Genetic Variability, Nutritional Composition and Phytochemical Screening of Eggplant (Solanum) species

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Abstract

Eggplants are one of the most important fruit and leaf vegetable, and playing crucial role both in food and source of income. The aim of this study was to assess agro-morphological genetic variability, nutritional composition, phytochemical screening and bioassay of eggplant. For agromorphological studies, twenty genotypes were used in randomized complete block design (RCBD) in two replications within two seasons. Crude extracts of fresh fruit was used for nutritional, phytochemical and antibacterial analysis. Several morphotypes such as leaves, stems, flowers and fruits characteristics were observed and showed significant variations. The one way ANOVA showed highly significant variation in genotypes and in genotype-season interaction. The mean performances of the combined revealed that the maximum fruit weight was 285.5 g and the minimum fruit weight was 78 g. The phenotypic variance and phenotypic coefficient of variance were higher than their corresponding genotypic variance and genotypic coefficient of variance, respectively for all the characters studied. Moreover, the presence of nutritional composition (such as carbohydrates, lipids, proteins and moisture content), secondary metabolites (alkaloids, saponins, Tennins etc) and microbial activities of crude extract were also detected in this study. In conclusion, eggplant had high genetic variability that may be the promising one for the researcher, breeders and pharmacists to develop cultivars that provide good nutrition, important secondary metabolites and antimicrobial activities/good in bioassay.

Key words: Bioassay, eggplant, genetic variability, phytochemical

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1. Introduction

1.1. Background and Justification

Eggplants (*Solanum* species) belong to the family Solanaceae and consist of about 1500 morphologically diverse species (Taher et al., 2017). *S.melongena*, *S.macrocarpon*, *S.aethiopicum*, *S.incanum, S.scabrum*, *S.dasyphyllum*, *S.erianthum* are among the most commonly reported species. Eggplant is mostly found in tropical Africa, South America and Asia, and occasionally grown in France and Italy. The plant is believed to have originated from Africa (Adeniji et al., 2012).

Regarding its ecology, eggplant is grown as annual under temperate conditions in countries like Southern Europe and South of the United States of America but grown as a perennial herb in both the tropical and subtropical climate (Afful *et al*., 2018). Eggplant is widely spread and cultivated in parts of African areas, and the cultivation of this African vegetable have high level of antioxidant compounds and tolerance to the most harmfully pathogen *Fusarium* (Toppino *et al*., 2008). Eggplant grows in different parts of Ethiopia including in Eastern Ethiopia (Awash basin, Hararghe), South and South eastern part of Ethiopia (East Shoa, West Arsi, Wolayita, Sidama, Gamo Gofa), Western and South western part of the country (Hunde, 2017).

Eggplants fruit is very nutritious and uses for medicinal purposes due to its composition, which has very low calories with good minerals like potassium, calcium, magnesium, sodium, iron, and phytochemicals that contain phenolic components and flavonoids (Taher et al., 2017). The plants are easy to raise, relatively free of disease and pests. Eggplant consumption has a lot of health benefits including effectiveness in blood cholesterol reduction, avoid heart problems and help for weight loss (Okon *et al*., 2010). Eggplant is very rich in iron and vitamins (vitamins A, B1 and B6) (and also contains some appreciable amount of calcium (Afful *et al*., 2018).

Genetic variability within inter-mating genotypes of eggplant is the basis for selection as well as for plant improvement. Thus, conservation of this plant genetic variability is essential for present and future human well-being (Okon *et al*., 2010; Uddin et al. 2021). One of the best ways of assessment of genetic variability within and between plant populations have been done through qualitative and quantitative characterizations of the traits (Singh 2001).

Studying agronomic and morphological traits-based genetic diversity of plants such as eggplant are important and easily observable markers, usually used farmers, and breeders for classification and evaluation of yield or yield related traits (Govindaraj *et al*., 2015).

Eggplant plays an important role for nutrition, medicine and also has great export potential; however, no much attention has been given to research and conservation of this plant. In addition, there is also limited information presently on eggplant. To the best of our knowledge, genetic variability of the wide range of plant genotype and the diversity of plant for its phytochemical screening and nutritional composition have not been well investigated. This study is, therefore, the field experiment was conducted in two seasons to detect the genetic variability, for proper conservation and breeding programmes using agro-morphological characterization, to determine its nutritional composition, phytochemical screening and bioassay of the plant.

1.2. Statement of the Problem

Eggplants play an important role for nutrition, sources of different secondary metabolites and have antibacterial activities. In addition, eggplants also provide very low calories in its fruit with good mineral content that is helpful for our health. However, no much attention has been given to research and conservation of it, and limited information is available concerning the eggplant. Hence, diversity in chemical and nutritional composition of different types of cultivars was useful for the selection and breeding of improved varieties of eggplant (José et al. 2016; Sunseri et al. 2010). Genetic variability of the wide range of plant germplasm and the diversity of plant for its, nutritional composition, phytochemical screening and bioassay have not been systematically studied. Testing at different seasons help to clearly understand the extents of the existing genetic variability for proper conservation and breeding programmes using agro-morphological characterization. This study is, therefore, had been analysed genetic variability, nutritional composition, phytochemical screening and bioassay activities of the eggplant genotypes.

1.3. Significant of the Study

This study generated valuable information on the genetic variability, nutritional composition, phytochemicals, and bioassay activity in eggplant. The information is useful for breeders, researchers to select appropriate parents of eggplants. Moreover, further study is helpful using sophisticated techniques for exploitation of its nutritional contents, secondary metabolites, and antimicrobial activities.

1.4. Objectives

1.4.1. General Objective

- To assess agro-morphological genetic variability, nutritional composition, phytochemical screening and bioassay of eggplant.

1.4.2. Specific Objectives

- To analyse the genetic variability using qualitative and quantitative traits
- To determine the nutritional composition of the selected eggplant
- To extract and analysis the phytochemical screening and bioassay of the plant

2. Literature Review

2.1. Botany of Eggplant

Most of the eggplant grows upwards, and the leaves have alternate, simple; stipules absent and blade broadly ovate. The plant is mainly self-pollinated (Lester and Daunay, 2003).The flowers are bisexual, regular, white and sometimes pale purple. According to José, *et al*. (2016), flowers are either solitary or in few-flowered inflorescences and latter is supra-axillary with lower flower hermaphrodite and upper ones male.

A wide variation has been observed in fruit shape, colour, size, diameter of corolla and taste. The fruit ranges from smooth to more or less strongly ribbed. The colour of the fruit can be pure white, creamy white, dark green, pale green, purple or brown, with a bitter taste that varies depending on saponin content. Some fruits can be stripped with two or more colours (Norman, 1992). The fruits are consumed raw or cooked. The fruits shape is round, elongate-round or oval with smooth or grooved surface and taste varying from sweet to bitter, particularly in the case of oval-fruit cultivars. At full maturity, the fruits turn red or reddish-orange due to high carotene content (Sękara *et al*., 2007). Fruit surfaces vary from smooth to grooved or ribbed. The leaves are often consumed in the same way as spinach. Appropriate flower pollination is one of the principal conditions for achieving good quality yields and seeds in eggplants (José, *et al*., 2016).

Consumers' preference for fresh fruit is influenced by fruit acidity at commercial harvest among other fruit quality traits (fruit colour, taste and phenolic contents). In addition, fruit browning is an important fruit quality trait associated with the quantity of phenolic compounds in the fruit epidermis (Adeniji et al., 2012).

