Ethiop. J. Agric. Sci. 31(3) 1-25 (2021)

Evaluation of Banana (*Musa* spp.) Cultivars for Growth, Yield and Fruit Quality

Asmare Dagnew[1], Wegayehu Assefa[1], Girma Kebede[1], Lemma Ayele[1], Tewodros Mulualem[2], Awoke Mensa[3], Dereje Kenbon[4], Endriyas Gabrekirstos[1], Masresha Minuye[1], Abraham Alemu[2], Jemal Beker[4] and Mesfin Seyoum[2]

[1]*Melkassa Agricultural Research Center, P.O. Box 436, Adama, Ethiopia*
[2]*Jimma Agricultural Research Center, P.O. Box 192, Jimma, Ethiopia*
[3]*Arba Minch Agricultural Research Center, P.O. Box 2228, Arba Minch, Ethiopia*
[4]*Tepi Agricultural Research Center, P.O. Box 34, Tepi, Ethiopia;*
Corresponding author e-mail address: asmaredm@gmail.com

አህፅሮት

ይህ ጥናት የተካሄደው ዘጠኝ (አራት ከውጪ የገቡ እና አምስት ከሀገር ውስጥ የተሰበሰቡ) የሙዝ ዝርያዎችና አንድ በመመረት ላይ የሚገኝ የማወዳደሪያ ዝርያ በአራት የተለያዩ የሀገሪቱ አካባቢዎች ለሁለት የምርት ዓመታት ያላቸውን የዕድገት፣ ምርት እና ጥራት ሁኔታ ለመገምገም ነበር፡፡ በእያንዳንዱ የሙከራ ቦታ እያንዳንዱ ዝርያ ሶስት ጊዜ በተለያየ ረድፍ ተተክሎ አስፈላጊው እንክብካቤ እየተደረገላቸው ተገምግመዋል፡፡ የተገኘው መረጃ እንደሚያመለክተው በተክል ቁመት፣ ተተክሎ ማበብ እስከሚጀምር እና ተተክሎ ምርት እስከሚደርስ በሚወስደው ጊዜ፣ በአምባዛ (ዘለላ) ክብደት፣ በፍሬ ውፍረት፣ በፍሬ ርዝመት፣ በፍሬ ክብደት፣ በምርት መጠን፣ በልጣጭ ውፍረት፣ የሚበላው ክፍል ከልጣጩ ጋር ባለው ጥምርታ፣ በሚሟሙ ጠጣሮች መጠን፣ በአሲድ መጠን፣ በፒኤች፣ በፍሬ እርጥበት እና በፍሬ የአመድ ይዘት መጠን በዝርያዎች መካከል ከፍተኛ ልዩነት ተመዝግቧል፡ እንደአጠቃላይ ዝርያዎቹ አጭርና ወፍራም ተክል (ግንድ) ነበራቸው፡፡ ዝርያዎቹ ተተክለው እስኪያብቡ ከ243.8 እስከ 316.8 ቀናት እንዲሁም ተተክለው ምርታቸው እስኪሰበሰብ ከ374.4 እስከ 446.7 ቀናት ወስዶባቸዋል፡፡ የሁሉም የሙከራ አካባቢዎች አማካይ የምርት መጠን ከ43.67 እስከ 52.46 ቶን በሄክታር ሆኖ ተመዝግቧል፡፡ አምስት ዝርያዎች ከማወዳደሪያው ዝርያ አኳያ ተወዳዳሪ (ተመሳሳይ) የሆነ ምርት አስመዝግበዋል፡፡ በስሜት ህዋሳት አማካኝነት በተካሄደ የትንተና መረጃ መሰረት ሁሉም ዝርያዎች በቀማሾች ዘንድ ተመራጭ ሆነዋል፡፡ ከማወዳደሪያ ዝርያው አኳያ እጩ ዝርያዎች ከፍተኛ የሚሟሙ ጠጣሮች መጠን፣ ፎስፎረስ እና ፖታሲየም እንዲሁም አነስተኛ የአሲድ መጠን አስመዝግበዋል፡፡ የፍሬ እርጥበትና የአመድ ይዘት መጠን እንደቅደምተከተላቸው ከ71.53 እስከ 76.56 በመቶ እና ከ2.5 እስከ 3.36 በመቶ ሆኖ ተመዝግቧል፡፡ የዕድገት፣ የምርትና የጥራት መረጃዎችን መሰረት በማድረግ ‘ሌዲ ፊንገር’ እና ‘ድንኬ-1’ የተባሉት ዝርያዎች በዋና ዋና የሙዝ አምራች አካባቢዎች ወደምርት እንዲገቡ ምክር ተሰጥቷል፡፡

Abstract

A study was conducted to evaluate four introduced and five local banana cultivars with a check variety for growth, yield and quality performances at four locations for two crop cycles. The experiment was laid out in a randomized complete block design with three replications. The results revealed significant varietal differences in plant height, days to shooting, time from planting to harvest, bunch weight, finger diameter, length and weight, yield, peel thickness, pulp-to-peel ratio, soluble solids, titratable acidity, pH, moisture and ash contents. The cultivars had generally short and thick plants. Cultivars took from 243.8 to 316.8 days to flowering while from 374.4 to 446.7 days to first harvest. The yield ranged from 43.67 to 52.46 t ha^{-1}. Five cultivars had comparable yields to the check. The sensory results indicated that all the cultivars were generally preferred. The candidate cultivars recorded higher soluble solids, phosphorus and potassium, but lower titratable acidity than the check. The moisture and ash contents ranged from 71.53 to 76.56% and 2.50 to

3.36%, respectively. Considering the growth and yield performances as well as fruit physicochemical and sensory characteristics, 'Lady Finger' and 'Dinke-1' are recommended for production in the major banana growing areas of Ethiopia.

Keywords: Banana, growth, yield, quality, Ethiopia

Introduction

Bananas (*Musa* spp.) are important fruits in the tropics and subtropics. Ethiopia is among the tropical countries where its vast arable land is suitable for banana cultivation. Banana ranks first among fruit crops in area coverage (67,387 ha) and production (539,443 t) (FAOSTAT, 2019). The bulk of banana is produced in traditional agricultural system mainly for home consumption and to supply to local markets (Dawit and Asmare, 2008; Asmare and Derbew, 2013). Moreover, banana plays an important socioeconomic role in food security and income generation of the rural communities in the country (Natnael, 2016). It also provides both on-farm and off-farm employment opportunities (Asmare and Derbew, 2013).

Despite its importance, the national average yield of banana is estimated at 8.0 t ha^{-1}, which is far less than the world average (22.6 t ha^{-1}) (FAOSTAT, 2019). The low productivity of banana is mainly attributed to limited provision of production technologies such as improved varieties and crop management practices, diseases and insect pests, poor postharvest handling and marketing, and insufficient support from the extension system (Asmare and Derbew, 2013; Natnael, 2016). Over the years, eight dessert and four cooking banana varieties were registered and made available for production (MoARD, 2006). However, these varieties have not yet met the ever-growing demand for improved banana varieties that are suitable for different agro-ecological conditions across the country. Thus, introduction of improved cultivars from foreign sources and collection of superior genotypes from local sources, and their evaluation and adoption was of paramount importance to increase productivity and production of banana in Ethiopia.

Materials and Methods

Description of the study areas

A multi-locational banana variety trial was conducted at Melkassa, Jimma, Tepi and Arba Minch agricultural research centers that have different agro-ecological conditions (Table 1) from July 2015 to June 2017.

Table 1. Agro-ecological descriptions of the study sites

Locations	Geographic Coordinates		Altitude (masl)	Annual Rainfall (mm)	Mean Temperature (°C)		Soil Type
	Latitude	Longitude			Minimum	Maximum	
Melkassa	8°24' N	39°21' E	1550	763	14.0	28.4	Andosol (Sandy loam)
Jimma	7°46' N	36°00' E	1753	1561	9.0	28.0	Eutric Nitosols (Reddish brown)
Tepi	7°30' N	35°18' E	1200	1522	15.0	30.0	Nitosols (Sandy clay loam)
Arba Minch	6°05' N	37°33' E	1170	930	16.0	30.5	Black sandy loam

masl = meters above sea level

Experimental materials and design

Twenty-nine banana cultivars sourced from the Bioversity International and eight locally collected banana genotypes were evaluated at Melkassa Agricultural Research Center from 2010 to 2014. Based on the preliminary results, 10 cultivars, i.e., four of the introduced ('Chinese Dwarf' (AAA), 'Lady Finger' (AA), 'Parecido al Rey' (AAA) and 'Williams Hybrid' (AAA)) and five local ('Ambo-2', 'Ambo-3', 'Amboweha Selle-3', 'Dinke-1' and 'Dinke-2') were selected and along with the standard check ('Williams-I') were evaluated at four sites (Table 1). The experiment was laid out in a randomized complete block design with three replications. Eight plants of each cultivar were planted on each plot. The plants were spaced at 2.5m x 2.5m (Seifu, 1999), providing a population of 1600 plants ha^{-1} in the first year, and three different aged plants (parent, first ratoon and second ratoon) per mat in the remaining two years. Supplementary irrigation was applied during dry period through furrow. Diammonium phosphate and urea were broadcasted by hand, each at the rate of 300g per mat per year in three equal splits. Weeds were controlled by hand hoeing.

