Vol. 19(6), pp. 643-653, June, 2023
DOI: 10.5897/AJAR2022.16195
Article Number: DCDBE7970877
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

ACADEMIC JOURNALS
expand your knowledge

African Journal of Agricultural Research

Full Length Research Paper

Phenotypic characterization and beta-carotene quantification towards selection for high beta-carotene maize accessions

Gilbert ANSAH[1]*, Samuel AMITEYE[1,2], Harry Mensah AMOATEY[1], Vivian ODURO[1], Maxwell ABIVE-BORTSI[2], Jacob Teye KUTUFAM[2], Doris Akua DZIMEGA[2], Jonathan Okai ARMAH[2], Innocent Kwaku DORVLO[1] and Godwin AMENORPE[1,2]

[1]Department of Nuclear Agriculture and Radiation Processing, School of Nuclear and Allied Sciences,
College of Basic and Applied Sciences, University of Ghana, Accra, Ghana.
[2]Biotechnology Centre, Biotechnology and Nuclear Agricultural research Institute (BNARI),
Ghana Atomic Energy Commission (GAEC), P. O. Box AE 50, Accra, Ghana.

Received 28 August, 2022; Accepted 21 December, 2022

Yellow maize varieties in Ghana have low beta-carotene levels, but if improved, they could lessen the negative health effects of vitamin-A deficiency. Finding promising yellow maize accessions that could be used to breed higher beta-carotene varieties was the goal of the study. The study involved the collection of 100 local accessions, phenotypic identification, evaluation of genetic relatedness, and quantification of the beta-carotene and total carotenoid contents. The focus of the work was general trait analysis of the maize collections including existing local pro Vitamin A accessions from National Research Stations. A factor score for 15 traits revealed that the main drivers of variation in the first component axis were 100 seed weight, cob weight, and number of kernels per row, whereas the main contributors to variation in the second component axis were cob height, plant height, and leaf length. The third component axis was dominated by 50% anthesis, 50% silking and 50% leaf senescence. The three component axis accounted for 54.19% of the observed variation. Variability was also observed in kernel beta-carotene and total carotenoid contents. It is possible to develop higher beta-carotene varieties from the accessions *NZER1* and *HONAMPA*, which have the highest beta-carotene contents (5.19 and 4.34 μg/g, respectively) and fall within the recommended range (3 to 8 μg/g) for first-generation medium to high pro-vitamin-A maize genotypes.

Key words: Beta-carotene, plant breeding, carotenoid, phenotype, maize, pro-Vitamin A, traits, germplasm.

INTRODUCTION

One of the crucial cereal crops that support Ghana's national economy and systems for ensuring food security is maize. An estimated 50 to 60% of the nation's cereal production comes from maize cultivation. According to

---

*Corresponding author. E-mail: ansahgilbert22@gmail.com.

Ragasa et al. (2014), the crop is a primary staple for more than 50% of the population and also acts as a key component in the production of poultry feed. Vitamin-A deficiency is a serious public health issue in several countries in sub-Saharan Africa, including Ghana (WHO, 2007). Pre-school children, expectant and nursing mothers are the main populations affected by vitamin A deficiency. This vitamin deficit has been linked to several health problems, including impaired immunological response, gastrointestinal disease-related death, and childhood blindness (Muzhingi et al., 2011). White maize grains lacks vitamin A but are nutritionally rich in carbohydrates (Okai et al., 2015). However, because yellow maize has significantly higher quantities of beta carotene, the most potent precursor for the synthesis of vitamin A and is, therefore of more nutritional benefit when consumed.

Given that a large portion of the population uses maize to prepare a variety of foods, reducing vitamin-A deficiency in developing countries through bio-fortification using maize offers a higher potential for success than other food fortification methods that are comparably more expensive, unsustainable, and difficult to access by rural communities (Muzhingi et al., 2011; Sommer and Davidson, 2002). It is anticipated that eating yellow maize varieties high in beta-carotene will greatly help combat vitamin-A deficiency. For this reason, the Ministry of Health has made a concerted effort to promote the health advantages of yellow maize, and the Ghanaian people have been urged to eat more dishes made with yellow maize. As a result, yellow maize is currently becoming more popular, and its use in various food products is expanding quickly in Ghana (Acheampong et al., 2020). Yellow maize consumption is on the rise, which indicates that production levels must keep up with demand if food security issues are to be avoided in the near future.

A comprehensive breeding program focused at creating superior yellow maize varieties with farmer-preferred features is necessary for the success of such a food production goal. Prior until this, a variety of pro-vitamin A enhanced and yet high yielding maize varieties had been created and released. These varieties which are quality protein maize (QPM) also had better protein quality and drought resistance. With the help of these improved varieties, maize production increased from 2016 to an estimated 2.9 million metric tons in 2019. However, compared to other maize-producing nations in the region, this amount of production was far lower. Additionally, the majority of the existing pro Vitamin A (PVA) maize varieties fall short of the Harvest Plus Project's recommended threshold of 15 μg/g for efficient management of vitamin-A deficiency in populations (Pfeiffer and McClafferty, 2007; Harjes et al., 2008; Halilu et al., 2016).

Another significant trend that threatens future food security is farmers' heavy reliance on the extensive cultivation of just a handful of these improved hybrid maize varieties, the majority of which are white varieties resistant to pests and diseases. A growing concern is the significant loss of germplasm resources and the decline in bio-diversity brought on by genetic erosion. In light of this, the most sustainable approach to maize breeding in Ghana will be to select promising accessions from a large germplasm collection in order to create higher yielding, pest and drought resistant, and high beta carotene content varieties that will lessen the effects of vitamin-A deficiency. In this context, the current maize genetic resources must be preserved and improved upon by extensive germplasm collection, preservation and breeding (Prasanna, 2012). Crop accessions are regarded as a great resource for genetic diversity since they represent local adaptations of plant species and include the entire gene pool. Germplasm resources must be accurately defined and categorized in order to act as the foundation for any successful breeding operation. Crop improvement through plant breeding, release, and popularization depends on accurate plant characterization (Chavan, 2010).

