EVALUATION OF GRAIN YIELD AND CANNING QUALITY TRAITS OF COWPEA GENOTYPES

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EVALUATION OF GRAIN YIELD AND CANNING QUALITY TRAITS OF COWPEA GENOTYPES

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DECLARATION

I declare that the (mini-dissertation) hereby submitted to the University of Limpopo, for the degree of M.Sc. in Agronomy has not previously been submitted by me for a degree at this or any other university; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

Mohlala M.P (Miss) 02/11/2021

Surname, Initials (title) **Date**

DEDICATION

This dissertation is dedicated to my late father Lucas Mohlala, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother Hellen Mohlala. Not forgetting all my beloved sisters and brothers.

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ABSTRACT

Cowpea (*Vigna unguiculata* (L.) Walp) is an important annual leguminous crop grown in arid and semi-arid areas in Sub Saharan Africa. Most of the cowpea production in South Africa is mainly used for domestic consumption and, as seed for planting and little gets to be used in food processing, thus, there is a need to expand the utilization of cowpea through food processing. This study aimed to evaluate cowpea genotypes for phenotypic and canning quality traits. Field experiments were conducted at two locations in Limpopo Province, namely Syferkuil Agricultural Experimental Farm and Ga-Molepo village during the 2017/2018 growing season. The field experiment was comprised of 100 cowpea genotypes laid out in an Alpha Lattice Design replicated twice. Cowpea canning analysis was done using tomato puree following ARC-GC in-house method at the Agricultural Research Council-Grain Crops in Potchefstroom, North West Province of South Africa. Collected data on yield was analysed using Genstat 18th edition and XLSTAT 2021.1.1.1081 software for canning quality data. The results revealed significant differences among the cowpea genotypes based on the number of seeds per pod and 100 seed weight for Syferkuil. Significant differences were also observed among the studied genotypes for 100 seed weight at Ga-Molepo.

The highest yield recorded across locations was for genotypes RV 555 (875.4 kg/ha), RV 207 (756,3 kg/ha), RV 439 (694.6 kg/ha) and RV 554 (682.3 kg/ha) respectively. The number of pods per plant recorded a high positive association with pod number per plant and number of seeds per pod. Grain yield of RV 558, RV 556, RV 207, RV 439 and RV 553 was high at Syferkuil and at Ga-Molepo RV 353, RV 194, IT99K-494-6, RV 341 and RV 202 recorded the highest yield. The Principal Component Analysis (PCA) revealed the three most important PCs contributing to a total variation of 76.71%. PC1, PC2, and PC3 contributed 51.01, 13.97 and 11.73%, respectively. For canning ability, out of 79 cowpea canned genotypes, only 11 genotypes were spoiled and had a bad odour. About 68 genotypes were suitable for canning including genotypes that had an excellent appearance without cracks or loose skins and even colour. Furthermore, there was vast variability among the genotypes based on yield and yield components as well as canning quality traits. Genotypes with high grain yield and had canning ability are recommended for canning. Data produced from this study will add useful information to the database of the characteristics of these cowpea genotypes.

Key words: Canning ability, cowpea, genotypes, and grain yield.

CHAPTER 1

1.1 GENERAL INTRODUCTION

Cowpea, (*Vigna unguiculata* (L.) Walp) from the Fabaceae family, is an annual grain legume that is normally cultivated as a highly nutritious and palatable food source to man and livestock throughout the tropics and sub-tropics of the world (FAO, 2016). It is mainly produced in Asia, America, Europe, and Africa with Nigeria being the major producer (FAO, 2016). Cowpea is a valuable crop to use as an intercrop with cereals or rotations with cereals in the semi-arid tropics (Singh *et al.,* 2002) and it has been domesticated in Africa for centuries. It is widely grown in both high and low rainfall areas of South Africa (Kay, 1979). Dadson *et al.,* (2005) state that cowpea is primarily grown in drier regions of the world where it is one of the most drought-resistant legumes. It is usually better adapted to drought, high temperatures and other biotic stresses than other crop plant species (Martins *et al.,* 2003; Hall, 2004). Cowpea leaves and immature pods can be consumed as green vegetables (Singh *et al*., 2002; Gerrano *et al*., 2015, 2017).

According to Prinyawiwatkul *et al*., (1996) cowpea seeds are a good source of carbohydrate (50–60%) and an important source of protein (18–35%) (Singh,1997). They also contain an appreciable quantity of micronutrients such as vitamin A, iron and calcium. The crude protein from the seed and leaves ranges, respectively between 23 and 32% (Diouf, 2011). Polyphenolic compounds found in cowpea can interact with proteins and reduce their digestibility, as well as alter organoleptic and functional properties of the seed flour (Okafor *et al.,* 2002). The main cowpea producing areas in South Africa are KwaZulu-Natal, Limpopo, Mpumalanga and North West (DAFF, 2011). However, the production and productivity of cowpea in South Africa are low due to the lack of improved varieties and good quality seeds for planting (Singh and Singh, 1990). Other limiting factors include drought, biotic stresses that include weeds, diseases, and insect pests (Asiwe, 2009). Lack of suitable varieties and limited breeding work occasioned by insufficient funding has resulted in low productivity and a low rate of adoption of improved varieties by farmers (Asiwe, 2009).

According to International Union for the Protection of Plant Varieties, new crop genotype has to be distinct from other varieties and uniform in their characteristics which are genetically stable in yield. Varietal development and its identification are some of the most important aspects of the seed industry and seed trade. The Agricultural Research Council (ARC) identified cowpea as a potential crop to diversify the food production base and reduce food and nutritional insecurity, particularly for resource-poor households in marginal cropping areas (Shargie, 2016). In most developed countries, cowpeas are packaged dry, either raw or pre-cooked, canned in water, tomato sauce or molasses; and canned in combination with other vegetables and meat or as constituents of soups, salads, and dips. Even though the traditional drying method of cowpea is economically cheaper, canning is proven to give cowpea a longer shelf life (Bressani, 1993; Afoakwa, *et al.,* 2003). Canning of foods such as beans aims to preserve the product, inhibiting chemical changes, enzymatic alterations, and microbial development. Hence, this study aims to evaluate cowpea genotypes for yield performance and canning ability.

1.2 PROBLEM STATEMENT

In South Africa, 2.8 million households with an estimation of 11.5 million people are vulnerable to food and nutrient insecurities (DAFF, 2011). Recently, there has been a continuous and increasing demand for nutritional foods rich in proteins, vitamins and essential minerals. The high demand for proteins has spurred the need for alternative sources including pulses because a nutritious and varied diet is a critical means by which good human health can be maintained. Pulses such as cowpeas are good sources of proteins and can form part of the food requirements with great health benefits when added to the diet. Hence, there is a need to invest in pulse production to close the gap of demand.

Gerrano *et al*. (2015); Gerrano, van Rensburg, and Kutu (2019) reported that previous most studies evaluated phenotypic variability among cowpea genetic resources from sub-Saharan Africa, very few studies about the selected cowpea genotypes for canning ability have been conducted in South Africa. In South Africa, cowpea is mostly produced by smallholder farmers and most of the cowpea grain produced in South Africa is mainly used for domestic consumption or as seed planting and little gets to be used in industrial processing (Henshaw, 2000), thus, there is a need to expand the utilization of cowpea through food processing. Recently, there is a shift towards the improvement of the nutritional quality of cowpea especially the nutrient content of leaves and immature pods (Gerrano *et al*., 2015; 2019). Canning is one of the methods which increase the shelf life of products. However, the suitability of cowpea for canning is still neglected, therefore there is a need to evaluate some existing cowpea germplasm for morphological characteristics and their suitability canning in South Africa.

1.3 RATIONALE

Grain legumes play an important role in the world's food and nutrition requirements, especially in the dietary pattern of low-income groups of people in developing countries (Tharanathan and Mahadevamma, 2003). They are considered as "resource-poor meat" and are important inexpensive sources of protein, dietary fibre, and starch. They contain almost two to three times more protein than cereals (Akyaw *et al.,* 2014). Due to their high protein and lysine content, they also represent good sources of supplementary protein when added to cereal grains and root crops, which are low in essential amino acids (Akyaw *et al.,* 2014). The inclusion of legumes in the daily diet has many beneficial physiological effects in controlling and preventing various metabolic diseases such as diabetes mellitus, coronary heart disease, and colon cancer (Tharanathan and Mahadevamma, 2003). Small-scale farmers and rural communities' benefit from the cultivation of this crop, which includes improvement of soil fertility.

Among different physical treatments used to process cowpea, one method which can increase the shelf stability of cowpea products is canning. Most of the cowpea varieties are susceptible to storage pests such as bruchids (Singh and Singh, 1990; Chijindu *et al.,* 2009; Amusa *et al.,* 2014). Smallholder farmers consume all their products within a short period due to the storage pests. Hence, canning cowpea is relevant to reduce hunger during periods of lack of cowpea grain for consumption. Cowpea is a good source of protein and minerals, thus canned products will be available throughout the year decreasing the incidence of protein malnutrition (Giga, 2001). Availability of cowpea throughout the year in the form of a canned product will enhance or promote its production, importance and consumption within the country. Furthermore, it will motivate farmers to produce it on a larger scale. In South Africa, cowpea and other legumes are available in the supermarkets as a canned products however, it is important to produce and process cowpea genotypes with qualities that meet desired consumer preferences. This study will help the farmers to select suitable genotypes of high yields and also expand their cowpea market through canning. It will also assist the researchers to breed cultivars with good agronomic traits suitable for canning ability.

1.4 PURPOSE OF THE STUDY

1.4.1 Aim

Characterization of cowpea germplasm using grain yield and canning quality traits.

1.4.2 Hypotheses

(i) Hundred cowpea genotypes do not vary phenotypically.

(ii) Hundred cowpea genotypes do not vary in their canning quality trait.

1.4.3 Objectives of the study are to:

(i) Assess variability among cowpea phenotypes.

(ii) Assess variability of cowpea genotypes for canning quality traits.

CHAPTER 2

LITERATURE REVIEW

2.1 Origin, importance and utilization of cowpea

Cowpea (*Vigna unguiculata*) is an annual herbaceous legume from the genus *Vigna*. Cowpea seed is a nutritious component in the human diet, as well as a nutritious livestock feed. Cowpea originated in Africa and is widely grown in Africa, Latin America, Southeast Asia and the southern United States (FAO, 2016). Due to its tolerance for low rainfall, it is an important crop in the semi-arid regions across Africa and other countries (Sanjeev *et al.,* 2018). Small-scale farmers and rural communities obtain numerous benefits from the cultivation of this crop (Hall, 2004). Coker *et al*. (2014), adds that cowpea is cultivated as a vegetable, which means that it can be eaten as leafy green vegetables, green pods, shelled dried peas and fresh shelled green peas; and it is significant as animal feeds as well. These include the haulm used as fodder for animals, income through the trade of the seed and a source of nutritious food (Singh *et al.,* 2002). Cowpea is regarded as a basis for an inexpensive source of protein that provides the cheapest supplement to the urban and rural poor in Nigeria (Faith *et al.,* 2014). Most of the cowpea production in South Africa is used for domestic utilization for various food preparations while little or non-get into industrial processing, Thus, there is a need to expand the utilization of cowpea through industrial processing. Cowpea can be consumed at all stages of growth as a vegetable crop (DAFF, 2011).

2.2 Cowpea production and productivity worldwide

According to FAOSTAT (2020), Africa is the largest producer of cowpea worldwide with 5 million tonnes, followed by America (77000 tonnes), Europe (28000 tonnes), and Asia (15000 tonnes) and globally, cowpea is cultivated in an area of approximately 9.8 million ha with about 91% of this being in West Africa. Cowpea is largely produced and consumed in the west and central Africa, with Nigeria leading the production at a rate of 2.14 million metric tonnes annually (FAOSTAT 2017). According to the United Nations Food and Agricultural Organization (FAO), approximately 4 million metric tons of dry cowpea grain are produced annually on about 10 million ha worldwide. Cowpea is also grown considerably in countries such as Senegal, Togo, Benin, Ghana, Chad in West Africa; Tanzania, Somalia, Kenya, Zambia, Zimbabwe, Botswana and Mozambique in eastern and southern Africa; India, Pakistan, Sri Lanka, the Philippines, Bangladesh, Indonesia and China in Asia; and Brazil, West Indies, Cuba and the southern USA in America (Mahalakshmi *et al.,* 2007).

2.3 Cowpea production in South Africa

The production level of cowpea in South Africa is still very low compared to other countries in Africa. Small-scale farmers under dryland farming conditions are large producers of cowpeas. The major cowpea producing areas in South Africa are KwaZulu-Natal, Limpopo, Mpumalanga and North West (DAFF 2011). Despite an increase in cowpea production in Africa, the trend in South Africa has remained constant. Production level is low due to lack of adequate improved varieties, absence of quality seeds and absence of strong research and production on cowpea (Ndamani, 2015).

