MORPHOPHYSIOLOGICAL ANALYSIS OF FIFTEEN SWEET POTATO GERMPLASM

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JUNE 2020

MORPHOPHYSIOLOGICAL ANALYSIS OF FIFTEEN SWEET POTATO GERMPLASM

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REGISTRATION NO. 18-09278

A Thesis
Submitted to the Department of Horticulture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JANUARY-JUNE, 2020

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CERTIFICATE

This is to certify that the thesis titled ***"MORPHOPHYSIOLOGICAL ANALYSIS OF FIFTEEN SWEET POTATO GERMPLASM"*** *submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***HORTICULTURE,*** *embodies the results of a piece of authentic research work carried out by* ***SAJARATUL MUNTAHA,*** *Registration No.* ***18-09278****, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma to any other organization.*

I further certify that such help or sources of information as has been availed during the course of this investigation have been duly acknowledged.

Dated: June, 2020
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DEDICATED

TO MY BELOVED PARENTS

AND

SIBLINGS

ACKNOWLEDGEMENT

Alhamdulillah, all praises are due to ALLAH for the strength and blessings to complete this work in fulfilling the Master of Science in Horticulture degree successfully.

The authoress pays her heartiest gratitude to her Supervisor Prof. Dr. A F M Jamal Uddin, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207 for providing important guidance, suggestions and inspiration to accomplish her research work. The entire work would not have been possible without his support and encouragement. Despite his tight academic schedule, he always reviewed her research progress. His courage will always inspire her.

The authoress is grateful to her Co-Supervisor Prof. Dr. Mohammad Humayun Kabir, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207 for worthy advice, constructive criticism and encouragement during this research work.

The authoress expresses her deepest gratitude to all the honorable teachers, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka-1207 for their cordial co-operation and support at different stages to complete this research work. The authoress is also thankful to all the stuffs for helping her during the research work.

The authoress thanks her beloved parents and siblings whose selfless sacrifice, efforts, continuous support and prayers have enabled her to reach the goal of this study.

The authoress

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ABSTRACT

A field experiment was performed to study morphophysiological analysis and yield of fifteen sweet potato germplasm at the Horticulture Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The duration of this field research was from September 2018 to March 2019. The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications were done. The fifteen sweet potato germplasm (Germplasm 1: G_1, Germplasm 2: G_2, Germplasm 3: G_3, Germplasm 4: G_4, Germplasm 5: G_5, Germplasm 6: G_6, Germplasm 7: G_7, Germplasm 8: G_8, Germplasm 9: G_9, Germplasm 10: G_{10}, Germplasm 11: G_{11}, Germplasm 12: G_{12}, Germplasm 13: G_{13}, Germplasm 14: G_{14}, Germplasm 15: G_{15}) were used as the treatments of the study. Different vegetative growth, reproductive growth and yield related parameters were studied. On the basis of the directions of the Union for the Protection of Plant Varieties (UPOV), these fifteen sweet potato germplasm were classified according to their morphological differences. The germplasm G_4 showed the highest value (7.300) for the number of tuberous roots/plants. But the highest value for weight of a single root (157.4 g), tuberous root yield/plant (1091.0 g) and tuberous root yield/ha (60.60 t/ha) were observed in G_7. So, the results exposed that, the yield related characteristics were better in the germplasm 7 (G_7). In addition, statistically identical result was also found in case of tuberous root yield/ha in G_3 (59.07 t/ha). Furthermore, the germplasm G_1, G_2, G_3, G_5, G_6, G_9, G_{10}, G_{11}, G_{13}, G_{14} and G_{15} can be utilized to have food grade color, industrial dye, etc.

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ABBREVIATIONS AND ACRONYMS

AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
cm	Centimeter
CV%	Percentage of coefficient of variance
DAE	Department of Agricultural Extension
DAP	Days After Planting
DAT	Days After Transplanting
e.g	For example
et al.	And others
etc.	Etcetera
FAO	Food and Agriculture Organization
G	Germplasm
g	Gram
ha-1	Per hectare
hr	Hour
kg	Kilogram
LSD	Least Significant Difference
m	Meter
Max	Maximum
Min	Minimum
mm	Millimeter
No.	Number
^{o}C	Degree Celsius
pH	Potential of Hydrogen
RCBD	Randomized Complete Block Design

SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
t/ha	Ton per hectare
TSP	Triple Super Phosphate
UPOV	Union for the Protection of Plant Varieties
%	Percent

*Significant at the 5% level of probability

CHAPTER I

INTRODUCTION

1.1 Background

Sweet potato (*Ipomoea batatas* L.*)* is a herbaceous perennial vine belonging to the Convolvulaceae family (Cuminging *et al.,* 2009). It is a dicotyledonous plant. In many countries of the world, it is treated as an important root crop. This crop is cultivated in all the tropical and subtropical regions, particularly in Africa, Asia and Pacific (De Moura *et al*., 2015). More than 100 countries in the world produce sweet potato crop (Woolfe, 1992). Central America is considered as the place of origin of sweet potato crop (Huang and Sun, 2000 and Zhang *et al.*, 2000). In the world, sweet potato occupied the 7th position after wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*), Irish potato (*Solanum tuberosum*), barley (*Hordeum vulgare*) and cassava (*Manihot esculenta*) (Hironori *et al*., 2007). In case of tropical countries, the crop ranks fourth (FAOSTAT, 2008). The production of sweet potato tuberous root was calculated about 105 million metric tons by the year 2013, where developing countries contributed about 95% of this total production (FAOSTAT, 2015). In Bangladesh, it is considered as fourth important crop after rice (*Oryza sativa*), wheat (*Triticum aestivum*) and potato (*Solanum tuberosum*) (Delowar and Hakim, 2014). Generally, in different underdeveloped or low lands, sweet potato is mainly cultivated by the marginal farmers (Ahmed *et al.,* 1998). It is considered as the 'Poor man's crop'. According to different studies, it plays a great role in saving the lives of millions of children and also helps to create a better future.

Compared to other crops, there are many advantages in the production of sweet potato, for example, production requires less input but the yield and nutritional status do not get hampered, it can also grow against unfavorable conditions, such as, this crop can adapt and tolerate low fertility of soil, high temperature and drought conditions (Mekonen *et al.,* 2015). Sweet potato roots contain different sugars, proteins and minerals. The crop is widely differentiated through various morphological characteristics. It can be individualized on the basis of its morphological features: shape, size; skin and flesh color of tuberous roots, yield; color and shape of leaves and so on (Acheampong, 2012 and Zhang *et al.*, 2000).

1.2 Problem statement

Comparing with other tropical and subtropical countries, the average yield of sweet potato root is very low in Bangladesh (Verma *et al.,* 1994). Cultivating local and poor quality of sweet potato varieties is one of the main reasons of less amount of tuberous root production. More than half of the world's population is affected through lack of micronutrients in their diet charts and causes malnutrition problem. In Bangladesh, there is also the problem of malnutrition. Cancer, diabetes, blindness, weak immune system etc. are some of the major health problems in this country. Generally, sweet potato of white or pale yellow fleshed one is cultivated in Bangladesh. These white fleshed color tuberous roots are less sweet in taste and contain fewer amounts of nutrients. A sweet potato variety of orange colored flesh named "Kamala shundari" has been already released by BARI. Till now, this variety did not get popularity to be produced continuously. To increase the consumption rate of sweet potato among the general people of Bangladesh and for continuous production of this crop, it is necessary to evaluate the sweet potato germplasm to find out suitable variety. So, evaluation of sweet potato germplasm of higher nutritional quality and yield is necessary.

1.3 Problem justification

As sweet potato does not need extra input and extra care, so it can easily be grown in any condition. It can be a solution for the rapidly growing population of developing countries by producing more food on less area with less inputs. The tuberous roots are considered as anti-diabetic, anti-oxidant and anti-proliferative due to the presence of valuable minerals and nutritions (Abubakar *et al*., 2010). Sweet potatoes with different flesh colors contain high amount of beta carotene, anthocyanins, phenolics, dietary fiber, ascorbic acid, folic acid and minerals too (Woolfe, 1992). It is suggested that, red-fleshed sweet potato variety has higher phenolic contents and antioxidant activity than a blueberry fruit variety with high antioxidant contents (Cevallos-Casals and Cisneros-Zevallos, 2003). Orange-fleshed sweet potato contains higher levels of pro-vitamin A and can play a great role in case of vitamin A deficiency (Labadarios *et al.,* 2007). Sweet potato variety with purple-flesh significantly contains greater amount of anthocyanin. Due to the presence of antioxidant in purple-flesh tuberous roots, this variety has an important role against cancer in human health (Suda *et al.,* 2003).

1.4 Objectives

So, this experiment was conducted with these two objectives-

- To study the morphophysiological characteristics and yield of fifteen sweet potato germplasm; and
- To find out the suitable germplasm for adoption in Bangladesh.

CHAPTER II

REVIEW OF LITERATURE

To study the morphophysiological analysis of different sweet potato germplasm, an experiment was carried out at Sher-e-Bangla Agricultural University. Different researchers worked worldwide and their research findings have been reviewed below.

2.1 Taxonomy

The species of sweet potato is *Ipomoea batatas* L., section Eriospermum, subgenus Quamoclit, genus *Ipomoea* and under the morning glory family (Convolvulaceae) (Austin and Huaman, 1996). It is an allohexaploid (6x = 90) crop (Jarret and Austin, 1994). There are more than 100 improved and traditional varieties of sweet potatoes are found globally.

