	75.00 b	2.917 c
	Local	12.44 a	40.57a	49.61 c	9.74 b	103.33 a	2.750 c
	Tumaini	9.00 c	31.82a	109.58b	19.25 a	65.33 c	3.667 b
	Vuli-AR I	10.90 b	31.88a	99.33 b	20.32 a	57.67 d	3.750 b
	Vuli-II	10.68 b	43.66a	165.70a	22.15 a	65.33 c	4.917 a
Mean		10.83	36.1	99.5	17.3	73.33	3.600
CV%		5.4	18.2	21.7	24.9	2.4	5.4
F test		***	ns	***	*	***	***
LSD		1.055	11.95	39.30	7.84	1.430	0.3523

NB: Wk: Week, LSD: Least Significant Difference, the means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan's multiple range tests. *, ***: significant at $p \leq 0.05$, $p \leq 0.001$ respectively, ns = not significant.

Table 9: Growth parameters of different cowpea varieties in sandy clay soil in Makhandi village (Northern, Singida)

Textural class	**Variety**	**No of Leaves Wk 9**	**Plant height Wk 9**	**Fresh weight (g) Wk 9**	**Dry weight (g) Wk 9**	**50% Flowering**	**Branches Wk 9**
Sandy clay	Fahari	12.667a	34.16a	86.33bc	14.44c	75.00 b	4.583 b
	Local	9.917 b	29.92a	134.31a	21.82a	102.67 a	5.500 a
	Tumaini	7.667 d	32.68a	64.92 d	9.46 d	65.00 c	2.433 d
	Vuli-AR I	9.067bc	32.58a	97.28 b	15.96b	57.67 d	4.973 b
	Vuli-II	8.250cd	32.80a	81.57 c	15.12bc	65.33 c	3.000 c
	Mean	9.51	32.43	92.9	15.36	73.13	4.098
	CV%	6.3	7.0	7.0	3.9	3.7	6.0
	F test	***	ns	***	***	***	***
	LSD	1.096	4.153	11.77	1.101	4.949	0.4503

NB: Wk: Week, LSD: Least Significant Difference, the means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan's multiple range tests. ***: significant at $p \leq 0.001$. ns = not significant.

Table 10: Growth parameters of different cowpea varieties in sandy clay loam in Merya village (Northern Eastern, Singida)

Textural class	Variety	No of Leaves Wk 9	Plant height Wk 9	Fresh weight (g) Wk 9	Dry weight (g) Wk 9	50% Flowering	Branches Wk 9
Sandy clay loam	Fahari	10.00 b	48.25a	148.2 a	13.28 c	73.67 b	6.083 a
	Local	10.42 b	48.75a	70.2 d	21.22 a	106.67 a	4.000 b
	Tumaini	7.75 c	32.50d	77.8 bc	23.18 a	65.00 c	6.700 a
	Vuli-AR I	11.60 a	34.17c	132.9ab	14.89 bc	58.67 d	6.083 a
	Vuli-II	10.23 b	45.83b	168.4 a	17.19 b	64.67 c	6.000 a
Mean		10.00	41.90	119.5	17.95	73.73	5.77
CV%		4.2	1.8	27.2	7.7	1.8	10.5
F test		***	***	**	***	***	***
LSD		0.767	1.344	59.04	2.516	2.349	1.103

NB: Wk: Week, LSD: Least Significance Difference, the means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan’s multiple range tests. **, ***: significant at p ≤ 0.01, p ≤ 0.001 respectively, ns = not significant.

Table 11: Growth parameters of different cowpea varieties in sandy loamy sand in Msikii village (Eastern, Singida)

Textural class	Variety	No of Leaves Wk 9	Plant height Wk 9	Fresh weight (g) Wk 9	Dry weight (g) Wk 9	50% Flowering	Branches Wk 9
Loamy sand	Fahari	10.92 a	43.66 a	217.9 b	35.53 a	77.67 b	5.417 a
	Local	12.00 a	39.21 a	253.0 a	35.98 a	103.67 a	5.250 a
	Tumaini	11.00 a	55.18 a	149.6 d	23.43 b	65.67 c	4.167 b
	Vuli-AR I	10.25 a	40.54 a	185.1 c	31.96 a	60.00 d	4.000 b
	Vuli-II	10.50 a	47.52 a	149.4 d	25.47 b	65.67 c	3.750 b
Mean		10.93	45.2	191.0	30.47	74.53	4.517
CV%		14.4	21.4	5.0	7.2	3.9	5.9
F test		ns	ns	***	***	***	***
LSD		2.872	17.62	17.23	3.983	5.356	0.4842

NB: Wk: Week, LSD: Least Significant Difference, the means along the same column bearing similar letter do not differ significantly at 5% level of significance based on Duncan's multiple range test. ***: significant $p \leq 0.001$. ns = not significant.

4.2.6 Days to maturity

The results for the number of days to maturity in different soil types are shown in Tables 12, 13, 14 and 15. Results showed that, cowpea varieties had significant differences ($p < 0.001$) on average number of days to maturity in different soil types. Local variety was observed to mature later than all other varieties in every soil type and took 135 days from planting. The earliest maturing variety was Vuli-AR-I, which took 75 days from planting and the intermediate were Vuli-II, Fahari and Tumaini that took 80 – 81 days, 89 – 100 days and 82.6 – 83.6 days respectively (Fig. 9). The existed difference in days to maturity is probably due to genetic variation amongst the selected varieties. These results are similar to findings by Aliyu and Makinde (2016) who reported that expression of wide range of genetic variability observed among cowpea varieties offers wide opportunity to quality improvement that would allow selection of individuals with better attributes for maturity period and seed yield.

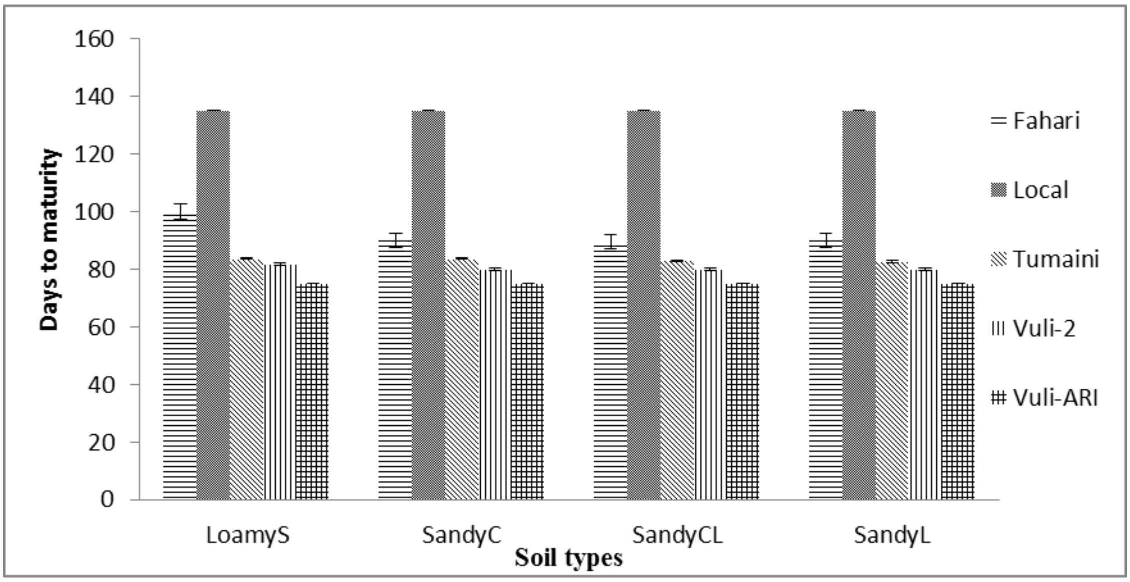

Figure 9: Days to maturity for different cowpea varieties in different soil types.
NB: LoamyS = Loamy sand, SandyC = Sandy clay, SandyCL = Sandy clay loam and SandyL = Sandy loam

4.2.7 Number of pods per plant

The results for the number of pods/plant in different soil types are shown in Tables 12, 13, 14 and 15. Cowpea varieties showed no significant differences ($p < 0.05$) on average number of pods/plant in sandy clay, sandy clay loam and loamy sand soils, but significant differences were observed in sandy loam (Tables 12, 13, 14 and 15. In sandy loam the largest average number of pods per plant was observed in Tumaini (32.58) and the lowest average in local variety (12.33) (Table 10 and Fig. 10). In sandy clay Vuli-AR-I (30.92) had the largest average number of pods than other varieties and local variety (12.33) had the lowest average number of pods (Table 13 and Fig. 10).

In sandy clay loam the largest average number of pods was observed in Vuli-AR-I (21.33) variety than other varieties and the lowest average number of pods was observed in local variety (12.67) Tables 14 and Fig. 10). In loamy sand the largest average number of pods/plant was observed in Tumaini (35.17) and the lowest average number was observed in local variety (13.17) (Table 15). Generally, all improved varieties had significant higher yield than local variety in both soils. Tumaini variety had the highest number of pods (35.17) which was observed in loamy sand (Fig. 10). This observation supports earlier reports by Aribisala *et al.* (2014) that plants respond differently to environmental factors depending on their genetic makeup and their adaptation capability. The variability among species on number of pods per plant may be attributed to genetic variation among cowpea varieties but also soil type composition. The present results are consistence with the finding by Aribisala *et al*. (2014) that particles size fractions, pH and exchange acidity influence plant growth, productivity and yield during cropping season.