Data collection

Data on plant growth, yield, and fruit quality characteristics were collected for two crop cycles, and averaged.

Growth parameters

The growth parameters measured were plant height, pseudostem girth, number of functional leaves per plant, days to shooting, days from shooting to harvest, and days from planting to harvest. Plant height was measured from ground level to the neck of the inflorescence at shooting, while pseudostem girth was measured at 30cm above the ground using a measuring tape at harvest. The number of functional leaves per plant was determined by counting all leaves with at least 50% green area at flowering stage (Orjeda, 1998).

Yield and yield components

The traits evaluated included bunch weight, number of hands per bunch, number of fingers per hand, fruit length, fruit diameter, fruit weight, and marketable and total fruit yields. Bunch and finger weights were measured using balances. Fruit length was measured using a measuring tape while fruit diameter was measured at the middle of each fruit, perpendicular to its large axis, with a digital caliper (Orjeda, 1998; Aquino *et al.*, 2017). Marketable and total fruit yields were estimated from plot yields and expressed as t ha^{-1} per year.

Sensory and physicochemical characteristics of fruits

These characteristics of the cultivars were determined to establish their quality profile. Sensory attributes and consumer acceptability of fruits including color, aroma, texture, taste, peelability and general acceptability were scored by panelists based on a five-point scale with 1 = poor and 5 = excellent of a given attribute. Peel thickness was measured by a digital caliper. Peel and pulp weights were determined by separating the peel and the pulp by hand peeling and weighing the peel and pulp separately. Pulp-to-peel ratio was obtained by dividing the pulp weight by the peel weight. The chemical variables measured were total soluble solids (TSS), total titratable acidity (TTA) and pH. TSS was estimated using a hand refractometer (Model 9099, Atago, Japan) and the results obtained were expressed in °Brix. TTA was estimated by titrating 0.01M NaOH against 10ml of filtered juice using phenolphthalein indicator, and the values were expressed in the amount of malic acid in mg/100g of pulp (Horwitz, 2000). The ratio of TSS to TTA was determined by dividing TSS value by TTA value. The pH of fresh fruits was estimated using a digital pH-meter. Moisture (%) was determined using oven drying method (Horwitz, 2000). Ash (%) was estimated according to Horwitz (2000). Mineral concentration (phosphorous, potassium and sodium in mg/100g pulp) was determined using wet digestion method (Lima *et al*., 1996).

Disease reaction

Data on the reaction of cultivars to black Sigatoka and Fusarium wilt diseases under natural field conditions were recorded based on a 0 to 5 rating scales (Capo *et al*., 2003; Ulloa *et al*., 2006).

Statistical analysis

Data were combined over locations after carrying out the homogeneity of variances (Gomez and Gomez, 1984) and subjected to the Analysis of Variance using SAS 9.2 (SAS Institute, 2008). Treatment means were compared using the least significant difference (LSD) at 5% level of significance. Correlation analysis was done to determine the relationship between variables. Additive main effect and multiplicative interaction (AMMI) model was used for genotype by environment interaction (GEI) analysis. The relationship among test environments, genotypes and GEI, genotype main effect and genotype by environment (GGE) was visualized using biplots generated from plotting the first two principal components. The yield stability of genotypes was graphically displayed using the average environment coordinate axes. AMMI and stability analyses were done using the GEA-R 4.0 (Pacheco *et al*., 2016).

Results and Discussion

Plant growth characteristics

There were highly significant differences ($p < 0.001$) among the banana cultivars regarding plant height, time to flowering and total time from planting to first harvest. On the other hand, cultivars did not show significant variations in pseudostem girth, number of functional leaves and time from flowering to bunch maturity (Table 2).

'Ambo-3', 'Williams Hybrid' and 'Amboweha Selle-3' had comparable plant height as the check; while plants of six of the cultivars were shorter than the control. Banana plants can be characterized as short (less than 3m), medium (3 to 7m) and tall (above 7m). In the present study, four cultivars had plants with medium height (3.05 to 3.16m) whereas the others had short plants (2.12 to 2.75m). Plant height influences planting density and crop management (Kamira *et al*., 2016; Aquino *et al*., 2017). Short cultivars are usually preferred as they are less prone to toppling by strong winds; do not need support; the increase in planting density may result in greater economic return; and they are easy to harvest (Njuguna *et al*., 2008; Goncalves *et al*., 2018).

Pseudostem girth size ranged from 81.4 to 88.13cm (Table 2). Previous findings demonstrated genetic variations among banana genotypes in plant girth size ranging from 51.5 to 76.3cm (Melon, 2000), 43 to 76.6cm (Njuguna *et al*., 2008), 46.45 to 76.28cm (Sagar *et al*., 2014), and 77 to 90cm (Kamira *et al*., 2016). Plant girth is linked to pseudostem vigor and resistance to damage by wind. It indicates the ability of a plant to support the bunch, and insights the genetic variability for this trait among genotypes (Aquino *et al*., 2017; Goncalves *et al*., 2018).

The number of functional leaves per plant ranged from 11.5 to 13.3 and was not statistically significant among banana cultivars (Table 2). The result implies that more vigorous banana cultivars do not necessarily have more green leaves than shorter ones. At least eight active leaves per plant are needed for proper fruit development and bunch maturation, with 9 to 12 leaves being ideal for commercial banana production (Mattos *et al*., 2010). The result is consistent with previous findings for different banana genotypes (Njuguna *et al*., 2008; Uazire *et al*., 2008; Sagar *et al*., 2014; Kamira *et al*., 2016).

The cultivars showed significant differences in the time they took to reach shooting and harvesting stages (Table 2). 'Chinese Dwarf' and 'Williams Hybrid' were the earliest to flower, and had the shortest crop cycle duration; whereas

‘Parecido al Rey’ took the longest period to flower and harvest. The cultivars that took shorter time to flower were also early in attaining their maturity. These results are consistent with previous findings (Gaidashova *et al*., 2008; Kamira *et al*., 2016; Goncalves *et al*., 2018). Njuguna *et al*. (2008) reported that the longest time to shooting (648.7 days) was twice the shortest (314.5 days). Also, they noted a difference of 53 days between the cultivars that took the shortest and the longest from flowering to harvest. The differences among the cultivars regarding time taken to shooting, from shooting to bunch maturity and from planting to harvest could be explained by their innate genetic variability. Maturity period and attainment of acceptable eating quality at early stage of development are important agronomic attributes of banana (Nowakunda *et al*., 2000; Njuguna *et al*., 2008).

Table 2. Mean plant growth performance of ten banana cultivars across four sites and two crop cycles in Ethiopia from 2015 to 2017

Cultivars	PHT	PGM	LN	DPF	DFH	DPH
Chinese Dwarf	2.55c	85.45	13.1	243.8d	135.5	379.3e
Lady Finger	2.62bc	82.35	11.5	269.7c	136.0	405.7d
Parecido al Rey	2.55c	85.42	11.8	307.9a	138.8	446.7a
Williams Hybrid	3.15a	88.13	12.0	246.4d	128.0	374.4e
Ambo-2	2.75b	82.85	12.1	316.8a	126.7	443.5ab
Ambo-3	3.16a	83.27	13.3	289.5b	150.8	440.3ab
Amboweha Selle-3	3.05a	86.25	12.2	291.6b	136.2	427.8c
Dinke-1	2.75b	85.48	12.6	265.3c	139.2	404.5d
Dinke-2	2.12d	83.68	12.6	279.8bc	139.0	418.8c
Williams-I (check)	3.10a	81.40	12.5	274.1c	148.3	422.4c
Mean	2.78	84.43	12.4	278.5	137.9	416.3
LSD (5%)	0.18	4.91	1.26	15.27	18.94	9.31
Significance	***	ns	ns	***	ns	***
CV(%)	5.63	4.98	8.70	3.45	11.76	1.91

Means with the same letter(s) in a column are not significantly different at 5% probability; PHT=plant height (m); PGM=pseudostem girth measurement (cm); LN=number of functional leaves; DPF=days from planting to flowering; DFH=days from flowering to harvest; DPH=days from planting to harvest; *** significant at $p < 0.001$; ns=non-significant at $p < 0.05$; LSD=least significant difference; CV(%)=coefficient of variation

Yield and yield attributes

Bunch weight varied significantly among the ten banana cultivars (Table 3). ‘Dinke-1’ produced the highest bunch weight but did not significantly differ from ‘Amboweha Selle-3’ and ‘Williams-I’. The result is in line with previous findings by different authors (Kamira *et al*., 2016; Sagar *et al*., 2017; Goncalves *et al*., 2018) who found varietal differences in bunch weight among different banana genotypes. While ecological factors could influence the performance of bananas, the type of genotype could be more important determining factor on bunch weight (Njuguna *et al*., 2008; Kamira *et al*., 2016). Finger size (weight, length and diameter) had significant positive relationship with bunch weight (Table 4). Large finger size can be a major factor contributing to the bunch weight (Sagar *et al*., 2017). Based on the bunch size, it is likely to identify genotypes that produce higher yields. Hence, fruit size can be used to estimate yields when bunches are lost or damaged.