2.2. Importance of Eggplants

2.2.1. Nutrition and Phytochemical Investigation of Eggplant

Eggplant is an important source of plant-derived nutrients, valued for its composition in phytochemicals and especially minerals such as P, K, Ca, and Mg. In addition, considerable differences were found in the mineral composition among varieties and germplasm accessions, revealing the existence of ample variation, which can be exploited for the selection of germplasm for nutritionally improved characteristics (Gramazio *et al*., 2019). Eggplant is an important Solanaceous crop that grown for domestic consumption and also for export (Norman, 1992; Okon *et al*., 2010). Nutritionally, the plants are grown for its edible leaves and edible fruits (Afful *et al*., 2018). According to Norman (1992), eggplant is grown

in Savannah Africa for both the leaves and immature fruits while in the humid zone of West Africa it is mostly grown for its immature fruits. According to Chinedu *et al*. (2011), eggplant is very rich in nutrients. According to Arivalagan *et al*., 2013, eggplant is a fairly good source of iron, calcium, phosphorus, potassium and vitamin B group (Horna *et al*., 2007).

Eggplant fruit do contain ascorbic acid and phenolics, both of which are powerful antioxidants (Hanson et al., 2006). Medicinal properties are attributed to its roots and fruit (Lester and Daunay, 2003). It helps the body to boost the immune system, enhance free circulation of blood as well as strengthen the body tissues. The soup from the cooked green fruits offers treatment of hypertension (Arivalagan *et al*., 2013). Eggplant is low in sodium, low in calories and very rich in high dietary fibre (José, *et al*., 2016). It is also high in potassium, a necessary salt that helps in maintaining the function of the heart and regulate blood pressure as well as protect the heart against cholesterol effects (Afful *et al*., 2018).

Several studies have been carried out to estimate the genetic variation of eggplant using agro-morphological traits to assess the phenotypic variability among its genotypes (Adeniji *et al*., 2012; José *et al*., 2016; Sunseri *et al*., 2010). Some of these studies were based on accessions from gene banks, while others were based on field collections. Eggplant is widely spread and cultivated in parts of African areas, and the cultivation of this African vegetable have high level of antioxidant compounds and tolerance to the most harmfully pathogen *Fusarium* (Toppino *et al*., 2008).

Phytochemical screening of the eggplants revealed the presence of alkaloids, flavonoids, phytosetols, saponins, ascorbic acid, cardiac glycosides, tannins and terpenols (Sanchez–Mata et al., 2010; Shalom et al., 2011; Asl and Hossein, 2008). Similarly, the nutritional composition of eggplants also well studied (Chinedu *et al*. 2011; Gramazio *et al*., 2019). Eggplants are ideal fruits for individuals with high serum lipid levels, high blood pressure and other ischemic heart diseases. Eggplant genotypes have low carbohydrate level/ low energy content that may be very helpful for weight management and for diabetic patients (Afful et al 2019).

2.2.2. Genetic Information about Eggplant

Genetic variation in genotypes of crop species is important for successful selection and yield improvement programs (Akpan et al., 2016). The significant differences observed among the

genotypes for all the traits in planting under both different season and locations may the existence of sufficient inherent genetic variability among the genotypes. This variation can be exploited for further yield improvement of eggplants. The phenotypic variances of the traits can be partitioned into heritable (genotypic variance) and non-heritable (environmental variance) components. If the magnitude of environmental variances was lower than their corresponding genotypic variances, indicating that the genotypic component of variation was the major contributor to total variation in the traits studied (Toppino *et al*., 2008).

Eggplant plays an important role for nutrition, medicine and also has great export potential; however, no much attention has been given to research and conservation of this plant. In this respect, analysis of diversity, proximate composition, phytochemical screening and bioassay will be an important breeding objective. This study was focused on on analysis of genetic variability, nutritional composition, phytochemical screening and isolation bioassay of the plant.

3. Materials and Methods

3.1. Plant Materials

The eggplant materials were collected from Southern Ethiopia, Eastern Ethiopia, and the remaining plant materials were obtained from the Ethiopian Biodiversity Institute (Addis Ababa) and from Melkassa Agricultural Research Center. Twenty plant genotypes were grown at Melkassa Agricultural Research center for morphological studies, when the fruit matured, harvested and used for nutritional, phytochemical analysis and for bioassay activities (Figure 1).

Figure 1. Morphological differences among eggplant Grown at Melkassa agricultural research center, Ethiopia

3.2. Description of the Study Area

The study was carried out at Melkassa Agricultural Research Center located in Central Rift Valley of Ethiopia. Melkassa Agricultural Research Center (MARC) is found 117 km South East of Addis Ababa at a geographic co-ordinate of 8°24'N and 39°12'E. MARC is located at an altitude of 1550 m.a.s.l. The area receives mean annual rainfall of 763 mm, about 70% of which is received during the main rainy season from June to September. The mean annual maximum and minimum temperature of the site is about 28.6°C and 13.8°C, respectively. The agro-climatic condition of the area is classified as semi-arid. The soil texture is dominantly loam and clay loam (Dasta Tsagaye and Yosef Alemu, 2021).

3.3. Experimental Procedure and Design

The field experiment was conducted at Melkassa Agricultural Research Center (MARC) in two seasons, from May 2021/ to January 2023. The experimental design was laid out in randomized complete block design (RCBD) of two replications using 20 eggplant genotypes. Each plot had two rows of three meters with spacing of 0.8 m intra raw and 0.8 m inter raw. To study various qualitative and quantitative parameters, five individual plants in the middle were tagged within each plot to avoid bordering effect. Hence, all plants per genotype were taken and monitored until maturity. Other cultural practices like cultivation and weeding were done whenever needed. The laboratory experiments were conducted at Departments of Applied Biology and Department of Applied Chemistry, School of Applied Natural Science, Adama Science and Technology University.

3.3.1. Morphological Measurements

The descriptor lists developed by Ihtizaz *et al*. (2015) was used in this study. In total of 23 agro-morphometric (11 qualitative and 12 quantitative) traits were recorded at the correct growth stages (Table 1). For most of the quantitative morphological traits, the data were collected on sample of five selected and tagged middle plants from each collection per plot and per replication. Traits such as days to first flowering, days to 50% flowering, days to 90% maturity and fruit yield were recorded on plot basis.