2.4 Importance of evaluating cowpea genotypes

The evaluation of traits is being exploited to address the preferences of consumers and producers as well as the numerous cowpea production constraints (Magloire, 2005). Substantial progress has been achieved through the development of cultivars targeting these biotic and abiotic stress factors. Understanding the level of genetic diversity is essential for the effective conservation and utilisation of germplasm resources (Ndamani, 2015). The introduction of new value-added cowpea products into the market would significantly raise revenues from cowpea production. Following is a summary of different breeding methods used in cowpea improvement programmes for many years (Horn and Shimelis, 2020). Therefore, it is crucial to understand the genetic diversity of cowpea in South Africa for sustainable cowpea production.

2.5 Breeding of cowpea genotypes

The general strategies of most breeding programs develop a range of high yielding cowpea varieties adapted to different agro-ecological zones that possess regionally preferred traits for plant type, growth habit, days to maturity and seed type (Tarawali *et* *al.,* 1997). Certain traits and their heredity exist in crops that are of the breeder's interest. Varietal differences of cowpea in terms of growth pattern, the seed maturity date is extremely diverse from cultivar to cultivar, making breeding programs for cowpea more complex than other crops (Baker, 1989 in Ekpo et al., 2012). In crop plants, genetic diversity arises as a consequence of the interaction of evolutionary forces mutation, selection and random genetic drift and the influence of humans through domestication and selection (CIAT, 2011). Concerted efforts are being placed on cowpea to boost its productivity including deployment of modern quantitative genetics and genomic tools (Boukar *et al.*, 2018).

These are expected to hasten the rate of genetic gain, allowing farmers to benefit from the full genetic abilities of the crop. Additionally, the need to meet consumers' demand has revolutionized breeding, now requiring breeding for clearly defined product targets and profiles (Ragot *et al.* 2018). To provide farmers with the quality seed of improved cultivars, breeding programs and seed systems should be based on information on the genetic diversity available in the germplasm. Nonetheless, limited studies are conducted on breeding cowpea for canning ability.

2.6 Canning process

There are several ways of adding value to beans which includes processing, canning and precooked products (According to Siddiq and Uebersax (2013). Canning is the heat sterilization process during which all living organisms in food are killed, to assure that no residual organisms could grow in the can (Brock *et al.,* 1994). Properly sealed and heated canned foods should remain stable and indefinitely unspoiled in the absence of refrigeration. The canning of beans is mainly composed of two processes, namely the blanching process and thermal heat sterilization. Typical industrial processing for canning beans includes the following stages: cleaning and classification of grains, hydration, manual or electronic classification after hydration, blanching, packaging, the addition of sauce or brine, seaming of cans, thermal processing, and labelling (White and Howard, 2013). Sterilization is the most important step that should normally be performed at 121 °C for at least three minutes (Jones and Beckett, 1995; Alemu,2018). Canning beans for quality evaluation are usually followed by a two-week storage period at ambient conditions before evaluation, to allow proper bean-tomato sauce equilibration (Bolles *et al.,* 1990). During the first seven days of equilibration water migration activity increases within the can, indicating that beans in a can are in a dynamic system during the first week after processing (Bolles *et al.,* 1982; White and Howard, 2013).

2.7 Canning quality attributes of cowpea

According to Phillips and Mcwatters, (1991) to make cowpeas edible and to increase their storage life, they are usually processed and preserved by cooking or sterilization to develop acceptable flavour, texture, and inactivate anti-nutritional factors to make the bean protein nutritionally available to human life. This process usually involves the soaking of the cowpeas in water, draining and cooking or sterilizing in fresh boiling water or brine. Factors such as storage conditions, soaking treatment and cooking method influence the cook ability and acceptability of the cowpea. Alemu, (2018) stated that organoleptic properties within the final canned products are one of the major quality evaluation standards. However, not all cultivars are set apart with equally acceptable quality. The problems affecting consumers are often related to the occurrence of bean discolouration, hardness of the beans and breakage of the seed coat after the canning process.

The canning industry is constantly improving processing methods, enhancing quality and product safety. Processing methods designed, heighten the retention of nutrients and effective use of energy (Uebersax, 2006). Canning quality parameters such as seed moisture content, seed coat hardness for water absorption, percentage split in grains, seed size, seed coat texture, maturity status (semi-dry or mature dry stage) and protein quality are considered when processing dry beans, chickpea, and kidney beans (Uebersax and Hosfield,1985). One of the main forms of processed beans reported in the market are cooked and canned beans, a very common form in developed countries throughout Europe and North America. In this type of processing, beans are usually prepared by hydration operations, grain blanching in hot water, canning, brine addition, and addition of other components such as tomato sauce, pork meat or flavour additives, followed by hermetic canning and thermal processing. Canned beans have simple characteristics with wide acceptance in the international market (Uebersax, 2006).

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CHAPTER 3
GENETIC VARIABILITY OF COWPEA GENOTYPES BASED ON YIELD AND YIELD COMPONENTS.

3.1 ABSTRACT

Cowpea is one of the most important pulse crops grown for food and fodder in South Africa. It is rich in protein, vitamins and minerals. However, it has been neglected in terms of research and production. The objective of the study was to assess variability among cowpea phenotypes. The field experiments were conducted at Syferkuil Agricultural Experimental farm and Ga-Molepo village in the Limpopo Province during the 2017/2018 growing season. The experiments consisting of 100 cowpea genotypes were laid out in an alpha lattice design replicated twice. The yield traits were measured according to the cowpea descriptor list and analysed using analysis of variance, Pearson correlations and principal component analysis in GenStat software version 18. The results showed significant differences among the cowpea genotypes based on the number of seeds per pod and 100 seed weight for Syferkuil. Significant differences were observed at Ga-Molepo for 100 seed weight. Across locations, significant differences were recorded for the number of seeds per pod and grain yield. The Principal Component Analysis (PCA) revealed the three most important PCs contributing to a total variation of 76.71%. PC1, PC2, and PC3 contributing to total variation for the number of branches per plant, number of pods per plant and grain yield (kg/ha). The number of pods per plant recorded a high positive association with the number of seeds per pod. Grain yield for the best 15 genotypes including RV 558, RV 556, RV 207, RV 439 and RV 553 was higher than the local check at Syferkuil and at Ga-Molepo RV 353, RV 194, IT99K-494-6, RV 341, Bechauna white and RV 202 recorded the high yield. Across locations, the highest yield was recorded for genotypes RV 555, RV 207, RV 439, RV 554 and Bechauna White. The above-mentioned genotypes and 72 other cowpea genotypes that showed high yield in both locations can be recommended for farmer’s use in Limpopo Province. They can also be useful as parents in cowpea improvement.

Keywords: Cowpea, variation, yield, yield components.

3.2 INTRODUCTION

Cowpea has outstanding features, which is high adaptability to extreme conditions of temperature, drought, tolerate alkaline soil conditions and possess the high potential of biological nitrogen fixation (Singh *et al.,* 1997). Therefore, the introduction and evaluation of different cowpea performance in rainfed as well as irrigated conditions and its contributing traits are of pivotal importance to get self-sufficiency in pulses (Srinivas *et al.,* 2017). Despite its importance and wide cultivation, the overall productivity of cowpea is very low with average yield particularly in Africa ranging from 100 to 400 kg/ha (Singh, 2000). This is due to several biotic, abiotic and physiological constraints.

In South Africa, cowpea grain yield is very low according to Asiwe (2009) who reported a yield range between 250 and 1000 kg/ha with an average of 500 kg/ha. Land size planted to cowpea ranged between 0.25 and 2.0/ha per farmer. Low yields in South Africa are attributed to many factors including biotic and abiotic factors. Among the biotic constraints, incidences of diseases, insect pests and parasitic weed *Striga spp* cause yield reduction (Asiwe, 2009). The major cowpea producing provinces are Limpopo, KwaZulu-Natal, Mpumalanga and North West Provinces. Despite an increase in cowpea production in most parts of Africa, South African cowpea production is still at subsistence level.

Doumbia *et al*., (2013) reported that agronomic parameters were used successfully for the selection of desirable traits, for example, plant morphology, seed coat colour and pod characteristics in cowpea. They also contributed to the understanding of the association between yield and its component traits to facilitate effective selection for yield improvement (Manggoel *et al.,* 2012; Mofokeng *et al.,* 2020). On the other hand, the purpose of germplasm conservation to find superior cultivars for plant breeding programs must be expanded. There are series of activities needed to achieve this, which consists of collection and characterization, evaluation/selection, expansion of genetic diversity, evaluation and testing, cultivar release and propagation (Syukur *et al.,* 2015 in Karuwal *et al.,* 2019). Hence, the objective of the present study was to assess the variability of cowpea genotypes using grain yield and yield related traits.

3.3 RESEARCH METHODOLOGY

3.3.1 Description of the study area

The study was conducted at Syferkuil Agricultural Experimental farm (23°50' S; 29°0' E) of the University of Limpopo, in the Limpopo Province of South Africa. The climate of the area is classified as semi-arid. About 80% of the annual rainfall occurs mostly in the summer months of October to March and the annual average rainfall for the area is between 401 to 500 mm. The annual average maximum and minimum temperatures reported in the year of this study were 25 and 10°C (77 and 50°F), respectively. The soils in this farm developed from Granite parent material. The micro-topography of the 7-ha field consisted mainly of workable and friable to partially cloddy soils. Replicated on-farm rain-fed field experiment was conducted in semi-arid area of Ga-Molepo, Tshebela village of Limpopo Province during 2018/19 growing season. It is having long-term seasonal rainfall of about 432.5 mm with a maximum temperature of 25.7 °C, minimum temperature of 11.9 °C and soil type is loamy sand (Moshia, 2008).

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3.3.2 Plant material

Hundred cowpea genotypes were obtained from the Agricultural Research Council-Grain Crops gene bank situated in Potchefstroom, North West Province of South Africa. The cowpea material used in the study are shown in Table 1.

3.3.3 Research design and management

The experiment comprised of 100 cowpea genotypes with Bechuana White as a local control, laid out in an Alpha Lattice Design with two replications in each location. Each genotype had two rows per plot with an intra- row spacing of 25 cm and inter-row spacing of 75 cm. Weed control was done when necessary, insect pests such as aphids were controlled using insecticide Malathion with a concentration of 12ml in 10 L of water. Insect control was done at the seedling stage and during pod formation to avoid insect damage. Five middle plants per genotype were used to collect data for yield and yield components.

3.3.4 DATA COLLECTION

3.3.4.1 Plant data collection: Agronomic data were measured according to cowpea descriptor list (IBPGR, 1993). The following plant variables were measured: grain yield components such as the number of branches per plant was measured before harvesting, whereas, number of pods per plant, number of seeds per pod, 100 seed weight and grain yield were recorded after harvesting. Whereby, number of branches per plant, number of pods per plant, number of seeds per pod, were measured from five plants. Plants were sampled randomly from the two mid rows in each plot, counted manually to determine the average number of branches, number of pods per plant and number of seeds per pod. About 100 seeds weight was measured by counting 100 cowpea seeds from each genotype and weigh them using a weighing scale. Grain yield was determined from the seed weight from net plot.

3.3.4.2 Statistical analysis

The data for measured yield parameters from each site, combined data of both sites and principal component analysis were analysed using GenStat Software version 18 and ANOVA procedure. Means were separated by Duncan multiple range test at 5% level of significance.

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Table 1: List of cowpea genotypes and their place of origin for this study.