2.2 History of sweet potato

According to Loebenstein (2009), about 5000 years ago, sweet potato was originated in the tropical America (Austin, 1988 and Yen, 1982). On the basis of the morphological analysis of the wild *Ipomoea* species and sweet potato, Austin (1988) argued that the origin of sweet potato was between the Orinoco River in Venezuela and the Yucatan Peninsula of Mexico. In the Central America, most of the diversity was recorded. So, the Central America was suggested as the center of origin of sweet potato and the primary center of diversity (Huang and Sun, 2000 and Zhang *et al.,* 2000). In 1492, Columbus brought sweet potato to Europe. In the sixteenth century, Spanish took sweet potato from Mexico to the Philippines. Portuguese brought it to Southeast Asia, the East Indies, Africa and India in the 16th century.

The origin of sweet potato is either Central or South America (Roullier *et al.,* 2013*).* There was a global decrease in sweet potato production area by about 31% between the early 1960s and late 1990s. In Asia, Bangladesh and Vietnam are important sweet potato-producing countries and over the last 30 years, these countries have an increase in area (Woolfe, 1992). There has been a reduction in the area for sweet potato production in the USA. On the other hand, sweet potato has changed from staple to an industrialized food in Japan (Widodo *et al.,* 2015). Nonetheless, there is a progress in the area under sweet potato production in Africa (Allemann *et al.,* 2004).

2.3 Occurrence and distribution

The world's leading producer of sweet potato is Asia which provides over 90 million tons per year. About 65 per cent of the world's sweet potato production area is associated with China. China is thought as the world's biggest sweet potato producer and consumer. Worldwide the total global sweet potato production is about 105 million tons (CIP 2015). Sweet potato is produced mainly in the eastern lowlands and in the Sichuan Basin in Cina (Hijmans *et al.*, 2001). Developing countries produced more than 95 percent of world's total sweet potato (CIP 2015). It is also produced extensively in New Guinea, Cuba and Haiti in the Caribbean region, Vietnam in Asia and Java (Indonesia) (Hijmans *et al.,* 2001). Sweet potato is also the main crop of many Oceania island countries- the Solomon Islands, Papua New Guinea, New Caledonia and Tonga (Rossel *et al.,* 1999). Considering the production and harvested area, now a days Uganda is the biggest sweet potato producer in the world after China and in Africa. But maximum yields have been found in Burundi, Madagascar and Rwanda (Kpaka *et al.,* 2013).

As a healthy food, there is a cumulative demand for sweet potato in Kenya. Western Kenya chiefly the Kakamega, Rachuonyo, Bungoma and Busia are the massive sweet potato growing areas. It has become a great cash crop in Mosocho and Suneka divisions in Kisii Country. On the other hand, Central Kenya produces a low amount of sweet potato in the country (Mcharo and Ndolo, 2013).

2.4 Ecology

Sweet potato is produced at altitudes from 1000 m up to 2500 m above sea level. The crop is thoroughly grown between the latitudes l0°S and 15°N, that causes 24 per cent and 40°N and 20°N, which makes 70 per cent of entire world production (Hijmans *et al.,* 2001). At the time of vegetative cycle, the most conducive temperature is 20 to 25°C. When temperature is low that is 15 to 20°C during night and high such as 25 to 30°C at the day, the maximum amount of yield can be acquired. Vegetative growth is favored by high temperatures at day and the formation of tuberous roots is favored by low temperatures during the night (FAO, 1990). This crop is a short-day plant but photoperiod, short days and temperature fluctuations affect the appropriate outgrowth of tuberous roots. It can be produced in different soils. But the greatest output of sweet potato production is acquired in brown humic, ca1cimorphologic and ferralitic soils. A depth of more than 25 cm, good drainage and friable soil is best for sweet potato production (Woolfe, 1992). This crop prefers optimum pH of 5.5 to 6.5. An excessive

acidic or alkaline soil sometimes creates bacterial infections and affects the yields negatively (Onwueme and Charles, 1994). The crop is mostly grown on mounds. Its root growth is increased and developed by deep cultivation. Easy drainage and harvesting of sweet potato crops are promoted by mounds and ridges (Villordon *et al.*, 2006).

2.5 Definition of plant morphology

Plants form, its development and evolution are considered in plant morphology. In the narrow sense, plant morphology refers to external form and anatomy refers to internal form. On the other hand, in wide sense, plant morphology may refer to both internal and external from the molecular and cellular level to the organism level (Sattler, 1978). On the basis of theory, plant morphology is related to ecology, evolutionary biology, molecular genetics and physiology (Sattler and Rutishauser, 1997).

2.6 Morphology of sweet potato

Sweet potato is a perennial and herb type vine that bears medium-sized gamopetalous flowers. The crops have palmately lobed or alternate heart-shaped leaves. In case of vegetative propagation slips or vines are used and grown as annual plant (Woolfe, 1992). Vines of sweet potato grow horizontally on the ground. Sweet potato plants can be different typed such as erect or semi erect and spreading or very spreading (Huaman, 1999). The skin color of tuberous roots may vary from cultivar to cultivar and these can be yellow, orange, purple, beige, red and brown. The tuberous roots are long and tapered at both ends. Moreover, flesh color of sweet potato also ranges from beige to white, red, pink, violet, yellow, orange, and purple. White or pale-yellow colored fleshes are less sweet and moist than the sweet potato with orange, red, pink flesh ones (Yada *et al.*, 2010).

After planting the crops from stem cutting the adventitious roots arise from the cuttings within two days and these roots grow rapidly to form the plant root system. Different researches have demonstrated that, sweet potato roots can enter into the soil up to a depth of more than 2m, where the depth of roots depend on state of soil (Onwueme, 1978 and Kays, 1985). Roots are produced at different nodes of the growing vines. Sweet potato roots are divided into the adventitious roots which originate from the subterranean nodes and from the existing roots the lateral roots arise. The adventitious roots of sweet potato plant are subdivided into storage, fibrous and pencil roots according to Kays (1985). Primary, secondary and tertiary roots are the subdivision of the lateral roots.

Fibrous roots of sweet potato crops uptake water and nutrients from soil. On the other hand, photosynthetic products are stored in storage roots. The thick mature pencil roots have lignifications besides this, the other roots do not contain any lignification but are fleshy and known as storage roots (Austin, 1988).

Storage root is the chief organ or part of sweet potato plants, for which this crop is cultivated (Onwueme and Charles, 1994). Number of storage roots per plant may vary from cultivar to cultivar (Villordon *et al.,* 2009). When the cells of central metaxylem and protoxylem points do not lignified, and then storage roots grow from pentarch or hexarch roots (Wilson and Lowe, 1973). The activity of the anomalous cambia and the vascular cambium increase the size of storage roots (Wilson, 1982). Cambium activity is increased by soil moisture, optimum temperature and potash. In contrast, activity of cambium is decreased by poor transplants quality, less temperatures, compact and dry soil, shade, extreme amount of nitrogen, small seed (Villordon *et al.,* 2010*).*

Generally, from adventitious roots, the production of storage roots occurs (Loebenstein and Thottappilly, 2009). Different management practices, condition of environment, soil factors and propagating material are responsible for differences in number of storage root production (Villordon *et al.,* 2009). From 7 to 91 days after transplanting (DAT), production of sweet potato tuberous roots starts (Ravi *et al.,* 2009).

Storage roots yield depends on fibrous root number. There are different shapes of storage roots, such as, ovate, obovate, elliptic or long-elliptic, round-elliptic, oblong, irregular. Skin color of storage roots greatly differ- may be yellow, orange, white cream, pink, purple-red and dark purple. Color of fleshes of storage roots also vary- could be white, beige, yellow, orange and purple (Mwanga *et al.,* 2011).

Pencil roots generally develop from adventitious roots under such conditions that are not favorable for the storage root production (Wilson and Lowe, 1973). Pencil roots are generally 5 to 15 mm in diameter.

Fibrous roots are produced from thin adventitious roots (Chua and Kays, 1981). The fibrous roots are less than 5 mm in diameter. The roots create lateral roots and make a dense network in the roots area which forms the nutrient and water absorbing system of plants.

From the existing roots the lateral roots of sweet potato originate. Storage, pencil and fibrous roots have a lot of lateral roots at different densities of their axis. From adventitious roots primary lateral roots originated, primary laterals induce to form secondary laterals and from secondary lateral roots tertiary laterals are produced (Kays, 1985).

The stems of sweet potato are long and thin and can produce roots at the nodes. Different cultivars have different stem length, and may range from 1 m to more than 6 m. Length of internode also differ, which ranges from a few centimeters to 10 cm. There is an obvious effect of planting density on the internode length and on vine length (Somda and Kays, 1990a). The color of stem is mainly green, sometimes purplish pigmentation is also found.

At various growth periods, generally three types of branches are produced by sweet potato plants such as, primary, secondary and tertiary. Branching intensity in sweet potato plants may be affected by the soil moisture, nutrient supply, photoperiod and spacing (Kays, 1985; Somda and Kays, 1990a and Sasaki *et al.*, 1993). Pubescence of vines tips can be absent, sparse, medium and dense too (Leon- Velarde, 2000).