Table 1. Morphological traits scored method

A. Qualitative traits			
Trait	**Code**	**Description**	**Scores**
Leaf arrangement	LA	Positioning of leaf at 50% flowering	Opposite(1), Alternate (2), Whorl(3)
Leaf shape	LS	Shape of leaves during harvest	Ovate(1), Triangular(2), Round(3)
Steam colour	SC	Colour of the stems at initiation of flowering	Deep Purple(1), Pale Purple(2), Green(3)
Petiole colour	PC	Colour of the petiole at initiation of flowering	Deep Purple (1), Pale Purple(2), Green(3), Deep Green (4)
Corolla colour	CC	Colour of the corolla at initiation of flowering	Purple (1), white(2), violet (3)
Fruit colour	FC	Colour of the Fruit at physiological maturity	Cream(1), Cream White(2), Cream Purple(3), Purple(4)
Spot on fruit	SF	Presence or absence of spot on fruit at physiological maturity	Present (1). Absent (2)
Fruit surface	FTS	Fruit surface during harvest	Smooth (1), grooved or ribbed(2)
Spot colour	STC	Colour of the spot at physiological maturity	White (1), black (2), orange (3)
Fruit shape	FS	Fruit shape during harvest	Elongated(1), Round(2), Oval(3)
Fruit taste	FT	Taste of fruit during physiological maturity	Sweat (1), bitter (2)
B. Quantitative traits			
Leaves number	LN	Average number of leaves formed per plant	5 plants/plot/rep/location
Plant height (cm)	PH	The distance of the height of main stem from the ground to the tip of the flowering	5 plants/plot/rep/location
Branch number	BN	Average number of branches formed per plant	5 plants/plot/rep/location
Branch length (cm)	BL	The length of the branches from the base to the tip of the branch	5 plants/plot/rep/location
Days to first flowering	DFF	Number of days from germination to the appearance of the first flower	Plot based
Days to 50% flowering	DTF	Number of days from germination to 50% of the plants showing flowers	Plot based
Days to 90% maturity	DNM	Number of days from date of germination to the date when the plants in each plot attained 90% physiological maturity	Plot based
Number of fruit per plant	NFP	Total number of fruits per plant at the time of harvesting	5 plants/plot/rep/location
Fruit length (cm)	FL	The length of the fruit from the apex to the base of the fruit stalk	5 plants/plot/rep/location
Fruit diameter (cm)	FD	The broadest part of the fruit diameter	5 plants/plot/rep/location
Fruit weight (g)	FW	The weight of the fruit at physiological maturity	5 plants/plot/rep/location
Fruit yield	FY	The total yield of the fruit per plot	Plot based

3.3.2. Nutritional Composition Analysis

The health fruits were selected thoroughly and washed with tap water to remove dirt and unwanted particles. The stalks were removed and the edible portion of fruits was prepared for analysis.

Moisture content: Moisture content was determined by heating 2g of fresh sample to a constant weight in a crucible and placed in an oven to maintain at 105 °C.

Ash content: It was determined by the total incineration of 2 g fruit sample in furnace that maintained at 550°C for 5 - 6 hrs until the ash turned white.

Crude fibre: 2 g of dried sample was digested with 0.25 M sulphuric acid and 0.3 M sodium hydroxide solution. The insoluble residue obtained was washed with hot distilled water and oven dried at 100 °C until constant weight.

Crude protein analysis: Kjeldahl method was used to determine the crude protein content of the samples. The protein content was calculated by multiplying the nitrogen content obtained from the digestion, distillation and titration of 2 g sample by a factor of 6 (Kjeldahl 1883).

Fat content: Crude fat was obtained using Soxhlet apparatus, fat content was determined according to the standard procedure (Quamruzzaman et al. (2020).

Test for carbohydrate: To 2 mL of each crude extracts, 2 drops of Molisch's reagent was added and shaken well. 2 mL of concentrated Sulfuric acid was added on the side of the test tube. A reddish violent ring appeared at the junction of two layers indicates the presence of carbohydrate (Santhi *et al*., 2011).

3.3.3. Phytochemical Screening Tests of Crude Extracts

Phytochemical screening of the plant extracts were carried out using standard procedures of colour and precipitate forming reagents to check for the presence or absence of secondary metabolites/to determine the secondary metabolites, such as alkaloids, carbohydrates, flavonoids, glycoside, phenols, quinones, tannins, saponins, terpenoids, and steroids compounds. The extracts were dissolved individually in respective solvent and then the test was performed.

Test for alkaloids: 10 mL of the extract was stirred with 5 mL of the 1% aqueous HCl on a steam bath. A few drops of dragendorff's reagent were used to treat 1mL of the filtrate.

Turbidity or orange/orange-red precipitation with this reagent was taken as evidence for the presence of alkaloids (Adegoke et al. 2010).

Test for flavonoid: The crude extract was treated with 10% NaOH solution; formation of intense yellow color indicates presence of Flavonoid (Ashvin and Rajaram 2013).

Test for glycoside: To 2 mL of each crude extracts, 3 mL of glacial acetic acid and 1 drop of 5% ferric chloride was added to test tubes. Carefully 0.5 mL of concentrated H_2SO_4 was added. Reddish brown color appears at a junction of the two layers and formation of bluish green in the acetic acid layer indicated the presence of glycosides (Prashanth and Krishnaiah 2014).

Test for phenols: A small amount of each crude extracts (1 mL) was dissolved in 2 mL of distilled water. To this solution 2 mL of 5% ferric chloride solution was added. Formation of blue, green or violet color indicated presence of phenolic compounds (Prashanth and Krishnaiah 2014).

Test for quinones: To test the Quinone phytochemical presence, in a test tube 1mL of extract and 1mL of concentrated sulphuric acid (H_2SO_4) was added. Formation of red color shows the presence of Quinone's.

Test for tannins: To test the tannin phytochemical presence, in a test tube 1mL of 5% ferric chloride added to solvent free extract. The presence of tannin is indicated by the formation of bluish black or greenish black precipitate.

Test for saponin: 5 mL of distilled water was added to each crude plant extracts in a test tube and it was shaken vigorously. The foam formation indicated the presence of saponins (Jaradat et al. 2015).

Test for terpenes: To 5 mL of the crude extract, 2 mL of chloroform and 3 mL of concentrated H_2SO_4 was added, and formation of a reddish brown ring confirms the presence of terpenes (Obianime and Uche 2008).

Test for steroids: 2 mL of chloroform and concentrated H_2SO_4 was mixed with the entire crude extracts. In the lower chloroform layer the formation of red color indicates the presence of steroids (Jaradat et al. 2015).

3.3.4. **Antibacterial assay**

The plant crude extracts were tested for antibacterial activity. The antibacterial activities of crude fruit samples were tested against Gram positive bacterium *Staphylococcus aureus* (*S. aureus*), and Gram negative bacterium *Escherichia coli* (*E. coli*) using Mueller Hinton (MHA) medium. All the microbial were obtained from Plant Pathology laboratory of the School of Plant Science, Haramaya University.

Preparation of inoculums

The test bacterial strains was transferred from the stock cultures and was streaked on Mueller Hinton (MHA) plates and incubated for 24 hrs. Well separated bacterial colonies were then used as inoculums. Bacteria were transferred using bacteriological loop to autoclaved MHA that was cooled to about 45 ^{o}C in water bath and was mixed by gently swirling the flasks. The medium was then poured to sterile Petri plates that was allowed to solidify and used for the bio-test.

Preparation of test solution

The crude extract (0.2 g/mL) and fraction of F_3 (0.06 g/mL) was dissolved in $CHCl_3$ and MeOH (1:4) and the fruit extracts was used to test antimicrobial activities.

Testing for antibacterial activity

A well of 6 mm was performed in disc plate with Mueller Hinton agar (HiMedia, Mumbai-India) inoculated with isolated bacterial strains. Various concentrations (25, 50, 100 mg/ml) of dried extracts were prepared in sterilize distilled water. Then, the inoculated bacteria were incubated at 37 ^{o}C for 24 hrs. All the tests were performed in triplicate. The antibacterial activity was evaluated by measuring of the inhibition zone against the tested organism. Ceftriaxone, the commercial standard drug used as control during this study.

3.4. Statistical Analysis

3.4.1. Morphological Trait Analysis

The data that subjected to the analysis of variance (ANOVA) was computed using SAS statistical program and GLM procedure software to demonstrate the existence of differences among the genotypes. Mean comparisons among genotypes were separated using the Tukey's ("honestly significant difference" or "HSD") procedure at 5% probability.