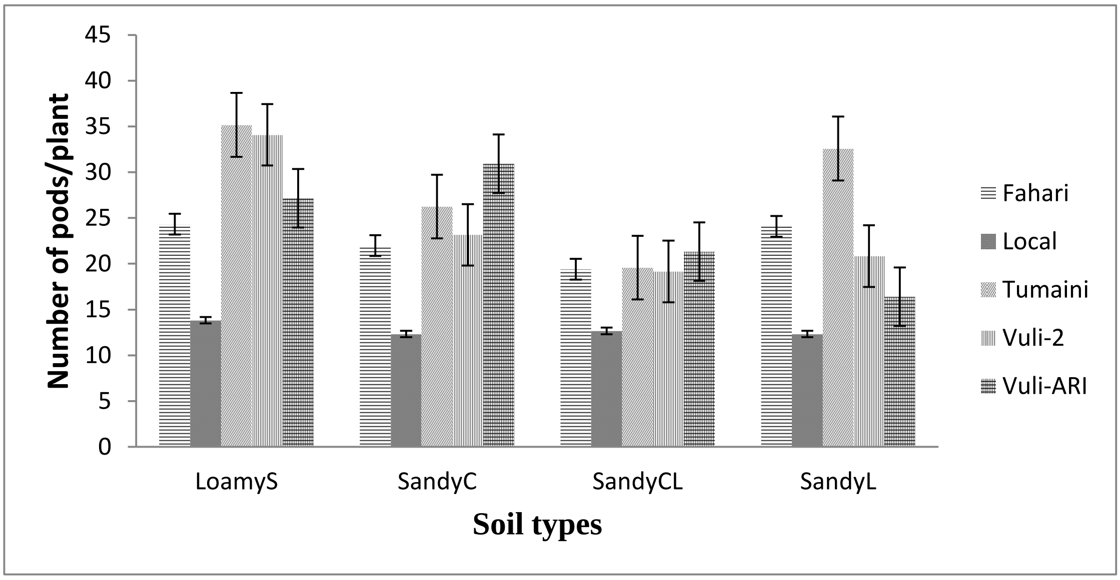

Figure 10: Number of pods per plant for different cowpea varieties in different soil types.
NB: LoamyS = Loamy sandy, SandyC = Sandy clay, SandyCL = Sandy clay loam and SandyL = Sandy loam

4.2.8 Grains per pod

The results for the number of grains/pods in different soil types are shown in Tables, 12, 13, 14 and 15. Cowpea varieties had highly significant differences ($p < 0.001$) on average number of grains per pods in different soil types. In sandy loam the largest average number of grains per pod was observed in Tumaini (17.25 grains/pods) and the lowest average number was observed in local variety (8.33 grains/pod) (Table 12). Sandy clay, Fahari (17.42 grains/pod) had the largest average number of grains per pods than other varieties similar to Tumaini (17.17 grains/pod) and Vuli-AR-I (17.50 grains/pod) while local variety (8.33 grains/pod) had the lowest average number of grains per pods (Table 13). In sandy clay loam the largest average number of grains per pods was observed in Tumaini (16.92 grains/pod) similarly to Vuli-AR-I (16.83 grains/pod) and Fahari (16.50 grains/pod) while the lowest average number of grains per pod was observed in local variety (8.67 grains/pod) (Table 14). In loamy sand, the largest average number of grains per pod was observed in Fahari (16.0) and the lowest average number was observed in local variety (9.33) (Table 15). Generally, all the improved varieties had significantly higher number of grains per pod than local variety in both soils. The highest number of grains per pods was observed in Tumaini and Fahari in both soils and lowest number of grains per pod was observed in local variety for both soils (Tables 12 – 15 and Fig. 11). The variation in number of grains per pod among varieties may be due to the genetic variation. These results are in agreement with the results reported by (Aribisala *et al.,* 2014; Kamai *et al.,* 2014) who indicated that number of grains per pod are normally attributed to cowpea variety.

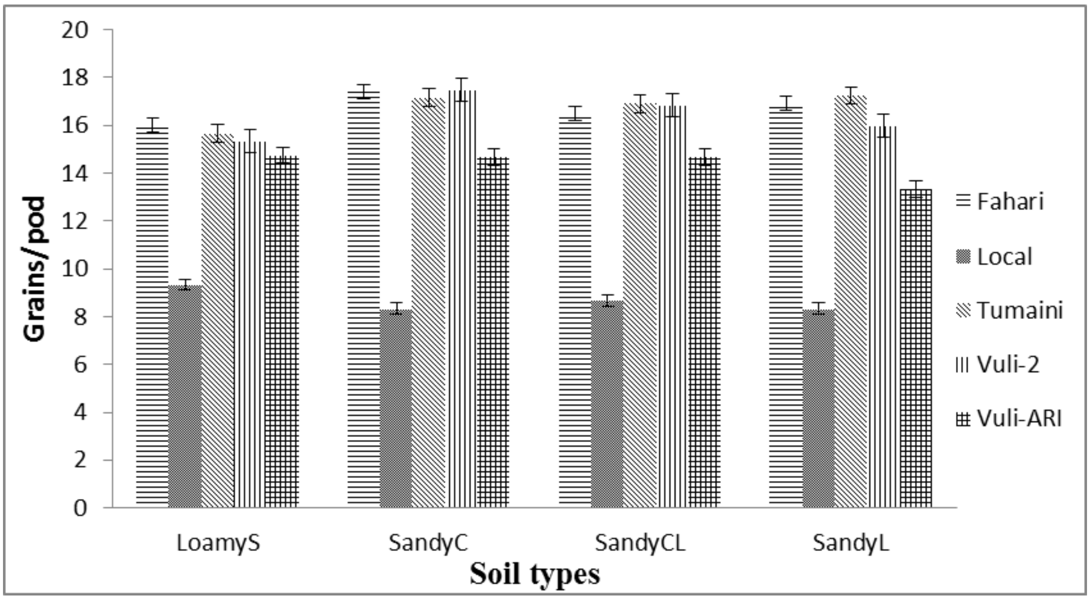

Figure 11: Number of grains per pod for different cowpea varieties in different soil types.
NB: LoamyS = Loamy sand, SandyC = Sandy clay, SandyCL = Sandy clay loam and SandyL = Sandy laom

4.2.9 Weight of 100 cowpea grains

The results for the weight of 100 grain seeds in different soil types are shown in Tables 12, 13, 14 and 15. Cowpea varieties had high significant differences ($p < 0.001$) on average weight of 100 grains in different soil types. In sandy loam the highest average weight of 100 grains was observed in Vuli-AR-I (18.95 g) and the lowest average weight was observed in Vuli-II variety (12.15 g) similar to Fahari (12.76 g) and Tumaini (12.65 g) respectively (Table 12). In sandy clay, Vuli-AR-I (18.95 g) had the highest average weight of 100 grains than other varieties and Vuli-II (11.75 g) variety had the lowest average weight of 100 grains (Table 14). In sandy clay loam, Vuli-AR-I (19.59 g) had the highest average weight of 100 grains and the lowest was observed in Vuli-II (13.2 g) similar to Fahari (13.6 g) and Tumaini (13.37 g) (Table 15). Generally, it was observed that Vuli-AR-I had the highest average weight of 100 grains in all types of soils followed by local varieties. The highest weight of

100 grains of Vuli-AR-I may be due to their large size of the seeds (Fig. 14). Seed weight which is the measure of the seed size was observed to be consistent for each variety in all soil types which indicate that soil types did not have any effect to grain weight or seed size. Due to this fact the variation observed from one variety to another may be due to genetic variability among these varieties and uniformity. Similar results were reported by (Addo-quaye *et al.,* 2011), where the 100 grain weight was influenced by both genetic and environmental factors..

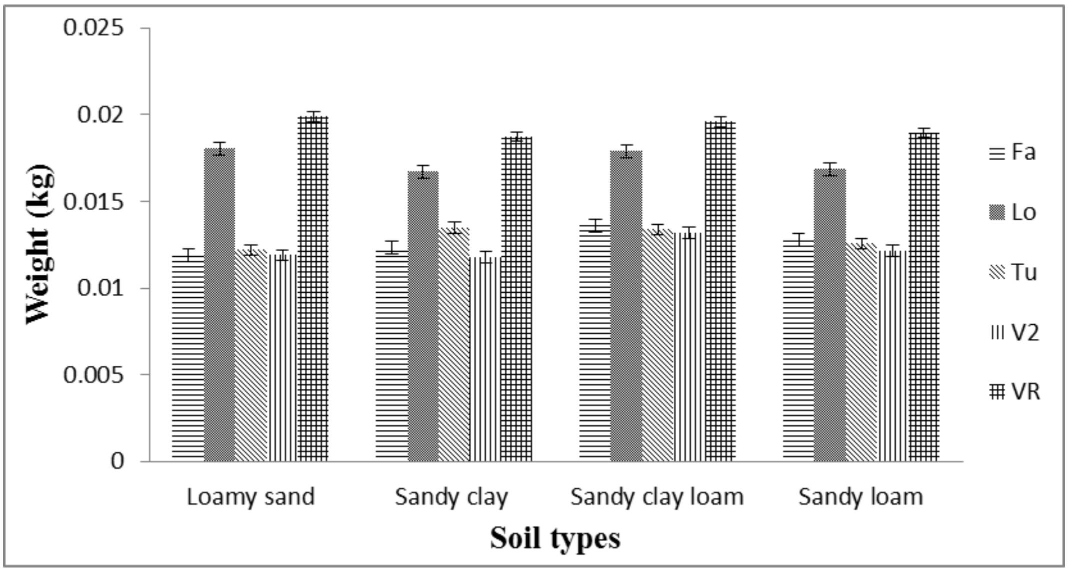

Figure 12: Weight of grains per plant for different cowpea varieties in different soil types.
NB: Fa = Fahari, Lo = Local, Tu = Tumaini, V2 = Vuli – II and VR = Vuli-AR- I