Unfortunately, not enough time and money have been spent on study over the years to fully characterize the Ghanaian maize genetic resources that are available, especially with regard to measuring the total carotenoid and beta carotene levels. The best ways to find and select elite materials for breeding higher performing varieties is to thoroughly characterize and describe local crop germplasm and also use elite materials available and already have recommended levels of carotenoids, can be accessed from CGIAR centers working on pro-vitamin A varieties. Some already released in Ghana. The first steps in conserving and preserving genetic resources are phenotypic evaluation and genetic diversity descriptions in gathered germplasm (Osei et al., 2014; Figàs et al., 2015; Sacco et al., 2015). Characterizing genetic variation frequently entails separating accessions based on well-established, highly heritable physical or phenotypic descriptors (IPGRI, 1996). These descriptors primarily represent a broad spectrum of genetic variation, according to which accessions are divided into several varietal classes (Gepts, 2006; Upadhyaya et al., 2008). However, phenotypic trait characterization along with molecular analysis has been demonstrated to produce more thorough data for accession identification (Clement et al., 2010; Dias et al., 2013); germplasm fingerprinting (Pereira-Dias et al., 2020); and establishment of genetic diversity and relatedness (Xu et al., 2013; Zhou et al., 2015; Mohan et al., 2016; Lázaro, 2018).

This study aimed at the collection and characterization of 100 local maize accessions based on phenotypic and nutritional assessment with respect to beta carotene content in order to establish genetic relatedness among the accessions, speed up breeding efforts in the crop, and as a preliminary work towards a large scale maize molecular characterization. The findings will offer fresh information about the regional biodiversity of maize and the bio-fortification approach for vitamin A in an effort to reduce vitamin-A deficiency.

MATERIALS AND METHODS

Germplasm collection

From farmers, research facilities (CSIR-Crop Research Institute, CSIR-Savanna Agricultural Research Institute), and marketplaces all over the nation, one hundred (100) local maize accessions were gathered. The materials were set up for characterization on the Biotechnology and Nuclear Agriculture Research Institute (BNARI) experimental fields, which are located at Latitude 5.672617729637774 and Longitude -0.2146581024463941.

Experimental plot design, agronomic practices and data collection

The field was prepared and demarcated into three replications in a 10×10 lattice design based on randomization using Genstat12 edition. The accessions were planted on May 29, 2018. Single row plots of two plants per hill later thinned to one, two weeks after planting at 80 cm between rows and 40 cm between plants. On the third and sixth weeks following planting, manual first and second weed control procedures were respectively carried out. On the third week, NPK (15-15-15) fertilizer was administered at a rate of 7 g per hill, following the Ministry of Food and Agriculture's guidelines (GTZ/MOFA, 2006). On the basis of a descriptor created by the International Board for Plant Genetic Resources and CIMMYT, information was gathered regarding the vegetative and yield metrics on five middle plants on each plot. 32 accessions that performed well in terms of 100 seed weight and were primarily yellow in colour were chosen for the measurement of traits and estimation of the levels of beta-carotene and total carotenoids.

Carotenoids and Beta-carotene quantification using HPLC

The Rodriguez-Amaya and Kimura-described technique for beta-carotene extraction was followed (Rodriguez-Amaya and Kimura, 1998). An extract portion was utilized for High Pressure Liquid Chromatography (HPLC), and an additional portion was used to measure absorbance. The beta-carotene content was quantified using Agilent HPLC 12 equipment.

Data analysis

Statistical analysis was done using Genstats12 edition, Microsoft Excel and SPSS. Analysis of variance was appropriately carried and means were separated by least significant difference and error bars with standard error. A principal component analysis was also conducted to determine the percentage contribution of various traits to the total genetic variation. Cluster analysis was performed based on similarity matrix. Total carotenoids were calculated using the formula:

$$Totalcaroteniod = \frac{\text{Absorbance} + \text{Total Volume of extracts} \times 10^4}{\text{Sample weight} \times \text{A}\frac{1}{2}}$$

RESULTS

Variability in phenotypic characteristics

Figures 1 to 3 display the phenotypic traits determined and the related percentage of occurrence in the collected accessions. The primary tassels on all accessions lacked any secondary ramifications. In 59% of the accessions, the stem colour was mostly green, while in 41% of the accessions, purple stem color was mixed with the green (Figure 1A). 53% of the accessions had good husk cover, 41% had intermediate husk cover, and 6% had poor husk cover in terms of husk cover integrity (Figure 1B). The majority of the accessions (72% of accessions) had cylindrical cobs (Figure 1C and Figures 2A, B, C, D, E, F and H), whereas the remaining 28% had conical cobs (Figures 1C and 2G). In addition, the culms of 87% of the accessions had pubescence, while the culms of the remaining 13% did not (Figure 1D).

Cob colours were yellow-white (Figures 2A and 3G), yellow (Figure 2B, F), orange (Figure 2C), white (Figure 2D), orange-white-purple (Figure 2E) to red (Figure 2H). The configuration of the kernel rows on the cob was primarily regular (Figure 2A), straight (Figures 2B and 3F), spiral (Figure 2C), and irregular (Figures 2D and 3H). The majority (64%) of the accessions had a linear arrangement of the kernel rows. In 31% of the accessions, regular kennel row layout was seen, whereas in 3% of the accessions, kennel row arrangement was irregular. In 2% of the accessions, spiral kennel row arrangements were seen (Figure 1F). Figures 3A and D show red kernels, whereas Figures 3B, C, E and F show brown, orange, white, cream and yellow kernels (Figures 3G and H) respectively. The percentage of accessions with different colours of kernels varied from 38% for white accessions to 42% for yellow accessions, 9% for yellow-white, 5% for red accessions, 3% for cream accessions, 2% for orange accessions, and 2% for brown accessions (Figure 1E). Regarding the kennel upper surface, 41% of the accessions had an indented upper kennel surface. 38 accessions (38%) had flat kennel surfaces, while 21% had rounded kennel surfaces (Figure 1G). We also noticed dent and flint varieties of kernels. Flint type kernels were detected in 52 accessions (Figure 1H and Figures 3B, C, D and E), while dent type kernels were discovered in 48 accessions (Figures 1H and 3F and H). Alueorone layer variation was also noted. The alueorone layer was colourless in the vast majority (91%) of the accessions (Figures 3E, F, G and H), while red alueorone layer was seen in 5% of accessions (Figures 3A and D). In 2% of the accessions, brown-colored alueorone layers were seen, while 2% of the accessions also included orange-colored layers (Figure 3C).

Variability in qualitative traits among accessions

The number of leaves found above the highest ear ranged from 4.5 to 6.8, respectively. Over the top of the highest ear, there were, on average, 5.4 leaves. Over the highest ear, the majority of the accessions (24) possessed five leaves. 14 accessions with six leaves and eight accessions with 5.5 leaves came after this group.