- Significance tests of the correlation coefficients will be determined using the Student's t-test. $t = r / \sqrt{(1-r^{2}) / (n-2)}$, where *r* is the correlation coefficient and *n* is the number of observations.
- Genotypic variance is the part of the phenotypic variance that can be attributed to genotypic differences among the phenotypes (Dudley & Moll 1969). Hence, variance components (genotypic, phenotypic and error variances) were estimated using the formula of Prasad *et al*. (1981) as follows:

  $V_g = [MSG - MSE / r]$

  $V_p = [MSG / r]$

  $V_e = [MSE / r]$, Where MSG, MSE and r are the mean squares of genotypes, mean squares of error and number of replications, respectively.

- Phenotypic (PCV) and genotypic (GCV) coefficients of variation will be evaluated according to the methods of Burton (1952), Johnson *et al*. (1955) and Kumar *et al*. (1985) as:

  $PCV = (\sqrt{Vp / \overline{X}}) \times 100$

  $GCV = (\sqrt{Vg / \overline{X}}) \times 100$, where Vp, Vg and $\overline{X}$ are the phenotypic variances, genotypic variances and grand mean per site, respectively, for the character under consideration.

- **Heritability (Broad sense heritability) (h^2B)**: percentage of the ratio of the genotypic variance (Vg) to the phenotypic variance (Vp) estimated on the genotypic mean basis as described by Allard (1991).
- **Genetic advance (GA)**: a percent of the mean assuming selection of the superior 5% of the genotypes will be estimated in accordance with the methods illustrated by Fehr (1987) as: $GA=K(Sp)h^2B$

  GA (as % of the mean) = $(GA/\overline{X}) \times 100$, where K is a constant (which varies depending upon the selection intensity and, if the latter is 5%, it stands at 2.06), Sp is the phenotypic standard deviation ($\sqrt{Vp}$), h^2B is the heritability ratio and $\overline{X}$ refers to the site mean of the character.

4. Results and Discussions

4.1. Morphological Characteristics of Eggplant Genotypes

4.1.1. Qualitative Traits Distribution

Several morphotypes were observed for a number of qualitative traits including leaf, stem, flower and fruit characteristics and summarized in (Table 2). In general, most of the morphotypes are proportionally distributed but some are rare. Details are presented below.

4.1.1.1. Leaf Characteristics

Two leaf related characteristics that include leaf arrangement and leaf shape were recorded. Regarding leaf arrangement patterns, alternative arrangement was the most frequent (65 %), followed by opposite arrangement (20 %), and whorl arrangement was the least (15%), indicating that difference in leaf arrangement may be due to the selection of different eggplant genotypes. Regarding leaf shape, three phenotypic classes, triangular, ovate and round, were observed in the frequency of 70 %, 0 %, and 30 %, respectively (Table 2). A similar finding was observed by Younas et al. (2022) in the study on eggplant, since, qualitative traits were evaluated under common environment, the observed variations among the character states could be attributed to genetic variation within and among the genotypes. Hence, they are bases for further improvement programs and conservation measures of the crop. However, some of the phenetic characters, for example, whorl leaf arrangement, oval leaf shape, deep purple leaf and stem colors, were rare polymorphic phenotypes, that might be resulted from either recurrent (rare) mutation events or natural selection pressure against the traits. Similarly, the distinctive leaf related morphological characters were reported by Quamruzzaman et al. (2020) and Younas et al. (2022).

4.1.1.2. Stem Characteristics

Eggplant is herbaceous plant, mostly upright in nature. Our results demonstrated that a total of three stem related characteristics such as stem colour, stem spot and stem growth habit were observed. Genotypes with pale purple stem colour were the most frequent (60%) followed by green (25 %) and deep purple (15 %). It has been observed that 85 % of the total genotypes have no spots on stem, and only (15 %) had spot on stem. For stem growth habit, three phenotypic classes (erect, open and intermediate) growth patterns were recorded. Most genotypes (60 %) exhibited erected (upright and longer) stems while the rest showed open (stunted and horizontal) (35%) and intermediate (5%) growth patterns (Table 2). The eggplant genotypes having spot on the stem were resistant to insect attack It was also noted that insect attack was more prevalent on the green stem as compared to stem with purple-

green colour and no such clue was present in the previous study (Younas et al., 2022). The same finding was reported by Uddin (2021) that eggplant is a herbaceous plant, mostly upright in nature was (49.23 %), intermediate was (17.69 %) and 33.08 % had prostrate growth habit among all the studied genotypes.

4.1.1.3. Flower Characteristics

Two flowers related phenetic characters, petiole colour, and corolla colour were recorded. Regarding petiole colour, genotypes with pale purple were the dominant (60 %) followed by green (25 %), deep purple (10 %), and deep green (5 %). With regards to corolla colour, most of the genotypes were purple colour (70%), followed by white colour (15%), and violet colour (15%) (Table 2).Similarly reported by Akpan et al. (2016) flower characteristics is important for demarcation of the species in eggplants.

4.1.1.4. Fruit Characteristics

In the present study, it was observed that the eggplant genotypes showed high variation in fruit characteristics as well. A total of six fruit related characteristics that included fruit colour, spot on fruit, fruit surface, fruit spot colour, fruit shape and fruit taste were observed (Table 2). In the current research, it has been observed that 85% of the total genotypes have no spots on fruit, and few (15 %) have spot on fruit. Genotypes with cream purple colour were the most frequent (35%) followed by cream colour (25%), purple colour (25%) and white colour (15 %). Eggplant fruits traits variations are important in protection from UV irradiation, insect attack in plants as well as socio-economic value. More fruit colour variation was noted by Uddin et al. (2021), which support our present study. Akpan et al. (2016) and Kaur et al. (2019) stated that the fruits colour divided the eggplant fruits into six colour groups i.e., green (37.27%), purple (25.45%), milky white (13.62%), purple-black (12.72%), light purple or lilac grey (9.09%), and scarlet red (1.08%).

Genotypes with smooth fruit surface were the most frequent (90%) followed by grooved/ribbed surface (10%). For fruit spot colour, three phenotypic classes (white, black and orange) colour were recorded. Genotypes with orange fruit spot colour were the most frequent (50%), followed by black colour (25%) and white fruit spot colour (25%). Genotypes with round fruit shape were the most observed (40 %), followed by elongated fruit shape (35%), and oval fruit shape (25%). Regarding the fruit taste, most of the fruit had bitter taste (75 %), and the rest had sweat taste (25 %) (Table 2). The results indicating the existence of enormous amount of genetic variability for fruit related characteristics.

Determination/estimation of variability is an important prerequisite for realizing response to selection as the progress in the breeding depends upon its amount, nature and magnitude.

Table 2. Groups of traits, specific qualitative morphological traits, their scores and equivalent phenetic characters, and frequency and percent coverage in each score during the analysis of 20 eggplant genotypes.

