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Banana production in Zimbabwe: an analysis from a biotechnological pespective

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Abstract
Globally, banana (*Musa Spp.)* is ranked fourth in terms of gross value production following rice, wheat and maize and its production in Zimbabwe is ranked 57 amongst 132 producing countries. Banana farming in Zimbabwe has been found to produce more profit as compared to maize and tomatoes as far as the dollar to ton ratio is concerned and therefore can be a major contributor to the economy of Zimbabwe. The review serves to troubleshoot and addressed the unavailability of proper documentation of the currently produced banana cultivars' origin, genetic information and nutritional analysis such that germplasm conservation and improvements can be employed. The fruit requires an identification system for breeding purposes and assessments, which would then pose as an easy way of knowing characteristics, strengths and weaknesses of a particular cultivar before production. Apart from knowing the genetic characteristics of bananas, its geo-spatial distribution requires assessment. Banana production in Zimbabwe is concentrated in the warm and humid areas of Natural Region but similar climatic conditions are found in areas dotted across Zimbabwe. Using species distribution models, cultivars can be mapped to new environments mimicking the original production conditions.

Keywords: *Musa Spp*. germplasm, genetic characterization, gene pool, morphological characterization, species distribution models

Introduction

Banana production in Zimbabwe

Zimbabwe is an agriculture based economy (Maiyaki, 2010) [1]. The country has over 39 million hectares of land with 33.3 million reserved only for agriculture. According to FAO statistics, agriculture contributes only 17 % to Zimbabwe's gross domestic product (GDP), an increase from 2017's 10.46 %. Despite the low GDP percentage, agricultural activities provide employment and income for 60-70 % of the Zimbabwean population. Agriculture supplies approximately 60 % of the raw materials required by the agro-industrial sector contributing up to 40 % of the total export earnings (FAO Zimbabwe, 2018) [2]. Mutenga, (2019) [3], supported these statistics highlighting that banana production amongst tobacco, cotton, sugar, horticulture and tea, collectively contributes 40 % by value of national export to the country's GDP.

Generally, bananas grow very well in areas with an optimal mean monthly temperature of 27 ° C and require a lowest mean annual temperature of 12-13 ° C (Tushemereirwe 2001) [4]. The plant has a high affinity for water, requiring approximately 25 mm per week for minimal optimal growth. The annual rainfall required by bananas is in the range of 1500-2500 mm but with very good management or irrigation schemes, they can grow well in areas with a mean annual rainfall of 1200 mm and below. These conditions are the major reason why banana production is high in the Eastern Highlands, in Zimbabwe where such conditions can be met. Banana production in Zimbabwe has proved great potential in becoming a major income generating crop as highlighted by Chaipa (2015) [5], Murendo *et al*. (2018) [6], Draft (2018) [7], and Mutenga (2019) [3]. Banana production in Zimbabwe has proved to be more viable compared to commonly grown field and horticultural crops (Matimaire, 2018) [8, 11]. Findings from research surveys indicated that 1 hectare of tomato, for example, yields 15,000 kg, and with the average price of US $0.50 cents per kilogram, US$7500/ ha can be generated (ZFU, 2019) [9]. Maize, a staple field crop has an average yield of 5 tons per hectare and a price of $300 per ton, thus capable of generatingUS1500/ ha (ZFU, 2017) [10]. Banana on the other hand, the 45 ton/ ha average yield has a market value of $550 per ton (Matimaire, 2018) [8, 11], which converts to USD 24 750 (ZFU, 2017) [10]. Being a perennial crop, banana, like all the other perennials, banana offers food security making it a favorable crop for developing countries.