The leaves of sweet potato plants are simple and arranged spirally on the stem. This arrangement of the leaves of sweet potato plants is known as 2/5 phyllotaxis. There, in two circles, five leaves are spirally arranged around the stem (Huaman, 1991). The total leaf number may range from 60 to 300 per plant (Somda *et al.*, 1991). With the reduction of plant density leaf number of per plant increases (Somda and Kays, 1990b). Increasing irrigation (Indira and Kabeerathumma, 1990; Holwerda and Ekanayake, 1991; Nair and Nair, 1995) and N application (Nair and Nair, 1995) also increases the number of leaves per plant. Length of petiole may vary from cultivar to cultivar and range from 9 to 33 cm (Yen, 1974). At the joining place with the stem, petiole becomes swollen. Petiole carries two small nectaries at the joining point. The leaf lamina is widely variable in size and shape with different genotypes and also on the same plant. Generally, the color of leaf is green. Sometimes purple-colored leaves may also find. The general outline of leaves may be different such as reniform, rounded, triangular and cordate. Size of mature leaves ranges from16 to 25 cm (Huaman, 1992). Anthocyanin coloration on abaxial vein is generally green.

Flowers of sweet potato may be solitarily or cymose inflorescence. These flowers grow from the leaf axis vertically and upward (Purseglove, 1972 and Onwueme, 1978). The flowers have five petals and five united sepals. They joined together and form a corolla tube like funnel-shaped. The flower tube is purple colored. The stamens are connected to the base of the flower tube and the number of stamens is five. With the length of the style, stamens height change. The two longest stamens are as same length as the style in most cultivars. The filament is hairy and white in color. The anther bears enormous round shaped pollen grains on the surface and the color of anther is white. The ovary has two carpels; each carpel

consists of one locule. The two ovules are located in each locule and each ovary contains maximum four ovules (Onwueme, 1978).

The flowers open before morning and stay open for a few hours. Then the flower closes before noon on that day. When the weather becomes cool, the time length of the flowers to remain open becomes slightly longer. Pollination occurs by insects, generally by bees. The construction of the flower is dependent on the environmental situation. The flower stays open and become receptive for a very short period. The presence of variation between style and the stamen length, causes morphological difficulties into the pollinating system. For these reasons, seed production becomes difficult in sweet potato (Onwueme, 1978).

2.7 Planting material

Propagation of sweet potato can be done with vine cuttings or by sprouts from tuberous roots. 20 to 50 g of healthy tubers should plant at 3 cm depth (Ikemoto, 1971). For direct planting, the use of sprouts from tuberous roots of sweet potato is not advised, because it gives less amount yields than stem cuttings (Ikemoto, 1971).

Vine cuttings are mainly used for the propagation of sweet potato and vine cutting is also better than the use of sprouts from tuberous roots. The plants that attained from vine cuttings have no soil-borne diseases. Total harvested tubers produced from vine cuttings can be saved for consumption or marketing purpose. And there is no need to reserve some of these tubers for planting purposes, when the propagation is done with vine cuttings. Yield is better in vine cuttings than sprouts and the tuberous root grows with more identical shape and size.

Apical cuttings are preferred to the middle and the basal parts of the stem in case of vine cuttings propagation (Shanmugavelu *et al.*, 1972). Middle and basal parts of the vine cuttings may be used when the planting material supply is not enough, but in that case, the yield will be less. When the length of the vine cuttings used is increased than tuberous roots yield also enhanced (Onwueme, 1978). A length of vine cuttings of about 30 cm is advised in that case. Vine cuttings of larger than the recommended, cause's wastage of planting material. On the other hand, short cuttings grows more slowly and results in poor yields.

To make sure a sufficient supply of cuttings during the planting time, different techniques can be adopted such as, sprout from storage roots, successive planting and nurseries.

For the utilization of vine cuttings from the antecedent crop, nursery plots are mainly introduced during harvesting (Onwueme, 1978). At the time of non-growing season, nursery plots include the maintenance of sweet potato plots.

To cope with the scarcity of vines a technique sometimes followed. A part of the field is planted with the available vines and when these plants become developed, vine cuttings are taken. Then these cuttings are used for the plantation of next portion. Until the whole fields become planted, the process is repeated. This technique can be united with either the sprouting of storage root or the nursery plot method (Onwueme, 1978).

For the sub-tropical and temperate regions, production of sprouts from storage roots is a standard process of planting material production. In this system, tuberous roots are grown in soil or sand and the tuberous roots are planted closely. The tuberous roots are overwhelmed shallowly with soil and watering should be done regularly. About two weeks after sprouts emerge. These sprouts can utilize for plantation within few weeks after bedding. For maximizing the sprout production, the larger tuberous roots should cut transversely into two or three pieces. So that proximal dominance will reduce. Plant growth regulators can also use which have been indicated that these can develop the production of sprouts. Such as ethephon treatment at 1500 ppm and so on (Tompkins *et al*., 1973).

2.8 Weeding, planting and fertilization

A. Weeding

Vines of sweet potato grow so fast and attain full canopy within six weeks (Onwueme, 1978). So that, fast growing vines can effectively cover the whole ground surface in a short time. Therefore, weeds are problem only for first two months of sweet potato plant. Approximately, four weeks after planting a single weeding performed. In different parts of the world, various types of herbicides are used to minimize weed problem. Chloramben (3.3 kg. ha-1), Diphenamide (2.7- 4.4 kg. ha-1) etc. herbicides are recommended in the U.S.A. (Talbert, 1967). There is evidence that, herbicides do not affect the quality of tuberous roots or processing quality (Hernandez *et al*., 1969; Constantin *et al*., 1975 and Hammett and Monaco, 1982). In southern Ethiopia, weeds are not a great problem and generally weeds are controlled by hand there.

B. Planting

In general, vine cuttings with 3-4 nodes are used for planting and the vines are planted horizontally or vertically. According to Chen *et al*. (1982), higher yield can be found when

vine cuttings are planted horizontally. During planting, about one-half to two-thirds of vines length are inserted into the soil and this work is generally done manually. Single row or multiple row planters are also available. The sweet potato vine cuttings are generally planted about 25 to 30 cm apart on ridges (Onwueme, 1978). Sweet potato can tolerate differences in planting density partially. If there is a greater number of a plant per hectare than number of roots per plant, average weight per root and also output per plant reduced. Sweet potato should plant at early stage of the season to use the full rainy season properly.

C. Fertilization

Generally sweet potato crops are produced in poor soil i.e., the soil is not enough fertile. This crop prefers sandy soil which is often infertile. In very fertile or soils with higher fertilized the yield of storage roots are often decreased. Generally sweet potato plants highly required potassium. Yields about 22 t/ha of tuberous roots and 30 t/ha of vine growth required approximately 29 kg P, 80 kg N and 185 kg K per hectare (AVRDC, 1975).

2.9 Harvesting

The accurate growing period of sweet potato depends on the environmental circumstances under which the crop is produced and also on the cultivars. The crop growing period varies from 12 to 35 weeks that depends on the cultivars and growing conditions (Chen and Xu, 1982 and Hahn and Hozyo, 1984). On the contrary, a time period of 25 to 50 weeks has also been suggested for some cultivars (Huett, 1976 and Huett and O' Neill, 1976).

Leaf yellowing notifies that the crop is ready to harvest. When the harvesting is done too soon, then the yield will be low. Again, if the crop is harvested too late, then the tuberous roots will be unpalatable, fibrous and may attack by different sweet potato weevil. All the storage roots of a sweet potato field do not mature at the same time. For this reason, harvesting should be done at the time when a maximum number of storage roots get maturity.

2.10 Curing and storage of tubers

The harvested storage roots need to be cured to develop fast healing of the injuries that occurs at the time of harvesting. To reduce the infection by different microorganisms at storage time and to prepare the tuberous roots more resistant against wounds at the time of handling, curing is essential. So, after harvesting, curing should be done as early as possible. To store the tuberous roots, the storage roots must be cured prior to 4-5 days of storing. Sometimes tuberous roots are stored in underground pits and then overwhelmed with grass. Tuberous roots can also be stored on platforms or stored in baskets, but in these cases, sprouting and

spoilage of tuberous roots may occur with these storing methods. So that, the tuberous roots cannot be stored for more than one or two months.

2.11 Yield

The cultivars of sweet potato greatly vary in the amount of yield (Wilson and Lowe, 1973). In case of root and tuber crops, the principal elements of yield are mean weight and the number of storage roots (Wilson and Lowe, 1973). In many countries average yield of fresh tuberous root is about 10 to 25t /ha in 16 to 20 weeks is gained (Bhagsari and Harmon, 1982; Li and Kao, 1985; Bhagsari, 1990 and Sen *et al.,* 1990). About 15t /ha has been calculated as the world average yield of storage root (FAO 2000). On the other hand, 30 to 73t /ha have been indicated as experimental storage root yields (Bhagsari and Ashley, 1990).

2.12 Economic importance of sweet potato

Sweet potato is thought as one of the most important main foods of the world and plays a great role in food security. It is an important commercial crop of many developing countries (Kivuva *et al.,* 2014). Storage roots of sweet potato are taken either fresh or boiled. Sometimes sweet potatoes are chipped, dried and then made into flour which may be used for the preparation of snacks and baby foods (Engoru *et al.,* 2005a). Worldwide sweet potato is principally used in fresh form as human consumption. A small amount, less than 1 per cent are used to make dried chips and flour. In China, for the production of noodles, starch and snack foods on an industrial scale, approximately 15 per cent of the entire sweet potato production is used (Chang and Anton, 2014).