Group character	**Individual trait**	**Score**	**Phenetic characters**	**Number of accessions (frequency)**	**Relative % of each phenotype**
Leaf characteristics	Leaf arrangement	1	Opposite	4	20
		2	Alternate	13	65
		3	Whorl	3	15
	Leaf shape	1	Ovate	14	70
		2	Triangular	0	0
		3	Round	6	30
Stem characteristics	Steam colour	1	Deep Purple	3	15
		2	Pale Purple	12	60
		3	Green	5	25
	Stem spot	1	Present	3	15
		2	Absent	17	85
	Stem growth habit	1	Open	7	35
		2	Erect	12	60
		3	Intermediate	1	0.05
Flower characteriatics	Petiole colour	1	Deep Purple	2	10
		2	Pale Purple	12	60
		3	Deep Green	1	5
		4	Green	5	25
	Corolla colour	1	Purple	14	70
		2	White	3	15
		3	Violet	3	15
Fruit characteristics	Fruit colour	1	Cream	5	25
		2	White	3	15
		3	Cream Purple	7	35
		4	Purple	5	25
	Spot on fruit	1	Present	3	15
		2	Absent	17	85
	Fruit surface	1	Smooth	18	90
		2	Grooved/ ribbed	2	10
	Fruit spot colour	1	White	5	25
		2	Black	5	25
		3	Orange	10	50
	Fruit shape	1	Elongated	7	35
		2	Round	8	40
		3	Oval	5	25
	Fruit taste	1	Sweat	5	25
		2	Bitter	15	75

4.1.2. Quantitative Traits Distribution

4.1.2.1. Analysis of Variation in Eggplant

The one-way ANOVA of all characteristics showed highly significant variation, among genotypes, except for leaf number, indicating considerable genetic variability among the genotypes. The genotype by season interaction was also highly significant for all characteristics, except for leaf number and fruit weight (Table 3). This indicates that field experiments at different seasons and several environmental conditions are required for evaluating the variability of plants. Genetic variability plays an important role in selecting genotypes for making rapid improvement in yield and other desirable characters as well as to select potential parents for hybridization programmes. The information on nature and pattern of genetic variation within the available material can aid in designing strategies effective for its conservation (Adeniji et al. 2012). Bashar et al. (2015) suggested that significant differences observed among the genotypes for all the traits in planting under both seasons, and the existence of sufficient inherent genetic variability among the genotypes. This variation can be exploited for further yield improvement in eggplants (José et al. 2016).

Table 3.Mean squares for 12 quantitative traits of 20 egg plants genotype grown at Melkassa agricultural research centers

Source of variation	Mean square and significant tests						
	DF	LN	DFH	PH	DFF	NB	BL
Genotype	19	1.53	7.44	352.297**	8.76*	154.18	86.07*
Season	1	0.03	20704.61*	434992.26*	14137.90*	943.77	16.707*
Rep	1	1.25	42.05	6200.481*	21.53*	520.84	12.21**
Genotype*Season	19	0.74	9.57**	391.120**	11.90*	52.16**	86.14**
Error		0.83	5.84	221.309	1.08	86.25	38.30*
CV (%)		8.51	3.17	9.49	1.076	26.44	11.05

Significant at P<0.05. LN = Leaf number, DFH = days to 50% heading, PH = plant height, DFF = days to 50% flowering, NB = number of Branches, BL = branch length, DNM = days to 90% maturity, NFPP = Number of fruit per plant, FL = Fruit length, FD = Fruit diameter, FW = Fruit Weight, FY = Fruit yield

Table 3. Continued

Source of variation	DF	Mean square and significant tests					
		DNM	NFPP	FL	FD	FW	FY
Genotype	19	152.5	536.14*	312.05	11.34*	0.075	1117.34*
Season	1	20464.00*	395606.26*	133501.89*	4130.73*	0.48*	24888.971*
Rep	1	20464.00*	854.78	599.68*	5.77	0.31*	8439.06*
Genotype*Season	19	33.93**	1310.478*	357.46*	13.90*	0.07	2269.08*
Error		154.9	146.5389	197.69	3.72	0.04	41.58
CV (%)		7.25	7.87	9.87	12.33	6.53	29.36

* Significant at P<0.05. LN = Leaf number, DFH = days to 50% heading, PH = plant height, DFF = days to 50% flowering, NB = number of Branches, BL = branch length, DNM = days to 90% maturity, NFPP = Number of fruit per plant, FL = Fruit length, FD = Fruit diameter, FW = Fruit Weight, FY = Fruit yield

The mean performances of the combined data also showed significant variations that the maximum days taken for 50% flowering were 87.92 while the minimum days72.3 days. In addition, the maximum fruit weight was 285.5g and the minimum fruit weight was 78g (Table 4). The phenotypic traits such as plant height, days to heading, days to flowering and days to maturity showed significant variation, indicating of higher genetic diversity occurring among the materials that can serve as the genetic resource for its improvement (Toppino et al. 2008; Afful et al. 2018).

Table 4. Estimates of mean performance and ranges for 12 quantitative traits of eggplant grown at Melkassa Agricultural Research Centers (MARC)

Quantitative traits	Mean performance of data		
	Mean	Range	
		Minimum	Maximum
Leaf number (LN)	122.01	5.50	267.00
Days to 50% heading	76.18	72.75	80.50
Days to 50% flowering	81.22	73.20	87.92
Plant height (cm)	88.30	59.00	152.00
Number of branches	12.23	5.00	38.50
Branch length (cm)	52.28	32.25	90.50
Days to 90% maturity	125.67	98.00	165.00
Number of fruit per plant	52.33	20.00	164.00
Fruit length (cm)	80.30	32.90	152.95
Fruit diameter (cm)	48.40	31.2	80.50
Fruit weight (gm)	144.63	78.00	285.50
Fruit yield (Kg)	6.60	3159	13,448.00

4.1.2.2. Variance Components

Phenotypic variance (Vp), genotypic variance (Vg), genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability (h^2B) genetic advance and genetic advance as percentage of mean (GAM) were shown in Table 5. In the present study, the phenotypic variance (Vp) and phenotypic coefficient of variance (PCV) were higher than their corresponding genotypic variance (Vg) and genotypic coefficient of variance (GCV), respectively for all the characters studies (Table 5).

The highest PCV was observed for branch length (99.12%) followed by plant height (98.80%), number of branch (92.01%), days to 90% maturity (84.86%) and fruit weight (82.82%). Likewise, the highest GCV was recorded for branch length (84.86) followed by number of branch (81.83), and fruit diameter (77.42) (Table 5). The PCV and GCV values greater than 20% are regarded as high, values between 10-20% are regarded as medium and less than 10% are classified as low (Deshmukh et al., 1986). Therefore, according to the classification high PCV and GCV values were recorded for plant height, number of branches, branch length, fruit length, fruit diameter, fruit weight and fruit yield, which suggests the possibility of improving this trait through selection. The phenotypic and genotypic variations were closer to each other for the traits; indicating that the magnitude of the environment variation was relatively lower than the genotypic variation of the traits. The phenotypic variances of the traits under study were partitioned into heritable (genotypic variance) and non-heritable (phenotypic variance) components in both early and late season planting experiments. The magnitude of genotypic variances was lower than their corresponding phenotypic variances for most of the traits (Uddin et al., 2021). This is an indication that the genotypic component of variation had low contributor to total variation in the traits studied.

4.1.2.3. Heritability and Genetic Advance

Heritability used to measure the phenotypic variance that is attributed to genetic causes, and it provides information on the extent to which a particular morphogenetic character can be transmitted to the offspring. Heritability was classified as low (below 40%), medium (40-59%), moderately high (60-79%) and very high (above 80%) as suggested by Singh (2001). In the present study, the magnitude of heritability for different traits was measured and it ranged from 14.79 to 92.51% (Table 5). The characters such as branch length (92.51%), days to 50% flowering (80.28%) and fruit diameter (81.76%) had very high heritability. High heritability in broad sense values indicate that the characters under study are less influenced

by environment in their expression. However, days to 90% maturity (14.79%) exhibited the lowest heritability which indicates greater role of environment on the expression of the traits. Uddin et al. (2021) reported that all the traits showed high heritability values, indicating that the major part of the variability was due to genotypic causes.