Accession number	Place of origin /collection	Accession number	Place of origin /collection
IT98D-1399	IITA	RV 439	ARC-Grain Crops
IT98K-476-8	IITA	RV 440	ARC-Grain Crops
IT99K-494-6	IITA	RV 441	ARC-Grain Crops
AGRINAWA	ARC-Grain Crops	RV 442	ARC-Grain Crops
Bechuana white	ARC-Grain Crops	RV 443	ARC-Grain Crops
Dr Saunders	ARC-Grain Crops	RV 446	ARC-Grain Crops
Glenda	ARC-Grain Crops	RV 457	ARC-Grain Crops
ITOOK-1263	IITA	RV 464	ARC-Grain Crops
JANA FOD	ARC-Grain Crops	RV 465	ARC-Grain Crops
OLOYIN	IITA	RV 469	ARC-Grain Crops
ORELU	IITA	RV 470	ARC-Grain Crops
PAN 311	IITA	RV 471	ARC-Grain Crops
RV 111	ARC-Grain Crops	RV 477	ARC-Grain Crops
RV 113	ARC-Grain Crops	RV 487	ARC-Grain Crops
RV 115	ARC-Grain Crops	RV 497	ARC-Grain Crops
RV 126	ARC-Grain Crops	RV 498	ARC-Grain Crops
RV 157	ARC-Grain Crops	RV 499	ARC-Grain Crops
RV 161	ARC-Grain Crops	RV 500	ARC-Grain Crops
RV 165	ARC-Grain Crops	RV 501	ARC-Grain Crops
RV 173	ARC-Grain Crops	RV 502	ARC-Grain Crops
RV 189	ARC-Grain Crops	RV 503	ARC-Grain Crops
RV 194	ARC-Grain Crops	RV 504	ARC-Grain Crops
RV 202	ARC-Grain Crops	RV 505	ARC-Grain Crops
RV 204	ARC-Grain Crops	RV 506	ARC-Grain Crops
RV 205	ARC-Grain Crops	RV 512	ARC-Grain Crops
RV 207	ARC-Grain Crops	RV 531	ARC-Grain Crops

RV 28	ARC-Grain Crops	RV 533	ARC-Grain Crops
RV 315	ARC-Grain Crops	RV 534	ARC-Grain Crops
RV 320	ARC-Grain Crops	RV 535	ARC-Grain Crops
RV 329	ARC-Grain Crops	RV 539	ARC-Grain Crops
RV 341	ARC-Grain Crops	RV 542	ARC-Grain Crops
RV 342	ARC-Grain Crops	RV 543	ARC-Grain Crops
RV 343	ARC-Grain Crops	RV 545	ARC-Grain Crops
RV 344	ARC-Grain Crops	RV 546	ARC-Grain Crops
RV 347	ARC-Grain Crops	RV 547	ARC-Grain Crops
RV 351	ARC-Grain Crops	RV 548	ARC-Grain Crops
RV 352	ARC-Grain Crops	RV 549	ARC-Grain Crops
RV 353	ARC-Grain Crops	RV 551	ARC-Grain Crops
RV 360	ARC-Grain Crops	RV 553	ARC-Grain Crops
RV 361	ARC-Grain Crops	RV 554	ARC-Grain Crops
RV 382	ARC-Grain Crops	RV 555	ARC-Grain Crops
RV 386	ARC-Grain Crops	RV 556	ARC-Grain Crops
RV 403	ARC-Grain Crops	RV 558	ARC-Grain Crops
RV 409	ARC-Grain Crops	RV 559	ARC-Grain Crops
RV 411	ARC-Grain Crops	RV 84	ARC-Grain Crops
RV 414	ARC-Grain Crops	RV 192	ARC-Grain Crops
RV 416	ARC-Grain Crops	RV 550	ARC-Grain Crops
RV 417	ARC-Grain Crops	RV 10	ARC-Grain Crops
RV 419	ARC-Grain Crops	RV 16	ARC-Grain Crops
RV 438	ARC-Grain Crops	RV 43	ARC-Grain Crops

ARC = Agricultural Research Council, IITA = International Institute of Tropical Agriculture.

3.4 RESULTS

Number of branches per plant

There were no significant differences (P≤ 0.05) in number of branches per plant in both locations (Table 2), however, according to the observations RV 115 presented a high number of branches with 18 branches per plant followed by RV 353, RV 558, Dr Saunder and RV 111 with 17 branches than Bechuana White which had 16 branches ,whereas RV 343,RV 441, RV 442, RV 504 and RV 506 had lower number of branches than other genotypes with 5 branches at Syferkuil. At Ga-Molepo. The genotype RV 440 presented a high number of branches per plant with 14 branches followed by Orelu, RV 341, RV 498 and RV 416, RV 194 and IT99K-494-6 with 11 branches than Bechuana White which had 7 branches. RV 548, RV 505, RV 504, RV 499, RV470 and RV 113 had the least branches of 6.

Number of pods per plant

There was no significant difference (P≤ 0.05) in the number of pods per plant at both locations. This means that the genotypes performed the same at both locations.

Number of seeds per pod

The results show that there was a significant difference (P≤ 0.05) in the number of seeds per pod at both locations. At Syferkuil RV 353, RV 205 and Janafod had 17 seeds per pod followed by RV 439, RV 320, RV 202, and RV 173 with 16 seeds per pod than Bechuana White which had 14 seeds per pod. RV 440, RV 551, RV 457, RV 115 and Dr Saunders were the least performers with 8 seeds per pod at Syferkuil. At Ga-Molepo RV 360, IT98K-176-8, RV 353, RV 559, Janafod, RV 165, RV 512, Bechuana White and RV 531 presented a high number of seeds per pod of 14 seeds. Whereas RV 207, RV 503, RV 353, RV 543, RV 553, and RV 554 were the least performers with 6 seeds per pod.

100 seed weight

The results show that there was a significant difference (P≤ 0.05) in 100 seed weight at both locations. At Syferkuil, RV 352 and RV 403 presented a high 100 seed weight of 20 g followed by RV 344, ITOOK-1263, Agrinawa, OLOYIN, ORELU and RV 207 with 100 seed weight of 19 g, including 16 other genotypes which outperformed Bechuana white. RV 28, RV 470, RV 500, RV 551, RV 531 and RV 347 had the lowest 100 seed weight of 8.g than all other genotypes at Syfekuil. Genotypes RV,349, IT98D-1399, Janafod, RV 382 and RV 386 had high 100 seed weight of 15 g at Ga-Molepo.39 other genotypes had higher 100 seed weight than Bechuana White. Genotypes RV 28, RV 441 and RV 469 were the least performers at Ga-Molepo with 100 seed weight of 6 g.

Table 2: Yield components of different cowpea genotypes at Syferkuil and Ga-Molepo.

SYFERKUIL						GA-MOLEPO					
Genotype	**No of branches per plant**	**No of pods per plant**	**No of seeds per plant**	**100 Seed weight (g)**	**Grain yield (kg/ha)**	**Genotype**	**No of branches per plant**	**No of pods per plant**	**No of seeds per plant**	**100 Seed weight (g)**	**Grain yield (kg/ha)**
IT98D-1399	14.7	14.7	14.5	14.6	457.4	IT98D-1399	8.0	6.7	11.3	14.1	548.6
IT98K-476-8	9.9	9.9	13.3	15.5	447.5	IT98K-476-8	6.8	7.3	14.1	12.3	261.1
IT99K-494-6	12.9	12.9	14.6	14.6	868.5	IT99K-494-6	11.7	9.0	12.3	12.5	645.8
AGRINAWA	9.6	9.6	11.9	18.4	197.5	AGRINAWA	9.1	9.0	12.6	12.7	284.7
Bechuana white	16.4	16.4	14.4	16.3	773.9	Bechuana white	7.7	6.7	12.7	9.9	388.9
Dr Saunders	17.9	17.9	8.9	9.1	693.3	Dr Saunders	9.4	6.5	9.9	10.2	306.9
Glenda	14.0	14.0	10.9	14.2	455.8	Glenda	8.6	8.3	10.2	12.7	340.3
ITOOK-1263	13.7	13.7	14.2	19.6	681.0	ITOOK-1263	7.0	7.8	12.7	12.9	569.4
JANA FOD	9.2	9.2	17.2	11.7	284.9	Jana Fod	10.5	6.9	13	14.6	14.9
OLOYIN	12.4	12.4	13.4	18.7	451.8	OLOYIN	8.6	7.1	10.2	10.2	291.7
ORELU	7.2	7.2	11.1	18.6	83.8	ORELU	11.4	9.3	13.2	13.1	233.3
PAN 311	13.2	13.2	14.8	13.5	125.4	PAN 311	7.1	7.3	11.8	11.8	145.8
RV 111	17.3	17.3	13.3	13.9	848.2	RV 111	7.5	6.9	9.8	9.8	291.7
RV 113	11.7	11.7	12.2	14.2	205.3	RV 113	6.9	7.0	9.4	9.4	76.4
RV 115	18.3	18.3	8.9	9.5	673.2	RV 115	9.3	5.8	7.5	7.5	223.6
RV 126	11.6	11.6	9.2	11.4	97.9	RV 126	7.6	6.6	9.5	9.5	69.4
RV 157	16.1	16.1	12.6	13.4	853.7	RV 157	8.3	6.1	10.5	10.5	389.9
RV 161	7.5	7.5	14.5	12.0	401.2	RV 161	7.2	7.9	10.7	11.0	194.4
RV 165	6.5	6.5	10.6	12.3	353.7	RV 165	7.1	5.4	13.2	10.7	69.4
RV 173	14.6	14.6	16.3	14.6	274.7	RV 173	7.4	8.0	8.5	13.2	243.1
RV 189	7.6	7.6	14.6	11.8	278.7	RV 189	7.5	5.3	11	8.5	42.7
RV 194	8.6	8.6	10.8	15.5	488.6	RV 194	11.0	9.1	10.1	11.0	715.3
RV 202	11.6	11.6	15.9	15.8	723.3	RV 202	9.1	9.2	12.8	10.1	618.1
RV 204	9.9	9.9	15.0	15.5	680.3	RV 204	9.5	6.9	12.5	12.8	402.8

RV 205	15.9	15.9	17.6	15.1	601.1	RV 205	9.0	9.4	10.2	12.5	583.3
RV 207	13.1	13.1	13.0	18.5	891.4	RV 207	9.0	6.8	6.3	10.2	550.0
RV 28	16.1	16.1	11.5	8.9	365.1	RV 28	8.2	6.3	10.8	6.3	70.5
RV 315	9.6	9.6	14.2	13.1	135.8	RV 315	8.5	9.6	9.6	10.8	451.3
RV 320	11.1	11.1	15.7	13.4	580.6	RV 320	7.6	6.4	7.1	9.6	336.1
RV 329	7.5	7.5	13.7	11.0	360.7	RV 329	9.6	11.5	7.9	7.1	188.9
RV 341	13.6	13.6	9.3	15.3	284.0	RV 341	8.7	8.1	10.2	7.9	601.0
RV 342	6.6	6.6	12.4	15.1	152.3	RV 342	8.5	7.1	9.9	10.2	472.2
RV 343	5.1	5.1	13.3	11.7	167.3	RV 343	10.7	9.5	9.4	9.9	514.9
RV 344	12.6	12.6	12.0	19.4	298.3	RV 344	7.2	6.2	11.9	9.4	141.6
RV 347	6.1	6.1	11.6	8.3	28.4	RV 347	9.0	6.4	12.2	7.4	100.0
RV 351	12.9	12.9	10.3	12.8	87.2	RV 351	11.1	8.7	10	7.7	76.4
RV 352	8.6	8.6	13.6	20.8	288.6	RV 352	9.7	9.3	9.9	11.9	451.4
RV 353	11.9	11.9	17.0	13.3	371.9	RV 353	8.8	7.9	14.5	12.2	893.1
RV 360	13.9	13.9	14.1	14.3	427.5	RV 360	8.6	7.7	14.2	10.0	420.8
RV 361	12.5	12.5	10.3	15.1	166.2	RV 361	8.1	7.2	9.4	9.9	402.8
RV 382	11.6	11.6	14.4	15.9	694.0	RV 382	10.8	11.1	12.4	14.5	278.8
RV 386	10.3	10.3	12.8	20.9	626.0	RV 386	8.8	7.1	7.9	14.2	194.4
RV 403	8.8	8.8	12.3	20.6	645.4	RV 403	7.7	7.3	8	9.4	231.9
RV 409	13.4	13.4	14.1	14.7	548.2	RV 409	7.0	6.9	11.2	12.4	222.2
RV 411	10.6	10.6	10.7	12.0	449.6	RV 411	9.6	6.9	10.5	7.9	159.7
RV 414	7.4	7.4	11.1	16.8	40.0	RV 414	7.6	5.8	7.8	8.0	118.1
RV 416	14.1	14.1	12.4	18.7	596.8	RV 416	11.1	9.4	9.3	11.2	354.2
RV 417	16.4	16.4	16.3	14.8	396.9	RV 417	7.2	7.7	12	10.5	179.3
RV 419	7.1	7.1	13.7	18.9	330.3	RV 419	6.6	5.9	9.6	7.8	73.6
RV 438	10.9	10.9	10.3	11.3	167.8	RV 438	9.1	8.1	6.9	9.3	200.0
RV 439	9.1	9.1	15.7	14.6	937.1	RV 439	8.8	7.1	11.1	12.0	437.5
RV 440	16.2	16.2	6.6	18.0	215.4	RV 440	14.9	5.8	10.2	9.6	76.4
RV 441	5.1	5.1	11.6	12.3	181.2	RV 441	8.7	5.4	10.8	6.9	195.5
RV 442	5.6	5.6	10.5	17.2	287.1	RV 442	7.7	6.5	10.7	11.1	319.4