Production in Zimbabwe is being conducted on both large and small scale and on international rankings; production in Zimbabwe is ranked 21 in Africa and 57 in the world among 135 producing countries. Surveys of banana production showed that production in Zimbabwe is mainly done by mainly, small holder farmers (Chaipa, 2015, Murendo *et al*., 2018, Dube, 2018) [5, 6] under contract system (Murendo *et al*., 2018) [6]. Large scale banana producers in Zimbabwe large estates that include, Matanuska, Rosywood Mahemu, Roscorn Estate, Tagumi Estate and Rift Valley in the Eastern District of the country (Chidavaenzi, 2014) [12]. From 2007 to 2011 banana production average output hovered around 1 million metric tons per year, but a sharp decline, attributed to high nematode infestation, was noticed in the year 2012 (Mutenga, 2019) [3]. An increase in cropped land area between 2016 and 2017 failed to correspond to output and yield per hectare fell from an average of 50 metric tons per hectare to 0.6 metric tons per hectare (Mutenga, 2019) [3].

The paper highlights *Musa Spp*. production in Zimbabwe per sector, areas and scale of production, as well as germplasm improvement efforts thus far. To the best of the researcher's knowledge, there is no comprehensive research done in Zimbabwe on the genetic, morphological or nutritional analysis of the locally produced cultivars as well as setting up gene pools for banana germplasm conservation therefore this paper serves as an initial step towards achieving these goals.

Constraints of Banana Production in Zimbabwe

The economic meltdown in Zimbabwe resulted in the reduction and complete halt of most of the operations in the small holder irrigation schemes (Union, 2019) [13]. This has been due to high cost of maintenance versus poor output markets, low liquidity amongst small holder farmers (Union, 2019) [13]. Banana yield levels realized by small holder farmers in Zimbabwe are generally low and do not bring high revenues due to suboptimal timing of harvest. Farmers are either not technically equipped or have insufficient resources to produce high yield at the right time. They generally lack important production skills, including pests management practices, improved plant nutrition, irrigation and soil health practices (Chitamba *et al*., 2016, Abdoulaye *et al*., 2014) [14, 56]. Chaipa (2015) [5], highlighted that small holder farmers who operate under contract farming are greatly affected by pricing and market opportunities. The Food and Agriculture Organization of the United Nations (FAO) initially implemented contract farming project in Zimbabwe in the 2010/11 agricultural season (FAO, 2013). The Sentinel Survey, (Murendo *et al*., 2018) [6], revealed that some banana growers under contracts are provided with loans payable after 6 months at an interest rate of 12 %. With such problems as market price fluctuation, poor road networks, load shedding and old irrigation equipment amongst other factors, banana growers fail to sustain effective production and as a result, fail to repay the loans. Contracted growers are required to also provide collateral in form of land, money or group membership status and failure to provide also results in farmers being unable to access credit for farming (Murendo *et al*., 2018) [6]. Zim-AIDED (2017) [16], however highlighted the help provided by Zim-AIDED to Honde Valley farmers towards good production practices and higher yield. Poor agronomic practices, poor soil fertility and inadequate pest control are huge factors for poor a yield (Chitamba *et al*., 2016) [14, 56]. Plant parasitic nematodes hinder banana production causing yield loss of up to a minimum of 30 % and cumulative losses due to reduction in bunch weight may reach as far as 75 % if effective control measures are not implemented (Murendo *et al*., 2018) [6]. Tissue culture technology should be effectively used to produce clean pest free planting material. The unpredictability of natural disasters may contribute to difficulties in banana production. The Cyclone Idai of 2019, hit hard on banana production in Eastern District of Zimbabwe (Zinyuke, 2020a) [17]. The produce, planting material, fertile soils, market and transportation networks were destroyed by the national disaster and, as the farmers were still recovering from the cyclone, the Covid- 19 pandemic surfaced destroying the hopes of many famers (Zinyuke, 2020b) [18].

Banana Repositories

According to (Ruas *et al*., 2018) [19], the collection, conservation, characterization and breeding of plants and their wild relatives contribute to the preservation of biological diversity, and are essential components in ensuring food security. Gene banks are repositories where biological materials are collected, stored, catalogued and made available for redistribution. Their role is to preserve genetic diversity for future research and plant breeding (Africa, 2018).