4.2.10 Yield per plant and yield in kg ha^{-1}

The results for the yield/plant and yield in kgha^{-1} for different cowpea varieties in different soil types are shown in Tables 12, 13, 14 and 15. Cowpea varieties had high significant differences ($p < 0.05$) on average yield per plant in sandy clay soil and sandy clay loam soils, but no significant differences ($p > 0.05$) were observed on sandy loam and loamy sand soils. In sandy loam the highest average yield per plant was observed in Vuli-AR-I (13.42 g/plant) and the lowest average weight was observed in local variety (4.82 g/plant) (Table 12). In sandy clay Vuli-AR-I recorded the highest average yield per plant (14.26 g/plant) than other varieties and the lowest average yield per plant was observed in local variety (4.86 g/plant) (Table 13). In sandy clay loam, the highest performing variety Fahari (8.92g/plant) recorded similar weights to Tumaini (8.89g/plant) and Vuli-AR-I (8.38g/plant) respectively, while the lowest yield was observed in local variety (5.09 g/plant) (Table 14). In loamy sand, Vuli-AR-

I (11.03 g/plant) recorded the highest average yield per plant and the lowest was observed in local variety (5.07 g/plant) (Table 15). Generally, it was observed that Vuli-AR-I variety performed better in all soil types and local variety performed poorly in all soil types (Fig. 13). This may be due to the genetical ability of Vuli-AR-I to absorb nutrients and withstand stress caused by insect pests compared with other varieties (Agyeman *et al.,* 2014) Variation of yield among varieties in different soil types were in tune with findings of other scholars who reported that the variation among varieties could be due to its cumulative vigor during growth (Mekonnen *et al.,* 2016).

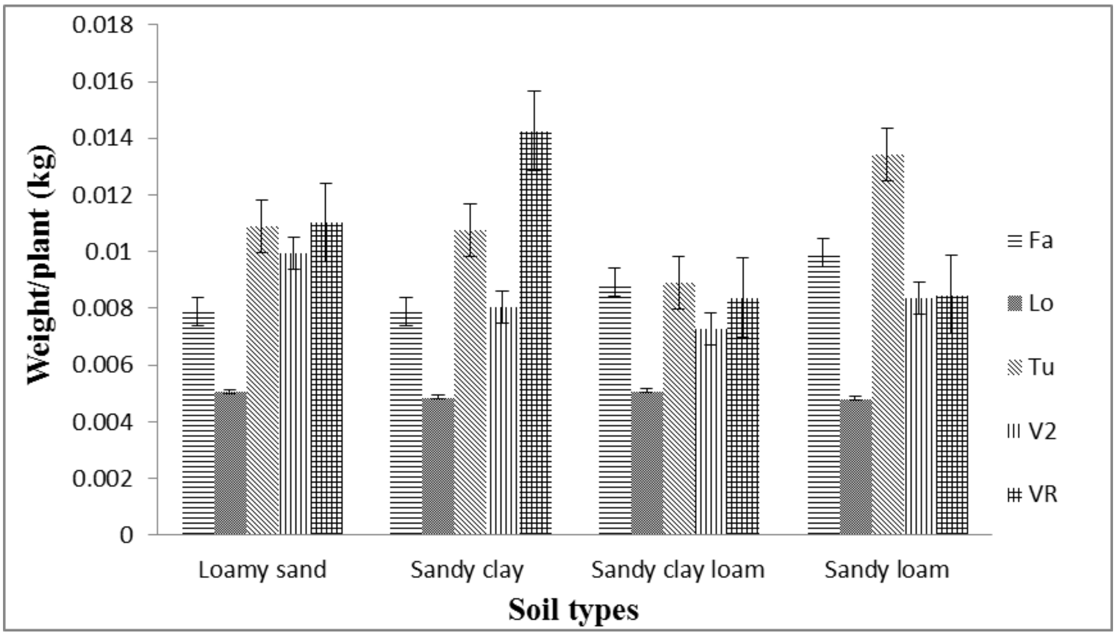

Figure 13: Grains weight per plant of different cowpea varieties in different soil types. **NB:** Fa = Fahari, Lo = Local, Tu = Tumaini, V2 = Vuli – II and VR = Vuli-AR- I

Cowpea varieties had high significant differences ($p < 0.05$) on average yield in kgha^{-1} in sandy clay and sandy clay loam soils, but no significant differences ($p > 0.05$) in sandy loam and loamy sand soils were observed. In sandy loam, the highest average yield was observed in Tumaini (894.8 kgha^{-1}) followed by Vuli-AR-I (847.7 kgha^{-1}) and Vuli II (835.8) respectively while the lowest average yield was observed in local variety (320.9 kagha^{-1}) (Table 12). In sandy clay, Vuli-AR-I (950.3 kgha^{-1}) recorded the highest average yield in kgha^{-1} than other varieties and the lowest average yield in kgha^{-1} was observed in local (323.9 kgha^{-1}) (Table 13). In sandy clay loam, Vuli-AR-I (838.3 kgha^{-1}) had the highest average yield in kgha^{-1} and the lowest average yield was observed in local variety (339.1kgha^{-1}) (Table 14). In loamy sand, Vuli-AR-I (1103.0 kgha^{-1}) had the highest average yield in kgha^{-1} and the lowest was observed in local variety (338.2 kgha^{-1}) (Table 15). Generally, it was observed that all improved varieties performed better than local varieties and the highest performing variety was Vuli-AR-I (950.3 kgha^{-1}) which was observed in sandy clay followed by Vuli-II (995.7 kgha^{-1}) (Fig. 14). Highest performance of some varieties may be due to their ability to adapt with the environment and genotype was improvements. On the other hand, varieties such as Vuli-ARI-I which bear their pods above the canopy have higher interception of solar radiation than varieties which have pods that are borne at lower height within the foliage of the plant (Kwaga, 2014). These results do not correspond with the results of Agbogidi and Egho (2012) who reported that plants respond differently to the environment. Further their genetic and differences in adaptation to environment indicate the variability between species.

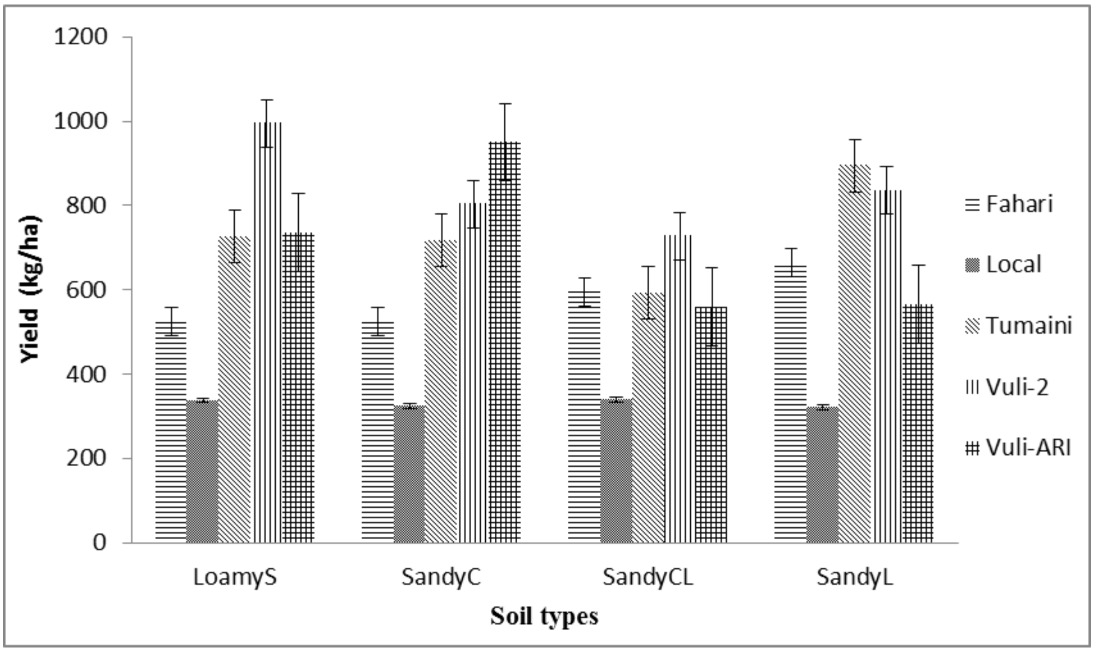

Figure 14: Yield in kg/ha for different cowpea varieties in different soil types.

NB: LoamyS = Loamy sand, SandyC = Sandy clay, SandyCL = Sandy clay loam and SandyL = Sandy laom

Table 12: Yield parameters of different cowpea varieties in sandy loam soil in iddsimba village (Northern, Singida)

Textural class	Variety	No Pods	Grains/Pod	100 seed weight	Yield/plant (g)	Yield (Kg/ha)	Days to maturity
Sandy loam	Fahari	24.08ab	16.92a	12.76 b	9.957 a	663.6 a	90.00 b
	Local	12.33 b	8.33 c	16.85 a	4.813 a	320.9 a	135.00a
	Tumaini	32.58 a	17.25a	12.56 b	13.420 a	894.8a	82.67 c
	Vuli-ARI	16.42 b	13.33b	18.95 a	8.477 a	565.2a	75.00 e
	Vuli-II	20.83ab	16.00a	12.15 b	8.360 a	835.8a	80.00 d
Mean		21.2	14.37	14.65	9.01	656	92.53
CV%		30.9	7.3	11.7	37.0	35.1	0.6
F test		*	***	**	ns	ns	***
LSD		11.95	1.897	3.127	6.067	419.3	0.939

NB: The means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan's multiple range tests. *, **, ***: significant at $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$ respectively, ns = not significant. LSD: Least Significant Difference.