RV 443	10.8	10.8	9.9	14.5	409.3	RV 443	9.5	5.2	10	10.2	173.6
RV 446	5.3	5.3	9.1	16.4	159.3	RV 446	9.0	7.9	11.3	10.8	243.1
RV 457	3.6	3.6	8.3	13.7	10.7	RV 457	9.9	8.4	8.8	10.7	231.9
RV 464	11.5	11.5	11.4	9.4	305.1	RV 464	7.7	5.3	12	10.0	54.5
RV 465	11.6	11.6	11.9	17.3	367.5	RV 465	10.3	7.5	9.3	11.3	429.7
RV 469	6.8	6.8	11.7	12.7	371.8	RV 469	8.2	7.7	9.7	5.4	194.4
RV 470	10.2	10.2	10.5	12.0	94.2	RV 470	6.6	4.3	9	7.8	34.7
RV 471	12.4	92.4	10.0	8.6	191.4	RV 471	10.1	9.9	10	7.0	41.7
RV 477	9.1	9.1	11.2	12.3	253.9	RV 487	7.0	5.8	8.7	8.8	62.5
RV 487	11.9	11.9	11.8	18.3	191.4	RV 497	6.3	6.0	10	12.0	283.3
RV 497	11.1	11.1	15.3	11.1	658.1	RV 498	11.4	7.7	9.8	9.3	215.3
RV 498	8.6	8.6	15.7	15.1	346.9	RV 499	6.1	5.0	8.6	9.7	69.4
RV 499	10.1	10.1	13.9	17.4	558.1	RV 500	7.9	6.2	10.8	9.0	256.9
RV 500	13.9	13.9	12.5	8.1	670.6	RV 501	8.8	7.7	12	9.0	243.1
RV 501	10.6	10.6	13.2	13.2	399.7	RV 502	7.3	5.4	13.3	10.0	198.6
RV 502	16.1	16.1	9.9	10.7	513.5	RV 503	7.1	7.4	7.5	8.7	194.4
RV 503	8.1	8.1	9.8	11.2	148.2	RV 504	6.7	5.7	8.3	10.0	98.3
RV 504	5.3	5.3	11.1	13.3	353.7	RV 505	6.3	5.1	12.6	9.8	54.5
RV 505	7.3	7.3	12.7	16.0	319.0	RV 512	7.1	4.7	13.2	8.6	48.6
RV 506	4.4	4.4	13.5	13.2	304.0	RV 531	8.2	6.7	13.8	7.9	125.0
RV 512	10.7	10.7	12.8	10.6	559.3	RV 533	10.1	7.1	9.9	11.0	126.4
RV 531	5.8	5.8	13.9	8.2	201.0	RV 534	9.5	7.9	10.6	9.7	108.3
RV 533	5.1	5.1	10.3	12.2	151.2	RV 535	8.7	8.0	6.7	11.6	173.6
RV 534	10.8	10.8	13.5	17.2	384.3	RV 539	10.5	9.2	7.6	8.8	444.4
RV 535	18.2	18.2	11.8	15.2	618.2	RV 542	9.3	8.2	8.2	10.8	194.4
RV 539	10.6	10.6	12.8	11.8	226.1	RV 543	10.7	6.9	6.7	12.0	362.2
RV 542	6.1	6.1	10.5	16.8	207.9	RV 545	10.0	7.5	8.6	8.6	201.4
RV 543	8.3	8.3	10.8	18.4	252.3	RV 546	9.6	7.6	5.6	13.3	430.6
RV 545	7.8	7.8	14.4	14.8	240.0	RV 547	7.8	5.7	13.2	8.6	97.2
RV 546	13.1	13.1	13.5	14.7	728.7	RV 548	6.6	6.1	12.3	7.5	381.9

RV 547	4.8	4.8	13.1	9.1	587.3	RV 549	8.9	7.1	11.1	15.5	286.1
RV 548	8.0	8.0	12.5	13.9	409.3	RV 551	8.5	7.4	9.1	8.3	163.9
RV 549	15.9	15.9	10.1	15.4	785.8	RV 553	10.0	8.6	6.6	12.6	236.1
RV 551	8.1	8.1	8.3	8.9	38.6	RV 554	7.5	6.5	6.4	13.2	208.3
RV 553	11.5	11.5	13.6	17.3	94.2	RV 555	7.2	7.5	7.6	13.8	598.6
RV 554	12.1	12.1	8.3	13.6	1.077.5	RV 556	8.5	7.1	10.5	9.9	288.9
RV 555	15.4	15.4	9.4	13.9	1.078.9	RV 558	9.5	8.1	7.9	10.6	271.1
RV 556	12.1	12.1	12.6	14.0	455.3	RV 559	8.1	7.1	14.1	11.1	76.4
RV 558	17.4	17.4	9.2	12.6	722.7	RV 84	7.3	5.1	11.2	11.0	78.8
RV 559	12.0	12.0	11.8	10.7	54.0						
MIN	3.6	3.6	6.6	8.1	10.7	**MIN**	6.1	4.3	5.6	5.4	14.9
MAX	18.3	92.39	17.6	20.9	1.078.9	**MAX**	14.9	11.5	14.1	15.5	893.1
SE	4.4	45.3	1.60	1.5	90.1	**SE**	2.8	3.7	10.2	1.2	151.9
CV	49.6	27.1	19.00	20.3	39.0	**CV**	31.5	21.5	15.5	11.6	31.4
P- VALUE	0.8585	0.73	0	0.003	0.00001	**P -VALUE**	0.7283	0.8781	0.0032	0.0021	0.0005
Significance difference	NS	NS	**	**	**	**Significance difference**	NS	NS	**	**	**

NS = Non-significant, ** = Significant at 5% probability level, LSD = Least Significant Difference, SE = Standard Error, CV = Coefficient of Variation.

Analysis of variance across locations.

In this study, some genotypes showed variations across the two locations with significant differences at $P \leq 0.05$ (Table 3). The number of seeds per pod had the mean range of 8.07-15.9 whereby Janafod presented a high number of seeds per pod of 16 seeds per pod. There were variations observed on grain yield with a mean range of 51.7-875.4 kg/ha and RV 555 had the highest grain yield of 875.4 kg/ha. No significant difference was shown among the cowpea genotypes for number of branches per plant, number of pods per plant, and 100 seed weight across the two locations.

Table 3: Yield components performance of different cowpea genotypes across Syferkuil and Ga-Molepo.

Genotype name	**No. of branches per plant**	**No. of pods per plant**	**No. of seeds per pod**	**100 seed weight(g)**	**Grain yield (kg/ha)**
IT98D-1399	10.34	9.742	14.25	14.6	498.6
IT98K-476-8	9.77	8.532	12.8	15.1	322.4
IT99K-494-6	11.85	9.981	13.53	14.6	755
AGRINAWA	10.16	9.251	12.27	18	207.3
Bechuana white	10.99	11.477	12.16	15.9	550.9
Dr Saunders	13.37	12.157	9.52	8.7	469.6
Glenda	12.92	11.091	11.74	13.8	365.6
ITOOK-1263	11.27	9.786	13.5	19.6	622.3
JANA FOD	11.26	7.152	15.91	12.2	210.7
OLOYIN	8.73	8.81	11.76	18.7	369.1
ORELU	9.92	7.263	12.04	18.6	153.8
PAN 311	8.91	9.286	13.26	13.5	131.7
RV 111	13.08	13.11	11.56	13.9	577.6
RV 113	8.66	9.439	10.78	14.6	175
RV 115	15.91	13.066	8.2	9.5	455.3
RV 126	12.08	10.07	9.35	11.7	104.7
RV 157	11.67	12.034	11.53	13.4	642
RV 165	9.44	6.934	10.6	12.3	217.3

RV 173	11.07	11.394	14.76	15	292.4
RV 189	8.43	7.362	11.57	12.47	179.3
RV 194	12.13	8.899	10.9	15.9	633.6
RV 202	11.04	10.482	13.02	16.2	704.7
RV 204	10.63	8.459	13.88	15.9	576.7
RV 205	10.36	12.719	15.01	15.5	625.6
RV 207	10.74	10.018	11.58	18.9	756.3
RV 28	10.87	11.254	8.91	9.3	266.3
RV 315	10.89	9.675	12.46	13.5	324.6
RV 320	9.31	8.814	12.64	13.8	493.3
RV 329	10.53	10.444	10.42	11	279.7
RV 341	10.61	11.771	8.6	15.6	474.3
RV 342	9.88	7.804	11.28	15.05	313.8
RV 344	11.6	9.494	10.68	19.8	254.3
RV 347	10.23	7.205	9.49	8.6	84.5
RV 352	10.1	8.999	12.73	21.2	402.1
RV 353	10.26	9.962	14.59	13.75	662.1
RV 360	9.3	10.843	12.06	14.7	457.5
RV 361	8.68	10.82	10.08	15.1	286.6
RV 382	12.16	12.257	14.45	15.9	506.3
RV 386	13.05	9.665	13.47	20.9	417
RV 403	10.99	9.035	10.83	20.6	445.3
RV 409	8.89	11.149	13.23	14.7	391.2
RV 414	8.43	6.63	9.53	17.2	111.7
RV 416	13.66	12.719	11.78	18.7	480.9
RV 419	8.69	6.554	10.74	19.3	237
RV 438	10.94	9.533	9.8	12.05	216.9
RV 439	9.88	9.061	13.84	14.6	694.6
RV 440	29.87	10.175	8.07	18.5	115.1
RV 441	9.11	6.155	9.26	12.6	222.2
RV 443	12.52	8.996	10.02	14.5	296.8

RV 446	10.51	7.548	9.92	16.4	204.3
RV 457	8.19	6.942	9.49	15.1	135.5
RV 464	9.93	9.423	10.7	9.4	172.1
RV 465	12.71	10.567	11.58	17.3	388.7
RV 487	10.39	8.918	10.31	18.75	161.1
RV 497	9.77	8.615	13.61	11.5	506.6
RV 498	10.95	8.203	12.49	15.55	315.3
RV 499	9.07	7.64	11.76	17.8	350.4
RV 501	11.14	9.234	11.11	13.6	355.7
RV 502	12.05	11.736	9.95	10.7	362
RV 503	9.26	8.733	9.2	11.2	174.7
RV 504	8.46	6.43	10.53	13.3	244.7
RV 505	7.65	7.237	11.23	17.52	179.2
RV 512	9.36	8.698	10.69	10.6	311.3
RV 539	12.01	9.979	10.28	12.2	367
RV 542	9.27	8.099	11.81	16.75	205
RV 543	10.48	8.535	11.25	19.92	323.4
RV 546	13.07	11.296	13.83	14.65	585.5
RV 548	8.89	7.986	10.29	13.85	399.5
RV 551	8.75	7.803	9.18	9.3	133.6
RV 553	11.38	10.134	10.41	17.7	197.4
RV 554	8.98	9.391	13.35	14	682.3
RV 555	10.75	11.523	11.03	14.3	875.4
RV 556	11.77	9.665	9.65	14.45	406.5
RV 558	13.65	11.821	11.56	12.65	496.3
RV 84	6.8	5	11	12.5	105.6
RV 341	11.6	13.178	9.26	15.6	351.7
MIN	6.8	5	8.07	8.6	84.5
MAX	29.87	13.178	15.91	21.2	875.4
P value	11.13	21.33	4.574	3.336	381
Significance difference	NS	NS	**	NS	**

SE	5.227	100.02	2.144	1.561	179.4
CV	48.5	10.48	18.88	10.6	32.59

NS and **, Non-significant and significant at 5% level of probability, respectively.

The results in Table 4 show that there was a significant difference (P≤ 0.05) in grain yield amongst the genotypes in both locations. Table 4 below shows the grain yield for the best 15 varieties at both locations. The genotype RV 555 had a high grain yield than the other evaluated genotypes with 1078.9 kg/ha at Syferkuil. The local genotypes Bechauna White was also part of the best genotype with a yield of 773.9 kg/ha at Syferkuil. At Ga-Molepo genotype RV 353 had a high yield of 893.1 kg/ha along with 14 other genotypes on table 4. However, Bechuana White does not form part of the best 15 genotypes, it obtained the grain yield of 388,9 kg/ha. The results also show that there were significant differences (P≤ 0.05) in grain yield across locations amongst the genotypes. Genotype, RV 555, had a high yield of 875,4 kg/ha. The local check Bechauna White was also part of the best genotype with a yield of 550 kg/ha across locations. Genotypes: RV 555, RV 207, IT99K-494-6, RV 202, RV 439, and ITOOK-1263 had high yield at Syferkuil, Ga-Molepo and across the locations than the local genotype Bechauna White.

Table 4 : Best 15 genotypes from both locations for grain yield

SYFERKUIL		GA-MOLEPO		ACROSS LOCATIONS	
Genotype	**Grain yield (kg/ha)**	**Genotype**	**Grain yield (kg/ha)**	**Genotype**	**Grain yield (kg/ha)**
1. RV 555	1078.9	RV 353	893.1	RV 555	875.4
2. RV 554	1077.9	RV194	715.3	RV 207	756
3. RV 439	937.1	IT99K-494-6	645.8	IT99K-494-6	755
4. RV 207	891.4	RV 202	618.1	RV 202	704.7
5. IT99K-494-6	868.5	RV 341	601	RV 439	694.6
6. RV 151	853.7	RV 555	598.2	RV 554	682.3
7. RV 111	848.2	RV 205	583.3	RV 353	662.1
8. RV 549	785.8	ITOOK-1263	569.4	RV 157	642
9. Bechuana white	773.9	RV 207	550	RV 194	633.6
10. RV 546	728.7	IT98D-1399	548.6	RV 205	625.6
11. RV 202	723.3	RV 343	514.9	ITOOK-1263	622.3
12. RV 558	722.7	RV 342	472.2	RV 546	585.5
13. Dr Saunders	693.3	RV 315	451.3	RV 204	576.7
14. ITOOK-1263	681	RV 439	437.5	Bechuana white	550
15. RV 204	680.3	RV 465	429.7	RV 382	506.3

Table 5 shows the results of the analysis of variance based on yield and yield components of 100 cowpea genotypes. The analysis of variance showed that the site was not significant for all traits. Genotype and site x genotype were significant at $P < 0.05$ for 100 seed weight. ANOVA revealed that 100 seed weight showed significant variability for genotype only and site*genotype to the other measured parameters across the locations.