The number of hands per bunch and number of fingers per hand did not differ among the cultivars (Table 3). The number of hands per bunch ranged from 10 to 12. Studies by Goncalves *et al.* (2018) and Mattos *et al.* (2010) obtained average number of hands of 7 and 6, respectively, which are less than the result of the present study. Menon (2000) reported the number of hands ranging from 5 to 10. The results of the present study showed that the number of fingers per hand varied from 15 to 18 (Table 3). Mattos *et al.* (2010) reported a mean number of fingers per hand of 14, which is low compared to our result. The hand constitutes the market unit, and the increase in the number of hands can increase the bunch weight, a trait that expresses the genotype yield (Mattos *et al*., 2010).

The mean finger weight, diameter and length varied significantly among the ten banana cultivars (Table 3). The control had the largest finger weight than all the cultivars and ‘Ambo-3’ had the smallest finger weight. ‘Parecido al Rey’ gave the thickest finger while ‘Lady Finger’ provided with the thinnest fruit. ‘Amboweha Selle-3’ had the longest finger although not significantly longer than five other cultivars. Varietal differences in fruit size were reported by different researchers (Gaidashova *et al*., 2008; Njuguna *et al*., 2008; Uazire *et al*., 2008; Mattos *et al*., 2010; Sagar *et al*., 2017). The results of the present study showed that cultivars with larger bunches generally had longer fingers than those with smaller ones. Similar result was reported by Njuguna *et al*. (2008). Finger length can be used for banana classification (Goncalves *et al*., 2018). Cultivars with long and slender fingers have better market preference (Nowakunda *et al*., 2000; Njuguna *et al*., 2008).

Highly significant differences were observed among banana cultivars in mean marketable and total fruit yields (Table 3). The lowest marketable yield was recorded from ‘Chinese Dwarf’ while the highest was obtained from ‘Williams-I’. Similarly, the maximum and the minimum total yields were recorded correspondingly for ‘Williams-I’ and ‘Ambo-2’. ‘Dinke-1’, ‘Parecido al Rey’, ‘Amboweha Selle-3’, ‘Williams Hybrid’ and ‘Lady Finger’ gave total yields which are comparable to the control. The present findings are consistent with previous results (Gaidashova *et al*., 2008; Sagar *et al*., 2017; Kamira, *et al*., 2016) who reported significant differences among genotypes in yields. Variations in yields among cultivars could be due to genetic differences and location factors (Fonsah *et al*., 2007; Sagar *et al*., 2014). However, the type of genotype could be a more crucial factor in determining the yield potential of a given banana cultivar (Njuguna *et al*., 2008).

Table 3. Mean yield and yield components of ten banana cultivars across four sites and two crop cycles in Ethiopia from 2015 to 2017

Cultivars	BWT	HPB	FPH	FWT	FL	FD	MY	TY
Chinese Dwarf	25.08bcd	11	18	159.44d	14.83abcd	4.00ab	37.33c	44.25c
Lady Finger	23.47cd	11	15	140.17ef	14.41d	3.89b	40.75abc	46.51ab
Parecido al Rey	26.19bcd	12	17	181.88c	14.87abcd	4.13a	44.48ab	49.81ab
Williams Hybrid	25.84bcd	12	15	175.55c	14.85abcd	4.00ab	41.32abc	46.70ab
Ambo-2	26.61bc	11	16	146.17e	14.74bcd	4.04ab	37.65c	43.67c
Ambo-3	23.71cd	10	18	139.18f	14.60cd	3.96ab	39.21bc	44.53c
Amboweha Selle-3	27.82ab	11	15	203.07b	15.44a	4.07ab	40.95abc	49.43ab
Dinke-1	30.38a	11	15	180.25c	15.38ab	4.10a	43.33ab	51.88a
Dinke-2	23.15d	10	16	120.74g	14.33d	3.98ab	39.63bc	44.73b
Williams-I (check)	28.21ab	11	16	218.80a	15.09abc	4.09a	45.87a	52.46a
Mean	26.05	11	16	166.40	14.85	4.03	41.05	47.40
LSD (5%)	3.22	2.10	3.03	6.52	0.65	0.19	5.63	6.15
Significance	*	ns	ns	***	*	**	***	***
CV(%)	21.67	16.52	17.1	3.35	7.71	8.42	24.04	22.75

Means with the same letter(s) in a column are not significantly different at 5% probability; BWT=bunch weight (kg); HPB=number of hands per bunch; FPH=number of fruits per hand; FWT=fruit weight (g); FL=fruit length (cm); FD=fruit diameter (cm); MY=marketable yield (t ha^{-1} per year); TY=total yield (t ha^{-1} per year); * significant at $p < 0.05$; *** significant at $p < 0.001$; ns=non-significant at $p < 0.05$; LSD=least significant difference; CV(%)=coefficient of variation

AMMI analysis

AMMI model revealed that genotype, environment and GEI significantly ($p < 0.01$) influenced the yield. Most of the variation observed was ascribed to the genotypes (70.1%), while the environment accounted for 12.5% and GEI for 17.3% of the total sum of squares. The significant effect for environment demonstrated that the experiment was carried out under divergent agro-climatic conditions causing variation in fruit yield. The magnitude of the GEI sum of squares was not similar with that of the genotypes, indicating that there was no similar response of some of the genotype across environments. The observed GEIs in the AMMI model were further partitioned among the first and second interaction principal components (PC1 and PC2) axes explaining 92.91% (PC1 and PC2 captured 62.44% and 30.47%, respectively) of the total variation (Figure 1). The significant GEI for yield indicated that each factor cannot independently explain all the variation observed, resulting in different performances of the genotypes in the tested environments.

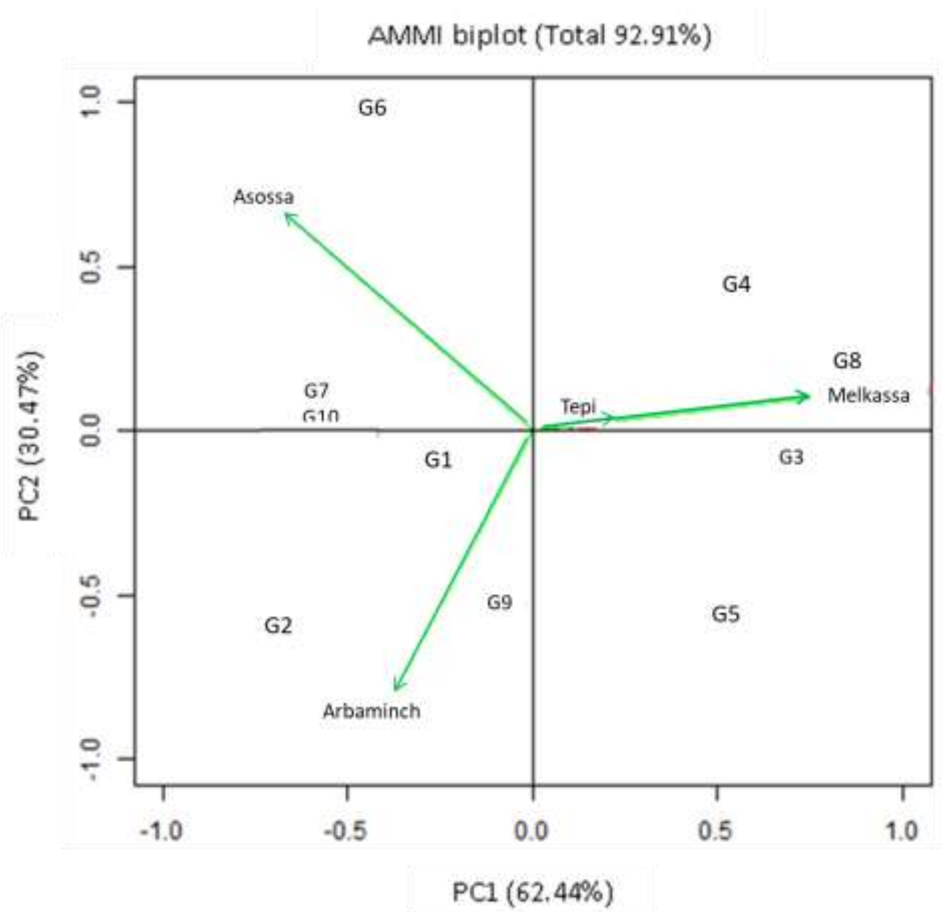

Figure 1. AMMI biplot of the genotype main effect and genotype by environment interaction analysis for yield potential based on 10 banana cultivars evaluated at four locations. Genotypes include: G1 = Lady Finger, G2 = Parecido al Rey, G3 = Chinese Dwarf, G4 = Williams Hybrid, G5 = Ambo-2, G6 = Ambo-3, G7 = Williams-I, G8 = Amboweha Selle-3, G9 = Dinke-1 and G10 = Dinke-2.