PGRFA (2007) [20] indicated that the most outstanding constraints in the use of plant genetic resources is the lack of publicly available evaluation data for most banana accessions and the capacity to manage the data. Researchers and breeders require such information for the selection of germplasm and further studies as highlighted by (Musa Net, 2006) [21]. INIBAP, (2006) highlighted that there are as many as 1,000 different banana cultivars and possibly up to 70 wild species in the world. Currently 56 institutes worldwide are conserving over 15,000 accessions that are made available for use by breeders, farmers, researchers and consumers. Major 'players' in the banana industry such as Latin America, Asia and the Caribbean Islands have managed to characterize their banana plants, a factor which has contributed to massive and successful production as indicated by Mattos *et al*. (2010) [24, 26, 47], Mukunthakumar *et al*. (2013) [24], Sunaryo *et al*. (2017) [25] and Mattos *et al*. (2010b) [23, 26, 47]. In Africa, countries such as Nigeria, Uganda and Kenya amongst other producing countries have characterized their lines and a few have managed to introduce GM banana for better yield (Reuben *et al*., 2016, Qaim, 1999) [27, 28].

Zimbabwe does not have a *Musa Spp*. gene bank but rather it has production areas and tissue culture facilities (TRB, 2020, Dube, 2018) [30]. The Chiredzi Research station, an arm of the Department of Research and Specialist Service (DRSS), harbors banana germplasm that can be included in gene bank. The coffee research station in Chipinge also has an established ex situ site of *Musa Spp* that can serve as a gene bank. Apart from these, most estates and plantation which include the Honde valley and Chipinge plantations, the Nyanyadzi, Middle Sabi, Mupangwe irrigation schemes, Njikizana and the Baguti plantation to mention but a few, are production sites as well as vital sources of germplasm for the establishment of *Musa spp* gene banks.

Methodology

Database Search

Meta-analysis allows quantitative analysis of experimental results reported by other authors and the estimations of effective size. The literature for this review was obtained through literature search on peer-reviewed publications and also greys literature. The process is highlighted by fig 1. For searches that could not yield results from the internet, information was gathered through phone calls to different institutions and banana plantation sites. Peer-reviewed articles from databases such as PubMed, NCBI, Directory of Open Access Journals (DOAJ), Web of Science, Science Direct, SciELO, BMC, Research-gate and Academia were used. For a wider scope of information, grey literature searches were obtained using search engines such as Google Scholar and FAO. The literature that was used dated prior to 2020 and since research of bananas is quite extensive, constructs were used both as individual words and in their combinations and these were, [world] +[Africa] + [Zimbabwe]+[*Musa spp*. genetic characterization]+ [*Musa spp*. Improvement]+[*Musa spp*. Tissue culture]+[virus indexing]+ *Musa spp*. morphological and agronomic characterization]+[nutritional and chemical composition of *Musa spp.*]+ [*Musa spp.* breeding] + [species modeling] + [GIS in species modeling]. The resultant publications were of no exact time limits as relevance was of the greatest priority.