Table 13: Yield parameters of different cowpea varieties in sandy clay soil in Makhandi village (Northern, Singida)

Textural class	**Variety**	**No Pods**	**Grains/Pod**	**100 grains weight**	**Yield/plant (g)**	**Yield (Kg/ha)**	**Days to maturity**
Sandy clay	Fahari	22.00ab	17.42 a	12.31 b	7.887 bc	525.6 ab	90.00 b
	Local	12.33 b	8.33 c	16.69 a	4.860 c	323.9 b	135.00 a
	Tumaini	26.25 b	17.17 a	13.48 b	10.770 ab	717.9 ab	83.67 c
	Vuli-AR I	30.92 a	14.67 b	18.72 a	14.257 a	950.3 a	75.00
	Vuli-II	23.17 ab	17.50 a	11.75 b	8.037 bc	803.4 a	80.00 d
	Mean	22.9	15.02	14.59	9.16	664	92.73
	CV%	30.3	6.2	11.3	29.0	36.3	0.9
	F test	**	***	*	**	ns	***
	LSD	12.64	1.796	2.999	4.840	439.3	1.485

NB: The means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan's multiple range tests. *, **, ***: significant at $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$ respectively, ns = not significant. LSD: Least Significant Difference.

Table 14: Yield parameters of different cowpea varieties in sandy clay loam in Merya village (North East part)

Textural class	Variety	No Pods	Grains/ Pod	100 grains weight	Yield/plant (g)	Yield (Kg/ha)	Days to maturity
Sandy clay loam	Fahari	19.42ab	16.50 a	13.60 b	8.920 a	594.6 ab	89.67 b
	Local	12.67 b	8.67 c	17.88 a	5.087 a	339.1 c	135.00 a
	Tumaini	19.58ab	16.92 a	13.37 b	8.890 a	592.6 ab	83.00 c
	Vuli-AR I	21.33 a	14.67 b	19.59 a	8.383 a	558.8 ab	75.00 e
	Vuli-II	19.17ab	16.83 a	13.20 b	7.280 a	727.8 a	80.00 d
Mean		18.4	14.72	15.53	7.71	563	92.53
CV%		21.9	6.3	10.4	28.8	26.9	0.6
F test		ns	***	***	ns	***	***
LSD		7.36	1.68	2.939	0.0313	275.7	0.939

NB: The means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan’s multiple range tests. *, **, ***: significant at $p \leq 0.001$. ns = not significant. LSD: Least Significant Difference.

Table 15: Yield parameters of different cowpea varieties in sandy loam sand in Msikii village (Eastern part)

Textural class	Variety	No Pods	Grains/Pod	100 grains weight	Yield/plant (g)	Yield (Kg/ha)	Days to maturity
Loamy sand	Fahari	24.33 a	16.00 a	11.88 b	7.867 a	524.3 ab	100.00 b
	Local	13.83 a	9.33 b	18.03 a	5.073 a	338.1 b	135.00 a
	Tumaini	35.17 a	15.67 a	12.20 b	10.903	726.7 ab	83.67 c
	Vuli-AR I	27.17 a	14.75 a	19.87 a	11.030	735.4 ab	75.00 d
	Vuli-II	34.08 a	15.33 a	11.89 b	9.957 a	995.2 a	81.67 c
	Mean	26.9	14.22	14.77	9.0	664	95.07
	CV%	46.3	12.6	10.6	47.2	48.9	3.8
	F test	ns	*	***	ns	***	***
	LSD	22.66	3.254	2.847	7.70	590.9	6.492

NB: The means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan's multiple range tests. *, ***: significant at $p \leq 0.05$, $p \leq 0.001$ respectively, ns = not significant. LSD: Least Significant Difference.

4.3 Influence of farmer's agronomic practices on yield of cowpea

4.3.1 Grains/pods

The results for the effect farmer's agronomic practices on grains/pod in different villages are shown in Table 16, 17 and 18. Results showed that cowpea varieties had significant differences ($p < 0.001$) on the number grains per pods under farmer's agronomic practices in different villages (Table 16, 17 and 18). In Merya village (Northern part) the highest number of grains/pods was observed in Fahari variety (17.42) and Tumaini variety (17.0) while the lowest number of grains/pod was observed in local variety (6.67). In Msikii village (Eastern part) the highest number of grains/pod was observed in Fahari (17.5) and Tumaini variety (17.0) while the lowest was observed in local variety (6.67). In Iddisimba village (Northern part) the highest number of grains/pods was observed in Fahari (17.5) and Tumaini variety (17.33). Generally, Fahari and Tumaini variety was observed to have the highest number of grains/pods (17 to 17.42 grains/pod) compared with other varieties in all villages while lowest number of grains/pods were observed in local variety ranging from 5.67 to 6.67. The variability among species in grains/pod may be due to genetic variation amongst the cowpea varieties but also soil fertility variation. The findings from this study iare consistence with the findings by Aribisala *et al.* (2014) who indicated that particle size fractions, pH and exchange acidity influence plant growth, productivity and yield during cropping season (Aribisala *et al.*, 2014).

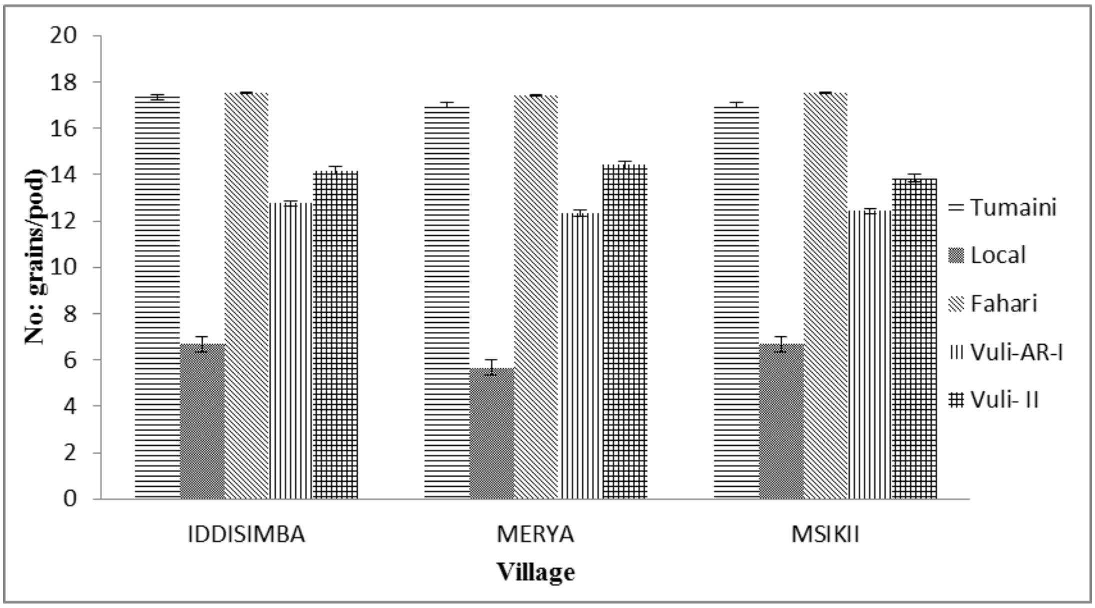

Figure 15: Influence of farmer’s agronomic practices on number of grains per pod in different villages

4.3.2 Weight of 100 grains

The results for the influence of farmer’s agronomic practices on weight of 100 grains in different villages are shown in Table 16, 17 and 18. Results showed that cowpea varieties had significant differences ($p < 0.001$) on weight of 100 grains under farmer’s agronomic practices in different villages (Table 14). In Merya village, highest weight of 100 grains was observed in Vuli-AR-I (0.020kg) and the lowest was found in Vuli-II (0.012kg). In Msikii village, the highest weight of 100 grains was observed in Vuli-AR-I (0.017 kg) and the lowest was observed in Fahari (0.012kg) and Vuli-II (0.012kg). In Iddisimba village, the highest weight of 100 grains was observed in Vuli-AR-I (0.21 kg) and the lowest was observed in Vuli-II (0.012 kg). Generally, in all villages the highest weight was observed in Vuli-AR-I variety which ranged from 0.017 to 0.021 kg while the lowest weight was observed in Vuli-II and Fahari which ranged from 0.012 to 0.013 kg. These variations may be due to the differences in grains size among the selected cowpea varieties. This is in agreement with the results reported by Etame *et al.* (2010).

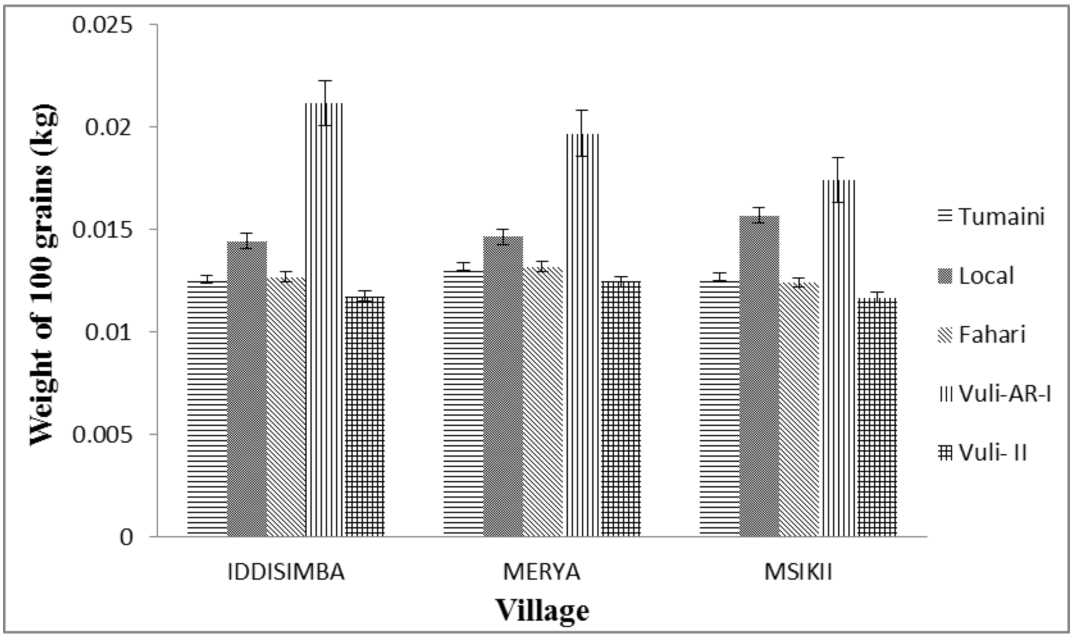

Figure 16: Influence of farmer’s agronomic practices on weight of 100 grains in different villages