The polygon view of GGE biplot based on environment scaling displayed a summary of the GEI pattern (Figure 2). The polygon was formed by connecting vertex genotypes (G3, G6, G7, G8 and G9). These genotypes had the largest vectors in their respective directions; the vector length and direction represented the extent of the response of the genotypes to the tested environments. All other genotypes were contained within the polygon and had smaller vectors, i.e., they were less responsive in relation to the interaction with the environments. Environments can be ranked based on their discrimination power and representativeness of mega environments. Tepi had the shortest environment vectors, whereas Melkassa, Arbaminch and Asossa had longer environment vectors, indicating their ability to discriminate between genotypes. Environment vectors for Tepi and Arbaminch had a very small acute angle between them, an indication that the ranking of genotypes was similar between the two locations.

'Parecido al Rey' (G2), 'Williams-I' (G7) and 'Dinke-1' (G9) were the responsive cultivars at Tepi and Arbaminch, while 'Amboweha Selle-3' (G8) was the most responsive at Melkassa. The environment comparison biplot identified Tepi as an ideal testing site for evaluating banana cultivars for yield (Figure 2). Similar GEI effects on yield were also reported on different banana genotypes (Cauwer *et al*., 1995; Ortiz, 1998).

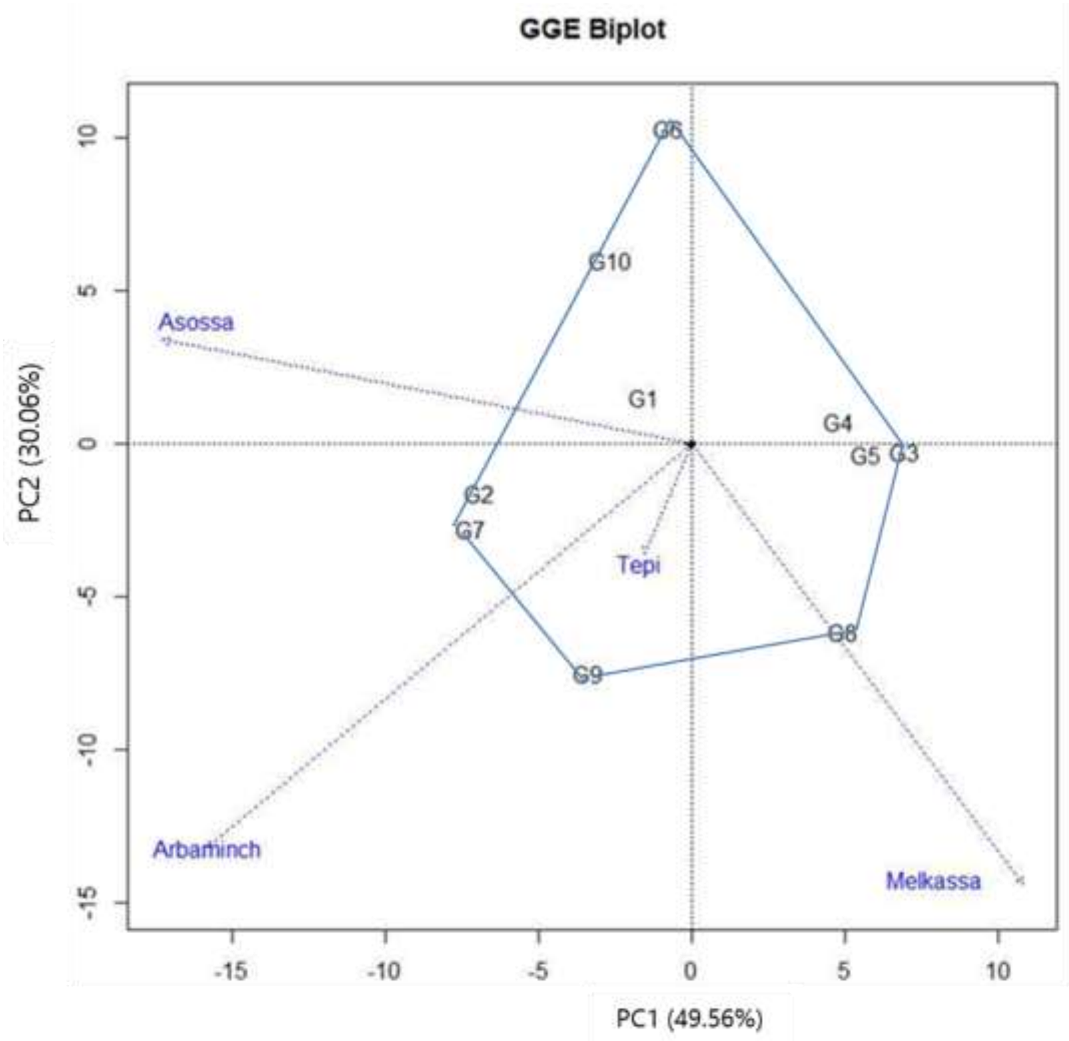

Figure 2. GGE biplot showing the relationship among the four test locations based on the yield potential of 10 banana cultivars; where, G1 = Lady Finger, G2 = Parecido al Rey, G3 = Chinese Dwarf, G4 = Williams Hybrid, G5 = Ambo-2, G6 = Ambo-3, G7 = Williams-I, G8 = Amboweha Selle-3, G9 = Dinke-1, and G10 = Dinke-2.

Yield stability

Yield performance and stability of banana genotypes were identified by plotting mean yield versus the coefficient of variation (Figure 3). Based on the stability parameters and the response to environmental change, 'Williams-I' (G7), 'Dinke-

1' (G9) and 'Parecido al Rey' (G2), all with above average yields, were regarded as stable high yielding cultivars across environments, whereas 'Amboweha Selle-3' (G8) had high yield but unstable performance. The other remaining genotypes showed below average yield performance. Genotypes G1, G6 and G10 were stable, while G3, G4 and G5 were more variable. Similar findings were also reported on different banana genotypes (Cauwer *et al*., 1995; Ortiz, 1998).

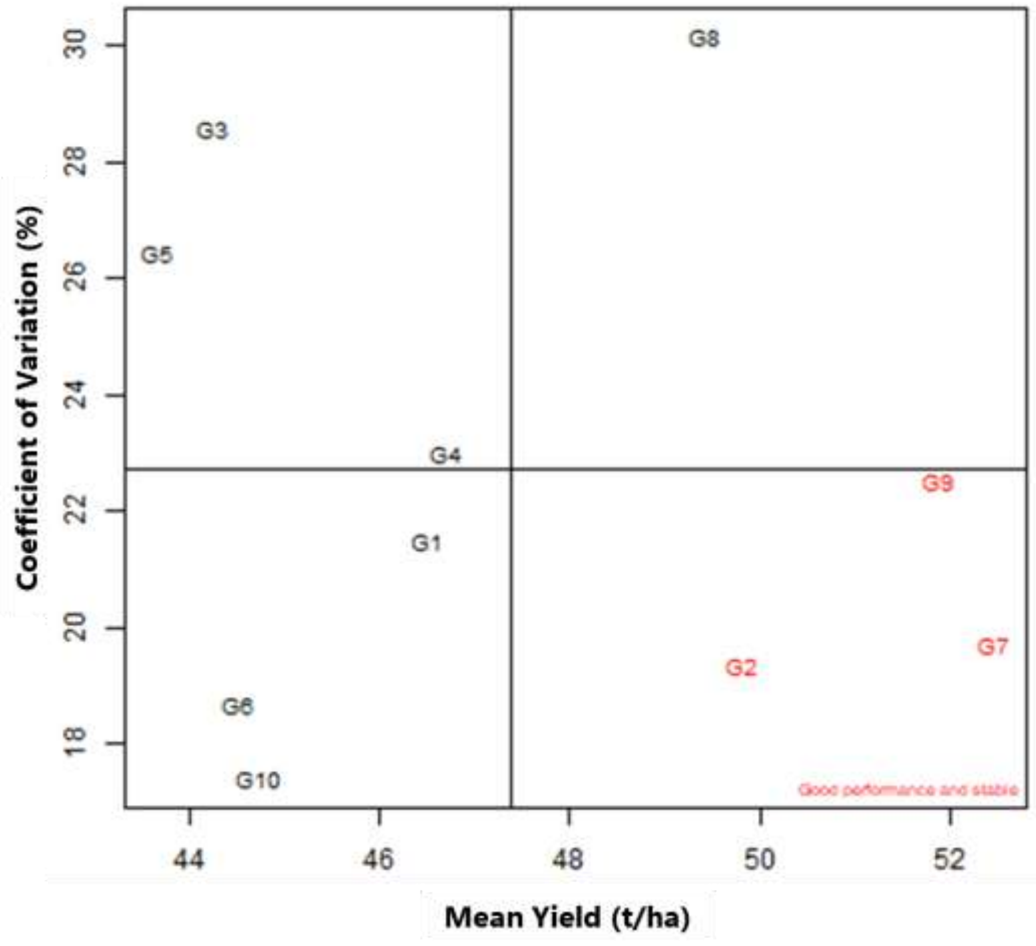

Figure 3. The relationship between mean yield (t/ha) and phenotypic stability (CV%) among 10 banana cultivars; where, G1 = Lady Finger, G2 = Parecido al Rey, G3 = Chinese Dwarf, G4 = Williams Hybrid, G5 = Ambo-2, G6 = Ambo-3, G7 = Williams-I, G8 = Amboweha Selle-3, G9 = Dinke-1, and G10 = Dinke-2.