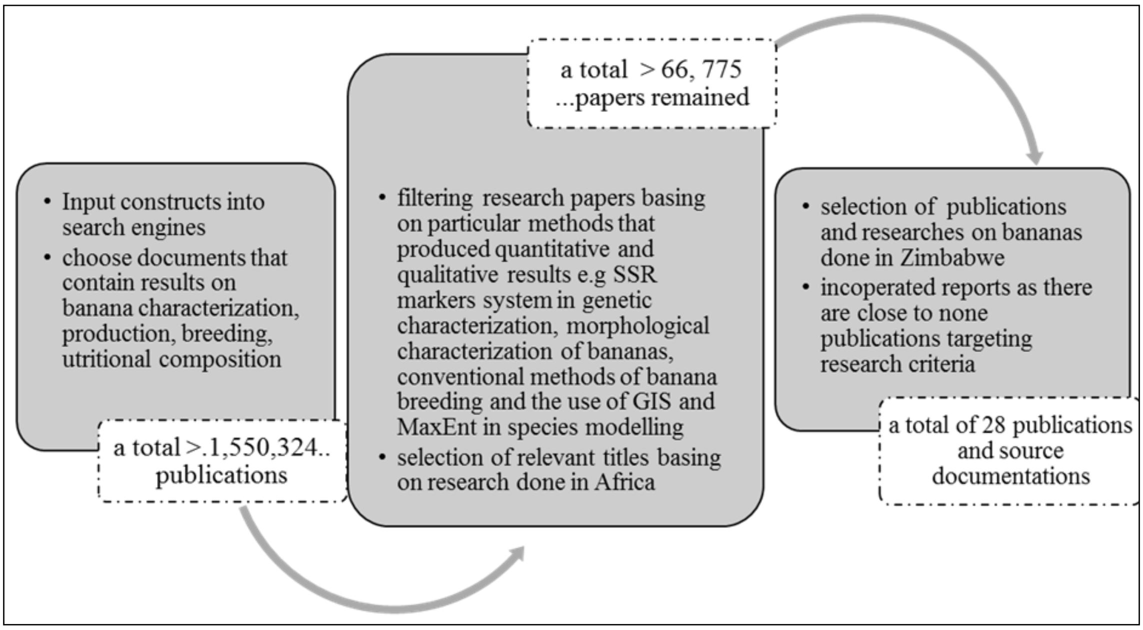

Fig 1: The schematic flow diagram of the literature database search process (Source: Author’s own)

Banana Identification

Just like how citizens or non-citizens undergo registration and identification card collection in a nation, plant species need identification and registration. Identifying how a plant can qualify to be called native or foreign/alien in a particular region is a highly debatable topic amongst botanist and word play has more often than not come in play during such circumstances (Pysek, 1994) [31]. Time factor has, over the years, been considered to be of paramount importance in an attempt to explain the stage at which a plant species can be classified as a native species, but to some extend it has been found to be of no scientific basis (Ansong *et al*., 2014). According to Pysek (1994) [31] plants occurring in regions where they are not native have been termed aliens, exotics, introduced, translocated, neophytes, naturalized, invaders amongst other names. Webb (1985) [32] suggested eight criteria which may be employed in defining the status of plants within a country which are fossil evidence, historical evidence, habitat and geographical distribution, frequency of known naturalization, genetic diversity, and reproductive pattern and possible means of introduction. In reference to Webb’s criteria’s, Pysek (1994) [31] went on to discover that only fossil and historical evidence can, without being scanty, prove the actual status of a plant as supported by Belnap *et al*., (2012) [33] and Smith, (1986) [34]. Determination of the native-ness of a plant species can therefore be guided by three factors which are: i) species that arrived before the neolithic period should be considered native even if introduced by man ii) species that became extinct during the last glacial and were re-introduced by man cannot be native and iii) the species that arrived in the area in recent years by means independent of human activities should be regarded as native.

A majority of researchers concur that these are a population of plants that have been cultivated for many generations in a certain region, being shaped by the biotic and abiotic stresses, crop management, seed handling and also eating preferences (Karamura *et al*., 2016; Introduction, (2009), Bioscience for Farming in Africa, (2016), Fischbeck, 2013) [35, 36, 37]. Most of the bananas being grown by local farmers in Zimbabwe are landraces, that according to Breseghello & Coelho (2013) [38], constitute a dynamic genetic entities that are continuously changing and, in some cases, showing quick changes when they are subjected to different climatic regions. Using Pysek's, (1994) [31] methods of giving status to species, the majority of bananas being produced in Zimbabwe are of the 'alien' status and have naturalized over the years. It is important therefore to document and distinguish these species as to which are of the native or alien status. This is vital step towards cataloguing, characterizing and target improving the banana collection.

The Rosywood Mahemu Estate for example, introduced Du Roi's, sourced from South African Laboratories. These are agronomically superior cultivars which are under production in Zimbabwe even though they are not of Zimbabwean origin. Plantations in the country produce cultivars that have naturalized over the years and have adapted to the Zimbabwean climate. Chipinge urban and the surrounding areas (GPS co-ordinate -20.190558, 32.626010) harbor a massive sight of what can be referred to as "invasive" banana species. Among them is a variety which constitutes huge plant that gives short, starchy golden fingers, locally called *Nzarayapera.* Such sites constitute a reservoir of unexplored germ lines, which can be used for further *Musa spp* improvement.