4.3.3 Yield/plant (kg)

The results for the influence of farmer’s agronomic practices on yield/plant (kg) in different villages are shown in Table 16, 17 and 18. Yield/plant showed significant differences ($p < 0.05$) in interaction of varieties and farmer’s agronomic practices at Msikii (Eastern, Singida) and Iddisimba village (Northern, Singida) and no significant differences in Merya (North – East, Singida) village (Table 16, 17 and 18). In Merya (North – East, Singida) the yield per plant was observed in Fahari variety (0.035 kg) and the lowest was observed in Tumaini variety (0.024 kg). In Msikii (Eastern, Singida), the highest yield per plant was observed in Tumaini variety (0.041 kg) and the lowest yield per plant was observed in local variety (0.014 kg). In Iddisimba village (Northern, Singida), the highest yield per plant was observed in Fahari variety (0.056 kg) and the lowest yield per plant was observed in local variety (0.019 kg) (Fig. 17). These results indicated that cowpea varieties responded differently to diverse environmental conditions. Different responses of variety might be due to genetic variations between varieties and environmental factors (Aribisala *et al.,* 2014).

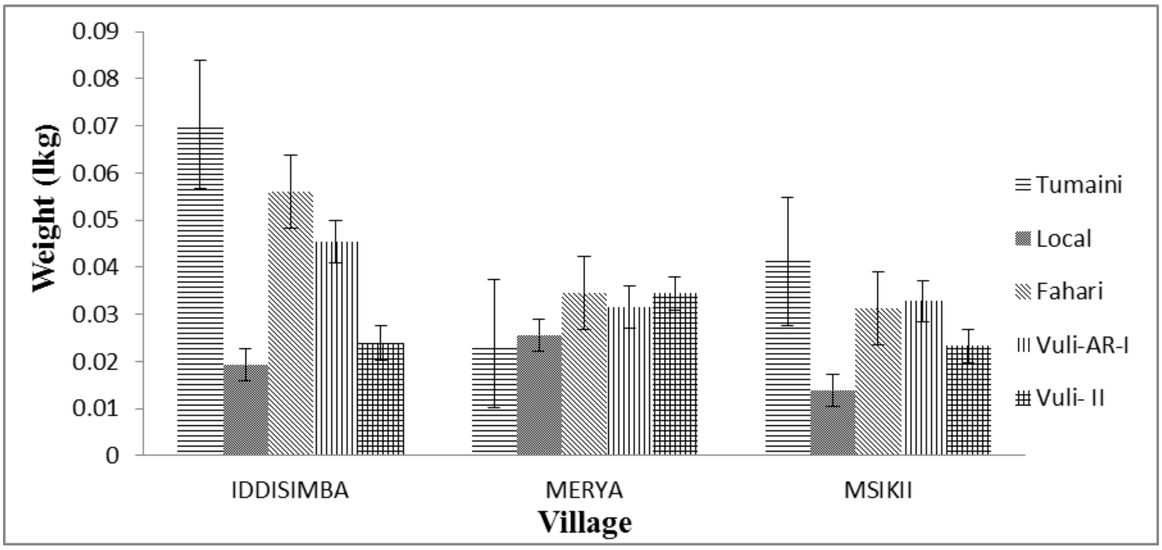

Figure 17: Influence of farmer's agronomic practices on grains weight per plan in different villages

4.3.4 Yield in kgha^{-1}

The results for the influence of farmer's agronomic practices on yield in kgha^{-1} in different villages are shown in Table 16, 17 and 18. Results showed that yield in kgha^{-1} had significant differences ($p < 0.05$) on interaction of varieties and farmer's agronomic practices in Iddisimba village (Northern, Singida) but not significant different (P>.005) in Merya (North – East, Singida) and Msikii (Eastern, Singida) (Table 16, 17 and 18). In Merya (North – East, Singida) the highest performance was observed in Vuli-AR-I (575.80 kgha^{-1}) similar to Fahari variety (526.90 kgha^{-1}) and the lowest yield was observed in local variety (337.80 kgha^{-1}). In Msikii village (Eastern, Singida) the highest yield was observed in Vuli-AR-I (458.60 kgha^{-1}) and the lowest yield was observed in local variety (202.60kgha^{-1}). In Iddisimba village (Northern, Singida), the highest yield was observed in Tumaini variety (650.50kgha^{-1}) and the lowest yield was observed in local variety (197.70kgha^{-1}) (Fig. 18). In general, improved varieties performed better than local varieties in all villages under farmer's practices. Variation in yield among these varieties may be due to their genetic ability to respond to the environment and management that are provided during growth period such as weed control and insect pest control (Agbogidi and Egho, 2012).

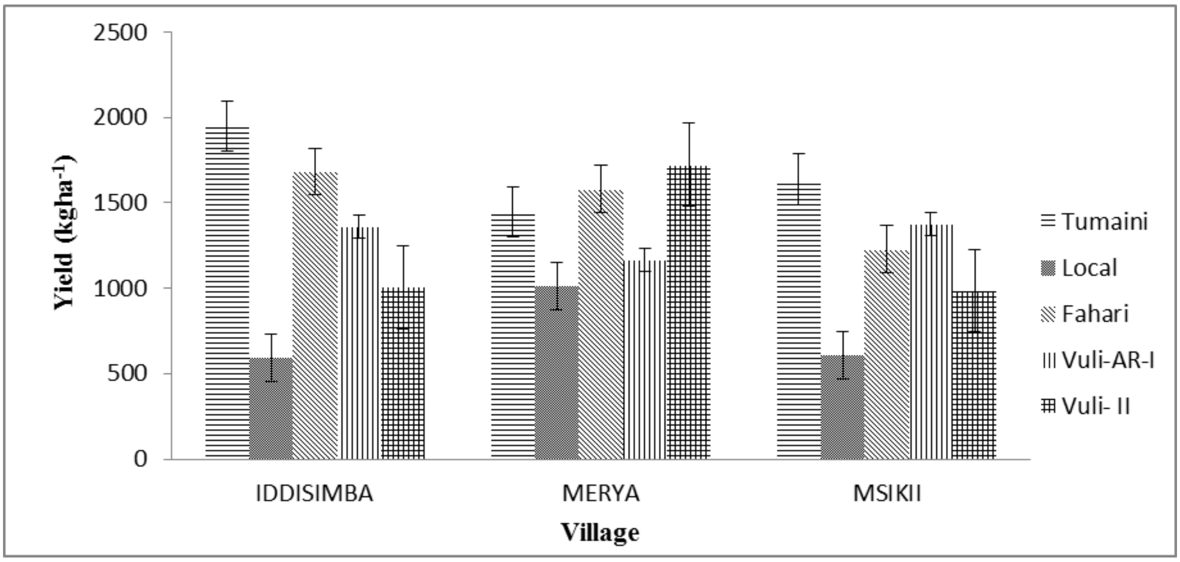

Figure 18: Influence of farmer's agronomic practices on yield in kg/ha in different villages

Table 16: Influence of farmers practices on yield of cowpea Merya village North-East Singida

Village	Variety	Grains/pod	100 grains wt	Yield/plant (kg)	Yield kg/ha
Merya	Fahari	17.42 a	0.013 c	0.035 a	526.90 a
	Local	5.67 d	0.015 b	0.026 a	337.80
	Tumaini	17.00 a	0.013 c	0.024 a	482.20 a
	Vuli-AR I	12.33 c	0.020 a	0.031 a	388.10 a
	Vuli-II	14.42 b	0.012 d	0.034a	574.10 a
Mean		13.37	0.0146	0.030	461.80
CV%		2.1	2.3	57.4	57.5
F test		***	***	ns	ns
LSD		0.5119	0.00060	0.0313	232.3

NB: The means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan's multiple range tests. ***: significant at $p \leq 0.001$ and ns = not significant. Wt: Weight LSD: Least Significant Difference.

Table 17: Influence of farmers practices on yield of cowpea Msikii village Eastern Singida

Village	Variety	Grains/pods	100 grains wt	Yield/plant (kg)	Yield kg/ha
Msikii	Fahari	17.50 a	0.012 c	0.031 ab	409.70 ab
	Local	6.67 d	0.016 b	0.014 b	202.60 b
	Tumaini	17.00 a	0.013 c	0.041 a	546.20 a
	Vuli-AR I	12.42 c	0.017 a	0.033 a	458.60 ab
	Vuli-II	13.83 b	0.012 d	0.023 ab	328.70 ab
Mean		13.48	0.014	0.028	389.15
CV%		3.2	1.7	33.5	36.4
F test		***	***	*	ns
LSD		0.788	0.00043	0.0173	257.718

NB: The means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan’s multiple range tests. *, ***: significant at $p \leq 0.05$ $p \leq 0.001$ and ns = not significant. Wt: Weight LSD: Least Significant Difference.