Values of genetic advance as a percentage of mean ranged from 1.16% for days to 50% heading to 20.27% for fruit yield. Relatively high heritability coupled with high genetic advance as percentage of mean was recorded for plant height (18.01%) and number of branch (13.19%) (Table 5). Akpan et al. (2016) reported that high heritability coupled with high genetic advance was observed for fruit yield, number of fruit per plant, number of branches per plant, and fruit circumference, which suggested that the selection based on these traits, can bring about significant improvement in fruit yield of eggplant genotypes. In addition, high heritability combined with high expected genetic advance proved the involvement of additive genetic variance, therefore simple selection may be effective for improvement of these traits.

Table 5. Estimates of mean, phenotypic variance (Vp), genotypic variance (Vg), phenotypic and genotypic coefficients of variation (GCV & PCV), broad sense heritability (h^2B), genetic advance (GA) and genetic advance as a percentage of the mean (GAM) for 12 quantitative traits

Quantitative traits	Mean	Vp	Vg	PCV%	GCV%	h^2B	GA	GAM
LN	122.01	0.71	0.42	7.60	5.83	59.20	1.22	9.98
DFH	76.18	15.13	10.72	44.57	37.55	70.85	1.46	1.16
DFF	81.22	13.54	10.87	40.83	36.58	80.28	1.65	2.04
PH	88.30	87.24	67.34	98.80	76.26	77.19	1.59	18.01
NB	12.23	10.33	8.09	92.01	81.33	78.32	1.63	13.19
BL	52.28	42.46	39.28	99.12	84.86	92.51	1.91	3.65
DNM	125.67	89.73	13.28	84.49	32.51	14.79	0.49	2.43
NFPP	52.33	28.07	14.8	73.24	53.18	52.73	1.09	2.08
FL	80.30	51.02	31.17	79.71	62.06	61.09	1.26	1.57
FD	48.40	35.48	29.01	85.62	77.42	81.76	1.68	3.48
FW(g)	144.63	98.76	76.98	82.82	72.96	77.95	1.61	11.1
FY(Kg)	6.60	3.48	2.26	72.62	58.51	64.94	13.38	20.27

* Significant at $P<0.05$. LN = Leaf number, DFH = days to 50% heading, PH = plant height, DFF = days to 50% flowering, NB = number of Branches, BL = branch length, DNM = days to 90% maturity, NFPP = Number of fruit per plant, FL = Fruit length, FD = Fruit diameter, FW = Fruit Weight, FY = Fruit yield

4.1.2.4. Correlation Coefficient Analysis in Eggplant

Correlation coefficient is used to find out the degree and direction of the relationship between two or more variables. Estimates of correlation coefficients for 12 quantitative traits data from both seasons are presented in Table 6. The result shows that leaf number was positively correlated with days to 50% heading (r = 0.66), fruit length (r = 0.81) and fruit diameter (r = 0.71), but negatively correlated with plant height (r =-0.87), days to 90% maturity (r = -0.97) and number of branches (r =0.75). Further, days to 50% flowering again positively and highly correlated with plant height (r = 0.85), number of branches (r = 77), days to 90% maturity (r = 0.97). Furthermore, fruit diameter was highly and positively correlated with fruit weight (r = 0.85), and fruit weight again positively correlated with fruit yield (r = 0.45), and fruit yield was positively correlated with number of fruit per plant (r= 0.66). However, days to 90% maturity had high and negative correlation with fruit length (r = -0.86), and fruit diameter (r = -0.80). This association indicates that number of fruit per plant serves as the first selection criteria for the improvement of fruit yield in eggplant.

Table 6. Estimates of correlation of coefficients for 12 quantitative traits of eggplant grown at Melkassa agricultural research center

	LN	DFF	DFH	PH	NB	BL	DNM	NFPP	FL	FD	FW	FY
LN	1	-0.95	0.66*	-0.87	-0.75	-0.26	-0.97	-0.36	0.81*	0.71*	0.50	0.05
DFF		1	0.14	0.85*	0.77*	0.37	0.97*	0.31	0.81	-0.73	-0.42	-0.06
DFH			1	0.11	-0.1	0.23*	-0.45*	-0.06	-0.12	-0.05	0.07	-0.09
PH				1	0.64*	0.35	0.90*	0.34	-0.76	-0.69	-0.45	-0.02
NB					1	0.64*	0.76*	-0.16	-0.67	0.01	-0.58	-0.46
BL						1	0.3	-0.3	-0.28	-0.58	-0.37	-0.46
DNM							1	0.34	-0.86	-0.80	-0.54	-0.12
NFPP								1	-0.33	-0.38	-0.37	0.66
FL									1	-0.36	-0.23	-0.25
FD										1	0.85*	0.35
FW											1	0.45*
FY												1

* Significant at P<0.05. LN = Leaf number, DFH = days to 50% heading, PH = plant height, DFF = days to 50% flowering, NB = number of Branches, BL = branch length, DNM = days to 90% maturity, NFPP = Number of fruit per plant, FL = Fruit length, FD = Fruit diameter, FW = Fruit Weight, FY = Fruit yield

4.2. Nutritional Composition of Eggplant Genotypes

4.2.1. Moisture Content

The results of nutritional composition of eggplant genotypes are present in Table 7. All eggplant genotypes had moisture contents ranging from 78.98% to 93.68% with an average of 90.42 (Table 7). Highest amounts were observed in Eg-1041943 (93.68%), 1041809-A (93.50%), and the lowest amount was observed in Eg-20657 (78.98%). Eletta et al. (2017) suggested that eggplants have high moisture content (91%). The moisture content of food is an index of its water activity and is used as a measure of stability and the susceptibility to microbial contamination. Eggplant had high moisture content, implies that dehydration would increase the relative concentrations of the other food nutrients and improve the shelf-life/preservation of the fruit.

4.2.2. Ash Content

The ash level shows the degree of the inorganic matter. Generally, ash content levels are less than 1%. In this study its content ranged from 0.37% to 0.62% with an average of 0.47% (Table 7). Eletta et al. (2017) obtained similar ash content to our study in eggplant cultivars with a range of 0.73% to 0.80%. Quamruzzaman et al (2020) also reported that values obtained ranged from 1.78 to 1.81%, indicating that the cultivars analysed have considerable concentration of mineral elements. Further, Nino-Medina et al. (2014) obtained a range with larger values from 0.80% to 1.04% than our study. Ash content, which represents a measure of the total amount of minerals present, makes both fruits good sources of minerals with *Solanum* species yielding higher level of minerals.

4.2.3. Crude Fibre Content

The crude fibre content of all the cultivars ranged from 1.01% to 1.92% and its average of 1.59 (Table 7). The highest amounts were observed in Eg-1041943 (2.48%) and Eg-1034845 (1.92%), with the lowest amount observed in 1041809-A (1.01 %). Similarly, Quamruzzaman et al (2020) reported that crude fibre contents ranged from 1.01% to 2.48%. Nino-Medina et al. (2014) obtained a crude fibre content ranging from 0.65% to 1.54%. Crude fibre is an important part of the digestive process; it traps carbohydrates during digestion, and thus keeps blood sugar levels in check. It reduces the risk of heart disease, by reducing cholesterol and regulates blood sugar and help against diabetes (Afful et al., 2019). Furthermore, the high crude fiber, low fat and low dry matter of the eggplants may be helpful in preventing diseases such as constipation, carcinoma of the colon and rectum and atherosclerosis.