Morpho-Agronomic Identification/Characterization

Genus *Musa* was firstly named by Carl Linnaeus in 1753, using the Linnaean binomial system and up until the 1940's different types of bananas and plantains were given Linnaeus' binomial names. The nomenclature was later abandoned for an alternate genome-based system (Cheesman, 1947) [39]. Classification of *Musa* species based on the morphological traits was firstly published in 1887 basing on the flesh of the fruit, inflorescence and the fruit size (Sagot., 1887). It was only five years later that Baker (1893), firstly designated the *Musa* sections. The process was carried out for over a decade until *Musa* was designated into five (5) sections namely *Emusa, Rhodochlamys, Callimusa, Australimusa* and the *Ingentimusa*. This process was pioneered by (Cheesman, 1947) [39] basing on the morphological features and the chromosome number. The introduction of genomics in the 21st century lead to the discovery that suggested that the five sections were not monophyletic, hence the groups were re-grouped into two classes, but there are still undetermined banana species to date.

Bananas have three ploidy levels in different combinations of the A (M. *acuminata*) and B (B. *balbisiana*) genomes (Jesus *et al*., 2009) [40]. America & Montcel (2008) [41], described bananas as herbaceous plants which can confer the aspect of a tree. The plant has a pseudo-stem which is formed by the concentric assembly of leaf sheaths, crowned by a rosette of large oblong to elliptic leaves. From a study by Allen *et al*, (1988), the leaves of a banana plant are produced successively until the inflorescence is cast. Wide morphological variability has been observed in the plant's inflorescence type, size, fruit orientation apex shape, pseudo-stem and fruit color (Vuylsteke *et al*., 1995) [42]. Cultivars differ in phenotype due to genetics and the environmental factors which is why the same Chinese Cavendish from the Honde Valley can be phenotypically different when grown in the Middle Sabi region of Zimbabwe. Characterization of banana plants based on morphology requires that particular plant descriptors be used. With reference to IPGRI-INIBAP, (1997) [22], descriptors are of different types and it is the *characterization* descriptors that enable quick discrimination between phenotypes. The scoring methods of qualitative and quantitative data can also be presented differently in accordance to the type of system being used. Morphological descriptors should be easily scored and must have a constant phenotypic expression in all environments that is low environmental influence and high heritability therefore strong and important descriptors are those that are not easily affected by the environment (Ortiz, 1997) [43]. Descriptors that possess low genotype by environment interaction are more important for agronomic evaluation and for classification. Ortiz, (1997) [43], went on to explain that the most important qualitative morphological descriptors are the male bud, hermaphrodite flower, pseudo stem pigment, foliage, petiole and male flower, pseudo stem waxiness and leaf orientation. The important quantitative morphological descriptors are the pseudo stem girth, height, fruit number and size. The researcher also highlighted that the quantitative descriptors selected generally have high heritability (>0.8), high repeatability (>2.0) and low coefficient of variation (9-15%) with the exception of height therefore can be regarded as morphological traits of importance in banana plants. Detailed morphological characterization is accompanied by the collection of passport data for each of the cultivars and there after descriptor images are taken for comparison purposes (Sunaryo *et al*., 2017) [25]. According to Ruas *et al*., (2018) [19], it is deemed wise to consult with local agricultural experts on the varieties that are present within a particular location and to have photographic evidence of each, because vernacular names may differ with location therefore duplication can be avoided. Difficulties in the identification of genotypes that are closely related using morphological descriptors has increased with the development of new varieties and since these descriptors are influenced by the environment some can only be evaluated during the late stages of development demanding time and physical space for evaluation (Jesus *et al*., 2009) [40]. Molecular characterization has therefore come to aid in distinguishing closely related cultivars.