Table 18: Influence of farmers practices on yield of cowpea Iddisimba Northern Singida

Village	Variety	Grains/pods	100 grains wt	Yield/plant (kg)	Yield kg/ha
Iddsimba	Fahari	17.50 a	0.013 c	0.056 b	560.50 a
	Local	6.67 d	0.014 b	0.019 c	197.70 c
	Tumaini	17.33 a	0.013 c	0.070 a	650.50 a
	Vuli-AR I	12.75 c	0.021 a	0.045 b	454.40 ab
	Vuli-II	14.17 b	0.012 d	0.024 c	334.90 bc
Mean		13.68	0.0145	0.043	439.61
CV%		2.9	1.2	17.1	25.7
F test		***	***	***	*
LSD		0.42	0.00083	0.015	167.49

NB: The means along the same column bearing similar letter(s) do not differ significantly at 5% level of significance based on Duncan’s multiple range tests. *, ***: significant at $p \leq 0.05$ $p \leq 0.001$ respectively, ns = not significant. Wt: Weight LSD: Least Significant Difference.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The general aim of this study was to evaluate four improved cowpea varieties and one local variety collected from the study site for their performance in different soil types in Singida Rural District, Tanzania. The same varieties were also evaluated on their yield performance under farmer's agronomic practices. Many breeders and agronomists have evaluated cowpea varieties in different environments but not much attention has been given to soil types' variation. This study evaluated cowpea growth and yield responses in different soil types and observed that cowpea varieties had significant differences ($P<.05$) on growth and yield in the different soil types. The best performing varieties were Vuli-AR-I, Vuli-II and Tumaini. Varietal performance per soil type in terms of yield were as follows; Sandy loam: Vuli-AR-I, Vuli-II and Tumaini; Sandy clay: Vuli-AR-I and Vuli-II; Sandy clay loam: Vuli-AR-I and Vuli-II; and Loamy sand: Vuli-AR-I and Vuli-II. Improved varieties were observed to perform better than local varieties in terms of both growth and yield, although under farmer's practices yield were observed to be less compared with the mother trial. Findings from this study portray a differential performance of cowpea varieties to different soil types under studied agro ecological environment. Therefore, in the whole concept of legume diversification to improve food and nutrition security, soil type should be taken into account as a component of agro-ecology variability.

5.2 Recommendations

This study recommends that evaluating crop varieties under different soil types is of importance in matching the variety performance with soil types. To get high yield of cowpea, farmers are advised to use improved seeds of cowpea. This is because improved varieties grow fast, mature early and yield more as compared with local varieties. These varieties have short duration to maturity and high yielding. Because SNAP will be continuing working with farmers in Singida with the aim of improving food security and nutrition, through legumes diversification, this research recommends the following:

i) To have long-term results, there is a need for repeating this evaluation to at least more than 2 seasons and sites for both short and long rains.

ii) More research is required on agronomic practices used by farmers in order to maximize yield of cowpea varieties and effect of leaves harvests' for vegetables on growth and yield of cowpea varieties on different soil types under farmer's management.

iii) Since the study area covers a small part of Tanzania (Singida Rural District) it is equally important to undertake the same evaluation in varying agro-ecological zones across the country for a better recommendation of the varieties.

iv) It should be kept in mind that there were many factors other than soil fertility constraints limiting the production of cowpea. In some fields low yields were due to other constraints like poor management practices, drought, insects and diseases. In these fields, the introduction of improved seeds will not be worthwhile due to these other intervening factors. Future research should therefore, focus on these other limiting factors cited.

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RESEARCH OUTPUTS

Potential of Legume Diversification in Soil Fertility Management and Food Security for Resource Poor Farmers in Sub Saharan Africa

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RESEARCH PAPER

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Potential of legume diversification in soil fertility management and food security for resource poor farmers in Sub-Saharan Africa

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Abstract

Declines in soil fertility and its effect on crop production is a major problem in sub Saharan Africa. It is a major factor limiting crop production and consequently food security in agrarian communities. The causes of soil fertility decline on smallholder farms in Southern and East Africa include continuous cropping without sufficient soil replenishment, degradation through erosion and leaching, and limited biological nitrogen-fixation. Using inorganic fertilizers to address this problem doesn't add organic matter and is not accessible for small scale farming communities who cannot access fertilizer or afford the high costs of purchase. In this review, we explore the literature on legume diversification as part of a sustainable approach to fertility management. Legumes in the farming systems can improve soil fertility through the rhizobium-legume symbiotic relationship (referred to as biological nitrogen fixation (BNF), and have the potential to enhance soil organic matter and conserve other soil resources as well. In addition legumes can provide multipurpose roles by contributing food, fodder and fuel to households. The information that is compiled in this review is vital to guide research efforts and farmers to integrate more relevant legume crops into their farming systems, particularly those types of legumes which produce large amounts of vegetative biomass that can be used to ameliorate soil fertility for enhanced food production and security.

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Introduction

Soil fertility refers to the ability of soil to provide plant with essential plant nutrients in adequate amounts and proportions for plant growth and reproduction, to sustain high quality and consistent crop yields (Watson *et al.,* 2002). Low soil fertility and degraded, soil structure can results in poor crop production. Degraded and infertile soils are turn often linked to food insecurity, particularly among smallholder farmers who depend largely on their own agriculture production for food and income (Tully *et al.,* 2015). It is clear that Food security is defined by the FAO to be "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2006). To achieve this, fertile soils are crucial for rising sufficient crops; yet, soil fertility status may be on the decline and causing major problems for sustainable production in Africa (Chukwuka, 2009).

Soils in Africa are typically highly variable in fertility, and in the way they respond to inputs (Omotayo and Chukwuka, 2009). Most soil resources in Africa have low nutrient levels with a high propensity towards nutrient loss due to their fragile nature (Silva and Uchida, 2000); although not all, as some are volcanic in nature and thus less nutrient depleted. Highly cultivated soils in the tropics have been observed to suffer from multiple nutrient deficiencies and nutrient imbalances (Kinsey, 2012). Nearly 40% of soils in SSA are low in nutrients reserves (<10% weather able minerals), 25% suffer from aluminum toxicity, and 18% have a high leaching potential (low buffering capacity) (Tully *et al.*, 2015). One study suggested that, in the 2002—2004 cropping season, about 85% of African farmland (185 million hectares) had nutrient removal rates of more than 30kg/ha of nutrients yearly, and 40% had rates greater than 60kg/ha yearly (Henao *et al.*, 2006).

Inorganic fertilizer applications across Africa are highly variable and nil in many instances, and very low in some east Africa countries, close to zero across much of Uganda for example, and higher in parts of Central Africa, in the range of 30 to 40 kilograms (kg) of nitrogen, phosphorus, and potassium (NPK)/ha yearly (Malingreau *et al.*, 2012; (Shiningayamwe, 2012).) Government subsidies have promoted the use of fertilizer in some instances, such as in Malawi and some regions of Tanzania – yet inorganic fertilizers alone do not address soil degradation, which is becoming of increased concern due to such factors as limited soil cover and poor nitrogen-fixation as well as physical soil degradation, soil erosion and leaching (Jonas *et al.,* 2011). In addition, use of inorganic fertilizers by resource poor farmers is constrained by profound lack of knowledge of application, high fertilizer cost, unavailability, access (Cagley and Gugerty, 2009; Njira *et al.,* 2012; IFDC, 2012; Williams *et al.,* 2014; Cedric and Nelson, 2014). Use of inorganic fertilizers also has been reported to have negative effects on water quality, soil fauna and soil health (Jonas *et al.,* 2011; Schröder, 2014).

Farmers apply different methods to addressing soil fertility, such as application of animal manure, recycling of crop residues and shifting cultivation (Henao *et al,* 2006; Omondi *et al.*, 2014). Shifting cultivation, which relies on extension of agriculture to new land, is no longer considered sustainable in many regions due to increasing pressure on land resources (Druilhe and Barreiro-hurlé, 2012; Baijukya, 2004; Shuaibu *et al.,* 2015). To address the challenges of improving soil fertility for small scale farmers, several approaches such as integrating legumes in the farming systems and legume diversification are now being advocated for soil fertility management (Snapp *et al.* 2010; 2002). Legumes harbor rhizobia bacteria which can fix atmospheric nitrogen (N) and convert it to a form that can be used by plants (Lindström, 1999). Fixed N can reduce or eliminate the need for inorganic N fertilizer either as intercrop or in rotation, making it an attractive and affordable source of N for resource-poor farmers (Toomsan *et al.,* 2004; Snapp *et al.* 2002). Legume diversification is a practice of growing more than one legume crop within one unit area to increase financial and biological stability of the farm (Johnston *et al.*, 2001). Much that these strategies are used in sustainable soil fertility management, limited literature is available on their application in Africa.

Therefore this review article aims at highlighting the potentiality of legume diversification in soil fertility management and food security for resource poor farmers in Sub Saharan Africa.

Legumes diversification in SSA

Legumes are important components of most farming systems in SSA, making positive contributions of legumes in improving soil fertility and food security (Amede, 2003). Farmers grow legumes either as a sole crop, by crop rotation, mixed farming or intercropping with cereals (Massawe *et al.*, 2016). It is estimated that there are about 30 species of economically important legumes grown in the SSA (Baldev *et al.*, 1988; Raemaekers, 2001; Gowda *et al.*, 2007). Among the major ones are common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), chickpea (*Cicer arietinum*), groundnut (*Arachis hypogaea*), pigeonpea (*Cajanus cajan*), and soybean (*Glycine max*). of these, cowpea (*Vigna unguiculata* L.) and common bean (*Phaseolus vulgaris* L.) are the most widely grown in SSA (Ronner *et al.*, 2013). Others that are important in one or other regions of SSA include faba bean (*Vicia faba*), lentil (*Lens culinaris*), field pea (*Pisum sativum*), Bambara groundnut (*Vigna subterranea*), hyacinth bean (*Lablab purpurea* also known as Dolichos lablab), Kerting's groundnut (*Macrotyloma geocarpum*), lima bean (*Phaseolus lunatus*), yam bean (*Sphenostylis stenocarpa*), mung bean or green gram (*Vignaradiata*), black gram or black bean (*Vigna mungo*), moth bean (*Vigna aconitifolia*), rice bean (*Vigna umbellata*), and horse gram (*Macrotylomau niflorum*) (Tsedeke Abate *et al.*, 2011).