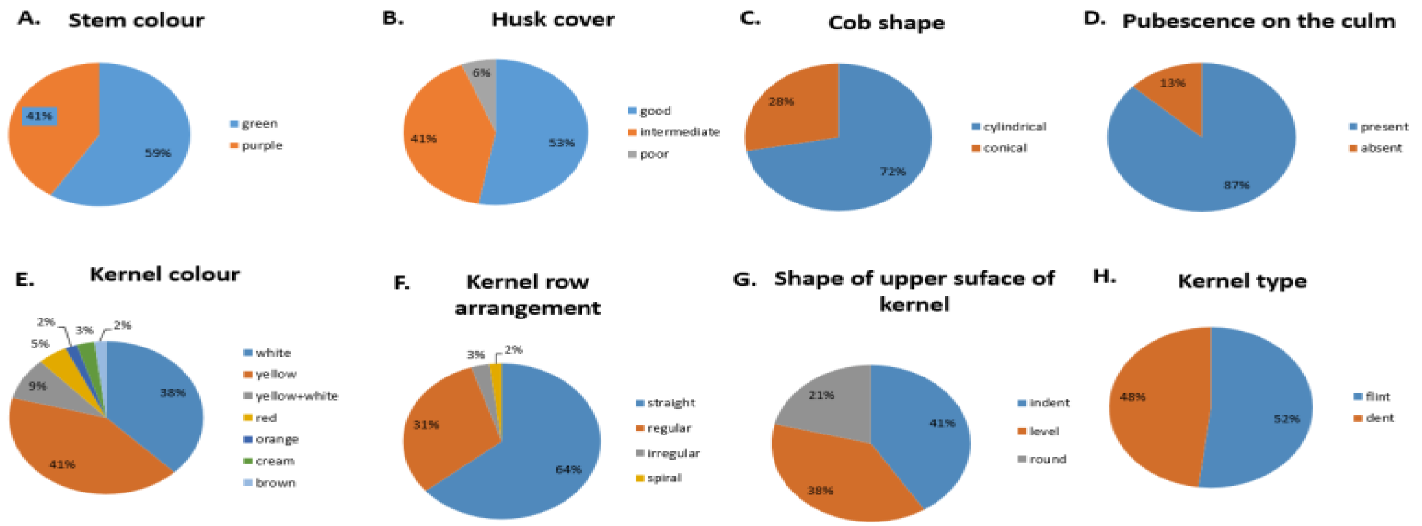

Figure 1. Proportion of accessions showing various qualitative traits in the collections.
Source: Data from this research work.

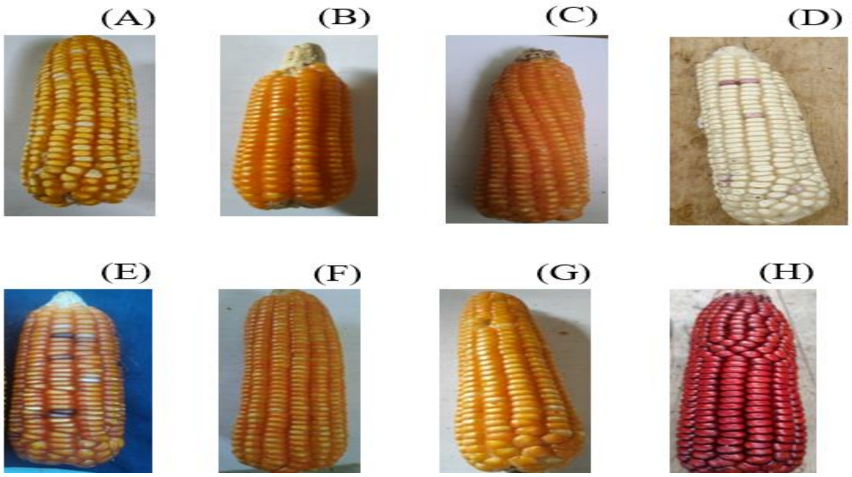

Figure 2. Variation in cob colour, cob shape and kernel row arrangement among accessions. Cob colour: (A, G) yellow-white; (B, F) yellow; (C) orange; (D) white; (E) Orange-white-purple; (H) red. Cob shape: (A, B, C, D, E, F, H) cylindrical; (G) conical. Kernel row arrangement: (A) regular; (B, F) straight; (C) spiral; (D, H) irregular.
Source: Data from this research work.

Lower than 5.5 leaves were present above the highest ear in the remaining accessions. The accessions' maturity phase classifications were evaluated. The range of days to 50% anthesis was 37 to 65, with a mean of 55.4 days. Days to 50% silking ranged from 44 to 71 days, with 61.01 days serving as the average. The mean anthesis-silking intervals ranged from 4 to 7 days, with a mean of 5.5 days. Days until 50% leaf senescence varied from 68 to 110 days, with 89.01 days serving as the average. The majority of the accessions (55), followed by 34 late maturing accessions and 9 early maturing accessions, were found to be medium maturing.

Genetic relationship based on phenotypic traits

In Figure 4, a dendrogram based on 28 phenotypic traits examined using a Euclidean coefficient single link similarity matrix illustrates the genetic relationships among 100 maize accessions. Six significant clusters were found. It is noteworthy that accession *TZE1*, which is thought to be an inbred line, is distinct from the other

Figure 3. Variability in kernel type, kernel colour and colour of aleurone layer. Kernel type: (B, C, D, E) dent; (F, H) flint. Kernel Colour: (A, D) red; (B) brown; (C) orange; (E) white; (F) cream; (G, H) yellow. Aleurone layer: (E, F, G, H) colourless, (A, D) red; (C) orange.
Source: Data from this research work.