Table 5: ANOVA Table for the yield and yield components across the locations.

Source of variation	**DF**	**No of branches per plant**	**No of pods per plant**	**No of seeds per pod**	**100 seed weight (g)**	**Grain yield (kg/ha)**
Site	1	1310.37	2563.3	223.82	3646.68	2728243
Genotype	94	29.91	82.1	10.26	35.23	119543
Site*genotype	97	17.71	75.9	6.15	**0.187****	55473
Error	374	27.32	100.4	4.59	2.436	32185

, * Indicates significance at 0.01 and 0.05 probability level

Principal Component Analysis

The Principal Component Analysis (PCA) (Table 6) revealed the three most important PCs contributing a total variation of 76.71%. The PC1, PC2, and PC3 contributed 51.01 13.97 and 11.73%, respectively. The most contributing trait to the total variation in PC1 was grain yield (kg/ha). In PC2 most contributing traits were number of branches per plant and number of pods per plant, while, in PC3 were number of pods per plant and number of branches per plant

Table 6: Principal Component factor of cowpea grain yield and yield components

Traits	PC1	PC2	PC3
No of branches per plant	0.18573	**0.25977**	**0.54147**
Grain yield kg/ha	**0.40230**	0.09953	-0.13323
Pod number per plant	0.09377	**0.16643**	**0.59856**
No Seeds per pod	0.16871	-0.56858	-0.00995
Latent roots	5.611	1.536	1.290
Percentage variation	51.01	13.97	11.73
Cumulative variation	51.01	64.98	76.71

The correlations among the variables for Syferkuil are shown in Table 7. The number of branches per plant was highly significant and negatively correlated with 100 seed weight, and also was significant and positively correlated with seeds per pod with 10%. Number pods per plant was highly significant and negatively correlated with 100 seed weight. The variables at Ga-Molepo on Table 8 show number of pods per plant was highly significant and negatively correlated with the number of branches per plant. While, grain yield positively correlated with the number of branches per plant, while 100 seed weight also negatively correlated with the number of pods per plant. Across locations, the number of branches negatively correlated with the number of seeds per plant whereas the number of pods per plant negatively correlated with 100 seed weight (Table 9).

Table 7: Correlation matrix of yield variables for different cowpea genotypes at Syferkuil.

TRAITS	NB	NP	NS	100SW	GY
NB	1,0000				
NP	0,3789	1,0000			
NS	**0,0315****	**0,0379****		1,0000	
100SW	**-0,0250*****	**-0,1496*****	0,1048	1,0000	
GY	0,3398	0,1546	0,2650	0,0627	1,0000

, * Indicates significance at 0.05 probability levels, NB= number of branches per plant, NP= pod number per plant, NS= number of seeds per pod, 100 SW= 100 seed weight, and GY= grain yield.

Table 8: Correlation matrix of yield variables for different cowpea genotypes at Ga-Molepo.

TRAITS	NB	NP	NS	100SW	GY
NB	1,0000				
NP	0,1245	1,0000			
NS	**-0,0121*****	0,1527	1,0000		
100SW	0,1084	0,1217	0,3128	1,0000	
GY	**0,0181****	0,3718	0,3304	0,1847	1,0000

, * Indicates significance at 0.05 probability levels, NB= number of branches per plant, NP= pod number per plant, NS= number of seeds per pod, 100 SW= 100 seed weight, and GY= grain yield.

Table 9: Correlation matrix of yield variables for different cowpea genotypes across the locations.

TRAITS	NB	NP	NS	100SW	GY
NB	1,0000				
NP	0,4403	1,0000			
NS	**-0,1801*****	0,0745	1,0000		
100SW	0,0898	**-0,0699*****	0,2411	1,0000	
GY	0,0993	0,5181	0,4599	0,1247	1,0000

, * Indicates significance at 0.025 and 0.05 probability levels, NB= number of branches per plant, NP= pod number per plant, NS= number of seeds per pod, 100 SW= 100 seed weight, and GY= grain yield.

Principal coordinate biplot

The relationships between the best 15 genotypes are further illustrated on the principal component biplots in the figures below. The PCA biplot in Figure 1 shows the 12 genotypes from Syferkuil were clustered around the origin, while genotypes RV 555, RV 554, RV 439 and RV 204 were placed at extreme positions from the origin in the PCA biplot, indicating that they are genetically distinct genotypes in grain yield. The genotypes from Ga-Molepo (Figure 2) were clustered into two groups around the origin showing wider variability in grain yield, while RV 194, IT99K-494-6 and RV 202 were far apart from the origin. Figure 3 for grain yield across locations also shown that 11 genotypes were close together around the origin and genotype RV 555, RV 207, IT99K-494-6 and RV 382 were distant from the other genotypes.

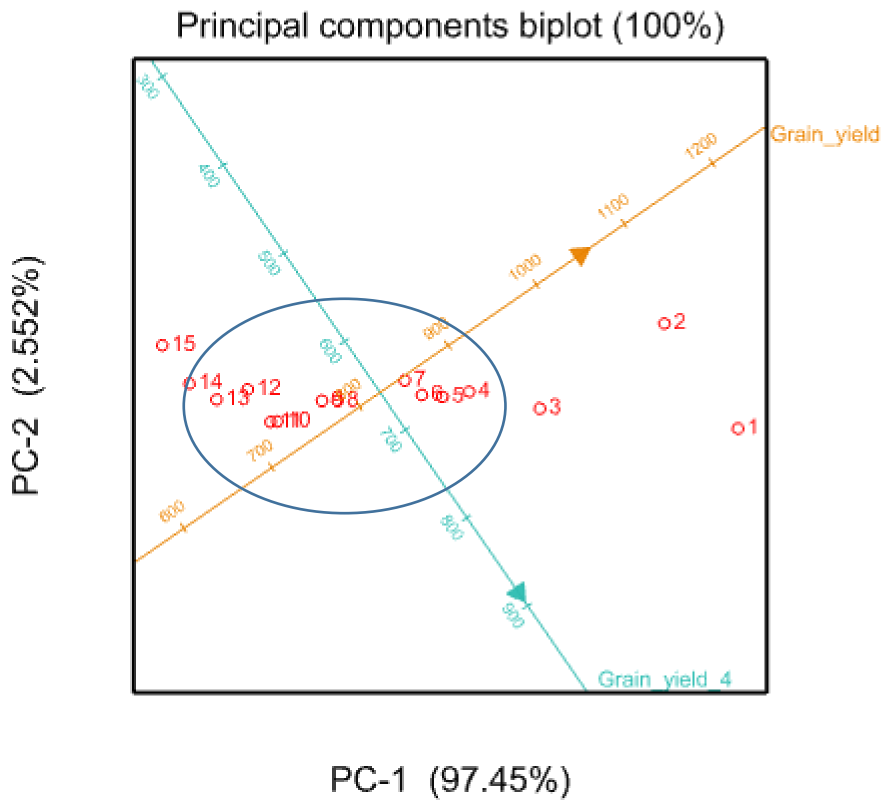

Figure 1: Principal component analysis score plot of PC1 describing the overall variation among the best 15 cowpea genotypes estimated using grain yield at Syferkuil.

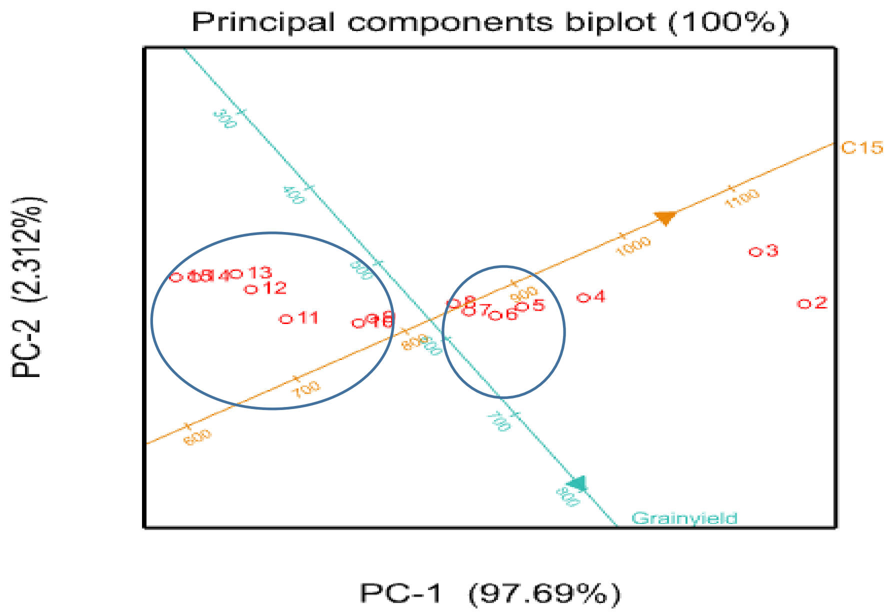

Figure 2: Principal component analysis score plot of PC1 describing the overall variation among the best 15 cowpea genotypes estimated using grain yield at Ga-Molepo.

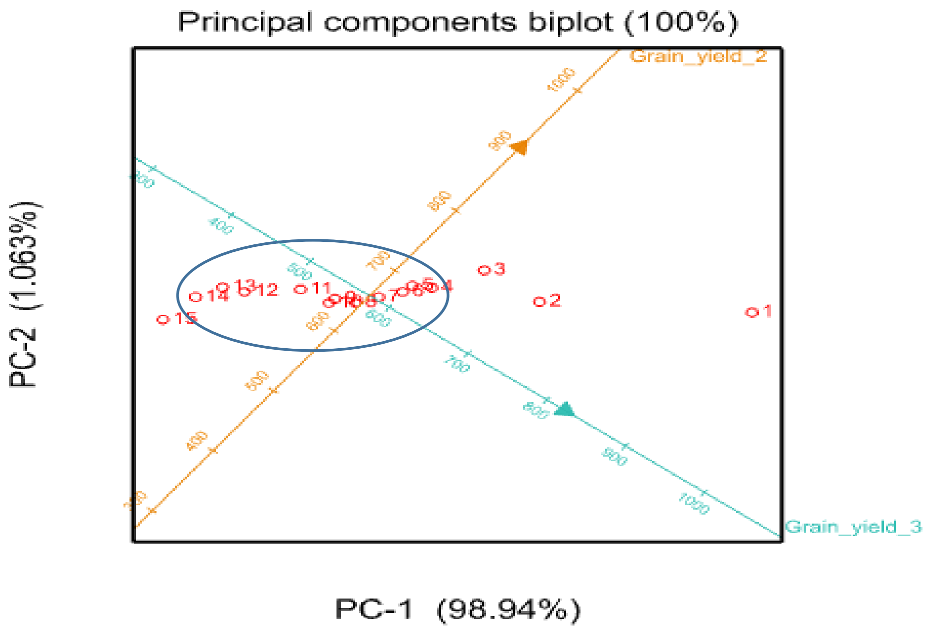

Figure 3: Principal component analysis score plot of PC1 describing the overall variation among the best 15 cowpea genotypes estimated using grain yield across locations.

3.6 GENERAL DISCUSSION

Results from Table 3 showed that the best 15 genotypes including the local check Bechuana White listed for both locations and across locations recorded high yields. This might be because of genotypes were influenced by genetic variation. Similar results were revealed by Quarrie *et al.,* (2006) that the significant and complex interaction effect for seed yield also indicated the complex genetic control of yield-related traits. Further supported by Ayaz *et al.,* (2004) and Masenya, (2016) who indicated that variation in cowpea yield components is species-dependent. These variations are also shown among the genotypes studied in this study. Meena *et al.* (2017) also reported that success in the development of high yielding genotypes is a consequence of the level of genetic variability and diversity of the breeding population. The observed lower yields from this study was due to genetic composition and morphological such as the number of pods per plant, seed size, and number of seeds per plant characteristics of the genotypes which is supported by Manggoel *et al.,* (2012) that the variability in traits is mostly governed by genetic factors with the little role of environment in the phenotypic expression of these characters. There was no significant difference ($P \leq 0.05$) in number of branches per plant and number of pods per plant for both locations on Table 2. This implies that the genotypes for both locations performed the same for number of branches per plant and number pods per plants.

The significant difference observed for the genotypes that performed best with number of seeds per pod contributed to the obtained high grain yield. The least number of seeds observed could have been affected by whether the pods consist of empty pods or not and also by losing some of the seeds while shelling the pods. Whereas high number of seeds per pod observed might be because of the pod length and genetic composition and their adaptation to the environment, these are supported by the results of Masenya (2016), who confirmed that variation in the number of seeds per pods among varieties is due to genetic factors [Fery (1985) in Masenya (2016)]. Supported by Futuless and Bake (2010) who reported that no single genotypes of cowpea can be suitable for all conditions, which may explain the variation observed for the measured number of seeds per pod. The number of seeds per pod is an important agronomic trait for cowpea that contributes to grain yield (Ogunbodede, 1989; Okeleye *et al.,* 1999 in Ringo 2017). The significant difference in 100 seed weight observed in the evaluated genotypes for both locations suggested that the seed size was the cause of the variation in 100 seed weight. These results are in agreement with Menssen *et al*., (2017) who reported that since the 100 seed weight was positively correlated to the width and length of pods and seeds, it can be rated as a valid descriptor for seed and pod size.