Integrating legumes in farming systems

Integrating legumes in farming systems is among the strategies used by smallholder farmers for crop diversification and effective utilization of the land in SSA (Matusso *et al.*, 2012). Intercropping is extensively practiced by smallholder farmers in SSA and commonly practiced in tropical parts of the world compared with other cropping systems (Amede, 2003; Massawe *et al.*, 2016). It is estimated that 80% of the legumes grown in SSA are intercropped with cereals (Tsedeke Abate *et al.*, 2011; Nyasasi & Kisetu, 2014).

Variations exist in cereal-legumes plant species used in intercropping across regions in SSA and the system commonly involves cereal being considered as the main crop (Massawe *et al.*, 2016). Cereals are, in most cases, the main food source hence more efforts are made to increase their yield than that of the legumes (Ronner *et al.*, 2013). Cowpea occupies the largest proportion (43%) of all grown legumes in SSA, followed by groundnut (34%), common bean (19%), soybean (<5%), pigeon pea (<2%), and chickpea (<2%) (Tsedeke Abate *et al.*, 2011). Legumes are also grown in association with what is known as doubled-up legume technology (legume-legume intercrop) whereby longer-duration legumes such as pigeonpea are intercropped with other short duration legumes such as cowpea, groundnuts or soybean, a cropping system that has been developed in Malawi (Smith *et al.*, 2016). Although intercropping has been used by smallholder farmers in SSA for thousands of years and is widespread in many parts of the world, it is still poorly understood from an agronomic perspective (Njoku and Muoneke, 2008). More research is needed to better understand how intercrops (legumes-cereal or legume-legume) function and to develop intercropping systems that are compatible with current traditional farming system.

Nitrogen fixation in legumes improves soil fertility

Legumes improve soil fertility through a symbiotic relationship between legumes and rhizobia bacteria called Biological Nitrogen Fixation (BNF) (Zahran, 1999). The terms Rhizobium or rhizobia are used collectively for the genera *Rhizobium*, *Bradyrhizobium*, *Sinorhizobium*, *Mesorhizobium*, *Allorhizobium*, and *Azorhizobium*, unless specified otherwise (Haque and Lupwayi, 2017). BNF is the process whereby a number of species of bacteria use the enzyme nitrogenase to convert atmospheric N_2 into ammonia (NH_3), a form of nitrogen (N) that can then be incorporated into organic components, e.g. protein and nucleic acids, of the bacteria and associated plants (Jessica *et al.*, 2014). Interactions between rhizobia and legume roots result in formation of root nodules, in which rhizobia use energy from the host plant to transform atmospheric N_2 into plant available forms of nitrogen (Massawe *et al.*, 2017).

The amount of N_2 fixed by a legume crop varies widely because it depends on the legume genotype, rhizobium strain and the soil environment (Lupwayi *et al.*, 2011). Legumes can supply up to 90% of their own N hence they do not usually require addition N (Bohlool *et al.*, 1992; Stagnari *et al.*, 2017).

Through BNF, legumes provide a relatively low-cost method of replacing nitrogen in the soil, enhancing soil fertility and boosting subsequent crop yields (Baddeley *et al.,* 2014; Saikia and Jain, 2007.).

There exist different rhizobia strains which are specific to some legumes (Andrews and Andrews, 2017; Oono *et al.*, 2009), due to this legumes have different N fixation rates capacities (Danso and Eskew, 1998; Nglade and Illen, 2015). Table 1 below indicates some common legumes and their N fixation rates capabilities. Having two or more legumes intercrop will doubles soil fertility benefits as both crops contribute fertility to the soil through N fixation (Mungai *et al.*, 2016).

Table 1. N fixation rates (kg ha^{-1} $crop^{-1}$) by some common legumes grown in SSA.

Legume	N. fixation rate (Kg/ha)	References
	35	(One Acre Fund, 2014)
	61 - 155	(Baijukya *et al.*, 2013)
	30 - 125	(Ennin *et al.*, 2004)
	30	(Martins *et al.*, 2015)
	42.68	(Yabuku *et al.*, 2010)
	120	(Woomer, 2010)
	28	(Chikowo *et al.*, 2004)
	47	(Rowe and Giller, 2003)
Vigna unguiculata (Cowpea)	73–354	(Silva and Uchida, 2000)
	16 - 27	(Argaw and Tsigie, 2017)
	35	(Devi *et al.*, 2013)
	25-45	(Miyamoto *et al.*, 2008)
	35	(Woomer, 2010)
	125	(Woomer, 2010)
Phaseolus vulgaris (Common bean)	40–70	(Silva and Uchida, 2000)
	200	(One Acre Fund, 2014)
	138 - 156	(Baijukya *et al.*, 2013)
	45-130	(Miyamoto *et al.*, 2008)
	60 - 240	(Ennin *et al.*, 2004)
	70	(Chianu *et al.*, 2011)
	60–168	(Silva and Uchida, 2000)
Glycine max (Soybean)	165	(Gibson *et al.*, 1982)
	76	(Egbutah and Obasi, 2016)
	150	(One Acre Fund, 2014)
	47 - 52	(Baijukya *et al.*, 2013)
	27.19	(Yabuku *et al.*, 2010)
	160	(Bationo *et al.*, 2007)
	50 - 150	(Ennin *et al.*, 2004)
	25-56	(Gibson *et al.*, 1982)
Arachis hypogaea (Groundnut)	26	(Montanez, 2000)
	30 -100	(Mhango *et al.*, 2016)
	40	(Bationo *et al.*, 2007)
	97	(Chikowo *et al.*, 2004)
	39	(Rowe and Giller, 2003)
	8 - 82	(Mapfumo *et al.*, 2000)
	168–280	(Silva and Uchida, 2000)
Cajanus cajan (Pigeonpea)	44	(Mendonça *et al.*, 2017)
	130-220	(Miyamoto *et al.*, 2008)
	140	(Haque and Lupwayi, 2017)
	89	(Sanginga, 2003)
	15 - 210	(Zahran, 2001)
Lablab purpurea (Hyacinth bean)	270	(Rochester *et al.*, 2000)
	55	(Egbutah and Obasi, 2016)
	28	(Egbe *et al.*, 2013)
	32 - 81	(Mukhtar *et al.*, 2016)
	32.53	(Yabuku *et al.*, 2010)
	10 - 62	(Ncube *et al.*, 2009)
Vigna subterranea (Bambara nut)	52	(Rowe and Giller, 2003)

The ability of legumes to fix N_2 allows farmers to grow them with minimal to no inputs of N fertilizer (Jessica *et al.*, 2014). Non-legume crops grown in association or in rotation with them usually have reduced fertilizer N requirement ("Nitrogen Cycling"), which has both economic and environmental benefits (Lupwayi *et al.*, 2011). There is a need for more definitive studies on the nutritional factors limiting N fixation in legumes in general, and in those legumes that have a potential in farming systems in SSA (Haque and Jutzi, 1984: Snapp *et al.*, 1998).

Incorporation of legumes crop residues in the soil (Organic materials)

Legumes improve soil fertility through their decomposed residues (Singh *et al.*, 2011). Application of organic materials is one of the strategy used by farmers in SSA for soil fertility management (Omotayo and Chukwuka, 2009). Organic matter includes any plant or animal material that returns to the soil and goes through the decomposition process (FAO, 2005). Organic materials contribute directly to the deposition of soil organic matter (SOM) and is important in improving the physical, chemical and biological composition of the soil (Moyin-jesu, 2015; Silva and Uchida, 2000). Most soils in SSA contain 2-10 percent organic matter (Omotayo and Chukwuka, 2009) and they are plant tissue such as crop residues, leguminous, cover crops, green manures, mulches and household wastes (Vanlauwe *et al.*, 2015). Plant residues contain 60–90 percent moisture, the remaining dry matter consists of carbon (C), oxygen, hydrogen (H) and small amounts of sulphur (S), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) (FAO, 2005). At maturity 30–40% of the N in legume crops is in the seeds, which are typically 25–30% protein (Chukwuka, 2009). When this grain is harvested, much of the N that has been fixed will be exported off of the property and the rest in the stem and other part which when incorporated in the soil it release nutrients (Lindemann *et al.*, 2007; Tully *et al.*, 2015). Although present in small amounts, these nutrients are very important from the viewpoint of soil fertility management.

The effects of applied materials vary with cropping systems, soil types, organic material management and environmental factors, the information on their interaction is scarce (Mugwe *et al.*, 2009). Legumes crop residues contains different amount of nutrients, hence legumes diversification allow double or multiple soil fertility contribution in the soil (Njira *et al.*, 2012). Organic matter contributed by legumes residues in the soil provide essential nutrients to plant as a result crop yield is increasing hence food security is assured to resource poor farmers (Tittonell, 2015). There is limited knowledge on the multiple benefits from legume residues on soil fertility improvement to SSA's smallholder farmers. More research should be done on the farming systems which will have high or better contribution of legumes crop residues on soil fertility improvement in different soil types in order to suggest the best legumes crop residue incorporation system which gives high returns to farmers.

Grain legumes – root systems and soil health

Most legumes have well-developed taproots reaching 6 to 8 feet deep and half inch in diameter which go deeper into the soil which helps them to recycle crop nutrients that are deeper into the soil. This result into effective use of applied fertilizers and reduces leaching of nutrients especially nitrate-nitrogen for the shallower-rooted crops (Sharifai, 1985). Moreover, nitrogen rich legume residues encourage earthworms and the burrows they create with the root channels and earthworm burrows increase soil porosity, promoting air movement and water percolation deep into the soil (Truscott *et al.,* 2009).