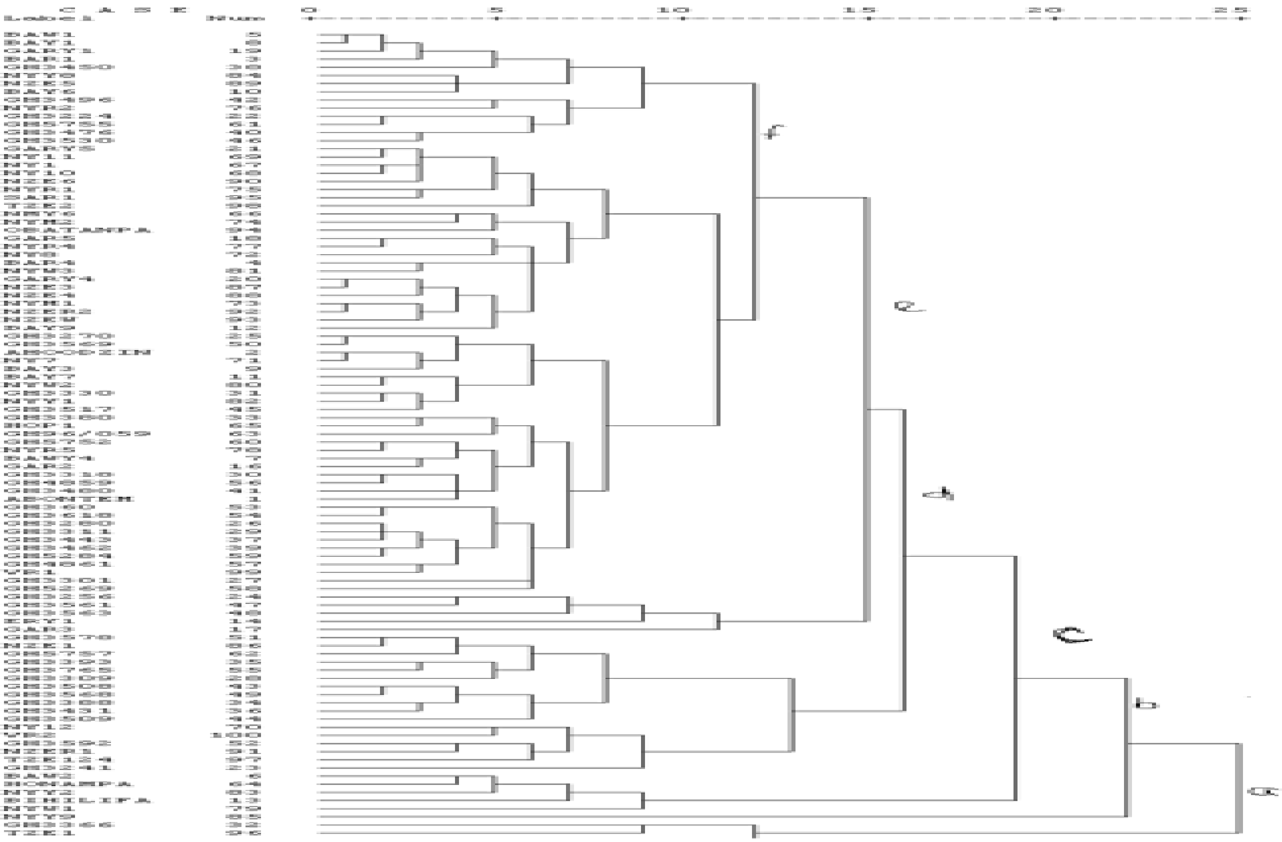

Figure 4. Genetic relatedness among maize accessions.
Source: Data from this research work.

accessions at a 75% similarity level. The genetic gap between *BAW1* and *TZE1* was found to be the greatest. *BAW1/BAY1, GARY4/NZE3* and *AHOODZIN/NY7* were three sets of duplicates that could be distinguished at 98% similarity.

Variability in quantitative traits among maize accessions

Table 1 summarizes the investigation of the variation in quantitative attributes among maize accessions. The

Table 1. Variability in quantitative traits for 100 maize accessions.

Traits	NL	CH/cm	PH/cm	LL/cm	LG/cm	CL/cm	CG/cm	K/R	R/C	CW/g	100SW/g
Mean	5.3	94.34	159.3	96.06	12.8	14.33	8.97	27.21	13.2	82.7	21.81
Min.	4.25	30	91	66.7	8	8	6.4	9	7	14.4	8.44
Max.	6.8	155.4	228	118.2	15.4	21	12	47	18	154.8	31.31
Range	2.55	125.4	137	51.55	7.4	13	5.6	38	11	140.3	22.87
VAR.	0.273	493.8	709.5	83.43	1.31	5.201	1.11	42.16	2.30	1028	29.65
CV	9.745	23.56	16.72	9.509	8.92	15.91	11.7	23.87	11.4	38.7	24.97
SS	26.2	14765	212140	2494	392.9	1555	334	1260	688.8	3074	2846
SD	0.522	22.22	26.64	9.134	1.14	2.281	1.05	6.493	1.51	32.0	5.445

CW: Cob weight, CG: Cob girth, CH: Cob height, CL: Cob length, LW: leaf width, LL: leaf length, NK: Number of kernels per row, NL: Number of leaves above the uppermost ear, NR: Number of rows per cob, PH: Plant height, 100 SW: Seed weight, CV: coefficient of variation, VAR: variance, SS: Sum of squares, SD: Standard deviation.

Source: Data from this research work.

leaves of accession *GH3309*, measuring 109.5 cm was the longest, followed by the leaves of accession *GH96/059*, measuring 108.10 cm. In *GH3592*, the shortest leaf measured 74.07 cm. The broadest leaf width was 11.38 cm in *GH3450*, and the narrowest width was 6.79 cm in *GH3366*. The shortest cob measured 68 cm in height in *TZE124*, while the tallest measured 132.2 cm in accession *GH3496*. Notably, the majority of the tallest plants had a mean height of 212 cm and was found in accession *GAR3*, while the shortest accession was *TZE1* with a mean height of 99.42 cm. The cobs produced by *GH3530* had the largest length, measuring 19.28 cm, followed by *GH3563* with 19.06 cm. The 10 cm-long cobs that were the shortest were discovered in *GH3309*. The cob girth measured in *GH3450* was the widest at 15.53 cm, while *GH3309* had the narrowest cob girth at 10.2 cm. Each of the *GH3592* and *GH96/059* accessions had 15.33 kernels per row. With a mean value of 38.62, *NYR2* had the most kernels per row, followed by NYY9 with 35.83. The mean number of kernels generated per row was lowest for accession *TZE1*. The accession *GH3280* produced the corn with the highest number of rows per cob (15.44 rows), and the accession *GH3509* produced the corn with the lowest number of rows per cob (10.53 rows). The lowest cob weight of 22.3 g was reported by *TZE1*. *NYY9* provided the highest value of 153.2 g, followed by *BAY6* with 135 g. With 31.31 g, *NYY9* produced the heaviest 100 seed weight, whereas GH360 generated the lightest weight (8.44 g).