Literature search however did not yield any record of morphological characterization of banana plants in Zimbabwe unlike other African countries like Kenya and Uganda that have managed to characterize their landraces and commercially produced bananas (Commission of the European Communities., 1971, Vuylsteke *et al*., 1995, Njuguna *et al*., 2008, Karamura *et al*., 2016) [44, 42, 45, 35]. However, the Chiredzi Research Station, an arm of the DRSS, is said to be carrying out the banana characterization process as well as micro-propagating the plantlets.

Genetic Identification/Characterization

Genetic characterization allows the identification of duplicates, estimate the extent of accessions of particular genetic diversity and also determine the phylogenetic relationships thereby allowing for mapping out origins of the cultivars (Park *et al*., 2009) [46]. The morphological, agronomical and physicochemical characterization of the banana fruit allied with estimates of genetic variability assessed using molecular markers is of paramount importance in the selection of progenitors in order to explore heterotic characteristics and breed bananas (Mattos *et al*., 2010) [23, 26, 47]. Molecular markers have been used extensively for germplasm characterization. For example, assessment of genetic diversity within the Musa genotypes has been done using random amplified polymorphic DNA markers (RAPD's) with over a thousand research publications, (Gubbuk *et al*., 2004, Mukunthakumar *et al*., 2013, Jesus *et al*., 2009, Azad *et al*., 2016) [48, 24, 40], using restriction fragmentation length polymorphism markers (RFLPs), (Beata & Andrzej, 2011) [50], microsatellites or simple sequence repeats (SSR), (Oriero *et al*., 2006, Karamura *et al*., 2016, Mattos *et al*., 2010) [23, 26, 47], fragment length polymorphism markers (AFLPs), (El-khishin *et al*., 2009), and diversity array technology markers (DArTs), (Martin *et al*., 2017, Beata & Andrzej, 2011, Paridah *et al*., 2016) [53, 50, 54] each method having its own pros and cons. Due to modern DNA sequencing technology and bioinformatics tools, the sequencing and assembly of genomes for economically important crops like bananas are becoming common hence understanding the genetic make-up allows for the detection of regions that could represent polymorphism associated with agronomic traits. Heslop-Harrison (2007) [55], explained that the knowledge of genomics and understanding of the crop allows for domestication, involving interactions of plant breeders and genomic scientists to then design the characteristics required from a banana cultivar and consider how to produce the ideal cultivar.

Nutritional Composition

Academia journals alone showed over 50,000 journals worldwide that explained the nutritional composition of bananas and in some, plantains. Literature reviewed that bananas may vary in their genetic characteristics but rarely do they give a huge difference in their nutritional composition (Pareek, 2015, Awedem *et al*., 2015, Ashok kumar *et al*., 2018) [57, 58, 59]. Ashokkumar *et al*., (2018) [59] showed that carotenoid rich cultivars were identified by a number of researchers, however, limited knowledge is available on the micronutrient composition differences between banana and plantains.

Bananas are vegetative parthenocarpic and develop their fruit from the inferior ovary of the female flower. It is during the development of the fruit, that the pulp to peel ratio increases from1:1 to 4:1 depending on the variety and maturity at harvest. It is at the storage ripening stage that the starch decreases from about 22% to 1% and at the same time soluble sugars increases from 1 to 20% (Forster *et al*., 2003). The hydrolysis of starch at this stage results in the increase in pulp to peel ratio. The fruit is rich in nutrients, starch, sugar, vitamin A and C, potassium, sodium, calcium and magnesium (Ashok kumar *et al*., 2018) [59]. Studies in Africa and South America revealed the relationship between yellow to orange flesh coloration and higher carotenoid content. According to Fungo & Pillay, (2011) [61], nutritional disorders due to inadequate intake of vitamin A, iron and zinc in East Africa and South Asia region are unusually high and interventions to alleviate these deficiencies rely on supplementation and food fortification programs which sometimes do not reach all of the affected people. Suitable solutions therefore can be developed through linking the agriculture, nutrition and health departments. Studies done by Mvumi, (2018) [62] in Zimbabwe on the post-harvest handling of bananas indicated revealed effort by a local company, Greenit Diversified Group, in producing gluten-free banana flour from unripe bananas (Mhlanga, 2018) [63]. Rwizi (2016) [64] reported banana entrepreneurial skills implementation in the Manicaland Province of Zimbabwe through the Zimbabwe Farmers Union's Young Farmers' Innovation Lab Program, in conjunction with the University of Zimbabwe (UZ), Harare Institute of Technology (HIT) and Africa University (AU). The young farmers process and deliver dry bananas to supermarkets. Such markets allow for large scale production of food fortification using the nutrients from identified banana cultivars. According to Vengesa, (2020), some few farmers in Zimbabwe produce flour from both peeled and unpeeled green bananas, stock-feed from fiber of the pseudo-stem and also banana pills.