In the world, Uganda is considered as the second leading consumer and producer of sweet potato tuberous roots. In accordance with the consideration of the Food and Agriculture Organisation, Uganda produces more than 2.5 million metric tons of sweet potatoes (FAO, 2012).

CHAPTER III

MATERIALS AND METHODS

In this study, the materials and methods are illustrated which were used to fulfill the experiment on morpho-physiological analysis of different sweet potato germplasm. This chapter includes a summary about experimental location, climate of the area, soil characteristics, planting materials, preparation of land, planting, manuring and fertilization, different intercultural operations, harvesting and data collection procedure.

3.1 Location and duration

This research work was carried out at Horticulture Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The duration of the experiment was from September 2018 to March 2019. The research work was implemented for the evaluation of the morphophysiological characteristics of 15 selected sweet potato germplasm. The experimental location was at 90°34′ E longitude and 23°75′ N latitude with the elevation of 8.45 meter from sea level.

3.2 Climate

In the study area, the condition of the climate was subtropical. During rabi season (October – March)- low humidity, low temperature, low rainfall and short-day period while at kharif season (April-September)- high temperature, high humidity, high rainfall and long day period was observed. In the Appendix II, the details about average precipitation, maximum and minimum temperature, relative humidity and sunshine hours of the study area from September 2018 to March 2019 are showen.

3.3 Soil

The experimental area was located in the Agro-Ecological Zone of Madhupur tract (AEZ-28) and ECE 25.28. According SRDI, soil pH was found 5.8-6.5. The texture of the soil of research field was silty clay loam. In the Appendix I, the condition of soil has been illustrated.

3.4 Planting materials

The planting materials of the experiment were the vines of the fifteen sweet potato germplasm and these germplasm were collected from two sources: Japan and local farm.

3.5 Design and treatment

The study was laid out in the Randomized Complete Block Design (RCBD) with three replications.

Treatments

The experimental treatment vis-a-vis the 15 germplasm were as follows. Of these only the 8th one was collected locally (as the check germplasm) whereas the rest 14 were from Japan.

Factor A: Sweet potato germplasm

Germplasm	Sources
Germplasm 1	Japan
Germplasm 2	,,
Germplasm 3	,,
Germplasm 4	,,
Germplasm 5	,,
Germplasm 6	,,
Germplasm 7	,,
Germplasm 8	Local
Germplasm 9	Japan
Germplasm 10	,,
Germplasm 11	,,
Germplasm 12	,,
Germplasm 13	,,
Germplasm 14	,,
Germplasm 15	,,

3.6 Layout of the experiment

The land selected for this research work was of 11m×9m. The area was divided into three equal blocks. Each block was again divided into 15 plots where 15 germplasm were planted randomly. In the experimental area, total 45 plots were created. Every plot was of 1.5m×1.2m or 1.8m^2 in size. Vines of sweet potato with 4-5 leaves were planted on the plots. Plant to plant distance 30 cm and row to row distance 60 cm were maintained in planting vines which

is recommended by BARI (2017). In each plot there were 10 plants, and each block contained total 150 plants.

3.7 Cultivation procedure

3.7.1 Preparation of land

The soil of the experimental units was prepared properly. For sweet potato production, good tilth of the soil was assured. The field was ploughed up to a depth of 6-7 inches with a power tiller. After that, ploughing of the experimental field for three times was done followed by laddering to attain the tilth required. Ploughing of land was done on the 20th September, 2018. Bigger clods were broken into smaller fragments and land corners were spaded properly. All the weeds, stubbles and inert materials were removed from the field. Weeding session was done at 1st October, 2018. At last, the experimental units were prepared as required. In each plot, furrows and ridges were made.

3.7.2 Fertilizing and manuring

In the experimental plots, fertilizers and manures were applied (Table 1**)** as recommended by BARI (2005).

Table 1. Doses of fertilizer and manure applied

Fertilizers and manure	**Doses/ha**	**Doses/plot**
Urea	300 kg	50 g
TSP	200kg	34 g
Magnesium Sulphate	120 kg	20 g
Gypsum	120 kg	20 g
Borax	10 kg	1.5 g
Cowdung	10 ton	1.5 kg

At the time of preparation of land, half of urea and the whole amount of gypsum, borax, TSP, magnesium sulphate, cowdung were applied as basal. The remaining amount of urea was applied in two equal installments as top dressing. About 30 and 60 days after planting (DAP), 1st and 2nd installments were done respectively.

3.7.3 Vine planting

On the 1st October, 2018, the vines of sweet potato having 4-5 leaves were planted in the furrows of the plots under experiment. Vines were planted keeping a plant-to-plant distance of 30 cm and row to row distance of 60 cm. After that, using the soil from ridges, some portions of vines were covered.

3.7.4 Intercultural operations

First weeding of the plots was done before the planting of the vines on the 1st October, 2018. After 30 days, intercultural operations like earthing up and weeding were done manually. Weeds were removed from rows after spading the soil. Urea was broadcasted between the rows followed by earthing up of soil. In the sweet potato field, pesticides or insecticides were not used. Irrigation was done for several times. The first irrigation was applied after one week of planting, the second irrigation was done after earthing up, the third time applied at 52 days and finally applied after 65 days of planting.

3.7.5 Harvesting

When the crops became fully matured, harvesting of all the germplasm was done on the 2nd week of March, 2019 and the entire field was harvested.

3.8 Recording of data

From every plot, different data on sweet potato plants and tuberous roots were recorded.

A. Morphophysiological characteristics

The following morphological data of leaf, root, flower etc. were collected:

a. Young leaf blade color
b. Mature leaf blade color
c. General outline of leaves
d. Depth of leaf lobing
e. Number of lobes per leaf
f. Anthocyanin coloration of tip
g. Anthocyanin coloration of upper side of leaves
h. Anthocyanin coloration of internode
i. Anthocyanin coloration of node
j. Anthocyanin coloration of petiole

k. Extent of anthocyanin coloration on abaxial veins
l. Intensity of anthocyanin coloration on abaxial veins
m. Pubescence of tip
n. Number of root
o. Root cracking
p. Types of storage root shape
q. Depth of eye on tuberous root
r. Types of storage root surface
s. Distribution of anthocyanin pigmentation in the storage root flesh

B. Characteristics of vegetative growth

a. Leaf length
b. Leaf width
c. Length of internode
d. Petiole length
e. Flower stalk/peduncle length

C. Characteristics of reproductive growth

a. Tuberous root length
b. Tuberous root diameter

D. Yield characters

a. Number of tuberous roots/plants
b. Weight of a single tuberous root
c. Tuberous root yield/plant
d. Tuberous root yield/ha

E. Color of tuberous root

a. Skin color
b. Flesh color
c. Flesh color after baking

3.9 Data recording procedure

A short description of the data recording procedure is given here.

3.9.1 Morphological characteristics of tuberous root

Different morphological characteristics such as young leaf blade color, mature leaf blade color, depth of leaf lobing, number of lobe in a leaf, anthocyanin coloration of tip, anthocyanin coloration of upper side of leaf, anthocyanin coloration of internode, anthocyanin coloration of node, anthocyanin coloration of petiole, extent of anthocyanin coloration on abaxial veins, intensity of anthocyanin coloration on abaxial veins, pubescence of tip, number of root, root cracking, types of storage root shape, etc. were recorded by visual observation.

3.9.2 Leaf length (cm)

The leaf length of each germplasm was calculated with a measuring scale and the average was recorded in centimeter (cm).

3.9.3 Leaf width (cm)

The leaf width for each germplasm was calculated with a measuring scale and the average was calculated in centimeter (cm).

3.9.4 Length of internode (cm)

The length of internode of each germplasm was measured with a measuring scale and the average of those data was taken in centimeter (cm).

3.9.5 Petiole length (cm)

The petiole length for each germplasm was measured by using a measuring scale and their average was calculated in centimeter (cm).

3.9.6 Flower stalk length (cm)

The flower stalk length of each germplasm was taken using a measuring scale and then the average was recorded in centimeter (cm).

3.9.7 Tuberous root length (cm)

The tuberous root length for each germplasm was measured by using a measuring scale and their average was calculated in centimeter (cm).

3.9.8 Tuberous root diameter (mm)

The tuberous root diameter for each germplasm was measured by using a measuring scale and the average was taken in millimeter (mm).

3.9.9 Number of tuberous roots/plant

At the time of harvesting, the number of tuberous roots per plant for each germplasm was calculated and the average number of tuberous roots per plant was also estimated.

3.9.10 Weight of a single tuberous root (g)

After harvesting the weight of tuberous root from each plot was weighed with the help of an electric balance. The average weight of a single sweet potato tuberous root was also calculated.

3.9.11 Tuberous root weight/plant (g)

With the help of an electric balance, tuberous root weight was measured. Then average weight of the sweet potato tuberous root per plant was also calculated.

3.9.12 Yield/hectare (ton)

The yield per hectare was estimated by using the data from single root weight and root weight per plant and then convert and expressed in ton/ha.