Correlation analysis and coefficients for fifteen traits

In 100 local maize accessions, the correlation coefficient for fifteen traits and the degree of association between the attributes were calculated. With respect to cob weight (r=0.4855), cob girth (r=0.4233), and the number of kernels per row (r=0.4362), 100 seed weight exhibited a moderately positive connection (r=0.4362). All parameters except cob weight (r=0.1811), cob girth (r=0.1266), and number of kernels per row (r=0.1599) had low positive correlations with anthesis silking interval. Cob weight (r=0.4708), leaf length (r=0.3013), leaf width (r=0.2718), and the number of roles per cob (r=0.2415) all have a moderately positive connection with cob girth. Cob height and plant height were shown to be highly favorably linked (r=0.7547), to be moderately positively correlated (r=0.7547) with leaf length, leaf width, and the number of rows per cob, and to be negatively correlated (r=0.7547) with cob weight and the number of kernels per row. The correlation between cob length and the number of kernels per row (r=0.6277) and cob weight (r=0.4925) was moderately poor. Cob weight and number of kernels per row showed a strong positive association (r=0.7525), however days to 50% silking, anthesis, and leaf senescence showed strong negative correlations (r=-0.3028, -0.3138, and -0.1889). Days to 50% anthesis and days to 50% leaf senescence are moderately favourably correlated (r=0.5839) and substantially positively correlated (r=0.9893) with days to 50% silking.

Principal component analysis for agronomic traits

The latent root values, percent variance, and cumulative percentage of fifteen morphological features are displayed in Table 2. Together, the three principal components accounted for 54.19% of the variation among the accessions and have latent root values larger than 1. The latent root value of PC1 was 3.537, which accounted for 23% of the total observed variance, the latent root value of PC2 was 2.716, which accounted for 18.11% of the total observed variation, and the latent root value of PC3 was 1.874, which accounted for 12.5% of the total observed variation. The main characteristics that contributed to PC1 were cob length, cob weight, and number of kernels per row. Cob height, plant height, leaf length, and leaf width dominated PC2. Days to 50% silking, cob length, days to 50% senescence, and days to 50% anthesis had the biggest effects on PC3.

Table 2. Principal component analysis showing the contribution of fifteen traits among 100 accessions

Trait	Component 1	Component 2	Component 3
100 seed weight	0.31948	-0.00578	0.22261
Anthesissilking interval	0.20400	-0.17759	0.02384
CG/cm	0.24547	0.12817	0.11239
CH/cm	-0.08256	0.43829	-0.30628
CL/cm	0.24305	0.18237	0.31938
CW/g	0.43986	0.09757	0.21389
Days to 50% silking	-0.34192	0.28613	0.35624
K/R	0.39125	0.09692	0.26869
LL/cm	0.15265	0.33850	-020734
LW/cm	0.18237	0.32849	-0.03110
PH/cm	0.06307	0.46963	-0.33812
R/C	0.06525	0.25099	-0.10572
Days to 50% anthesis	-0.35356	0.29693	0.34740
Days to 50% senescence	-0.24814	0.17212	0.44048
No of leaves above the uppermost ear	-0.12376	-0.04512	-0.11140
Latent roots	3.537	2.716	1.874
Percentage variation	23.58	18.11	12.50
Cumulative percentage	23.58	41.69	54.19
trace	15		

Source: Data from this research work.

Principal component score

The significant qualities that made up the PC1 in the principal component score for the three major components were cob weight, number of kernels per row, and cob length. While accession ERY1 had the lowest values for the features causing variance in PC1, entry *NYY9, OBATANPA* and *NZE5* had high values for cob weight, cob length, and number of rows per cob. Cob height, plant height, leaf length, and leaf width dominated PC2. Accessions *TZE1* and *ERY2* provided the lowest values for these feature, while accessions *NYY9, NYY8* and *MNMY6* exhibited high values. Days to 50% silking, cob length, days to 50% senescence, and days to 50% anthesis were the main causes of PC3. The early maturing accessions *ERY1, TZE1* and *ERY2*, as well as the late maturing accessions *GH3563, GH3450, GH3301* and *NYR2*, are responsible for the variance shown in PC3. In general, peripheral accessions make up a larger percentage of the observed variation.

Variability in total carotenoid and beta-carotene contents

The highest total carotenoid content was produced by *ERY1* (17.35 µg/g), followed by *NY1* (16.84 µg/g). *OBATANPA* has the lowest overall carotenoid concentration (9.11 µg/g). *NZER1* has the highest beta carotene content per gram (5.19 µg/g), followed by *HONAMPA* (4.37 µg/g). *BAY6* yielded the least amount of beta carotene, with a value of 0.94 µg/g (Figures 5 and 6). The total carotenoid content ranged from 9.11 (µg/g) to 17.35 (µg/g), respectively. The coefficient of variation was 17.46, and the range was 8.24; the variance was 4.953. The highest and lowest levels of beta carotene, however, were 5.19 (µg/g) and 0.94 (µg/g), respectively. The range was 4.25 in this instance, the variance was 0.935, and the coefficient of variation was 43.55. With the exception of DTA (r = 0.015), CH (r = 0.098), LW (r = 0.017), NLUE (r = 0.613), PH (r = 0.088), and RC (r = 0.091), total carotenoid had a negative correlation with all of the measures. Beta-carotene content also showed a negative correlation with most features, with the exception of DTA, DTS, LW and TC (r = 0.181, 0.188 and 0.392, respectively).

DISCUSSION

Variability in qualitative traits

Early, medium, and late maturing were the three maturity classifications that were found. Days to 50% anthesis, days to 50% silking, silking interval, days to 50% leaf senescence and days to maturity were used to categorize these maturities. Most of the accessions (55%) were categorized as medium maturing. In most cases, 50% leaf senescence was discovered 90 to 100 days after planting. Days to 50% anthesis, plant height, and cob

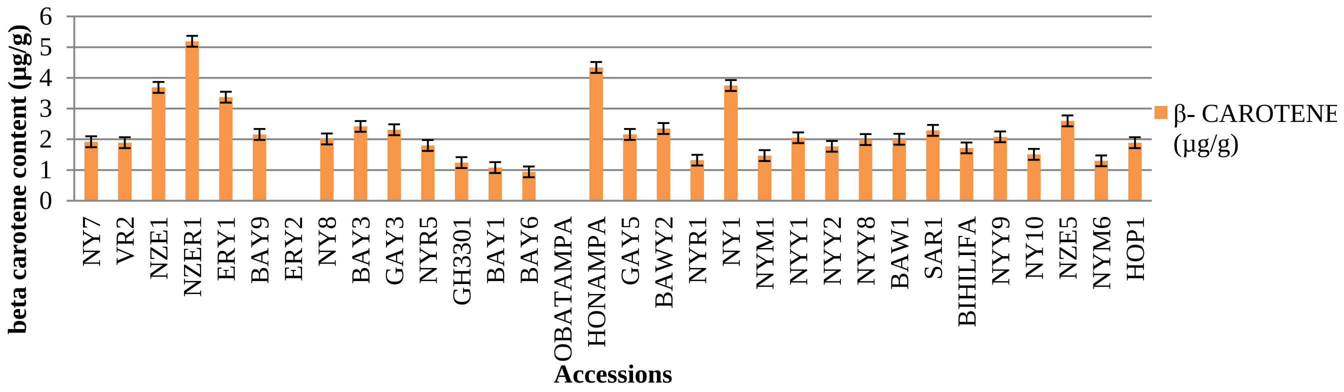

Figure 5. Distribution of beta-carotene content in 32 yellow maize accessions.
Source: Data from this research work.