Correlation between growth and yield related traits

Correlation coefficients between variables of growth and yield attributed characters are presented in Table 4. A highly significant positive correlation between days to shooting and days from planting to harvest (0.955) was found. There was also significant positive correlation between number of functional leaves at shooting and number of fruits per hand (0.649). All other growth related variables did not show significant correlations among themselves and with yield related characters. Total yield had significant positive correlation with bunch weight (0.764), fruit length (0.719) and fruit diameter (0.682), and highly significant positive correlation with finger weight (0.830). Bunch weight showed highly significant positive correlation with fruit length (0.915) and fruit diameter (0.799), and significant positive correlation with finger weight (0.772). Fruit weight had highly significant positive correlation with fruit length (0.842) and significant positive correlation with fruit diameter (0.719). Fruit length was significantly and positively correlated with fruit diameter (0.743). Yield is a complex character and influenced by a number of components. The characters which are associated with yield and less influenced by environment could be useful for banana yield improvement. However, the correlation coefficients in the present study indicated that the growth related characters were not good indicators for banana yield. Similar correlation studies on various banana cultivars were reported by Shaibu *et al*. (2012), Kumar *et al*. (2014) and Tak *et al*. (2015).

Table 4. Phenotypic correlations between variables of growth and yield attributes of banana cultivars

Parameter	PHT	PGM	LN	DPF	DFH	DPH	BWT	HPB	FPH	FWT	FL	FD	TY
PHT	1.000												
PGM	0.133	1.000											
LN	0.096	-0.064	1.000										
DPF	-0.063	-0.357	-0.234	1.000									
DFH	0.189	-0.469	0.530	0.045	1.000								
DPH	-0.003	-0.476	-0.062	0.955**	0.340	1.000							
BWT	0.365	0.209	-0.041	0.031	-0.033	0.020	1.000						
HPB	0.207	0.535	-0.623	-0.105	-0.507	-0.250	0.372	1.000					
FPH	-0.104	-0.171	0.649*	0.089	0.419	0.209	-0.392	-0.278	1.000				
FWT	0.557	0.205	-0.135	-0.065	0.150	-0.017	0.772*	0.526	-0.260	1.000			
FL	0.484	0.391	0.047	-0.035	0.021	-0.027	0.915**	0.357	-0.303	0.842**	1.000		
FD	0.130	0.232	-0.022	0.320	0.060	0.319	0.799**	0.430	-0.045	0.719*	0.743*	1.000	
TY	0.289	0.045	-0.216	-0.032	0.338	0.071	0.764*	0.370	-0.413	0.830**	0.719*	0.682*	1.000

* significant at the 5% level of probability; ** significant at the 1% level of probability. PHT=plant height; PGM=pseudostem girth measurement; LN=number of functional leaves; DPF=days from planting to flowering; DFH=days from flowering to harvest; DPH=days from planting to harvest; BWT=bunch weight; HPB=number of hands per bunch; FPH=number of fruits per hand; FWT=fruit weight; FL=fruit length; FD=fruit diameter; MY=marketable yield; TY=total yield.

Consumer acceptability

Significant differences were not observed among the ten cultivars for all sensory characteristics assessed based on the five-point scale by the panelists (Table 5). Though it was not statistically significant, panelists preferred all cultivars evaluated over the control in terms of color and texture. In the case of aroma, the panelists preferred six of the cultivars to the control. Panelists preferred the taste of fruits of all the cultivars except 'Chinese Dwarf' and 'Williams Hybrid' to the control. With regard to the peeling condition, the mean scores varied from 3.37 to 4.28. The higher the peeling condition score, the easier to peel the rind. The overall acceptability scores ranged from 3.57 to 4.38. The general acceptability, the final verdict of the panelists for the cultivars, indicated that all the cultivars except 'Chinese Dwarf' were better than the control.

Similar sensory findings were reported by various authors. The studies by Nowakunda *et al.* (2000), Coulibaly and Djedji (2004) and Uazire *et al.* (2008) found low sensory and general acceptability scores for introduced hybrids compared to the East African highland bananas. Coulibaly and Djedji (2004) reported similar mean values of the sensory scores given by the panelists for three banana cultivars. In Ghana, the panelists preferred the color, aroma and aftertaste of the Medium Cavendish compared to that of the Gros Michel; while similar mouthfeel and chewiness attributes were scored for both cultivars (Adubofuor *et al.*, 2016). Color is a very important attribute related to the attractiveness of the fruit that influences the initial acceptability of a product by consumers. The color differences observed among the banana cultivars could be due to their differences in sugar contents in the fruit (Adubofuor *et al.*, 2016; Aquino *et al.*, 2017). In the present study, 'Lady Finger' was the most favored cultivar by panelists for its sensory characteristics which may indicate its acceptability by consumers.

Table 5. Sensory evaluation results of ten banana cultivars

Cultivars	Color	Aroma	Taste	Texture	Peeling Condition	General Acceptability
Chinese Dwarf	3.72	3.64	3.35	3.29	3.37	3.57
Lady Finger	4.07	4.24	4.21	4.11	4.21	4.38
Parecido al Rey	3.77	3.83	4.04	3.94	3.51	3.96
Williams Hybrid	3.75	4.09	3.49	3.75	3.70	3.93
Ambo-2	4.17	4.21	3.92	4.20	4.01	4.25
Ambo-3	3.71	3.58	3.83	3.75	3.75	3.71
Amboweha Selle-3	3.71	3.65	3.89	3.96	3.78	3.84
Dinke-1	3.77	3.83	3.55	3.71	3.67	3.80
Dinke-2	4.10	3.88	3.67	4.06	4.28	4.01
Williams-I (check)	3.57	3.69	3.50	3.10	3.84	3.57
Mean	3.83	3.86	3.75	3.79	3.81	3.90
LSD (5%)	0.60	0.79	0.55	0.71	0.65	0.56
Significance	ns	ns	Ns	ns	ns	ns
CV(%)	9.12	12.00	8.61	11.00	9.94	8.31

ns = non-significant at $p < 0.05$; LSD = least significant difference; CV(%) = coefficient of variation

Fruit physicochemical characteristics

The banana cultivars exhibited significant differences in all physicochemical parameters analyzed (Table 6). The peel thickness varied from 2.1 to 4.2 mm. 'Parecido al Rey' and 'Lady Finger' had thicker peels than the control, whereas 'Dinke-1' had the thinnest peel. The pulp-to-peel ratio ranged from 2.21 to 3.19. 'Ambo-3', 'Williams Hybrid', 'Dinke-1' and 'Ambo-2' had higher pulp-to-peel ratios than the control, which indicates more flesh advantage for dessert bananas. On the other hand, 'Amboweha Selle-3' and 'Dinke-2' had the lowest pulp-to-peel ratios. The present results are consistent with the previous findings of different authors (Menon, 2000; Mattos *et al*., 2010; Aquino *et al*., 2017) who reported significant differences among banana cultivars in peel thickness and pulp-to-peel ratio. The peel thickness can be an element of fruit resistance to transport and storage since the thicker the peel the more resistant the fruit (Goncalves *et al*., 2018). Genotype and maturation stage influence the peel thickness and the pulp-to-peel ratio. The ratio increases with ripening due to the movement of water from the peel to the pulp because of the osmotic pressure gradient caused by the higher concentration of sugars in the flesh compared to the rind. Moreover, the increase in permeability of the peel during ripening causes the loss of water to the environment through transpiration, which reduces its thickness and weight (Aquino *et al*., 2017).

The TSS, TTA and pH values differed among the cultivars (Table 6). The results are in agreement with the previous findings reported by different workers (Mattos *et al*., 2010; Ara *et al*., 2011; Godoy *et al*., 2016; Aquino *et al*., 2017; Siji and Nandini, 2017) who found significant varietal differences among banana genotypes in their physicochemical characteristics. The TSS values ranged from 20.0 to 24.47 (Table 6). The result is consistent with the range of TSS values (15 to 25) established for banana fruit (Subedi and Walsh, 2011). 'Williams Hybrid', 'Lady Finger', 'Dinke-2', 'Ambo-2' and 'Dinke-1' had higher TSS than the control. The TSS value is linked with the sucrose concentration and influences the fruit taste. It is dependent on genotype and stage of maturity, which can be used as an index to determine fruit maturity and ripening (Aquino *et al*., 2017; Siji and Nandini, 2017; Dotto *et al*., 2019). On the other hand, all the cultivars except 'Amboweha Selle-3' had less TTA values and higher TSS/TTA ratios than the control. The pulp pH ranged from 4.69 to 5.20 (Table 5); which are in the acceptable range (4.5 to 5.2). The highest pH was recorded for 'Dinke-1' and 'Dinke-2' followed by 'Ambo-2', whereas the lowest was for 'Amboweha Selle-3'. Both TTA and pH levels are related to the content of organic acids and salts in the fruit. The high level of acidity indicates the high amount of malic acid in the pulp. The TTA measures the concentration of total hydrogen ion, which is more relevant to flavor than pH (Dotto *et al*., 2019). The TSS/TTA index indicates the degree of sweetness of the fruit, providing information about the flavor (Godoy *et al*., 2016). The pH may be used as a maturity indicator for banana harvesting

(Dotto *et al*., 2019). The pH is an important attribute of banana juice as it influences the levels and type of contamination and the kind of preservation necessary (Nowakunda *et al*., 2000).