3.10 Analysis of data

To know the significant difference among the fifteen treatments, the data gained for various parameters were analyzed statistically. Calculations of mean values of all the parameters were done. The analysis of variance was also accomplished. By using the LSD value at 5% level of significance, the significant difference among the treatments means was measured. For the statistical analysis a computer software MSTAT-C was used.

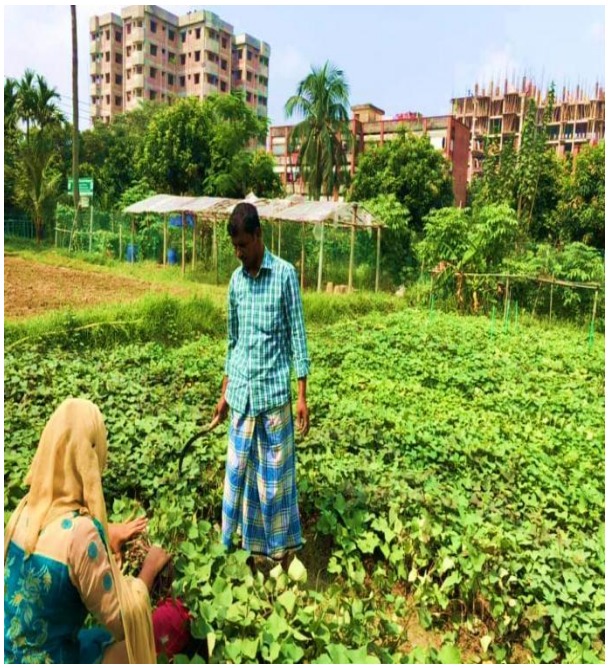


Plate 1. Collection of data

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, the discussion on the results obtained from the experiment has been included.

4.1 General features of the fifteen germplasm

a. Germplasm 1

Mature leaf blade color of this germplasm is green and young leaf is light green (Plate 2). Anthocyanin coloration of upper side of leaf is absent. Pigmentation of petiole and tip is present in this germplasm. Depth of leaf lobing is very shallow. Extent of anthocyanin coloration on abaxial veins is medium and intensity of coloration on abaxial veins is weak.

a. Mature and young leaf

b. Sweet potato flower

c. Skin and flesh color

d. Plant and leaf

Plate 2. Pictorial view of germplasm 1

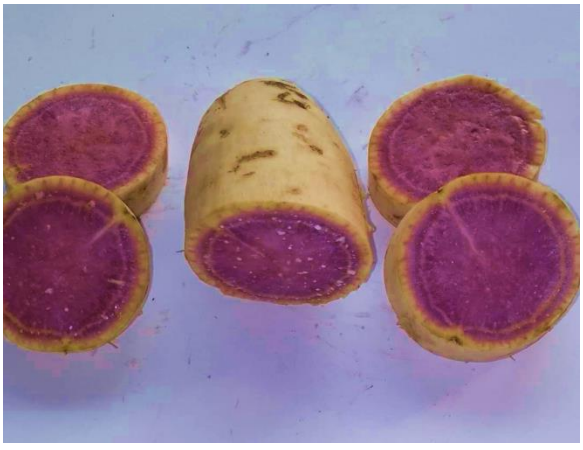
b. Germplasm 2

Mature leaf blade color of this germplasm is green and young leaf blade is light green (Plate 3). Leaf lobe is present and depth of leaf lobe is deep. Anthocyanin coloration of upper side of leaf is absent. Extent of anthocyanin coloration on abaxial veins is very large and intensity of anthocyanin coloration on abaxial veins is very strong. Anthocyanin coloration of petiole is strong for this germplasm. Pigmentation of tip is found.

a. Mature and young leaf

b. Plant and leaf

c. Sweet potato flower



d. Skin and flesh color

Plate 3. Pictorial view of germplasm 2

c. Germplasm 3

Young leaf blade color of this germplasm is light green and mature leaf blade is green (Plate 4). Extent of anthocyanin coloration on abaxial vein is very large and intensity of this anthocyanin coloration is very strong. Depth of leaf lobe is moderate. Anthocyanin coloration of upper side of leaf and tip is absent. Anthocyanin coloration of petiole is weak.

a. Mature and young leaf

b. Plant and leaf

c. Sweet potato flower

d. Flesh color

Plate 4. Pictorial view of germplasm 3

d. Germplasm 4

Color of mature leaf of this germplasm is green and young leaf is light green (Plate 5). Anthocyanin coloration on abaxial veins is absent. So there is no intensity of anthocyanin coloration on abaxial veins. Anthocyanin coloration of petiole and upper side of leaf blade is absent. Leaf lobe is present and depth of leaf lobing is shallow. Anthocyanin coloration of tip is absent in this germplasm.

a. Mature and immature leaf

b. Plant and leaves

c. Sweet potato flower

d. Flesh color

Plate 5. Pictorial view of germplasm 4

e. Germplasm 5

Color of mature leaf is green and young leaf is light green (Plate 6). Depth of lobing of leaf is moderate. Extent of anthocyanin coloration on abaxial veins is very large and intensity of this coloration on abaxial veins is very strong. Anthocyanin coloration of upper side of leaf blade is present but weak. Anthocyanin pigmentation of petiole is weak. Pigmentation of tip is not found.

a. Mature and young leaf

b. Sweet potato flower

c. Plant and leaves

d. Skin and flesh color

Plate 6. Pictorial view of germplasm 5

f. Germplasm 6

Mature leaf of this germplasm is green in color and young leaf is purplish brown color (Plate 7). Extent of anthocyanin coloration on abaxial veins is very small and intensity of this pigmentation on abaxial veins is very weak. Leaf lobe is absent in this germplasm and the leaf blade shape is cordate. There is no pigmentation in upper side of mature leaf and petiole. Anthocyanin coloration of tip is present and strong.

a. Mature and immature leaf

d. Plant and leaf

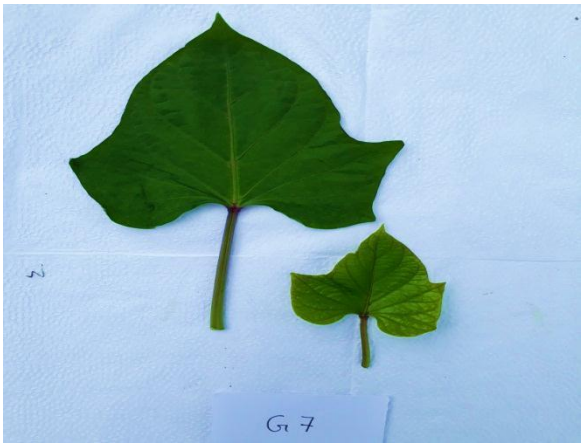
c. Sweet potato flower

d. Flesh color

Plate 7. Pictorial view of germplasm 6

g. Germplasm 7

The color of mature leaf is green and young leaf is light green (Plate 8). Leaf lobe is present and depth of lobing of leaf is very shallow. Pigmentation of tip and upper side of leaf blade is absent. Pigmentation of petiole is present but weak. Extent of anthocyanin coloration on abaxial veins is very large and intensity of such coloration is very strong.



a. Mature and immature leaf

b. Sweet potato flower

c. Plant and leaf

d. Flesh color

Plate 8. Pictorial view of germplasm 7

h. Germplasm 8

Mature leaf of this germplasm is green and young leaf is light green in color (Plate 9). Extent of anthocyanin coloration on abaxial veins is large and intensity condition is medium. Leaf lobe is present and depth of leaf lobing is moderate. Pigmentation of upper side of leaf blade and tip is absent. Anthocyanin coloration of petiole is present but weak.

a. Mature and young leaf

b. Plant and leaf

c. Sweet potato flower

d. Flesh color

Plate 9. Pictorial view of germplasm 8

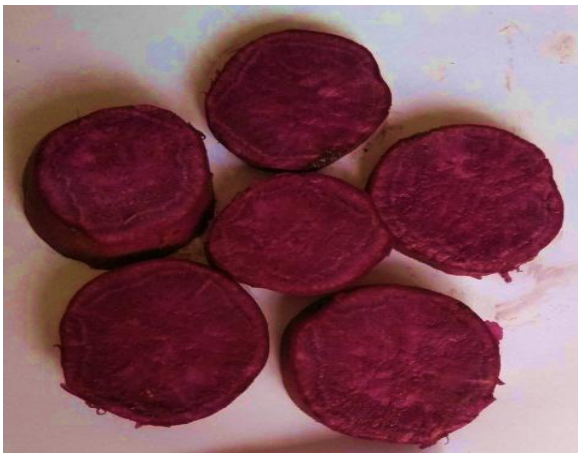
i. Germplasm 9

The color of young leaf is light green and mature leaf is green (Plate 10). Anthocyanin coloration in petiole is absent. Pigmentation of upper side of leaf blade and tip is also absent. Leaf lobe is present and depth of lobing is deep. Anthocyanin coloration on abaxial veins is absent, so there is no intensity of pigmentation.