Table 7. Nutritional composition of eggplant genotypes grown at Melkassa agricultural research center

No	Genotypes	Moisture content	Ash content	Crude Fiber	Protein content	Fat content
1	Eg-1034845	93.48	0.47	1.92	1.03	0.12
2	1041809-A	93.50	0.56	1.01	1.04	0.03
3	Eg-1041943	93.68	0.50	2.48	1.54	0.03
4	Eg-1041945	92.81	0.42	1.89	1.35	0.04
5	1041979-A	92.51	0.62	1.57	1.01	0.07
6	Eg-1046095	92.17	0.50	1.56	0.95	0.07
7	Eg-1046101	89.21	0.38	1.72	1.87	0.18
8	Eg-1046103	91.22	0.61	1.76	0.97	0.13
9	Eg-1048276	90.37	0.42	1.33	1.20	0.14
10	Eg-1048283	88.45	0.37	1.25	1.30	0.03
11	Eg-1049452	90.13	0.51	1.19	1.12	0.05
12	1049792-A	90.67	0.42	1.50	1.03	0.07
13	Eg-20303	89.45	0.50	1.89	1.50	0.15
14	Eg-20551	87.89	0.38	1.53	1.24	0.17
15	Eg-20657	78.98	0.40	1.72	1.12	0.13
16	Eg-21405	91.89	0.45	1.18	1.11	0.12
17	Eg-21418	90.89	0.47	1.35	1.20	0.16
18	Eg-30503	89.90	0.46	1.70	1.30	0.15
19	Eg-30951	90.76	0.50	1.47	1.23	0.14
20	Eg-37356	90.35	0.51	1.78	1.22	0.12
	Mean	**90.42**	**0.47**	**1.59**	**1.22**	**0.11**

4.2.4. Protein Content

The protein content observed in this study ranged from 1.01% to 1.87% (Table 2). The highest values were observed in Eg-1046101 (1.87%), Eg-1041943 (1.54%), followed by Eg-20303 (1.50 %), while the lowest value was 1041979-A (1.01 %). Sharma and Kaushik (2021) reported that obtained a range from 0.65% to 0.90%. The larger values observed in this study is very encouraging for future breeding. Agoreyo et al. (2012) reported that there was low protein content in the cultivars of eggplants. The low protein content implies that eggplants are eaten as fruits, their protein contents could be used to supplement the proteins from staple food.

4.2.5. Fat Content

Fats nutrients are essential for biological functions and integrity of cells and also increase the tastiness of food by absorbing and retaining flavours. In our study, the fat content ranged from 0.03 to 0.17% (Table 7). The highest fat content observed in the eggplant cultivars were Eg-1046101 (0.18 %) followed by Eg-20551 (0.17 %). The lowest value was observed in Eg-1048283 (0.03 %). Nino-Medina et al. (2014) analyzed the fat content in different eggplant types reporting values ranging from 0.03 to 0.04 %. Eggplants may therefore be ideal fruits for individuals with high serum lipid levels, high blood pressure and other ischemic heart diseases. In other words, a diet high in fat is said to be implicated in certain cardiovascular disorders such as atherosclerosis, cancer and aging (Ossamulu et al., 2014). Afful et al. (2019) stated that the low amounts of crude fat observed in the different eggplant accessions, implies that eggplants constitute a poor source of fat, as similarly observed by Ossamulu et al. (2014), and may be useful in the formulation of diet for obese and individuals with cardiovascular challenges.

4.3. Phytochemical Screening Tests of Crude Extracts in Eggplants

The bioactive constituents; alkaloids, saponins, flavonoids, glycosides, phenols, quinones, tannins, terpenes, saponins and steroids were present in eggplants genotypes. However, alkaloid and phenols were the most popular almost in all the genotypes while terpenoids and steroids were absent in some genotypes of eggplants (Table 8).

The phytochemical analysis showed high concentrations of alkaloids, Phenols and saponins, in our study (Table 8). Alkaloids and saponins are known to elicit antimicrobial abilities and defend plants against microbial and pathogenic attacks. Agoreyo et al. (2012) reported that there were higher alkaloids, tannins and saponins in eggplant, and have medicinal properties. The presence of these phytochemical constituents showed that the eggplant genotypes have medicinal properties. Dougnon et al. (2012) reported the roles of these phytochemicals as analgesic, anti-inflammatory, anti-hypertensive and anti-microbial. Tannin compounds also present in eggplant genotypes in moderate concentration, which have some antibacterial effects, antiviral and antiparasitic effect (Dougnon et al., 2012; Afful et al. (2019). Phenolics have various physiological functions, including antioxidant, antimutagenic and antitumor activities. They have been reported to be effective in scavenging free radicals, which are deleterious to the body and foods systems (Quamruzzaman et al., 2020). Several factors could be responsible for differences in total phenolic content of plants of similar origin. Some

include variation in fruit cultivars, processing techniques, harvest and post-harvest handling and storage conditions (Kalimuthu et al. (2017).

Table 8. Phytochemical screening of eggplant genotypes

S.No	Types of Test	Result
1	Alkaloids	+++
2	Carbohydrate	+
2	Flavonoid	++
3	Glycoside	+
4	Phenols	+++
5	Quinones	-
6	Tannins	++
7	Saponins	+++
8	Terpenes	+
9	Steroids	-

Key: (-) indicates absent, (+) indicates present, (++) indicates moderately present, (+++) indicates highly present

4.4. Antibacterial Activity of Eggplant Extracts

Evaluation of the antimicrobial activity of the plant extracts was determined initially by the disc diffusion method against different microorganisms. These organisms were frequently encountered in infectious diseases. The methanol-n-hexane (1:1) extract of eggplant fruit showed bacterial growth inhibition, and the commercial standard drug (Ceftriaxone) showed the greatest inhibition effect against both bacteria at concentrations (30 mg/ml) rather than the tested samples, were presented in Table 9.

Table 9. Minimum inhibitory concentration (MIC) (mg/ml) of eggplant extracts in pathogenic microorganisms

S.No	Pathogenic microbes	Ethanol extract Zone of inhibition (mg/ml)			Standard (Ceftriaxone)
		25	50	100	
1	*Staphylococcus aureus*	6.2	6.2	6.9	18.9
2	*Escherichia coli*	9.01	6.2	10.17	18.01

The effectiveness of the extracts in tested bacterial strains was determined by measuring the minimum inhibitory concentration (MIC), against *Staphylococcus aureus* (*S. aureus*) as well as (*Escherichia coli* (*E. coli*) (Figure 2). Among the two different bacteria used (*S. aureus, E.coli*,) in the case of *S. aureus* the zone of inhibition is higher (6.30±0.20 mm) in 50 mg/ml concentration against the control (16. 0±0.17 mm in 30 mg/ml). In the case of *E. coli* the zone of inhibition is higher in 25 mg/ml concentration (9.01±0.17 mm) against its control (18mm/ 30mg/ml) followed by 100 mg/ml concentration (10.17±0.14 mm). The study showed that eggplant genotypes can be used as the potential sources of novel antimicrobial compounds.