The significance difference observed in this study for number of seeds per pod and grain yield across the locations on genotypes expressed good adaptation across the two locations with high grain yield. The observed significance difference between the cowpea genotypes across the locations for the above-mentioned parameters are due to genetic make-up, phenology and good environmental conditions such as soil type, temperature and rainfall in one location than the other. These results are in in agreement with José *et al.* (2017) who reported that any genotype that demonstrates consistency of performance or small variation across environment is said to show general adaptations. RV 347, RV 84, RV 551, RV 457, RV 440, and RV 126 had the lowest yield across the locations this may be because they show inconsistency in adaption for across locations.

In this study, correlation analysis showed strong positive influence of number of branches per plant and number of seeds per pod at Syferkuil (Table 6) this implies that these variables contributed to the obtained high grain yield. Previous reports identified these traits being important yield-influencing attributes (Walle *et al.,* 2019). The noted variation was also reported by Amanullah *et al*. (2000) in Srinivas (2017) who found significant differences in yield and showed a positive relationship with the number of pods per plant and number of seeds per pod. Highly correlated traits could reduce the number of traits needed for germplasm characterization (Kamara *et al.,* 2017) and the knowledge of the relationship among plant characters is useful while selecting traits for yield improvements (Iqbal *et al.,* 2010).

The Principal Component Analysis (PCA) in Table 5 revealed that all the traits contributed to variation in respective of PC1, PC2, and PC3. The cowpea genotypes used in this study exhibited a wide range of phenotypic variability for grain yield and some yield component traits such as number of seeds per plant, and grain yield. Thus, wide variability extant of this nature could be attributed to inherent genetic properties of cowpea varieties and environmental influence, which could be exploited for improvement through selection and/or hybridization of individuals with desired quality characteristics. These results were supported by Gerrano *et al.* (2015) who reported that high heritable values for a trait indicate a relatively small contribution of the environment to the expression of the phenotype, making a selection of the trait easier.

Johnson, (1955) explains PCA as the most applicable statistical tool to identify the number of genotypes to be selected and used in the breeding program. Adugna, (2014) in Mofokeng *et al.* (2019) reported that the application of PCA tool and multivariate statistical analysis provides a useful means to estimate morphological diversity within and between germplasm collections. Figures 1, 2 & 3 revealed that the genotypes concentrated around the origin on PCA biplot, shows that these genotypes were genetically similar for the grain yield for the locations studied. These results were supported by Santos *et al.* (2015) who reported that the interaction effect shows that the genotypes responded differently in the test environments which can facilitate the identification of cowpea lines with specific or broad adaptation. Genotypes such as RV 555, IT99K-494-6 and 7 other genotypes that were genetically distant on all the PCA biplots indicates that they were high yielding and stable. However, (Yan and Tinker, 2006) indicated that stable genotypes should be selected only when they have high mean performances since a consistently low yielding genotype can as well be stable.

3.7 CONCLUSION

The results showed that evaluated cowpea germplasm performed better in yield parameters than the local check Bechuana White performed at Syferkuil. While Bechuana White and 14 other genotypes performed well at Ga-Molepo and across, inferring that there was variability amongst the assessed genotypes. The result also showed that there was a significant difference between Syferkuil and Ga-Molepo for the following yield parameters number of seeds per pod, 100 seed weight and grain yield, and we, therefore, reject the null hypothesis. As there was no significant difference in the number of branches and number of pods per plant, we accept the null hypothesis for these variables. Some genotypes expressed good adaptation across the two locations with high grain yield and yield parameters. There was a significant difference between the number of seeds per pod and grain yield. No significant difference was shown among the cowpea genotypes for the number of branches per plant, number of pods per plant, and 100 seed weight across the two locations. Although there was no significant difference in the number of seeds per pod and grain yield between the genotypes, some genotypes yielded very low. Genotypes with a high yield between 500 -800 kg/ha including the local genotype Bechuana White can be recommended for planting to achieve high yield.

The results of PCA suggest that the most important variables for the classification of the cowpea genotypes were the most contributing traits to the total variation which are grain yield, number of branches per plant and number of pods per plant. This suggests that these traits could be used in a selection criterion for genetic improvement of cowpea genotypes. Positive phenotypic correlations among each pair of yield traits indicated the possibility that the traits shared some common genes. It is therefore essential that cowpea breeders in South Africa should collect more information by characterizing various germplasm yields using agro-morphological traits. The eighty-nine (89) genotypes recognized with desirable traits can be recommended for direct production by growers and/or used in the breeding programme to develop new cultivars with high yield in South Africa.

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CHAPTER 4

SCREENING OF SELECTED COWPEA CULTIVARS FOR CANNING ABILITY.

4.1 ABSTRACT

Cowpea is a pulse crop containing high protein, vitamins and minerals. It is consumed as a high-quality plant protein source in many parts of the world. It is referred to as "poor man's meat" due to the high levels of protein found in the seeds and leaves. However, there are limited efforts for prolonging its shelf life in the form of seed canning in South Africa. The objective of the study was to screen cowpea genotypes for canning quality traits. The ARC-GC in-house method was used for canning. Seed samples were soaked in a 30°C and then blanched at 88°C. Soaked beans were canned in a tomato puree canning medium. Cans were left to stabilize for 14 days before opening. Drained mass, percentage of drained mass, splits and visual appearance were recorded. The texture of the canned beans was determined by using the Stable Micro Systems Texture Analyzer, which calculates the amount of force required to compress the beans and the force was recorded.

Data for the measured canning quality traits and the means were separated by Duncan multiple Range test were subjected to XLSTAT 2021.1.1.1081 software. Water uptake ranged from 58 to 139.9, splits ranged between 0% and 3.75%, and the force ranged between 1257.6 and 1275.9 N. From 79 cowpea genotypes evaluated, only 11 genotypes were spoiled and had a bad odour. Among the 68 remaining, seven genotypes had less water uptake as compared to others. The 61 genotypes exhibited high water uptake, good visual appearance and without splits were recommended for canning. The positive correlation recorded between all the measured canning quality traits demonstrated that acceptable canning ability are expected to contribute to cowpea production chain, and consequently to increase consumption of canned cowpea.

Keywords: Genotypes, quality traits, water uptake, *Vigna unguiculata.*

4.2 INTRODUCTION

Cowpea (*Vigna unguiculata*) is a pulse crop containing high protein, vitamins and minerals. It is consumed as a high-quality plant protein source in many parts of the world (Sharmar *et al.* 2013). Grain legumes play an important role in the world's food and nutrition requirements, especially in the dietary pattern of low-income group of people in developing countries. Hence, referred to as "poor man's meat" due to the high levels of protein found in the seeds and leaves (Tharanathan and Mahadevamma, 2003). However, there are limited efforts for prolonging its shelf life in a form of seed canning in South Africa. Phenotypic selection for superior canning quality has been successfully employed in cultivar development (Hosfield and Uebersax 1990). Although canning quality standards for canned beans are not clearly defined in South Africa. The important quality characteristics highlighted in canning are the water uptake, size uniformity, visual appearance and splits. Mendoza *et al.,* (2006) indicated that among quality traits, color is the first sensation that the consumer perceives and is used as an indicator for the acceptance or rejection of raw and cooked beans. In fact, color represents a fundamental physical property of any food, since it has been widely demonstrated that it correlates well with physical, chemical, and sensorial indicators of product quality Mendoza *et al.,* (2006).

Pan *et al.* (2010) suggested that pre-processing beans may bring benefits such as the increase in product value and greater profitability for farmers and food manufacturers. The ideal bean from a processor's perspective is one with rapid and even seed expansion during soaking Mendoza *et al.* (2006). Water uptake during soaking is an important consideration in bean improvement. Water uptake rate affects swelling capacity, which affects the number of cans of beans that can be produced from raw product (Hosfield, 1991). Thus, the quality of canned beans is determined not only by the canning process but also by the genetics of the raw cowpea used for processing which influences their chemical composition and structural and biological characteristics (Kelly and Cichy, 2012). Canning quality standards for canned cowpeas are not clearly defined in South Africa and a standardized technique for the canning of South African cowpea cultivars in a medium other than brine (i.e., tomato sauce). In South Africa, other legumes are available in the supermarkets as a canned product however, it is important to diversify the utilization and increase its shelve live through canning. A standardized technique should therefore be comparable to the standards of the USA (Hosfield and Uebersax 1980) and Canadian government regulations (Balasubramanian *et al.,* 1999) and also meet the requirements set by industrial canners. Hence, the objective of the study was to screen cowpea genotypes for canning ability using canning quality traits.

4.3 MATERIALS AND METHODS

4.3.1 Plant material

The cowpea genotypes were obtained from the Agricultural Research Council-Grain Crops (ARC-GC) cowpea gene bank. Grains used for this part of the study were obtained from both the field experiments in chapter 3. From the one hundred (100) planted cowpea genotypes, ten (10) genotypes did not germinate at both the locations, eleven (11) genotypes were not canned due to their weight (less than 10 grams and weevil damage). Seventy-nine (79) cowpea samples were evaluated/screened for canning ability; eleven cowpea samples were not successfully evaluated due to spoilage in the can.

4.3.2 Analysis for canning ability

The ARC-GC in-house canning method was used for canning. Hundred grams of cowpea grain samples were soaked at 30°C water bath for 30 minutes and then blanched at 88°C for 30 minutes. Cowpea weight after soaking was recorded as soaked mass. Soaked beans were canned in a tomato puree canning medium and heat sterilized at 121.1 °C for 30 minutes. Cans were left to stabilize for 14 days before opening. Bean splitting and visual appearance were evaluated subjectively on a scale from 1 to 10. A 10-point scale was used for visual appearance (1 = poor to 10= excellent); 10-point scale was used for splitting (1 = completely broken or mushy bean to 10 = beans without cracks, splits and loose skins). The drained and washed tomato sauce for 2 minutes was recorded as drained mass where it was determined by the procedure of Balasubramanian *et al.* (1999). Completely broken splits beans and loose skins were considered as splits and expressed as a percentage of drained mass. The texture of the canned beans was determined by using the Stable Micro Systems Texture Analyzer, which calculates the amount of force required to compress the beans and the force was recorded.

Canning quality Evaluation of Beans Hydration coefficient of the canned bean was determined by the procedure of Hosfield and Uebersax (1980). Other canning parameters were measured by a visual rating procedure (visual estimation seed size was determined subjectively using 1-7 scale (Uebersax and Hosfield, 1996). On this scale, value of 1 represents very uniform beans and value 7 represents very varied beans. The ratio of Dry: Drained weight is calculated by drained mass (bean weight after draining out the medium tomato sauce), divided by dry mass (the original dry bean mass before canning). Other parameters were measured as follows:

1. Soaked mass (Uebersax and Hosfield, 1996)

Soaked mass = Mass of soaked beans/ Mass of dry beans

2. Water uptake (WU) (Van Der Merwe *et al.,* 2006)

%Water Uptake = (Mass of soaked beans/ Mass of dry beans) x100

Water uptake of 80% is considered optimum.

3. Drained mass (Van Der Merwe *et al.,* 2006)

Drained mass = Washed drained mass/ mass of can contents

4.3.3 Statistical analysis

Canning quality data was subjected to XLSTAT 2021.1.1.1081 software. The means were separated by Duncan multiple Range test in XLSTAT 2021.1.1.1081 at 5% level of significance.

4.4 RESULTS

Table 10 revealed that soaked mass for the canned genotypes had a mean range of 158.9-240.1g with RV 446 being the highest, followed by OLYIN, RV 555, PAN 311, RV 411 and RV 416. Genotypes RV 542, RV 341, and TVU11986 recorded the lowest soaked mass. Water uptake ranged from 58 to 139.9%, with RV 446 having the highest water uptake than all the genotypes, followed by OLOYIN, Glenda, RV 555, PAN 311, and RV411. While RV 341, RV 352, RV 344, RV 353, RV 342, and TVU11986 showed the lower water uptake. Drained mass ranged from 191-243.5g, whereby Glenda, RV 554, RV 446, 97K-44935, OLYIN, RV 553 and TVU9620 obtained the highest mass than all the studied genotypes, whereas, RV 542, RV 16, RV 342, RV 499, TVU 11986, RV 551 and RV 464 obtained the lower drained mass.