Moisture and ash contents

The cultivars exhibited highly significant differences in their moisture content. They had the moisture levels that varied from 71.53 to 76.56%. Fruits of 'Ambo-3' had the highest moisture content, whereas 'Dinke-2' had the lowest (Table 6). The range of moisture content established for fresh banana fruit is from 74 to 80% (Anyasi *et al*., 2013). Similar findings were reported for Cavendish bananas (72.80-78.18%) (Wasala *et al*., 2012) and Gros Michel bananas (75-77%) (Abano and Sam-Amoah, 2011). The level of moisture content depends on the type of banana genotype (Dotto *et al*., 2019). The moisture content is an indicator for fruit freshness and shelf-life. Fruit with high moisture content is rich in nutrition, but has a short shelf-life (Oyeyinka and Afolayan, 2019).

Significant differences in ash contents were observed among the ten banana cultivars (Table 6). The ash contents ranged from 2.50 to 3.36%. 'Ambo-3' and 'Amboweha Selle-3' had the highest ash content, whereas 'Parecido al Rey' had the lowest. This result is in agreement with the finding of Adubofuor *et al*. (2016) who reported ash contents of 3.0% for the Cavendish and 3.3% for the Gros Michel bananas. The ash contents recorded in the present study were higher than the finding of Oyeyinka and Afolayan (2019) who reported bananas with 1.01% ash contents. The low ash contents of banana cultivars may indicate their low mineral concentrations (Dotto *et al*., 2019). Ash content increases with ripening, the average being 0.8% (Adeyemi and Oladiji, 2009; Anyasi *et al*., 2013). The ash content is highly important because the inorganic bulk is related to the composition of mineral elements (Adeyemi and Oladiji, 2009; Oyeyinka and Afolayan, 2019). Thus, the varietal differences might be associated with their different ability to absorb the minerals (Dotto *et al*., 2019).

Table 6. Physicochemical characteristics and moisture and ash contents of ten banana cultivars

Cultivar	PTK (mm)	PPR	TSS	TTA	TSS: TTA	pH	Moisture (%)	Ash (%)
Chinese Dwarf	3.32b	2.46cd	21.33cd	0.40d	53.82b	4.85bc	74.82cd	2.87cd
Lady Finger	4.10a	2.25de	23.97a	0.59b	40.36d	4.72bc	71.65g	2.65de
Parecido al Rey	4.20a	2.38de	21.00cd	0.51c	40.87d	4.79bc	71.74g	2.50e
Williams Hybrid	2.31c	3.00ab	24.47a	0.50c	48.94c	4.81bc	71.53g	2.87cd
Ambo-2	3.03b	2.84ab	22.30bc	0.37d	59.84a	5.16a	75.54bc	3.05bc
Ambo-3	3.18b	3.19a	20.00d	0.49c	40.96d	5.02ab	76.56a	3.36a
Amboweha Selle-3	3.13b	2.09e	20.33d	0.60a	34.23e	4.69c	75.71b	3.31a
Dinke-1	2.10c	2.93ab	22.13bc	0.49c	44.98cd	5.20a	73.35e	2.77d
Dinke-2	3.20b	2.21de	23.70ab	0.37d	63.97a	5.20a	72.58f	3.12ab
Williams-I (check)	3.32b	2.82bc	20.00d	0.61a	32.70e	4.80bc	74.57d	2.71de
Mean	3.19	2.62	21.92	0.49	46.07	4.92	73.81	2.92
LSD (5%)	0.49	0.37	1.63	0.03	4.82	0.30	0.72	0.25
Significance	***	***	***	***	***	**	***	***
CV(%)	9.12	8.16	4.34	3.78	6.10	3.56	0.57	4.91

Means with the same letter(s) in a column are not significantly different at 5% probability; PTK=peel thickness (mm); PPR=pulp to peel ratio; TSS=total soluble solids (°Brix); TTA=total titratable acidity (%); ** significant at $p < 0.01$; *** significant at $p < 0.001$; LSD=least significant difference; CV(%)=coefficient of variation

Mineral content

The average concentrations of P, K and Na varied from 41.20 to 77.89, 264.03 to 371.18 and 4.20 to 19.35 mg/100g, respectively (Table 7). Similar findings were reported by different authors (Ara *et al*., 2011; Adubofuor *et al*., 2016; Dotto *et al*., 2019; Oyeyinka and Afolayan, 2019) who noted variabilities in mineral concentrations among banana genotypes. In the present study, K was generally the most abundant in all the cultivars tested, which indicates the potential nutritional significance. Conversely, Na content was relatively low. The highest level of K obtained in this study is in close agreement with the findings reported by other authors (Adubofuor *et al*., 2016; Dotto *et al*., 2019; Oyeyinka and Afolayan, 2019). In contrast, Siji and Nandini (2017) obtained considerably higher K (261.66 to 546.66 mg/100g) and Na (170 to 260 mg/100g) contents for banana genotypes than the present results. Mineral elements are essential components of nutrition that involve in the different processes of the body (Siji and Nandini, 2017; Oyeyinka and Afolayan, 2019). Banana is valued for K content due to its role in maintaining normal blood pressure (Siji and Nandini, 2017), enhancing the shipping quality, extending the shelf life, and improving color and taste (Anyasi *et al*., 2013).

Table 7. Mineral contents (mg/100g) of ten banana cultivars

Cultivars	Phosphorus	Potassium	Sodium
Chinese Dwarf	47.01	316.29	9.98
Lady Finger	52.73	324.13	4.20
Parecido al Rey	41.25	264.03	4.20
Williams Hybrid	41.20	284.10	9.44
Ambo-2	55.60	316.01	10.02
Ambo-3	77.89	301.25	15.48
Amboweha Selle-3	53.11	371.18	7. 05
Dinke-1	74.82	326.89	9.19
Dinke-2	62.92	351.23	19.35
Williams-I (check)	51.95	309.14	4.63
Mean	55.85	316.42	9.35

Correlation between variables of fruit physicochemical characters

The correlation coefficients for physicochemical characters of banana fruit are presented in Table 8. The general acceptability of banana fruit presented highly significant positive correlation with color (0.859), aroma (0.884) and texture (0.864), while significant positive correlation with taste (0.744), peeling condition (0.662) and TSS (0.65). Fruit color at harvest showed significant positive correlation with aroma (0.748), peeling condition (0.722), TSS (0.633), and highly significant positive correlation with texture (0.786). Aroma had significant positive correlation with texture (0.602) and highly significant positive correlation with TSS (0.796). Taste was significantly and positively correlated with texture (0.747) and peel thickness (0.635). There was significant negative correlation between TSS and moisture content (-0.72). TTA had significant negative correlation with pH (-0.728) and sodium content (-0.69). The pH of the pulp presented significant positive correlation with phosphorous (0.668) and sodium (0.701) contents. Moisture content had significant positive correlation with ash content (0.701). Moreover, phosphorous content showed significant positive correlation with the sodium content (0.669). Similar finding was reported on different banana genotypes by Ledo *et al*. (2018).

Table 8. Phenotypic correlations between physicochemical characteristics of banana cultivars

Parameter	Color	Aroma	Taste	Texture	Peeling	GA	PTK	PPR	TSS	TTA	pH	MOIST	ASH	P	K	Na
Color	1.000															
Aroma	0.748*	1.000														
Taste	0.487	0.416	1.000													
Texture	0.786**	0.602*	0.747*	1.000												
Peeling	0.722*	0.537	0.434	0.551	1.000											
GA	0.859**	0.884**	0.744*	0.864**	0.662*	1.000										
PTK	0.169	0.039	0.635*	0.161	0.137	0.283	1.000									
PPR	-0.284	-0.040	-0.362	-0.316	-0.254	-0.293	-0.556	1.000								
TSS	0.633*	0.796**	0.056	0.462	0.478	0.650*	-0.181	-0.120	1.000							
TTA	-0.521	-0.145	0.266	-0.229	-0.033	-0.103	0.220	-0.112	-0.293	1.000						
pH	0.445	0.091	-0.209	0.229	0.268	0.077	-0.478	0.366	0.172	-0.728*	1.000					
MOIST	-0.233	-0.544	-0.134	-0.220	-0.166	-0.431	-0.158	0.266	-0.720*	-0.086	0.168	1.000				
ASH	0.062	-0.335	-0.049	0.211	0.194	-0.140	-0.324	0.094	-0.223	-0.231	0.277	0.701*	1.000			
P	0.072	-0.279	-0.012	0.086	0.242	-0.127	-0.362	0.383	-0.206	-0.150	0.668*	0.451	0.501	1.000		
K	0.240	-0.131	0.002	0.197	0.458	0.058	-0.180	-0.499	0.004	0.017	0.147	0.336	0.551	0.346	1.000	
Na	0.301	-0.179	-0.281	0.182	0.284	-0.094	-0.352	0.167	0.175	-0.690*	0.701*	0.241	0.669*	0.556	0.286	1.000

* significant at the 5% level of probability; ** significant at the 1% level of probability. GA=general acceptability; PTK=peel thickness; PPR=pulp to peel ratio; TSS=total soluble solids; TTA=total titratable acidity; MOIST=moisture content.