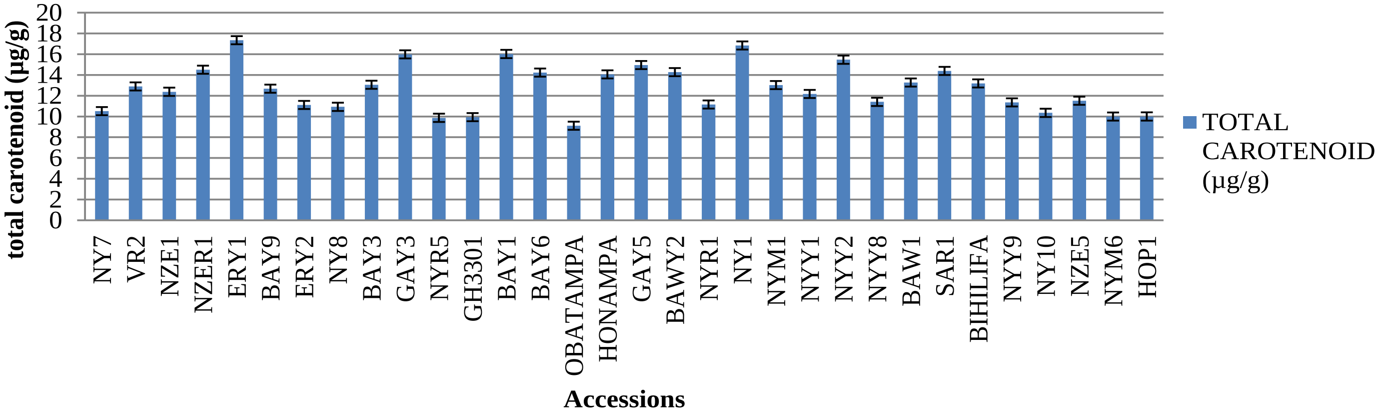

Figure 6. Distribution of total carotenoids content in 32 yellow maize accessions.
Source: Data from this research work.

height are crucial characteristics that affect maturity period and production (Izzam et al., 2017). This was due to the fact that early maturing plants tended to yield less and grow shorter than medium and late maturing plants. Buah et al. (2013) achieved comparable outcomes.

In the maize accessions, secondary and tertiary ramification on tassels was not frequently observed. Primary ramifications were seen in all of the accessions. Majority of the accessions had green stem color or green with different amounts of purple pigmentation. Variation in husk cover was also noted. For the cobs to be protected from harmful weather conditions, a good husk cover is necessary. Additionally, a proper husk cover is crucial for minimizing pest infestation both in the field and during storage. However, inadequate husk protection makes corn more vulnerable to attack by birds and insects. Due to the emphasis on increasing beta carotene content, yellow maize made up the majority of the accessions that were collected. The majority of the maize grown and eaten in Ghana is white, with a small amount being red or orange. Brown maize occasionally might be mixed in with the yellow or white grains. In Ghana, there are no farms growing red maize. Six primary clusters were found in a dendrogram generated for 28 morphological features, indicating substantial levels of diversity between the accessions. It is possible to cross two unrelated accessions to create new, better lines.

Variation in quantitative traits

All quantitative traits showed significant variance among the 100 accessions. Compared to other quantitative features, cob height, plant height, number of kernels per row, and cob weight exhibited highly significant variation. All of the tested parameters had low coefficients of variation, showing the consistency and dependability of the findings. Significant differences in agro-morphological features were detected amongst maize accessions, according to Kandel et al. (2018). The correlation matrix is used to determine how closely two qualities are related. Positive correlation means selection for one feature will automatically choose against the other, and high correlation suggests greater relationship between traits. Cob weight, kernels per row and cob length all showed strong positive correlations (r=7525, r=0.6277). Additionally, there was a weak positive correlation between cob weight and 100 seed weight (r=0.4855), cob girth (r=0.4708), and cob length (r=0.4925). Similar findings were found by Kandel et al. (2018) when they revealed that test weight and ear weight showed a favorable and very significant connection with grain yield.

The majority of the traits examined, with the exception of cob weight (r=0.1811), cob girth (r=0.1266), and number of kernels per row (r=0.1599), were found to have low positive correlations with anthesis silking interval. This outcome can be explained by the fact that protracted anthesis silking intervals negatively affect the majority of quantitative features and are typically the result of unfavorable field circumstances like drought. The yield positively correlated with plant height, the number of kernels per row, and the number of kernels per ear, and negatively correlated with anthesis days, silking days, the anthesis-silking interval, ear height, and maturity days. In maize, Kandel and Shrestha (2020), Muchie and Fentie (2016), Hussain (2011) and Sujiprihati et al. (2003) found a similar significant positive association between grain yield, ear weight, and thousand-grain weight. Hussain et al. (2016) revealed that days to pollen shedding exhibited significantly positive phenotypic correlation with days to silking (rp = 0.92, P = 0.01), ASI (rp = 0.61, P = 0.01) and plant height (rp = 0.36, P = 0.05).

Plant height had a low to moderately positive correlation with every other parameter, with the exception of the anthesis silking interval (r=-0.1282), and a strong positive correlation with cob height (r=0.7547) and leaf length (r=0.5480). Plant height and days to 50% anthesis were associated (r=0.0752). This observation is comparable to that made by Ortiz-Covarrubias (2019) who found a r=-0.22 correlation between plant height and days until 50% anthesis. Most of the investigated parameters, including grain yield and cob height, showed positive and very significant connection with plant height. Also revealed by Bello et al. (2010) and Hidoto (2010) was a strong link between grain yield and plant height. There are differences in plant height among genotypic variability in maize, according to several research findings (Bello et al., 2010; Hidoto, 2010; Bhadru et al., 2011; Kandel and Shrestha, 2020). The competitive situations, light interception, carbon and nutrient capture, and weed competition all affect plant height. The grain yield is positively correlated with the growth characteristics, such as plant height and leaf area (Bhadru et al., 2011, Kandel and Shrestha, 2020).