Banana Germplasm Improvement

Plant breeding is a science driven process of developing new plant varieties. There is a general consensus amongst researchers and breeders that the process involves the creation of multi-generation genetically diverse populations on which selection is practiced to create adapted plants with new combinations of specific desired traits (NAPB, 2019). According to Breseghello & Coelho, (2013) [38], the challenge of plant breeding resides in improving all of the desired traits of interest simultaneously. Improving the desired traits simultaneously is mainly hindered by the genetic correlations between traits which is caused by genes with pleiotropic effects, physical linkage between genes in the chromosomes and the population genetic structure amongst other factors.. Breseghello & Coelho, (2013) [38], further explained that the selection for a single trait changes the correlated traits, sometimes in the desired direction whilst in the other times it goes in an unfavorable direction. For this reason, selection therefore can lead to unanticipated changes which are normally within the range that is normally observed in the crop and thus assumed to pose no risk to consumers or the environment.

Over the years, numerous research programs have come up with several methods for the improvement of bananas and these include, conventional breeding, marker assisted selection, genetic engineering, induced mutation breeding, protoplast fusion and selecting some clonal variants. Amah *et al*., (2018) [66] highlighted that the marker-assisted selection technique of breeding is becoming more popular in the breeder's community as it offers the possibility of significantly reducing the amount of time required for banana improvement. However, despite its potential to enhance and hasten banana improvement, the application of molecular markers remains largely unexplored because of the intricate genetics, high genetic similarity and high polyploidy nature of bananas as well as the difficulty in developing segregating populations attributable to either male or female sterility (Amah *et al*., 2018) [66].

Amah *et al*. (2018) [66] explained that productivity, diseases resistance and yield have been priorities of banana breeding with an emphasis on simply inherited agronomic traits. The nutritional qualities however have been secondary due to limited resources, knowledge on genetics of these traits and also the overwhelming dire impacts associated with major diseases of banana. However, the recent advances in banana genomics and increased awareness of the nutritional importance of bio-fortification being surfaced by The Banana Genome Hub, developed by the French Agricultural Research Center for International Development (CIRAD), and the Biodiversity International proves that the interest in this area has risen.

Banana breeding is complicated by parthenocarpy, low fertility, low seed viability, polyploidy and associated irregular meiotic behavior, long generation times, diverse genome configuration and a narrow genetic base (Amah *et al*., 2018) [66]. The breeding cycle of bananas from crossing to release of a new variety takes up to 15 years as alluded by Pillay & Tenkouano (2011), but despite the long and complex breeding cycle, hybrids have successfully been developed containing diverse agronomic and disease resistance traits. According to an article from Kenya (Rateng', 2018) [68], Scientists in Nairobi have demonstrated that through genomic prediction models, that the time frame for banana breeding can be reduced to less than 15 year.

Literature in the public domain did not yield much as far as biotechnological applications to bananas are concerned which highlights the need for a board in Zimbabwe that specifically targets banana crop. Virus indexing, tissue culture and characterization of the banana plants are the future of the banana industry and therefore institutions such as the Chiredzi and Marondera Research Stations may need to focus on these techniques to help improve banana production. Besides targeting bio-fortification, molecular markers and other biotechnological methods can be applied to locally grown banana to improve drought resistance. As in the case of maize varieties that were bred to suit the different agroecological zones of Zimbabwe, bananas can also be bred for a similar objective. Breeding can therefore be used as an expansion tool of banana production in such semi-arid parts of Zimbabwe.