Genotype reaction to Fusarium wilt and black Sigatoka

Fusarium wilt was reported to cause over 60% estimated yield loss in dessert bananas (Tushemereirwe *et al*., 2000). As much as 27% of the total cost of banana production was apportioned to control the menace of black Sigatoka disease in Nigeria (Etebu and Young-Harry, 2011). These diseases are important in Ethiopia. The reactions of the cultivars to Fusarium wilt of bananas (also known as Panama disease), caused by *Fusarium oxysporum* f. sp. *Cubense*, and black Sigatoka (black leaf streak), caused by *Mycosphaerella fijiensis*, under natural field conditions are presented in Figure 4. 'Amboweha Selle-3' and 'Dinke-1' did not show any symptom of Fusarium wilt, while the other genotypes exhibited little incidence of Fusarium wilt disease; which might indicate their resistance. However, the cultivars showed varying degrees of symptoms to black Sigatoka disease. Plants of all the cultivars except 'Dinke-1' developed more symptoms of black Sigatoka disease than the control. 'Chinese Dwarf' and 'Dinke-1' showed the highest and the lowest scores of black Sigatoka disease, respectively. Similar findings were reported by Tushemereirwe *et al*. (2000) and Arinaitwe *et al*. (2019). A study by Tushemereirwe *et al*. (2000) found five resistant banana genotypes to both Fusarium wilt and black Sigatoka diseases, while twelve other cultivars were classified either as resistant or tolerant to Fusarium wilt disease. Arinaitwe *et al*. (2019) observed high degrees of variabilities among twenty-two banana accessions for their resistance to Fusarium wilt disease. Host plant resistance is an effective alternative to other methods for controlling diseases in banana (Ploetz and Pegg, 2000).

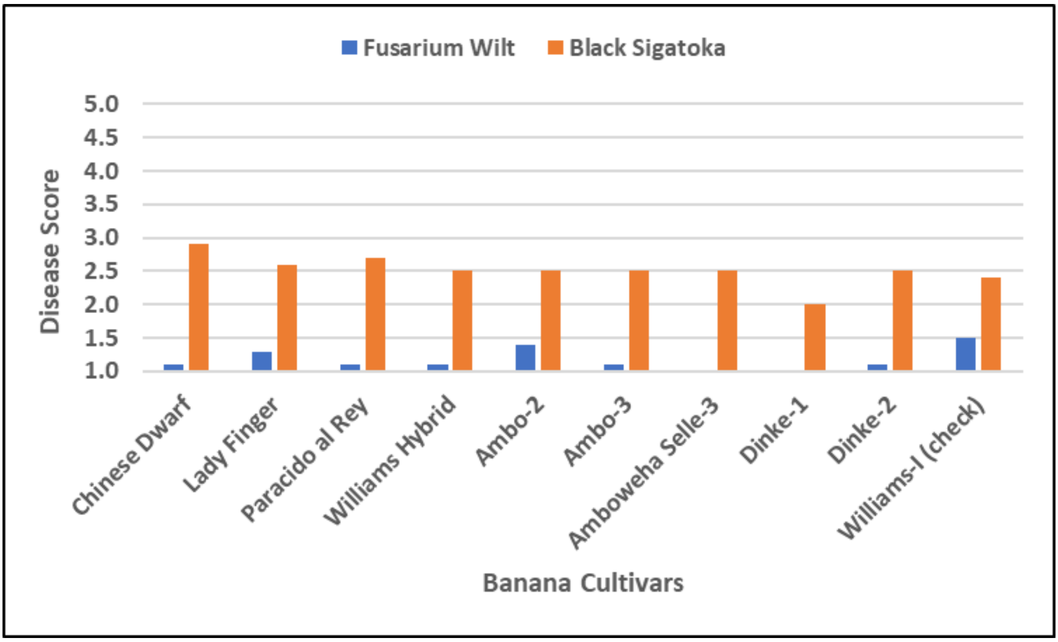

Figure 4. Black Sigatoka and Fusarium wilt diseases scores on different banana cultivars under natural field conditions. The diseases scores were recorded based on a 0 to 5 scale, where, **Black Sigatoka**: 0 = leaf symptoms mostly absent, 1 = reddish flecks on lower leaf surface, but no symptoms on the upper surface, 2 = regular or irregular reddish circular spots on the lower leaf surface, but no symptoms on the upper surface, 3 = regular or diffuse light brown circular spots on the upper leaf surface, 4 = black or brown circular spots, possibly with yellow halo or chlorosis of the adjacent tissues, on the upper leaf surface area of green tissue sometimes present, and 5 = black spot with dry center of the grey color, leaf completely necrotic, sometimes hanging down. (Capo *et al*., 2003); and **Fusarium wilt**: 0 = no leaf symptoms, 1 = initial yellowing on the first lower leaf, 2= yellowing extending mainly in the lower leaves, 3 = moderate to severe symptoms of yellowing on all the lower leaves with some discoloration of younger leaves, 4 = severe symptoms of intensive yellowing on all leaves, and 5 = dead plant (Ulloa *et al*., 2006).

Conclusion and Recommendation

Genetic variability was observed for most agronomic and fruit physicochemical characteristics in the ten banana cultivars evaluated. The cultivars had short to medium plant heights with generally thick pseudostems, which can be perceived as good features for harvesting and reduced wind damage. The candidate cultivars, namely 'Lady Finger' and 'Dinke-1' had significantly shorter crop cycle duration than the control, an important criterion for farmers in selecting cultivars. These cultivars gave comparable yields to the control. Besides genotype, experimental locations influenced yield. 'Williams-I' (control), 'Dinke-1' and 'Parecido al Rey' were found as stable high yielding cultivars across tested environments. The cultivars exhibited significant differences in all physicochemical parameters analyzed. Though cultivars were not significantly different in their sensory attributes, the general acceptability scores of all the cultivars were better than the control, indicating the consumers' preference for them. 'Lady Finger' was the most preferred cultivar by panelists. The moisture and ash contents were significantly different among the cultivars. The moisture content is an indicator for fruit freshness and shelf-life. The higher ash contents obtained in this study may indicate the high mineral levels of the cultivars. Furthermore, the mineral concentration analysis showed potassium as the most abundant in all the cultivars; which indicates their potential nutritional significance. The cultivars showed varying degrees of symptoms to Fusarium wilt and black Sigatoka diseases. From the results of the present study, ‘Parecido al Rey’, ‘Lady Finger’, ‘Dinke-1’ and ‘Amboweha Selle-3’ were recommended for commercial production in the target areas of the country. However, only ‘Lady Finger’ and ‘Dinke-1’ have been registered.

Acknowledgements

The authors acknowledge the Ethiopian Institute of Agricultural Research and Melkassa Agricultural Research Center for the financial support and facilitation of this study. We wish to thank the Jimma, Tepi and Arba Minch Agricultural Research Centers for their involvement and collaboration in the field trials.

References

Abano EE and Sam-Amoah LK. 2011. Effects of different pretreatments on drying characteristics of banana slices. ARPN Journal of Engineering and Applied Sciences 6(3):121–129.

Adeyemi OS and Oladiji AT. 2009. Compositional changes in banana (*Musa* spp.) fruits during ripening. African Journal of Biotechnology 8:858–859.

Adubofuor J, Amoah I, Batsa V, Agyekum PB and Buah JA. 2016. Nutrient composition and sensory evaluation of ripe banana slices and bread prepared from ripe banana and wheat composite flours. American Journal of Food and Nutrition 4:103–111.

Anyasi TA, Jideani AIO and Mchau GRA. 2013. Functional properties and postharvest utilization of commercial and noncommercial banana cultivars. Comprehensive Reviews in Food Science and Food Safety 12:509–522.

Aquino CF, Salomão LCC, Cecon PR, De Siqueira DL and Ribeiro SMR. 2017. Physical, chemical and morphological characteristics of banana cultivars depending on maturation stages. Revista Caatinga 30:87–96.

Ara N, Basher MK and Hossain MF. 2011. Growth, yield and quality of banana (*Musa sapientum* L.) influenced by different banana varieties/lines and planting time. Tropical Agricultural Research and Extension 14:45–51.

Arinaitwe IK, Teo CH, Kayat F, Tumuhimbise R, Uwimana B, Kubiriba J, Swennen R, Harikrishna JA and Othman RY. 2019. Evaluation of banana germplasm and genetic analysis of an F1 population for resistance to *Fusarium oxysporum* f. sp. *cubense* race 1. Euphytica 215:175.