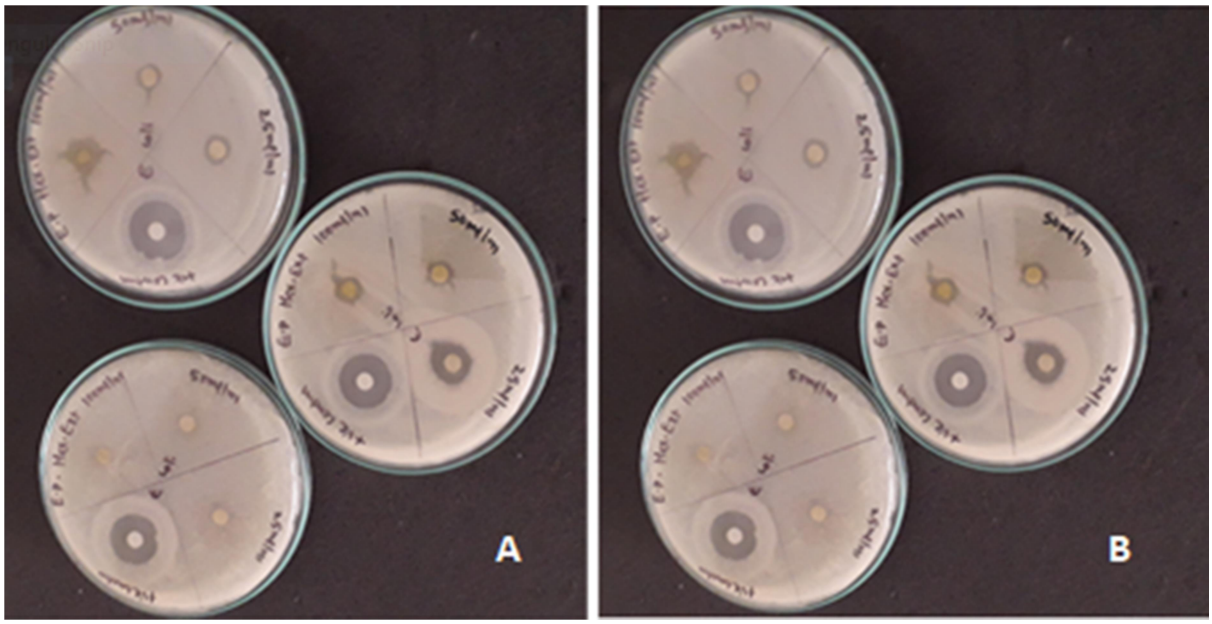

Figure 2. Zone of inhibition of gram positive bacteria (A: *Staphylococcus aureus*) and gram negative bacteria (B: *Escherichia coli*)

Salamatullah et al. (2021) reported that extract of eggplant fruit gave maximum inhibition against *Staphylococcus* aureus and *Escherichia coli*, and the inhibition level gradually increases in accordance with the level of increase in concentration. Similar results were observed in our study.

5. Conclusions and Recommendations

5.1. Conclusions

The present research study was conducted aiming to explore the genetic variability, nutritional composition, phytochemical screening and bioassy of eggplant. The results indicating the existence of enormous amount of genetic variability for fruit related characteristics. Determination of variability is an important prerequisite for realizing response to selection as the progress in the breeding depends upon its amount, nature and magnitude. Furthermore, eggplants contain high amount of moisture content implies that dehydration would increase the relative concentrations of the other food nutrients and improve the shelf-life of the fruit. Moreover, eggplant contain high crude fibre, low fat and low dry matter indicating that eggplants may be helpful in preventing diseases such as constipation, carcinoma of the colon and rectum and atherosclerosis. In addition, the low level of carbohydrate in eggplant genotypes may helpful for diabetic patients and for weight management. The phytochemical analysis showed high concentrations of alkaloids, Phenols and saponins, in our study, and the presence of these phytochemical constituents indicates eggplant genotypes have medicinal properties analgesic, anti-inflammatory, anti-hypertensive and anti-microbial activities. Therefore, this study generated information about the genetic variability, nutritional composition, phytochemical screening and bioassay in eggplant, for cultivation and conservation of the available resources.

5.1. Recommendation

Based on the study, the following recommendations were made:

- The information generated helpful parameters, indicating their relevance for similar genetic variability, nutritional composition, phytochemical screening and bioassay in eggplant analysis.
- Similar studies should be carried out on other genotypes from the remaining parts of the country using dense markers to generate a nationwide representation of the genetic structure of eggplants in Ethiopia.

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7. Appendix

Appendix 1, Table 1. Eggplant genotypes and the combine means of quantitative traits

No	Eggplant	Acce.NO	LN	PH	BN	BL	DFF	DNM	NFPP	FL	FD	FW	FY
1	S. melongena	Eg-1034845	144	76	8	32.25	77	110	40	98.18	64.9	144.5	5780
2	S.melongena	1041809-A	180	79	7.5	51.5	86	104	30	153	63.9	251.68	7550.4
3	S. melongena	Eg-1041943	250	60.5	5	43.25	82	101	29.5	90.2	71	285.5	8422.25
4	S.melongena	Eg-1041945	267	75.5	6	64.5	72	98	40.5	100	41.8	78	3159
5	S.melongena	1041979-A	190	59	6.5	40.25	74	100	38	80	65.1	167.05	6348
6	S.melongena	Eg-1046095	185	73	7.5	53.25	79	99	35	129	80.5	334.05	11707.5
7	S.melongena	Eg-1046101	190	61.5	6	46.25	81	108	52	152.2	35.2	98.26	5109.33
8	S.melongena	Eg-1046103	182	70	6	49.75	75	103	78	98.7	52.1	96.99	7565.38
9	S. melongena	Eg-1048276	165	73	7	55.25	86	106	38	93.9	58.7	143.4	5449.2
10	S.melongena	Eg-1048283	220	85	9	45.41	83	108	31.1	110	45.96	82.642	5453.97
11	S. melongena	Eg-1049452	150	90	8	40.56	76	109.6	35.4	109.8	41.84	54.206	4859.99
12	S.melongena	1049792-A	197	87	6	34.67	75	111.2	39.7	109.5	37.72	25.77	4266.02
13	S. incanum	Eg-20303	230	67	7	56.23	67	112.8	34	109.3	33.6	26.34	3672.05
14	S. incanum	Eg-20551	112	89	9	42.32	69	114.4	38.3	109	29.48	31.87	3078.08
15	S. incanum	Eg-20657	110	109	18	43.5	80	165	35	33.8	33	94	7050
16	S. incanum	Eg-21405	113	110	9	58	90	155	36	32.9	31.8	82	13448
17	S. incanum	Eg-21418	109	106	38.5	90.5	90	157	25	33.4	32.5	99	2475
18	S. incanum	Eg-30503	150	118	23.5	61.5	110	160	20	33.2	32.2	86	1720
19	S. incanum	Eg-30951	190	152	17.5	57	109	163	80	33.3	32.1	102	8160

20	S. incanum	Eg-37356	120	102	17.5	37.5	108	156	40	43	31.2	107	4280
	Mean		**172.7**	**87.1**	**11.1**	**50.17**	**83.45**	**122.05**	**39.78**	**87.61**	**45.73**	**119.51**	**5977.71**

Approval of Investigators

We hereby declare that the research report entitled "__**Genetic Variability, Nutritional Composition and Phytochemical Screening of Eggplant (*Solanum*) species**" is our original work; all sources are duly acknowledged and the report is compiled by incorporating the necessary comments and suggestions given by the reviewers.

	Name	**Signature**	**Date**
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Approval of Reviewers

I hereby confirm that (PI)Dr./Mr. _____has accomplished his/her work as per the approved proposal and incorporated all the comments given by the reviewers in his/her terminal report of the project entitled _____ _____ and hence the report qualifies for submission as standard research output.

	Name	**Signature**	**Date**
Reviewer 1.	_____	_____	_____
Reviewer 2.	_____	_____	_____

Approval: **School Ethical Review Board (School Scientific Committee)**

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2.	_____	_____	_____
3.	_____	_____	_____
4.	_____	_____	_____