a. Mature and immature leaf

b. Plant and leaf

c. Sweet potato flower



d. Flesh color

Plate 10. Pictorial view of germplasm 9

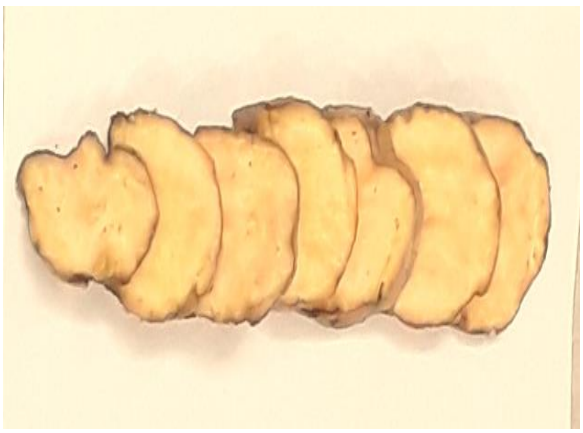
j. Germplasm 10

The color of young leaf is light green and mature leaf is green (Plate 11). Anthocyanin coloration of petiole is absent. Pigmentation of upper side of leaf blade is weak. Extent of anthocyanin coloration on abaxial veins is very large and intensity of anthocyanin coloration is also very strong. There is no leaf lobe in the leaf of this germplasm. The shape of leaf blade is cordate. Pigmentation of tip is not found.

a. Mature and immature leaf

b. Plant and leaf

c. Sweet potato flower



d. Flesh color

Plate 11. Pictorial view of germplasm 10

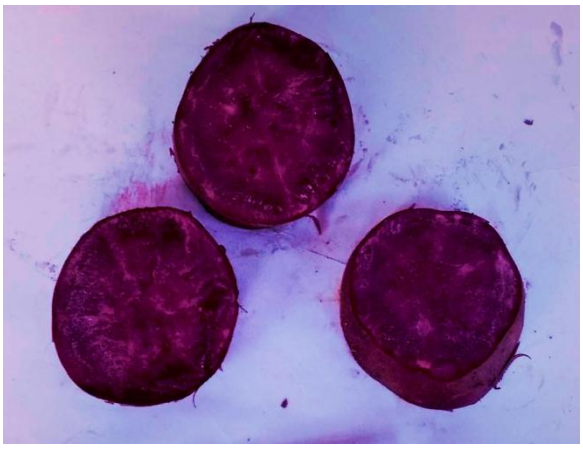
k. Germplasm 11

Mature leaf of this germplasm is green and young leaf is light green in color (Plate 12). Anthocyanin coloration on abaxial veins is absent, so there is no intensity of color. Pigmentation of petiole is absent. Anthocyanin coloration of upper side of leaf blade is weak. Pigmentation of tip is absent. Leaf blade lobe is present and depth of leaf lobing is deep.

a. Mature and young leaf

b. Plant and leaf

c. Sweet potato flower

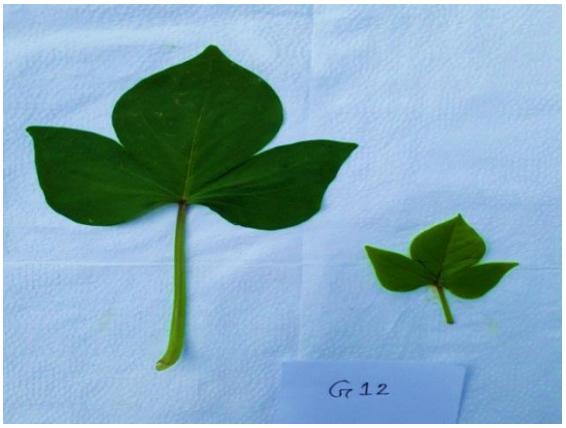


d. Flesh color

Plate 12. Pictorial view of germplasm 11

l. Germplasm 12

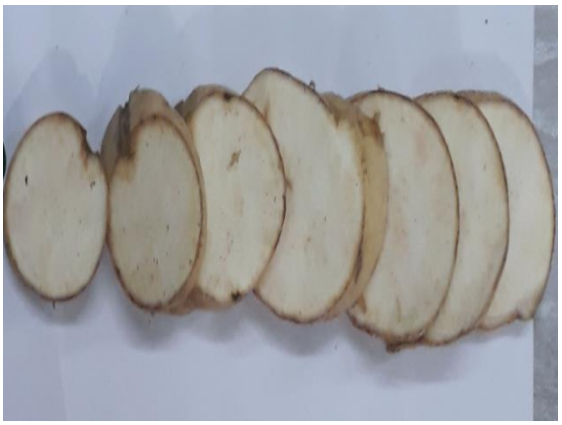
In this germplasm anthocyanin coloration of petiole is very weak. Young leaf color is light green and mature leaf color is green (Plate 13). Extent of anthocyanin coloration on abaxial veins is very large with very strong intensity of this color. Leaf lobe is present and the depth of leaf lobing is moderate. Pigmentation of tip is not found. Anthocyanin coloration of upper side of leaf blade is absent.



a. Mature and Young leaf

b. Plant and leaf

c. Sweet potato flower

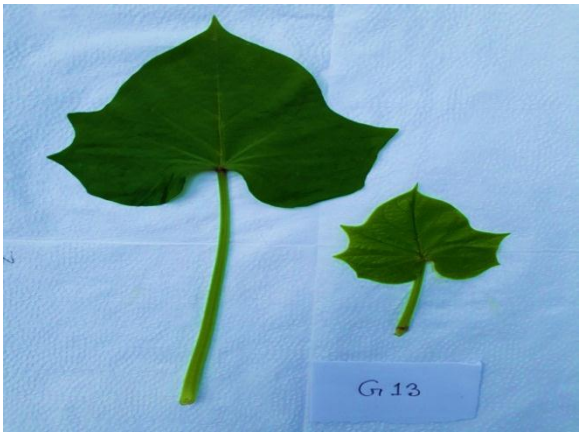


d. Flesh color

Plate 13. Pictorial view of germplasm 12

m. Germplasm 13

Mature leaf is green and young leaf is light green in color (Plate 14). Leaf lobes are present and depth of leaf lobing is shallow. Extent of anthocyanin coloration on abaxial veins is large with strong intensity of the anthocyanin coloration. There is no pigmentation in the petioles. Anthocyanin coloration of upper side of the leaf blade is weak. Anthocyanin coloration is absent at the tip.



a. Mature and immature leaf

b. Plant and leaf

c. Sweet potato flower

d. Flesh color

Plate 14. Pictorial view of germplasm 13

n. Germplasm 14

Anthocyanin pigmentation of petiole is absent (Plate 15). Color of young leaf is light green and mature leaf is green. Anthocyanin coloration on abaxial veins is absent. Leaf blade lobe is present and depth of leaf lobe is deep. Anthocyanin pigmentation is absent on upper side of leaf blade. Pigmentation is not found on tip.

a. Mature and immature leaf

b. Plant and leaf

c. Sweet potato leaf

d. Flesh color

Plate 15. Pictorial view of germplasm 14

o. Germplasm 15

Color of mature leaf is green and immature leaf is light green (Plate 16). Anthocyanin coloration on abaxial veins is absent. Leaf blade lobe is present and depth of lobing is deep. Anthocyanin coloration of petiole and upper side of leaf is absent. There is no anthocyanin coloration on tip.

a. Mature and young leaf

b. Plant and leaf

c. Sweet potato flower

d. Flesh color

Plate 16. Pictorial view of germplasm 15

4.2 Different morphological characteristics of germplasm

According to the instruction of Union for the Protection of Plant Varieties (UPOV), all the morphological traits were examined with visual inspection. Brief descriptions about all the morphological traits are given below.

4.2.1 Types of storage root shape

Storage root shape were examined by visually. All the germplasm showed a wide range of variation in the shape of storage roots. Irregular root shape was observed in germplasm 1, germplasm 7, germplasm 8, germplasm 12 and germplasm 13. Oblong shape was found only in germplasm 9. Long oblong was found in germplasm 3, ovate shape in germplasm 11 and obovate in germplasm 15. Remaining six germplasm showed long elliptic shape (Table 2). Size and shape of storage roots greatly depends on cultivars (Caliskan *et al.*, 2007). The finding is similar with there of Efisue (2015) and Fongod *et al.* (2012).

4.2.2 Depth of eyes on tuberous roots

Depth of eyes on storage roots were assessed by visual observation. Shallow type's eye depth was recorded in germplasm 9, germplasm 11, germplasm 14 and germplasm 15. And the rest of the germplasm had deep type of eye depth (Table 2).

4.2.3 Types of storage root surface

Tuberous roots of all the germplasm under this experiment had the same type of root surface, that is horizontal constriction (Table 2).

4.2.4 Distribution of anthocyanin pigmentation in the storage root flesh

In the storage root flesh, anthocyanin pigmentation distribution was observed by visual examination. Anthocyanin pigmentation covers most of the flesh of storage roots only in germplasm 2. In case of germplasm 1, germplasm 3, germplasm 5, germplasm6, germplasm 9, germplasm 10, germplasm 11, germplasm 13, germplasm 14 and germplasm 15 anthocyanin pigmentation covers all of the root flesh (Table 2). According to K'osambo *et al.* (1998) and Teow *et al.* (2007), distribution of anthocyanin pigmentation in the flesh of storage roots extensively varied due to genotypes. The same result was also reported by Yada *et al.* (2010) and Fongod *et al.* (2012).

4.2.5 Root cracking

Root cracking was observed by visual observation. Cracking was found in germplasm 1, germplasm 10, germplasm 13 and germplasm 14. In another germplasm, root cracking was not found (Table 2). Cracking of roots occur due to susceptible and resistant quality of different cultivars (Nwankwo *et al.*, 2012). The similar finding was also reported in the findings of Huaman (1992).