Variability in beta-carotene and total carotenoid content

The content of beta carotene and total carotenoids in kernels varied. The majority of conventional yellow-kernel maize varieties have beta carotene levels ranging from 0.01 to 4.7 mg/g (Aluru et al., 2008; Chander et al., 2008; Safawo et al., 2010). The beta carotene concentration of five genotypes, *NZER1, ERY1, NZE1, HONAMPA*, and *NYI*, exceeded 3 µg/g, which is within the range (3-8 µg/g) advised for first-generation medium pro-vitamin A maize genotypes (Pfeiffer, 2007; Alhassan 2016). By enhancing the absorption of iron from non-haem sources and having anti-carcinogenic properties, the production and consumption of these genotypes can reduce health issues including poor eye sight (Graham and Rosser, 2000; Hess et al., 2005). The majority of the yellow maize grown in underdeveloped countries has kernel beta-carotene values between 0.5 and 1.5. Beta-carotene concentration in eight of the 32 accessions is greater than 1.5 µg/g but far lower than the 15 µg/g level recommended by the harvest plus project for elimination of vitamin A deficiency diseases in developing countries. Beta-carotene and total carotenoid content showed a strong positive connection, indicating that a higher total carotenoid content can also result in higher beta-carotene content (Tufchi et al., 2014). The consequence is that the total carotenoid content can be used to select for high beta-carotene content (Tufchi et al., 2014).

Low association between visible grain colour and total carotenoids was found which is consistent with the findings of Sefawo et al. (2010). This makes it more challenging to visually choose grains with high beta-carotene concentration. On the other hand, De Almeida Rios et al. (2014) proposed a strong correlation between grain colour and carotenoids content. The consequence is that selection for high beta carotene genotypes based on grain color is technically achievable. When compared to the use of laboratory methods for the screening of genetic materials, this approach could save money and time. Additionally, there was little link found between yield characteristics and carotenoid content. This demonstrates that neither feature needs to suffer from simultaneous improvement. In areas where maize is already a staple diet and where vitamin-A deficiency is a public health issue, high beta carotene content genotypes could be chosen for further breeding of orange maize rich in beta-carotene as an effective food source to address the condition (Muzhingi et al., 2011). When doing phenotypic selection, orange maize is more correlated with carotenoid content compared to yellow and white maize. Accession NZER1 and HONAMPA which are orange in colour had the highest beta carotene contents and there can selected for further breeding purposes and recommended for production and consumption.

Conclusion

The study's findings showed the phenotypic diversity among the nation's maize accessions. The accessions showed significant differences in mean heights, grain weight, and maturation times and therefore conventional breeding methods can used to improve these traits for increased yield and drought tolerance etc. The maize accessions' beta-carotene and total carotenoid contents were measured and revealed significant variation, but they were found to be low. This supported the need to greatly increase the beta carotene content of a few promising types. Success in this area will aid in the fight against hunger, nutritional insecurity, and vitamin-A deficiency.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Acheampong PP, Ewool MB, Oppong A, Ribiero PF, BrobbeyL,Mochiah MB, Obeng E (2020). Willingness to pay for Pro vitamin A Crop Variety: the case of Yellow Maize in Ghana International Biometric Society conference 2020 (IBC 2020) CSIR-Crops Research Institute, Kumasi, Ghana.

Aluru M, Xu Y, Guo R, Wang Z, Li S (2008). Generation of transgenic maize with enhanced pro-vitamin A content. Journal of Experimental Botany 59:3551-3562.

Bello OB, Abdulmaliq SY, Afolabi MS, Ige SA (2010). Correlation and path coefficient analysis of yield and agronomic characters among open pollinated maize varieties and their F1 hybrids in a diallel cross. African Journal of Biotechnology 9(18):2633-2639.

Bhadru D, Reddy DL, Ramesha M (2011). Correlation and path coefficient analysis of yield and yield contributing traits in rice hybrids and their parental lines. Electronic Journal of Plant Breeding 2(1):112-116.

Buah SS, Kombiok JM, Kanton RA, Denwar NN, Haruna A, Wiredu AN, Abdulai MS (2013). Participatory evaluation of drought tolerant maize varieties in the Guinea Savanna of Ghana using mother and baby trial design. Journal of Science and Technology (Ghana) 33(2):12-23

Chander S, Meng Y, Zhang Y, Yan J, Li J (2008). Comparison of nutritional traits variability in selected eighty-seven inbreds from Chinese maize (*Zea mays* L.) germplasm. Journal of Agricultural and Food Chemistry 13;56(15):6506-6511.

Chavan NG (2010). Characterization of soyabean (*Glycine max L.*) varieties through morphological, chemical, molecular markers and image analysis. Thesis submitted to the department of seed science and technology, College of Agriculture. University of Agricultural Science, Dharwad 580005.

Clement CR, de Cristo-Araújo M, Coppens D'Eeckenbrugge G, Alves Pereira A, Picanço-Rodrigues D (2010). Origin and domestication of native Amazonian crops. Diversity 2(1):72-106.

Dias GB, Gomes VM, Moraes TM, Zottich UP, Rabelo GR, Carvalho AO, Moulin M, Gonçalves LS, Rodrigues R, Da Cunha M (2013). Characterization of Capsicum species using anatomical and molecular data. Genetics and Molecular Research 12(4):6488-6501.

Figàs MR, Prohens J, Raigón MD, Fernández-de-Córdova P, Fita A, Soler S (2015). Characterization of a collection of local varieties of tomato (*Solanum lycopersicum* L.) using conventional descriptors and the high-throughput phenomics tool Tomato Analyzer. Genetic Resources and Crop Evolution 62:189-204.

Gepts P (2006). Plant genetic resources conservation and utilization: the accomplishments and future of a societal insurance policy. Crop Science 46:2278-2292.

Graham RD, Rosser JM (2000). Carotenoids in staple foods: their potential to improve human nutrition. Food and Nutrition Bulletin 21:4.

GTZ/MOFA (2006). Agricultural extension handbook. published by Ghana German Agricultural Development Projects (ADPs) P 48.

Halilu AD, Ado SG, Aba DA, Usman IS (2016). Genetics of carotenoids for provitamin A biofortification in tropical-adapted maize. The Crop Journal 4(4):313-322. http//www.scince direct.com.

Harjes CE, Rocheford TR, Bai L, Brutnell TP, Kandianis CB, Sowinski SG, Stapleton AE, Vallabhaneni R, Williams M, Wurtzel ET, Yan J (2008). Natural genetic variation in lycopene epsilon cyclase tapped for maize biofortification. Science 319(5861):330-333.