The dry: drained ratio ranged from 1:9-2:4. Glenda and RV 554 had the highest ratio of 2.4. RV 497,97K-44935, RV 126, RV 165, RV 446, RV 411 and Pan 311 had a ratio of 2:3, whereas RV 342, RV 16 and RV 542 recorded the lowest ratio of 1.9. Whereas appearance ranged from 3-10, RV 416, RV 411, OLERU, TVU5138, 97K-44935 and RV 465 had an appearance rate of 10. While RV 315 had an appearance of 3. The size uniformity ranged from 4-7 with RV 416 and IT98K-476-8 being very varied from other canned genotypes with the value of 7. While OLOYIN and RV 28 having the size uniformity of 4 were showing that the genotypes were uniform in size.

Percentage splits ranged from 0 to 3.75, whereby, Bechuana White, RV 353, TVU 546, RV 419, RV 548, RV 464, RV 551, RV 16, RV 542, RV 512, RV 417, and IT99K-494-6 had 0% splits meaning that the genotypes were completely broken or mushy. While RV 440 recorded high percentage of splits of 3.75 followed by RV 553, RV 443, OLYIN, RV 554, RV 546, RV 126, RV 165, RV 501, RV 446, RV 205 and TVU 9620 meaning the genotypes had no cracks, splits or loose skins.The force for texture recorded ranged from 1257.6 - 1275.9 N. RV 165 obtained high force with 1275,9 N followed by Glenda, RV 497, RV 320, RV 204 and RV 446 with a force of 1274 meaning that these genotypes had a firmer texture. RV 457, OLOYIN, 97K-44935, RV 16, and RV 438 obtained a less force of 1257,1258, 1259,1260,1260.09 and 1260.29N respectively meaning that these genotypes had a softer texture.

Table 10: Canning quality traits and canning ability of different cowpea genotypes using tomato puree.

Number	Genotypes	Soaked Mass(g)	%Water Uptake	Drained Mass(g)	Dry: Drained Ratio	Appearance (1-10)	Size Uniformity	%Splits	Force(N)	Cultivar approval for canning
1	RV341	163.4	63.4	210.7	2.1	5	5	0.38	1262.11	No
2	RV409	204	103	217.5	2.2	6	5	0.64	1268.04	Yes
3	RV386	201.9	100.4	214.9	2.1	6	5	0.23	1264.58	Yes
4	RV556	210.2	109.6	215.4	2.1	6	5	0.23	1266.93	Yes
5	RV416	228.5	125.3	224.6	2.2	10	7	0.62	1268.43	Yes
6	Glenda	239	135.8	243.5	2.4	6	5	1.03	1274.09	Yes
7	RV497	225.1	123.5	231.5	2.3	6	5	0.39	1274.08	Yes
8	RV546	216.1	115.8	225.6	2.2	6	5	1.6	1272.65	Yes
9	RV352	175.2	72.6	218.3	2.1	8	6	0.64	1271.65	No
10	RV157	223.6	121.6	228.1	2.2	7	6	0.04	1265.77	Yes
11	RV202	191.7	90	208.4	2	6	5	0.19	1262.37	Yes
12	RV554	216.2	115.4	238.4	2.4	5	5	2.14	1267.39	Yes
13	RV207	182.8	80.4	210	2.1	6	5	0.19	1269.09	Yes
14	RV440	223.1	121.3	218.9	2.2	7	5	3.75	1266.87	Yes
15	RV344	172.7	69.3	204.7	2	6	5	0.39	1271.25	No
16	RV443	225.2	123.1	228.5	2.2	7	6	2.8	1263.96	Yes
17	Bechuana White	184.1	83.4	204.9	2	6	5	0.7	1267.19	Yes
18	RV353	173.2	72.6	205.7	2	6	5	0	1273.09	No
19	RV439	224.5	124.2	225.4	2.2	5	5	0.22	1273.51	Yes
20	ITOOK 1263	210.7	109.8	225.4	2.2	6	5	0.27	1264.12	Yes
21	RV320	200.3	98.4	216	2.1	6	5	0.28	1274.87	Yes

22	RV315	184.1	83.5	212.3	2.1	3	5	0.28	1267.64	Yes
23	RV115	215.9	113.9	215.7	2.1	6	5	0.09	1269.13	Yes
24	RV205	193.5	89.6	219.6	2.1	4	5	1.37	1274.79	Yes
25	RV558	228	125.3	230.6	2.2	6	6	0.52	1262.38	Yes
26	RV417	225	125	217.4	2.2	7	6	0	1273.97	Yes
27	RV446	240.1	139.9	228.1	2.3	8	5	1.14	1274	Yes
28	RV555	233.1	133	223	2.2	7	6	0.09	1271.23	Yes
29	RV501	227.6	126.7	214.7	2.1	7	5	1.4	1270.67	Yes
30	98K-476-8	219.9	119.6	223.3	2.2	9	7	0.76	1265.67	Yes
31	RV411	231.6	131.4	227	2.3	10	6	0.22	1268.05	Yes
32	RV165	183.3	82.8	202.8	2	9	6	0.2	1271.88	Yes
33	AGRINAWA	187.4	86.7	207	2.1	8	6	0.14	1265.93	Yes
34	99K-494-6	222.9	122.1	224.9	2.2	6	6	0	1269.69	Yes
35	RV502	222.6	122.3	223.3	2.2	8	6	0.4	1268.91	Yes
36	RV382	188.4	85.5	206.5	2	6	6	0.29	1272.27	Yes
37	OLYIN	237.8	135.9	220.9	2.2	9	4	2.26	1258.13	Yes
38	RV498	222.3	118.7	220.1	2.1	8	5	0.55	1265.92	Yes
39	RV194	212.1	111.8	211.3	2.1	8	5	0.19	1268.24	Yes
40	Pan311	233.1	133.1	232.7	2.3	7	6	0.3	1267.94	Yes
41	OLERU	211.2	111.2	211.5	2.1	10	6	0.05	1266.37	Yes
42	RV361	202.5	102.3	212.6	2.1	8	5	0.19	1268.44	Yes
43	RV487	214.5	114.4	205.4	2.1	7	5	0.1	1264.09	Yes

44	RV503	198.1	98	217.3	2.2	8	5	0.18	1263.55	Yes
45	RV457	203.7	103.6	209.6	2.1	8	5	0.24	1257.6	Yes
46	RV499	203.5	103.4	195.3	2	9	6	0.15	1262.78	Yes
47	RV28	206.9	106.6	220.9	2.2	4	4	0.36	1263.52	Yes
48	TVU13004	206.6	106.3	216.7	2.2	8	5	0.05	1267.14	Yes
49	TV546	216.3	116	219.3	2.2	8	6	0	1269.8	Yes
50	86D	185.5	85.3	205.1	2	7	5	0.15	1265.03	Yes
51	TVU5138	214.8	114.7	217.2	2.2	10	6	0.05	1270.22	Yes
52	TVU13998	201.8	101.6	222.3	2.2	7	5	0.13	1272.32	Yes
53	97K-44935	216.3	116.2	226.2	2.3	10	6	0.8	1259	Yes
54	RV543	207.8	107.8	205.4	2.1	7	6	0.1	1267.78	Yes
55	RV419	208.9	108.8	218.9	2.2	7	5	0	1266.75	Yes
56	RV189	200.1	100	217.5	2.2	6	5	0.18	1270.68	Yes
57	RV465	204	103.9	205.9	2.1	10	6	0.1	1262.63	Yes
58	RV113	195.5	95.3	212.6	2.1	5	5	0.14	1265.97	Yes
59	RV548	205.2	105.2	211.5	2.1	8	5	0	1272.88	Yes
60	RV464	200.1	99.9	203.6	2	6	5	0	1259.57	Yes
61	RV441	214.5	114.2	213.3	2.1	8	5	0.56	1265.67	Yes
62	RV504	198.8	98.8	211.6	2.1	5	5	0.19	1273.08	Yes
63	RV329	203.9	103.8	208.3	2.1	8	5	0.05	1272.33	Yes
64	RV551	207	106.1	203.3	2	8	6	0	1263.25	Yes
65	RV43	209.7	109.4	212.4	2.1	7	5	0.05	1269.29	Yes

66	RV438	222.1	122.1	215.9	2.2	6	5	0.09	1260.49	Yes
67	RV342	172.4	72.1	192.4	1.9	7	5	0.1	1264.68	No
68	TVU11986	165.1	65	203	2	7	5	0.39	1266.67	No
69	TVU13778	192.1	92	216.2	2.2	7	5	0.6	1265.75	Yes
70	RV16	203.9	103.9	191.6	1.9	8	6	0	1260.09	Yes
71	RV126	225.3	125.2	227.3	2.3	7	5	1.54	1272.02	Yes
72	RV542	158.9	58.8	191	1.9	8	6	0	1273.45	No
73	RV10	215.5	115.3	218.7	2.2	8	5	0.69	1268.74	Yes
74	RV165	218.1	118	227.5	2.3	7	6	1.23	1275.91	Yes
75	RV329	225.5	125.4	222.1	2.2	7	5	0.59	1270.75	Yes
76	CH-47	183.6	83.6	204.4	2	7	5	0.34	1264.67	Yes
77	RV512	218	117.7	216.4	2.2	8	5	0	1262.13	Yes
78	RV553	226.4	126.1	227	2.3	4	5	2.86	1265.86	Yes
79	TVU9620	225.1	124.9	230.2	2.3	7	5	1.13	1269.85	Yes

Table 11 shows the summary of analysis of variance for 79 cowpea genotypes that were evaluated for canning quality. The mean range of soaked mass, % water uptake, drained mass, dry: drained ratio, % splits, appearance, size uniformity and force for the 79 canned genotypes were 158.90 – 240.10 g, 58,80-139 %, 191-243.5 g, 1.9-2.4, 0.00-3,75, 3-10,4-7 ,1257.60-1275.91 respectively.

Table 11: Summary of descriptive statistics for the measured canning quality traits for cowpea genotypes.

Variable	**Obs. with missing data**	**Obs. without missing data**	**Minimum**	**Maximum**	**Mean**	**Std. deviation**
Soaked Mass(g)	0	79	158,90	240,10	207,46	18,71
%WU	0	79	58,80	139,90	106,69	18,71
Drained Mass(g)	0	79	191,00	243,50	216,01	10,36
Dry: Drained Ratio	0	79	1,90	2,40	2,143	0,11
Appearance (1-10)	0	79	3,00	10,00	7,025	1,49
Size Uniformity	0	79	4,00	7,00	5,329	0,57
%Splits	0	79	0,00	3,75	0,501	0,72
Force(N)	0	79	1257,60	1275,91	1267,712	4,36

Table 12 shows that there was a significant positive correlation in soaked mass, % water uptake, drained mass, dry: drained ratio and % splits between genotypes. Whereas, there was also strong positive relationship between appearance and size uniformity and also between drained mass and force for the studied genotypes. Table 13 below shows that there was a positive correlation between soaked mass and % water uptake, drained mass, dry: drained ratio and % splits. There was also a positive correlation among appearance and size uniformity and also between drained mass and force.

Table 12: P-values of correlation matrix for the measured canning quality traits of 79 cowpea genotypes.

Variables	Soaked Mass(g)	%Water Uptake	Drained Mass(g)	Dry: Drained Ratio	Appearance (1-10)	Size Uniformity	%Splits	Force(N)
Soaked Mass(g)	**0**	**<0,0001**	**<0,0001**	**<0,0001**	0.100	0.295	**0.001**	0.848
%Water Uptake	**<0,0001**	**0**	**<0,0001**	**<0,0001**	0.083	0.303	**0.002**	0.901
Drained Mass(g)	**<0,0001**	**<0,0001**	**0**	**<0,0001**	0.242	0.970	**<0,0001**	**0.039**
Dry: Drained Ratio	**<0,0001**	**<0,0001**	**<0,0001**	**0**	0.842	0.973	**<0,0001**	0.123
Appearance (1-10)	0.100	0.083	0.242	0.842	**0**	**<0,0001**	0.231	0.122
Size Uniformity	0.295	0.303	0.970	0.973	**<0,0001**	**0**	0.190	0.622
%Splits	**0.001**	**0.002**	**<0,0001**	**<0,0001**	0.231	0.190	**0**	0.914
Force(N)	0.848	0.901	**0.039**	0.123	0.122	0.622	0.914	**0**

Significance difference level at 0,05

Table 13: Correlation matrix of canning quality traits of 79 cowpea genotypes.

Variables	**Soaked Mass(**g)	**%WU**	**Drained Mass(**g)	**Dry:** Drained Ratio	Appearance (1-10)	Size Uniformity	**%Splits**	Force(N)
Soaked Mass(g)	**1**	**0,999**	**0,723**	**0,733**	0,187	0,119	**0,357**	0,022
%WU	**0,999**	**1**	**0,711**	**0,733**	0,196	0,117	**0,343**	**0,014**
Drained Mass(g)	**0,723**	**0,711**	**1**	**0,933**	-0,133	0,004	**0,452**	0,232
Dry: Drained Ratio	0,733	0,733	0,933	1	**-0,023**	**-0,004**	0,432	0,175
Appearance (1-10)	0,187	0,196	-0,133	-0,023	**1**	**0,504**	-0,136	-0,175
Size Uniformity	**0,119**	**0,117**	**0,004**	**-0,004**	0,504	1	**-0,149**	0,056
%Splits	0,357/	0,343	**0,452**	0,432	-0,136	-0,149	1	**0,012**
Force(N)	*0,022*	0,014	0,232	0,175	-0,175	0,056	0,012	**1**

**Values in bold are different from 0 with a significance level alpha=0,05*

The figure 4 below shows that the genotypes are clustered into two clusters namely cluster A (blue) and cluster B (red) which are further subdivided into subgroups. Cluster A produced 3 subgroups which included 23 genotypes under these subgroups which were close. RV 382 was distantly related to other genotypes between two clusters with a distance of 1,702 to the centroid. Cluster B produced 6 subgroups which had 49 genotypes closely related. RV 503, RV 548, RV 43, RV 504, RV 419, RV 555 and TVU9620 were distantly related to other genotypes between subgroups in cluster B.