4.2.6 General outline of leaves

Leaves of all the germplasm had lobes except two germplasm. Germplasm 6 and germplasm 10 had no lobe and the shape of these germplasm leaves was same i.e., cordate (Table 2). Leaf outline must vary because of variation among germplasm (Yada *et al*., 2010 and Fongod *et al.*, 2012).

4.2.7 Young leaf blade color

There was a little bit difference among all the young leaf blade colors. Purplish brown color was present only in the immature leaf of germplasm 6. Remaining fourteen germplasm young leaf color was same i.e., light green (Table 2). Young leaf blade color varies due to different cultivars (Efisue, 2015). The similar result was reported by Yada *et al.* (2010) and Fongod *et al.* (2012).

4.2.8 Color of mature leaf blade

Like immature leaves, there was no variation among the mature leaves of all germplasm. All the mature leaves of fifteen germplasm showed almost the same green color (Table 2). Color of mature leaves sometimes varies due to genetic variation among different cultivars (Efisue, 2015). This finding is also in accordance with those of Yada *et al.* (2010) and Fongod *et al.* (2012).

Table 2. Morphological characterization of fifteen sweet potato germplasm

Morphological characteristics	Categories	Germplasm
1. Types of storage root shape	Irregular	G_1, G_7, G_8, G_{12}, G_{13}
	Oblong	G_9
	Long oblong	G_3
	Ovate	G_{11}
	Obovate	G_{15}
	Long elliptic	G_2, G_4, G_5, G_6, G_{10}, G_{14}
2. Depth of eye on tubers	Shallow	G_9, G_{11}, G_{14}, G_{15}
	Deep	G_1, G_2, G_3, G_4, G_5, G_6, G_7, G_8, G_{10}, G_{12}, G_{13}
3. Types of storage root surface	Horizontal constriction	All germplasm
4. Distribution of anthocyanin pigmentation in the storage root flesh	Covers most of the flesh	G_2
	Covers whole flesh	G_1, G_3, G_5, G_6, G_9, G_{10}, G_{11}, G_{13}, G_{14}, G_{15}
	No anthocyanin	G_4, G_7, G_8, G_{12}
5. Root cracking	Found	G_1, G_{10}, G_{13}, G_{14}
	Not found	G_2, G_3, G_4, G_5, G_6, G_7, G_8, G_9, G_{11}, G_{12}, G_{15}
6. General outline	Lobed	G_1, G_2, G_3, G_4, G_5, G_7, G_8, G_9, G_{11}, G_{12}, G_{13}, G_{14}, G_{15}
	Cordate	G_6, G_{10}
7. Young leaf blade color	Purplish brown	G_6
	Light green	G_1, G_2, G_3, G_4, G_5, G_7, G_8, G_9, G_{10}, G_{11}, G_{12}, G_{13}, G_{14}, G_{15}
8. Color of mature leaf blade	Green	All germplasm
9. Depth of leaf lobe	Deep	G_2, G_9, G_{11}, G_{14}, G_{15}
	Moderate	G_3, G_5, G_8, G_{12}
	Shallow	G_4, G_{13}
	Very shallow	G_1, G_7
10. Number of leaf lobe	Absent	G_6, G_{10}
	3	G_8, G_{12}
	5	G_1, G_2, G_3, G_4, G_5, G_7, G_9, G_{11}, G_{13}, G_{14}, G_{15}

Table 2. Morphological characterization of fifteen sweet potato germplasm (Cont'd.)

Morphological characteristics	Categories	Germplasm
11. Anthocyanin coloration of upper side of leaf	Weak	G_5, G_{10}, G_{11}, G_{13}
	Did not show	G_1, G_2, G_3, G_4, G_6, G_7, G_8, G_9, G_{12}, G_{14}, G_{15}
12. Anthocyanin coloration of petiole	Found	G_1, G_2, G_3, G_5, G_7, G_8, G_{12}
	Not found	G_4, G_6, G_9, G_{10}, G_{11}, G_{13}, G_{14}, G_{15}
13. Extent of anthocyanin coloration on abaxial veins	Absent	G_4, G_9, G_{11}, G_{14}, G_{15}
	Very small	G_6
	Medium	G_1
	Large	G_8, G_{13}
	Very large	G_2, G_3, G_5, G_7, G_{10}, G_{12}
14. Anthocyanin coloration of node	Strong	G_1, G_2, G_3, G_{10}, G_{12}, G_{13}
	Medium	G_5, G_7, G_8
	Weak	G_4, G_6, G_{11}, G_{15}
	Not found	G_9, G_{14}
15. Anthocyanin coloration of internode	Strong	G_1, G_2, G_{13}
	Weak	G_4, G_{10}, G_{12}
	No coloration	G_3, G_5, G_6, G_7, G_8, G_9, G_{11}, G_{14}, G_{15}
16. Anthocyanin coloration of tip	Found	G_1, G_2, G_6
	Not found	G_3, G_4, G_5, G_7, G_8, G_9, G_{10}, G_{11}, G_{12}, G_{13}, G_{14}, G_{15}
17. Pubescence of tip	Dense	G_1, G_9, G_{11}, G_{13}
	Medium	G_2, G_6, G_7, G_{10}, G_{12}, G_{15}
	Sparse	G_3, G_4, G_5, G_8, G_{14}

4.2.9 Depth of leaf lobe

Germplasm 2, germplasm 9, germplasm 11, germplasm 14 and germplasm 15 had deep type of leaf lobing. Moderate types of leaf lobing were observed in germplasm 12, germplasm 8, germplasm 5 and gemplasm 3. But germplasm 6 and germplasm 10 showed no leaf lobing

and the shape of these leaves were observed cordate types. Shallow types of leaf lobing was found in germplasm 4 and germplasm 13. Germplasm 1 and germplasm 7 showed very shallow types of leaf lobing (Table 2). Significant difference occurs due to variation in germplasm (Efisue, 2015). This finding is also parallel with the findings of Fongod *et al.* (2012) and Yada *et al.* (2010).

4.2.10 Number of leaf lobes

There is no leaf lobe in germplasm 6 and germplasm 10. Both germplasm 8 and germplasm 12 have 3 lobes. Other germplasm contains 5 lobes in leaves (Table 2). These variations occur due to variation among germplasm. The finding is supported by Fongod *et al.* (2012) and Yada *et al.* (2010).

4.2.11 Anthocyanin coloration on the upper side of leaf

On the upper side of leaf blade, anthocyanin coloration was found weak in germplasm 5, germplasm 10, germplasm 11 and germplasm 13. The rest of the germplasm did not show any coloration on upper side of leaf blade (Table 2). Such differences occur due to variation in genotypes (Yada *et al.*, 2010 and Fongod *et al.,* 2012).

4.2.12 Anthocyanin coloration on petiole

Pigmentation was found on the petiole of germplasm 1, germplasm 2, germplasm 3, germplasm 5, germplasm 7, germplasm 8 and germplasm 12. On the other hand, the rest of the germplasm did not show any pigmentation (Table2). The variation in the anthocyanin coloration of petiole depends on germplasm. According to Efisue (2015), variation in petiole pigmentation occurs must be due to genetic variation in the genotypes. The similar results were reported by Yada *et al.* (2010) and Fongod *et al.* (2012) too.

4.2.13 Extent of anthocyanin coloration on abaxial veins

Anthocyanin coloration was absent in germplasm 4, germplasm 9, germplasm 11, germplasm 14 and germplasm 15. Remaining germplasm had anthocyanin coloration on abaxial veins and showed a wide range of variation (Table 2). Difference occurs due to genetic differences in germplasm (Yada *et al.*, 2010).

4.2.14 Anthocyanin coloration of node

A strong anthocyanin coloration was recorded in the node of germplasm 1, germplasm 2, germplasm 3, germplasm 10, germplasm 12 and germplasm 13. Anthocyanin coloration was found medium in germplasm 5, germplasm 7 and germplasm 8. A weak coloration was observed in germplasm 4, germplasm 6, germplasm 11 and germplasm 15. Rest two germplasm showed no pigmentation (Table 2). Anthocyanin coloration of node depends on the genotype of sweet potato (Yada *et al.*, 2010).

4.2.15 Anthocyanin coloration of internode

Anthocyanin coloration of internode was observed strong in germplasm 1, germplasm 2 and germplasm 13. A weak coloration was found in Germplasm 4, germplasm 10 and germplasm 12. Rest of the germplasm showed no coloration of internode (Table 2). According to Yada *et al.* (2010), coloration of internode varies with genotypes.

4.2.16 Anthocyanin coloration of vine tip

Anthocyanin coloration of vines tip was found in germplasm 1, germplasm 2 and germplasm 6. And the remaining all germplasm did not show any anthocyanin coloration (Table 2). Anthocyanin coloration of tip depends on the genotypes of sweet potato germplasm (Yada *et al.*, 2010).

4.2.17 Pubescence of vine tip

Different germplasm showed various types of pubescence at tip. A dense pubescence was found in germplasm 1, germplasm 9, germplasm 11 and germplasm 13. Medium types of pubescence were observed in germplasm 2, germplasm 6, germplasm 7, germplasm 10, germplaasm 12 and germplasm 15. And others showed sparse types of pubescence at the tip (Table 2). The variation in case of vine tip pubescence occurs due to differences in sweet potato germplasm (Efisue, 2015). This finding is also supported by Yada *et al.* (2010) and Fongod *et al.* (2012).