Distribution Patterns of Musa spp. In Zimbabwe

In Zimbabwe, extensive banana, Manicaland province produced 81% (396 975 tons) of the total annual output during the 2017/ 18 cropping season, with the balance of 19 % (8 800 tons) coming from the rest of the country. Region 1 is the most favored banana producing area due to high rainfall. Bananas grow well in the tropical climate, which is found mainly in the Manicaland province of the region 1 of Zimbabwe. Findings from recent surveys (Matimaire, 2018a) [8, 11], have shown that vast hectares of land in the Eastern Highlands have a potential of producing over 32 550 tons of bananas per annum, but only 1600 hectares are currently under banana production and Chipinge alone has 1130 hectarage available for production but only 100 hectares are being utilized. Region 1 harbors plantations in the low-lying areas such as Rusitu Valley, Honde Valley, Burma Valley, Chipinge, Chibuwe and Mutema (Chitamba, 2016) [14, 56]. More than 4,000 people in Honde Valley alone depend on bananas for more than a third of their income (Lacey, 2018). In 2017 alone, the country exported 2000 tons to neighboring South Africa and Zambia which was 5% of the total production whilst the remaining 34 975 tons were sold locally. Burma valley produced 36%, Honde Valley 11%, Rusitu 14% whilst Mutema and Chibuwe combined produced 15% (Tsiko, 2018; Matimaire, 2018) [8, 11].

Apart from the Eastern Highlands, other parts of the country produce bananas on a smaller scale. Production in other regions of the country is not as large as that of region 1 although with irrigation schemes the plantations have successfully yielded quality fruits. The Middle Sabi's farm 32 has managed to produce banana on over 160 hectares of land positively transforming lives of A2 farmers (Mutanda, 2020). Mutanda, (2020), reported that it was through the partnering of the Farm with a private contractor, the MacCarter Bananas, that great success in production was noted. Statistical results of the reviewed studies showed that banana yield is highly depended on climate and rainfalls (Sabiiti *et al*., 2016). This however does not have to be the end of the story as cultivar can be mapped to new areas where they have a higher probability of thriving. Cultivar mapping is a technique that uses reviewed cultivar characteristics and performance within a locality and extrapolating the production of respective cultivars to new locations with similar climatic conditions. The mapping procedure therefore extends the banana production area, increasing production yield. This process can be aided through banana breeding programs thereby producing tailor-made cultivars that suit particular climatic conditions.

Conclusion

Zimbabwe is a rich country in terms of mineral availability; however, the agriculture sector provides more for the people than any other sector. This therefore makes agriculture the backbone of Zimbabwe. In these economic hardships, the majority tend to backyard farming for survival therefore there is need to enhance and pay more attention to the sector. With reference to a report by (Zim-AIDED, 2017) [16], the USAID-funded Zimbabwe Agricultural Income and Employment Development (Zim-AIED) engaged farmers in the Honde Valley to employ good agricultural practices, open access to formal markets and promote high-value tissue-cultured bananas. This gesture as a result increased the yield from 4 tons per hectare to 20 tons per hectare. It is these kinds of programs that help boost and improve the livelihood of the Zimbabwean people. Literature research has revealed that little has been achieved on bananas in Zimbabwe and there is a large gap in comparison to other crops and therefore engaging and implementing researches can help extend production as well as provide a resilient crop across the country. Towards satisfactory analysis of the *Musa spp*. production in Zimbabwe, a germplasm collection needs to be created in order for accessions to be closely monitored to consider possible gene-environment influence on the phenotype. As such, multi-locational gene banks have to be established across the geographical regions of the Zimbabwe. By so doing, accurate multifactorial assessments of genetic lines are made for the betterment of banana production in the country.

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