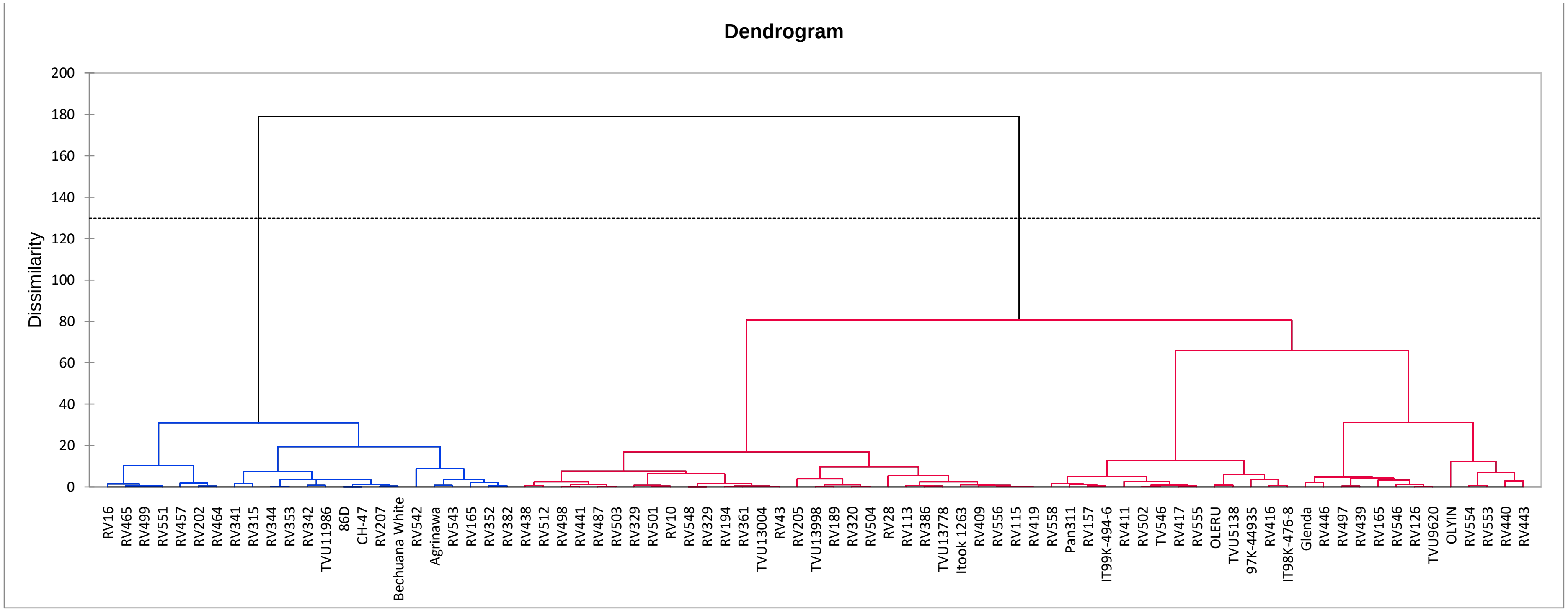

Figure 4: Dendrogram produced from average linkage cluster analysis showing genetic relationship between 79 cowpea genotypes.

A

B

C

Figure 5 (A.B & C): Different cowpea genotypes canned in a tomato puree.

Different cowpea genotypes that were successfully canned using the tomato puree by the Grain quality laboratory of the ARC-Grain Crops are shown on the Figure 5. It also shows the diversity of the cowpea material used in the study.

4.5 DISCUSSION

The general rule of canning is that samples with low water uptake are not considered for canning. Samples that also show a high percentage splitting are also not recommended. It is important to note that there are no commercial standards set for cowpea canning; we thus relied only on dry bean standards. Results revealed that the canned genotypes RV 446, OLOYIN, RV 555, PAN 311, RV 411 and RV 416 had high soaked mass which indicates large swelling capacities this may be caused by seed-coat permeability. The genotypes RV 542, RV 341, and TVu 11986 had low soaked mass which indicates that there was excessive solid loss, which may possibly cause splits. These results are supported by Hosfield, (1991) who reported that soaked mass is important in bean canning, as a larger quantity of beans is necessary to fill a certain can volume, when the soaked mass ratio is low. On the other hand, a higher soaked mass would therefore improve canning yield because soaked\drained mass relates to processors yield (Ghaderi *et al.,* 1984).

According to Bolles *et al.,* (1982) reported that water uptake takes place inside the can during the first 7 days after canning, due to increased water migration within the can. The cowpea genotypes that indicated high water uptake and low water uptake, and this was due to a cultivar-specific property such as seed-coat permeability. The general rule of canning is that samples with low water uptake are not considered for canning, hence the genotypes with low water uptake genotypes in this study were not considered for canning. Drained mass ranged from 191-243.5g which is less than South African standard of washed drained mass (WDWT) of 272 g due to their difference seed size. The obtained results were in accordance with Van Loggerenberg (2004), who reported for genotypes to record high and low drained mass might be because cowpea is a small seeded genotype. Hosfield (1991) indicated that a high percentage washed drained mass (PWDWT) value is an indication of the large swelling capacity of beans. Van

Loggerenberg (2004) also reported that beans canned in tomato sauce have significantly lower PWDWT and higher texture values than those canned in water. The results obtained varied because of tomato sauce used as a canning medium which reduces the pH resulting in hydrolysis of protein and starch, thereby increasing the number of OH groups available to bind water molecules (Nordstrom and Sistrunk, 1977). Varner and Uebersax, (1995) stated that dry: drained ratio shows the quantitative relation between two amounts showing the number of times one value contains or is contained within the other. The drained mass of dry beans is regarded as 'processors yield', as it would require a lower mass of dry beans with a higher drained mass to fill a can than in the case of beans with a lower drained mass. In this study the dry: drained ratio was 2:4, 2:3 and 1:9 which indicates that the drained mass was higher than dry mass in which was necessary to fill the can.

There were 6 genotypes which recorded 10 on the appearance which is in accordance to Van Merve *et al.* (2006) the appearance score measures the wholeness of cowpea seed. High values (closer to 5) indicate that the seed was free of splits and that the seed coat was intact grains. RV 416, RV 411, OLERU, TVu 5138 and RV 465 had an appearance rate of 10 which indicates that the seed was free of splits and that the seed coat was intact. While RV 315 had an appearance of 3, the grade 3 is attributed to beans samples that display loosened, non-agglutinated grains. Balasubramanian *et al.,* (1999) indicated that beans should be of uniform size and coloration and be shiny and luminous. Genotype RV 416 and IT98K-476-8 had the value of 7 which shows variations from other canned genotypes. While OLOYIN and RV 28 were showing uniformity in size, shape and colour. Hosfield and Uebersax (1980) reported that evaluation of size and shape of canned beans subjectively and they are important for the canning industry due to consumer preferences. Uniformity in size, shape and color is considered among important canning quality attributes thus, beans destined for canning purposes should be uniform in size with regular shape (Van Loggerenberg, 2004).

Splitting of cooked beans is one of the factors that determine the intactness of cooked beans and is determined subjectively. A 10-point scale was used for splitting for the canned genotypes whereby 12 genotypes recorded zero, which is equivalent to 1 =

completely broken or mushy bean, while other 56 genotypes had recorded from 3.75 which is equivalent to 10 on the point scale, 10 = beans without cracks, splits and loose skins and the remaining genotypes recorded average % splits meaning they had no splits or loose skins. Splits (10-point scale) would therefore discriminate between cultivar and environmental differences in bean canning quality than percentage splits. Merwe *et al.,* (2006) reported that the reason for smaller differences between cultivars with split (%) could be due to the fact that only totally split beans and bean parts are considered as splits, as compared with the splits (10-point scale), where all cracked beans were also considered to be broken. Texture is used as an indication of the degree of consumer acceptance of canned beans as it affects the perceived stimulus of chewing (Ghaderi *et al*., 1984). The texture of the canned beans was determined by using the Stable Micro Systems Texture Analyzer, which calculates the amount of force required to compress the beans. RV 457, OLOYIN, IT97K-44935, RV 16, and RV 438 had a softer texture which the consumers would prefer bean to be soft but with fewer splits, however soft texture is associated with seed breakdown (De Lange and Labuschagne, 2000). RV 165, Glenda, RV 497, RV 320, RV 204 and RV 446 had a firmer texture of which Van Lanngerensberg, (2004) reported that a firm texture is desirable in salad bars, it is important to separate a desirable firm texture from undesirable hard and undercooked cowpea.

Table 11 & 12 revealed that there was significant relationship on variables such as soaked mass and % water uptake, drained mass, dry: drained ratio and % splits. These results implicate that the cowpea seeds that had splits absorbed more water during blanching period. Similarly reported by Van Loggerenberg (2004) that the undesired expansion of beans in the can be avoided by increasing soaking and blanching period for large seeded beans to achieve the desired 80% weight increase before can filling. There was also a positive correlation on table 13 among appearance and size uniformity and also between drained mass and force. The positive correlation was similar to the findings of Taiwo *et al* (1998) and Wang *et al* (2003) who reported that correlation means that there is a stronger association between those variables which shows the ease in pressure put forth during chewing gives the impression of an adequately cooked sample, showing that higher absorption capacity produced a softer bean. Figure 5 showed the relationship between the genotypes for the measured canning quality traits. Clustering of genotypes indicated that most of the canning quality variances are attributed to genetic variation within accessions, there was some good relationships between canning quality traits and genetic distances. The distant clustering on the figure shows close relationships with little or no variation.

4.6 CONCLUSION

Eleven (11) cowpea samples were not successfully evaluated due to spoilage inside the can. These are RV 505, RV 111, RV 539, RV 204, IT98D-1399, RV 403, RV 442, Dr Saunders, RV 360, TVu14190 and RV 414. Bubbles foam and off odour was observed when opening the cans, and the legumes appeared to be mushy. From the remaining 68 genotypes canned in tomato sauce, seven genotypes (i.e., RV 341, RV 352, RV 344, RV 439, RV 342, TVu11986 and RV 542) were not promising for canning due to less water uptake (<80%). Water uptake, texture, size uniformity and % splits are considered as important canning quality attributes. Out of the 61 remaining genotypes that were successfully canned RV 446, RV 555, PAN 311, RV 411, RV 416, RV 542, RV 341, RV 553, RV 443, OLYIN and 34 other genotypes that had the high-water uptake, an excellent appearance without cracks or loose skins, and showing uniformity in size, shape and colour, therefore, they are recommended for canning. The positive association of canning quality traits among the cowpea genotypes revealed that these traits can be used for breeding of genotypes for canning quality. These genotypes with combined superior traits will contribute to increased cowpea production and utilization both at household and industry processing levels. The results showed that there was a variation in canning quality traits amongst the genotypes, therefore, we reject the null hypothesis. There is no standard sample used for sensory analysis in cowpeas. For future canning tests, it is recommended that a sensory panel be trained to test overall cowpea appearance, flavour (smell), colour, size and taste.

CHAPTER 5

5.1 GENERAL SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The studied 100 cowpea genotypes showed that the presence of genetic variability for the grain yield traits exists. As PCA outlined that, grain yield kg/ha, number of branches per plant and number of pods per plant contributed the most variation. This means the evaluated grain yield components was successful to characterize the levels of genetic diversity among selected cowpea genotypes. This recommends that these traits could be used in a selection index for genetic improvement of cowpea. The cowpea genotypes which performed well in yield and yield components at Syferkuil, Ga-Molepo and across locations are therefore recommended as high yielding cowpea genotypes.

The relationship between canning quality traits for the cowpea genotypes and yield components evaluated suggest that genotypes with desirable characteristics such as grain yield that ranges from 500-800 kg/ha and canning quality traits are recommended genotypes for cowpea canning .This includes genotypes such as Bechuana White the local check, RV 555, RV 558, RV 556, RV 207, RV 439, RV 553, RV 353, RV 194, IT99K-494-6, RV 341, RV 202 and 32 other genotypes. Genotypes that reveal good canning quality traits should be used for setting the standards of canned cowpea. There is also a need of researching about the nutritious value of canned cowpea, breeding of cowpea genotypes suitable for canning, cowpea canning in brine and determining canning standards of cowpea in future.

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