Hess SY, Thurnham DI, Hurrell RF (2005). Influence of provitamin A carotenoids on iron, zinc, and vitamin A status. HarvestPlus Technical Monography. P. 6. Washington, DC and Cali: International Food Policy Research Institute (IFPRI) and bInternational Center for Tropical Agriculture (CIAT).

Hussain N (2011). Screening of maize varieties for grain yield at Dera Ismail Khan. Journal of Animal and Plant Sciences 21(3):626-628.

Hussain N, Rehman HB, Faizal K (2016) Phenotypic and genotypic association between maturity and yield traits in maize hybrids (Zea mays L.) African Journal of Agriculture and Food Security 4(3):157-116

Izzam A, Sohail HR, Shahzad Ali M, Hussain Q (2017). Genetic variability and correlation studies for morphological and yield traits in maize (*Zea mays* L.). Pure and Applied Biology 6(4):1234-1243. http://dx.doi.org/10.19045/bspab.2017.600131

Rosser BP, Adhikari NR, Adhikari BB, Tripathi M (2018). Performance of hybrid maize in Chitwan Nepal. Bangladesh Journal of Plant Breeding and Genetics 31(1):43-51.

Kandel BP, Shrestha K (2020). Performance evaluation of maize hybrids in inner-plains of Nepal. Heliyon 6(12):e05542.

Kandel BP, Adhikari NR (2018). Adhikari BB, Tripathi M. Performance of hybrid maize in Chitwan Nepal. Bangladesh Journal of Plant Breeding and Genetics 31(1):43-51.

Lázaro A (2018). Tomato landraces: an analysis of diversity and preferences. Plant Genetic Resources 16(4):315-324.

Mohan V, Gupta S, Thomas S, Mickey H, Charakana C, Chauhan VS (2016). Tomato fruits show wide phenomic diversity but fruit developmental genes show low genomic diversity. PLoS ONE 11(4):e0152907.

Muchie A, Fentie D (2016). Performance Evaluation of Maize Hybrids (Zea Mays L.) in Bahir Dar Zuria District, North Western Ethiopia, Department of natural sciences, Addis Zemen Preparatory school, Addis Zemen Ethiopia. International Invention Journal of Agricultural and Soil Science 4(3) (2016) 2408-7254.

Muzhingi T, Gadaga TH, Siwela AH, Grusak MA, Robert M, Russell, RM, Tang G (2011). Yellow maize with high β-carotene is an effective source of vitamin A in healthy Zimbabwean men. The American Journal of Clinical Nutrition 94:510-519. Printed in USA. 2011 American Society for Nutrition.

Okai DB, Boateng M, Ewool MB, Ankamaa D, Osarumwense SO (2015). Nutritional evaluation of some new maize varieties: Effects on growth performance and carcass traits of albino rats. African Journal of Food, Agriculture, Nutrition and Development 15(4):10305-10316.

Ortiz-Covarrubias Y, Dhliwayo T, Palacios-Rojas N, Ndhlela T, Magorokosho C, Aguilar- Rincón VH, Andrea S, Cruz-Morales AS, Trachsel S (2019). Effects of drought and low nitrogen stress on provitamin A carotenoid content of biofortified maize hybrids. Crop Science 59:2521-2532. doi: 10.2135/cropsci2019.02.

Osei MK, Bonsu KO, Agyeman A, Choi HS (2014). Genetic diversity of tomato germplasm in Ghana using morphological characters. International Journal of Plant and Soil Science 3(3):220-231.

Pereira-Dias L, Fita A, Vilanova S, Sanchez-Lopez E, Rodriguez-Burruezo A (2020). Phenomics of elite heirlooms of peppers (*Capsicum annuum* L.) from the Spanish centre of diversity: Conventional and high-throughput digital tools towards varietal typification. Scientia Horticulturae 265:109245.

Pfeiffer WH, McClafferty B (2007). HarvestPlus: breeding crops for better nutrition. Crop Science 47:S88-S105.

Prasanna BM (2012). Diversity in global maize germplasm: characterization and utilization. Journal of Biosciences 37:843-855.

Ragasa C, Chapoto A, Kolavalli S (2014). Maize productivity in Ghana, Ghana strategy support program. International Food Policy Research Institute. Policy Notes.

Rios SD, Paes MC, Cardoso WS, Borém A, Teixeira FF (2014). Color of corn grains and carotenoid profile of importance for human health. American Journal of Plant Sciences 5:857-862.

http://dx.doi.org/10.4236/ajps.2014.56099.

Rodriguez Amaya DB, Kimaru, M (1998). *Harvestplus.* Handbook for Carotenoid Analysis pp. 49-50.

Sacco A, Ruggieri V, Parisi M, Festa G, Rigano MM, Picarella ME (2015). Exploring a tomato landraces collection for fruit-related traits by the aid of a high-throughput genomic platform. PLoS ONE 10(9):e0137139.

Safawo T, Senthil N, Raveendran M, Vellaikumar S, Ganesan KN, Nallathambi G, Saranya S, Shobhana VG (2010). Exploitation of natural variability in maize for β - carotene content using HPLC and gene specific markers. Electronic Journal of Plant Breeding 1(4):548-555.

Sommer A, Davidson FR (2002). Assessment and control of vitamin A deficiency: the Annecy Accords. Journal Nutrition 132:S2845-S2850.

Sujiprihati SS, Saleh GB, Ali ES (2003). Heritability, performance and correlation studies on single cross hybrids of tropical maize. Asian Journal of Plant Sciences 2(1):51-57.

Upadhyaya HD, Gowda CL, Sastry DV (2008). Plant genetic resources management: collection, characterization, conservation and utilization. Journal of SAT Agricultural Research 6:1-16.

WHO (2007). Global Database on Vitamin A Deficiency. The Vitamin A Deficiency database includes data by country based on xerophthalmia and/or serum or plasma retinol concentration GHANA Vitamin and Mineral Nutrition Information System (VMNIS) Last Updated: 2007-05-22.

Xu J, Ranc N, Muños S, Rolland S, Bouchet JP, Desplat N, Le Paslier MC, Liang Y, Brunel D, Causse M (2013). Phenotypic diversity and association mapping for fruit quality traits in cultivated tomato and related species. Theoretical and Applied Genetics 126:567-581.

Zhou R, Wu Z, Cao X, Jiang FL (2015). Genetic diversity of cultivated and wild tomatoes revealed by morphological traits and SSR markers. Genetics and Molecular Research 14(4):13868-13813.