Through their effects on soil biology, legume crops also improve soil structure by enhancing the formation and maintenance of soil aggregates (Schröder, 2014). Soil structure improvements are attributed to increases in more stable soil aggregates (Stein-bachinger *et al.*, 2015). The protein, glomalin, symbiotically along the roots of legumes and other plants, serves as "glue" that binds soil together into stable aggregates.

This aggregate stability increases pore space and tilth, reducing both soil erodibility and crusting i.e. reduces soil erosion, protects soil organic C from microbial breakdown, and increases water infiltration and air circulation (Tanner and Ababa, 2002). Lupwayi *et al.*, (2011) has reported order of crops in maintaining soil structure: lupin (*Lupinus angustifolius* L.) > lentil > canola > pea > linseed (*Linum usitatissimum* L.) > barley. Probably these results will be the same in SSA, but researches are needed on this area. In Nigeria, Obi (1999) observed the following order of legume and grass cover crops in cumulative water infiltration in a degraded soil: legumes (*Stylosanthes gracilis* L. and *Pueraria phaseoloides* L.) > grasses (*Panicum maximum* L., *Pennisetum polystachion* L., *Cynodon plectostachion* L., and *Axonopus compressus* L.) > bare soil. The order of soil organic C contents was similar, and the differences were related to soil structure. Therefore, the forage legumes had greater restorative effects of the soil than grasses and bare soil. These are some of the benefits of legumes, but unfortunately, they are often omitted because of difficulty in quantifying them. More research should be focused on influence of grain legumes on nutrients recycling and soil structure improvement.

Legumes diversification reduce risk of crop failure to smallholder farmers

Legume diversification is a practice of growing more than one legume crop in any year to increase biological stability of the farm, food security and financial status (Johnston *et al*, 2001). There are highly diverse species of grain legumes which are indigenous to various parts of the world (Katunga *et al.*, 2014). Soil fertility status and food security of smallholder communities are hindered by the reduction in legume species utilized in agricultural ecosystems (Small and Raizada, 2017). The potential for crop failure is worsened by the reliance on a few crop species (Koenen *et al.*, 2013). Plant species vary in their vulnerabilities and resistances to harsh condition such as environmental stress including heat, cold, drought, floods, pests, and disease. Due to this reliance on a few legumes crop species is a risk to farmers (Sundström *et al.*, 2014). Farming system relies on monoculture increases exposure of crops to pests, diseases, and environmental stress (Kim, 2005). Total crop yields are stabilized by the capacity for each individual crop species to adapt and be productive in different conditions, and hence, legumes diversification is an asset to farmers in adapting environmental changes (Rosegrant *et al.*, 2008). The consequence of reduced legumes crop species can be immense for smallholder farmers whose livelihood depends on their crop yield. For example, due to unpredictable rainfall in sub-Saharan Africa it has been experienced rainfall delayed by up to a month, thus reducing the growing season (Lobell and Gourdji, 2012). The unpredictable onset of the rain challenges farmers to utilize crops that will be productive in growing seasons of varying durations. When the growing season is delayed, the utilization of short maturing, drought-tolerant crops like cowpea and common bean, and short-duration varieties, is an important adaptive strategy for small holder farming system (Ebert, 2014).

Legume diversification in food security and nutrition

Legumes can survive under hot, dry and area with little N, the area where other crop such as cereals cannot perform better (Koenen *et al.*, 2013). They have aggressive taproots reaching 6 to 8 feet deep and a half inch in diameter that open water pathways deep into the soil (Sharifai, 1985). This increase the surface area for biodiversity-plant root zone interaction, for instance earthworms can burrow the soil and provide access of roots to nutrients and air for root respiration. Also facilitates activities of soil flora and fauna lending to a greater stability of the soil's total life (Truscott *et al.*, 2009; FAO, 2009; Michael, 2010; Cong *et al.*, 2014; UNEP, 2008; M. Williams *et al.*, 2014). These help legumes to survive on the environment where other crops cannot survive and give out a reasonable yield which helps smallholder farmers to get enough food in each year (Chibarabada *et al.*, 2017). Legumes provide an excellent break in a crop rotation that reduces the build-up of grassy weed problems, insects, and diseases as a result reduces the loss which can be caused by pest and increase crop yield (Khan *et al.*, 2007; Truscott *et al.*, 2009; Lupwayi *et al.*, 2011; Tanner and Ababa, 2002).

Due to these unique features, integrating legumes in the existing system can reduce the risk of crop failure and insuring food security to SHF in SSA (Kerr *et al.*, 2007). The ability to survive under different harsh environment differ from one legume to another and within species one variety to another (Staniak and Księżak, 2014). Having a diverse of legumes will widen or multiply a chance for utilizing the benefits brought by legumes due to their different capability to survive in different environment (Abate and Orr, 1981). Diverse foods outputs are obtained through multiple cropping, thus providing a chance of choice for using food commodities in smallholders farmers (Stagnari *et al.*, 2017).

Grain legumes are an essential source of protein, Carbohydrates, vitamins and micronutrients thus, a valuable component to attain nutritional security (Ebert, 2014). Legumes are consumed mainly in association with cereals with legumes constituting the main component of traditional dishes (Gepts, 2004). Some legumes provide food during its all stage of growth, they are consumed in many forms: seedling and young leaves are eaten in salads, fresh immature pods and seeds provide a green vegetable, and dry seeds are cooked in various dishes (Burstin *et al.,* 2011.).

Grain legumes contain a wide range of nutrients, including low glycaemic index (GI), high content of fibers, antioxidants, vitamins especially the B-group and minerals such as iron, calcium, phosphorus, zinc and magnesium (Messina, 1999; Mugendi and Njagi, 2010; Oboh, Osagie *et al.*, 2010). Low GI in legumes mean that they can release glucose into the bloodstream less rapidly making them preferred by people with diabetes and those who wish to reduce their body weights as well as for the community in general (Duranti, 2006; Williams *et al.,* 2008; Rovner *et al.,* 2009). Except soybeans, legumes contain low fat and large amount of fibers which may help control appetite by keeping one feeling fuller for longer. Legumes contain different nutritional value depending on the species (Table 2) hence having a diverse of legumes will provide an opportunity for smallholder farmers to benefit from different nutritional requirement from these legumes (Rivas-Vega *et al.,* 2006). Current trends suggest that there is an increasing gap between human population and protein supply (Chibarabada *et al.*, 2017). Legumes which are cheapest source of proteins still not widely used in the diet because of few diversity (Chibarabada *et al.*, 2017). Legumes diversifications are potential strategies for making legumes available and increase protein supply to communities in SSA.

Table 2. Nutritional value for some common grown grain legumes in 100 gram.

Legume crop	Carbohydrates	Proteins	Dietary fibre	Fat	Calcium	Iron
Cowpea	7	16	28	0	2	13
Pigeon pea	21	44	60	2	13	28
Common beans	21	42	64	1	15	28
Soybean	10	72	36	30	27	87
Groundnuts	5	52	36	75	10	25
Lablab	7	16	-	0	4	25
Bambaranuts	66	20	6	6	2	12
Chick pea	20	38	68	9	10	34
Green gram	21	48	64	1	13	37

Source: modified from United States Department of Agriculture (USDA).

Other benefits of Legumes to smallholder farmers in SSA

Resource poor farmers in developing countries both consume and sell legumes thus getting profit in terms of nutrition and income (Chibarabada *et al.*, 2017). Legumes diversification allows smallholder farmers to get multiple crops from same cropped land, while act as risk management system in case of failure for one of the companion crops (Smith *et al.*, 2016; Smýkal *et al.*, 2017). Due to this surplus legumes produced by farmers are sold as a raw materials and become a direct source of income to farmers and create employment to the processing industries (Bezner Kerr *et al.,* 2007) Legumes produces high value grains with 2-3 times higher price than cereals and oil crops, example fresh pods, peas and leaves attract highest prices in urban and export markets (Ebert, 2014). Legume diversification provide a wide ranges of food products which are processed locally from row materials creating remunerative employment, especially for rural women (CGIAR, 2016). Legume is processing into products such as soymilk, soy cheese and cowpea cake which are sold and become common income generating activities (ITC, 2016). This food processing activity plays a vital role in the survival and sustenance of their household and in meeting domestic financial obligations (Chibarabada *et al.*, 2017). However, these products are usually prepared under poor sanitary conditions, processors need to be trained on improved processing methods and food safety practices (Subuola *et al.*, 2012). Income obtained is used to buy other important food crops such as cereals (Banjarnahor *et al*, 2015). Legumes diversification is also important from marketing point of view, as getting more than one crop simultaneously, even if the selling price of one crop is less in the market, the other will be there to compensate (Preissel *et al.*, 2015). This information is well known to farmers especially in SSA, but its utilization is still minimal (ITC, 2016). Lack or little information, research, resource and skills are some of the reasons for low adoption of legume diversification. Keeping in view the economic benefits of legumes diversification, there is a need to promote it among the farming community.

Conclusion and recommendation

Legume diversification is a solution for soil infertility and food security among resource poor farmers in SSA due to unaffordability of inorganic fertilizers and limited access to fertile land. This review suggests that legumes contribute to soil fertility improvement and food security through nitrogen fixation and crop residues which contribute the organic matter into the soil. Legumes are a cost-effective option for improving the diets of low-income consumers who cannot easily afford other protein sources like meat, dairy products and fish. It is a source of income and employment to poor people. Legumes also will help poor resource farmers to solve some of the agronomic problems such as lowering soil pH, increase soil porosity, reduces the incidence of pest and disease resulting into yield increase and reduce food insecurity. Future research should focus on legumes diversification to different agro ecologies and especially in the resource poor farming systems. This would help to understand legumes which fit to a specific environment and farming system hence increases farmer's adoption to grow more legumes.

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Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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