Asmare Dagnew and Derbew Belew. 2013. Production, research and development status of fruits in Ethiopia. pp. 97–135. *In* Proceedings of the Workshop on The State of

Agricultural Science and Technology in Ethiopia, International Livestock Research Institute (ILRI), 28-30 November 2011, Ethiopian Academy of Sciences (EAS), Addis Ababa.

Capo YA, Mora ML, Rodríquez MAD, Acosta M, Cruz M, Portal N, Kosky RG, García L, Bermudez I and Padron J. 2003. Early evaluation of black leaf streak resistance by using mycelial suspensions of *Mycosphaerella fijiensis*. pp. 169–175. *In* Jacome, L., P. Lepoivre, D. Marin, R. Ortiz, R. Romero and J.V. Escalant (eds.), Mycosphaerella Leaf Spot Diseases of Bananas: Present Status and Outlook. Proceedings of the Workshop on Mycosphaerella Leaf Spot Diseases held in San Jose, Costa Rica on 20-23 May 2002. The International Network for the Improvement of Banana and Plantain, Montpellier, France.

Cauwer ID, Ortiz R and Vuylsteke D. 1995. Genotype-by-environment interaction and phenotypic stability of Musa germplasm in West and Central Africa. African Crop Science Journal 3(4):425–432.

Coulibaly S and Djedji C. 2004. Organoleptic qualities of the fruit of hybrids SH-3640 and CRBP-39. InfoMusa 13:27–30.

Dawit Alemu and Asmare Dagnew. 2008. Banana markets in Ethiopia. Research Report No. 35, The Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.

Dotto J, Matemu AO and Ndakidemi PA. 2019. Nutrient composition and selected physicochemical properties of fifteen *Mchare* cooking bananas: A study conducted in northern Tanzania. Scientific African 6:e00150.

Etebu E and Young-Harry W. 2011. Control of black Sigatoka disease: Challenges and prospects. African Journal of Agricultural Research 6:508–514.

FAOSTAT. 2019. Statistical Database. Available online at http://www.fao.org/faostat/en/#data/QC

Fonsah EG, Adamu CA, Okole BN and Mullinix BG. 2007. Field evaluation of Cavendish banana cultivars propagated either by suckers or by tissue culture, over six crop cycles in the tropics. Fruits 62:205–212.

Gaidashova SV, Karemera F and Karamura EB. 2008. Agronomic performance of introduced banana varieties in lowlands of Rwanda. African Crop Science Journal 16:9–16.

Godoy RCB, Waszczynskj N, Santana FA, Silva SO, Oliveira LA and Santos GG. 2016. Physico-chemical characterization of banana varieties resistant to black leaf streak disease for industrial purposes. Ciência Rural 46:1514–1520.

Gomez KA and Gomez AA. 1984. Statistical procedures for agricultural research. 2nd ed. New York: A Wiley-Interscience Publication.

Goncalves ZS, DRS da Invenção, Ledo CAS, Ferreira CF and Amorim EP. 2018. Agronomic performance of plantain genotypes and genetic variability using Ward-MLM algorithm. Genetics and Molecular Research 17(1):gmr16039882.

Horwitz W. 2000. Official Methods of Analysis of AOAC International. 17th ed. Gaithersburg: Association of Analytical Chemists International. Gaithersburg, MD.

Lima JL, Rangel AO and Souto MRS. 1996. Simultaneous determination of potassium and sodium in vegetables by flame emission spectrometry using a flow-injection system with two dialysis units. Analytical Sciences 12(1):81–85.

Kamira M, Ntamwira J, Sivirihauma C, Ocimati W, P van Asten, Vutseme L and Blomme G. 2016. Agronomic performance of local and introduced plantains, dessert, cooking and beer bananas (*Musa* spp.) across different altitude and soil conditions in eastern Democratic Republic of Congo. African Journal of Agricultural Research 11(43):4313–4332.

Kumar DS, Naidu MM, Swami DV, Krishna KU, Nagalaxmi R, Mamata K, Bhagavan BVK and Rajasekharam T. 2014. Correlation studies in different culinary cultivars of banana. Plant Archives 14(2):1075–1077.

Ledo AS, Silva TN, Martins CR, Silva AVC, Ledo CAS and Amorim EP. 2018. Physicochemical characterization of banana fruit by univariate and multivariate procedures. Bioscience Journal 34(1):24–33.

Mattos LA, Amorim EP, Amorim VBO, Cohen KO, Ledo CAS and Silva SO. 2010. Agronomical and molecular characterization of banana germplasm. Pesquisa Agropecuaria Brasileira 45:146–154.

Menon R. 2000. Preliminary evaluation of some banana introductions in Kerala (India). InfoMusa 9(2):27–28.

MoARD (Ministry of Agriculture and Rural Development). 2006. Crop variety register. Issue No. 9. Crop Development Department, Addis Ababa.

Natnael Mekonnen. 2016. Statistical analysis of factor affecting banana production in Gamo Gofa District, Southern Ethiopia. Engineering and Applied Sciences 1:5–12.

Njuguna J, Nguthi F, Wepukhulu S, Wambugu F, Gitau D, Karuoya M and Karamura D. 2008. Introduction and evaluation of improved banana cultivars for agronomic and yield characteristics in Kenya. African Crop Science Journal 16:35–40.

Nowakunda K, Rubaihayo PR, Ameny MA and Tushemerierwe W. 2000. Consumer acceptability of introduced bananas in Uganda. InfoMusa 9(2):22–25.

Oyeyinka BO and Afolayan AJ. 2019. Comparative evaluation of the nutritive, mineral, and antinutritive composition of *Musa sinensis* L. (banana) and *Musa paradisiaca* L. (plantain) fruit compartments. Plants 8:598.

Orjeda G. 1998. Evaluation of *Musa* germplasm for resistance to Sigatoka diseases and Fusarium wilt. INIBAP Technical Guidelines 3. International Plant Genetic Resources Institute, Rome, Italy; International Network for the Improvement of Banana and Plantain, Montpellier, France; ACP-EU Technical Centre for Agricultural and Rural Cooperation, Wageningen, The Netherlands.

Ortiz R. 1998. AMMI and stability analysis of bunch mass in multilocational testing of *Musa* germplasm in Sub-Saharan Africa. Journal of American Society of Horticultural Science 123(4):623–627.

Pacheco A, Vargas M, Alvarado G, Rodríguez F, López M, Crossa J and Burgueño J. 2016. GEA-R (Genotype x Environment Analysis with R) for Windows, version 4.0. International Maize and Wheat Improvement Center (CIMMYT).

Ploetz RC and Pegg KG. 2000. Fungal diseases of the root, corm and pseudostem: Fusarium wilt. pp. 143–159. *In* Jones D.R. (ed.) Diseases of Banana, Abaca and Enset. CAB International: Wallingford, UK.

Sagar BS, Raju B, Hipparagi K, Patil SN and Sahithya BR. 2014. Evaluation of banana genotypes for growth and yield under northern dry zone of Karnataka. The Bioscan 9:1773–1775.

Sagar BS, Raju B and Sahithya BR. 2017. Evaluation of banana genotypes under northern dry zone of Karnataka for yield and returns. International Journal of Current Microbiology and Applied Sciences 6:255–262.

SAS. 2008. SAS/Stat users' guide, version 9.2. SAS Institute Inc., Cary, NC: USA.

Seifu Gebre-Mariam. 1999. Banana production and utilization in Ethiopia. Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.

Siji S and Nandini PV. 2017. Chemical and nutrient composition of selected banana varieties of Kerala. International Journal of Advanced Engineering, Management and Science 3:401–404.

Shaibu AA, Maji EA, and Ogburia MN. 2012. Yield evaluation of plantain and banana landraces and hybrids in humid agro ecological zone of Nigeria. Journal of Agricultural Research and Development 2(3):074–079.

Subedi PP and Walsh KB. 2011. Assessment of sugar and starch in intact banana and mango fruit by SWNIR spectrometry. Postharvest Biology and Technology 62(3):238–245.

Tak MK, Kumar V, Attar S, Revale AK and Patel R. 2015. Correlation of banana cv Grand Naine with growth and yield aspect. Journal of Plant Development Sciences 7(1):1–6.

Tushemereirwe W, Kangire A, Kubiriba J and Nowakunda K. 2000. Fusarium wilt resistant banana considered appropriate replacements for cultivars susceptible to the disease in Uganda. Uganda Journal of Agricultural Sciences 5:62–64.

Uazire AT, Ribeiro CM, Ruth Bila Mussane C, Pillay M, Blomme G, Fraser C, Staver C and Karamura E. 2008. Preliminary evaluation of improved banana varieties in Mozambique. African Crop Science Journal 16:17–25.

Ulloa M, Hutmacher RB, Davis RM, Wright SD, Percy R and Marsh B. 2006. Breeding for Fusarium wilt race 4 resistance in cotton under field and greenhouse conditions. The Journal of Cotton Science 10:114–127.

Wasala WMCB, Dharmasena DAN, Dissanayake TMR and Thilakarathne BMKS. 2012. Physical and mechanical properties of three commercially grown banana (*Musa acuminata* Colla) cultivars in Sri Lanka. Tropical Agricultural Research 24(1):42–53.