4.3 Vegetative growth of different sweet potato germplasm

4.3.1 Length of leaf

Table 3. Variation in leaf length among fifteen sweet potato germplasm

Treatments	Length of leaf (cm)
G_1	6.133 gh
G_2	6.500 fg
G_3	6.500 fg
G_4	5.933 h
G_5	5.967 h
G_6	6.300 fgh
G_7	7.500 e
G_8	6.467 fg
G_9	10.77 b
G_{10}	7.367 e
G_{11}	9.833 c
G_{12}	7.967 d
G_{13}	6.667 f
G_{14}	11.20 a
G_{15}	10.83 ab
CV (%)	3.22
LSD (0.05)	0.4165

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

The length of leaves varied significantly among fifteen sweet potato germplasm (Appendix III). The germplasm 14 (G_{14}) shows the highest leaf length (11.20 cm) while the germplasm 4 (G_4) shows the lowest leaf length (5.933 cm) compared to another germplasm (Table 3). Leaf length of G_{14} (11.20 cm) is statistically similar with G_{15} (10.83 cm) and shows the highest leaf length. On the other hand, leaf length of G_4 (5.933 cm) is statistically identical with G_5 (5.967cm), G_1 (6.133 cm) and G_6 (6.300 cm) and showed the lowest leaf length. Length of leaf must vary from cultivar to cultivar (Huaman, 1992). This finding is also matched with the findings of Holtan *et al.* (2003), Gichuki *et al.* (2003) and Joseph *et al*. (2005).

4.3.2 Leaf width

Table 4. Differences of leaf width among fifteen sweet potato germplasm

Treatments	Leaf width (cm)
G_1	9.767 g
G_2	10.60 def
G_3	10.70 cde
G_4	10.83 bcd
G_5	9.900 g
G_6	10.17 efg
G_7	10.90 bcd
G_8	10.93 abcd
G_9	11.23 abc
G_{10}	10.00 fg
G_{11}	11.53 a
G_{12}	9.667 g
G_{13}	9.967 g
G_{14}	11.33 ab
G_{15}	11.40 ab
CV (%)	3.39
LSD (0.05)	0.6007

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

There was significant difference in leaf width of different sweet potato germplasm (Appendix III). The highest result (11.53 cm) of leaf width was found in germplasm 11 (G_{11}) and the lowest result (9.667 cm) was observed in germplasm 12 (G_{12}) compared to others (Table 4). Leaf width of G_{11} (11.53 cm) is statistically identical with G_{15} (11.40 cm), G_{14} (11.33 cm), G_9 (11.23 cm) and G_8 (10.93 cm) showing the highest result. Again, G_{12} (9.667 cm) is statistically similar with G_1 (9.767 cm), G_5 (9.900 cm), G_{13} (9.967 cm), G_{10} (10.00 cm) and G_6 (10.17 cm) while showing the lowest results. According to Khan *et al*. (2012), variation in leaf width happens because of genetic differences among sweet potato germplasm. The same finding is also reported by Liao *et al*. (2015), Shayanowako *et al.* (2014), Mangani *et al*. (2015) and Haque *et al*. (2015).

4.3.3 Length of internode

Table 5. Variation in length of internode among fifteen sweet potato germplasm

Treatments	Length of internode (cm)
G_1	4.333 c
G_2	4.433 c
G_3	4.033 cd
G_4	3.333 d
G_5	3.467 d
G_6	3.467 d
G_7	3.500 d
G_8	4.100 cd
G_9	6.400 b
G_{10}	6.433 ab
G_{11}	7.200 a
G_{12}	6.400 b
G_{13}	0.9333 f
G_{14}	2.300 e
G_{15}	2.233 e
CV (%)	11.09
LSD (0.05)	0.7737

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

In case of length of internode, fifteen different germplasm showing a significance difference (Appendix III). Germplasm 11 (G_{11}) showed the highest value (7.200 cm) of length of internode while germplasm 13 (G_{13}) showed the lowest value (0.933 cm) (Table 5). G_{11} (7.200 cm) showed statistically similar result with G_{10} (6.433 cm) and expressing the highest result. According to Egbe *et al.* (2012), length of internode depends on cultivars and time. The finding is also agreed with the finding of Fongod *et al.* (2012) and Yada *et al.* (2010).

4.3.4 Petiole length

Table 6. Differences of petiole length among fifteen sweet potato germplasm

Treatments	Petiole length (cm)
G_1	12.87 b
G_2	15.40 a
G_3	12.70 b
G_4	11.50 c
G_5	10.33 d
G_6	11.17 c
G_7	9.167 e
G_8	7.067 f
G_9	7.567 f
G_{10}	8.433 e
G_{11}	7.267 f
G_{12}	9.933 d
G_{13}	7.633 f
G_{14}	7.100 f
G_{15}	8.633 e
CV (%)	4.59
LSD (0.05)	0.7517

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Like the other vegetative growth traits, the petiole length showed significant variation among different germplasm (Appendix III). Germplasm 2 (G_2) showed the highest value (15.40 cm) for petiole length. On the other hand, germplasm 8 (G_8) showed the lowest value (7.067 cm) of petiole length (Table 6). Petiole length of G_8 (7.067 cm) is statistically similar with G_{14} (7.100 cm), G_{11} (7.267 cm), G_9 (7.567 cm) and G_{13} (7.633 cm) while expressing the lowest value. According to Haque *et al*. (2015), variation occurs in petiole length due to genetic variation in different cultivars. The result is also agreed by Liao *et al*. (2015). Moreover, Shayanowako *et al.* (2014), Khan *et al*. (2012), Kaspar *et al*. (2013), Datta *et al*. (2015) and Mangani *et al*. (2015) supported this finding too.

4.3.5 Flower stalk/pedicel length

Table 7. Flower stalk length variations among fifteen sweet potato germplasm

Treatments	Flower stalk length (cm)
G_1	8.633 e
G_2	11.20 b
G_3	7.367 f
G_4	6.967 g
G_5	14.07 a
G_6	7.667 f
G_7	6.933 gh
G_8	10.17 d
G_9	11.50 b
G_{10}	6.633 hi
G_{11}	10.63 c
G_{12}	6.433 i
G_{13}	6.533 i
G_{14}	6.900 gh
G_{15}	6.567 i
CV (%)	2.31
LSD (0.05)	0.3303

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Flower stalk length showed significant differences among different sweet potato germplasm (Appendix III). In case of peduncle length, germplasm 5 (G_5) showed the highest value (14.07 cm) and germplasm 12 (G_{12}) showed the lowest value (6.433 cm) compared to another germplasm (Table 7). G_{12} (6.433 cm) is statistically identical with G_{13} (6.533 cm), G_{15} (6.567 cm) and G_{10} (6.633 cm) and showed the lowest value. Differences occur in stalk length due to genetic variation among genotypes. This finding is also supported by Fongod *et al.* (2012) and Yada *et al.* (2010).

4.4 Reproductive growth of different sweet potato germplasm

4.4.1 Tuberous root length

Table 8. Variation in tuberous root length among fifteen sweet potato germplasm

Treatments	Tuberous root length (cm)
G_1	19.40 a
G_2	19.13 a
G_3	18.47 ab
G_4	14.60 de
G_5	18.80 ab
G_6	15.47 cd
G_7	17.43 abc
G_8	16.47 bcd
G_9	12.23 ef
G_{10}	15.37 cd
G_{11}	9.533 g
G_{12}	19.57 a
G_{13}	18.33 ab
G_{14}	15.63 cd
G_{15}	11.53 fg
CV (%)	9.44
LSD (0.05)	2.546

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Fifteen germplasm showed a significance variation in terms of tuberous root length (Appendix IV). The highest value (19.57 cm) of tuberous root length was found in germplasm 12 (G_{12}) while the lowest value (9.533 cm) recorded in germplasm 11 (G_{11}) (Table 8). G_{12} (19.57 cm) is found statistically similar with G_1 (19.40 cm), G_2 (19.13 cm), G_5 (18.80 cm), G_3 (18.47 cm), G_{13} (18.33 cm) and G_7 (17.43 cm) and showed the highest value for tuber length. G_{11} (9.533 cm) is statistically similar with G_{15} (11.53 cm) and showed the lowest value. According to Egbe *et al.* (2012), length of tuberous root depends on sweet potato varieties. Tuberous roots length greatly affected by genotypes of sweet potato and environmental condition and these are the finding of Mau *et al.* (2019). Hasan *et al*. (2013) and Ganga *et al.* (2014) also supported the findings.

4.4.2 Tuberous root diameter

Table 9. Differences of tuberous root diameter among fifteen sweet potato germplasm

Treatments	Tuberous root diameter (mm)
G_1	44.17 cd
G_2	45.02 cd
G_3	59.62 a
G_4	41.26 de
G_5	51.15 b
G_6	25.26 g
G_7	44.37 cd
G_8	37.09 e
G_9	31.30 f
G_{10}	16.36 h
G_{11}	30.20 fg
G_{12}	40.13 de
G_{13}	13.14 h
G_{14}	47.19 bc
G_{15}	6.410 i
CV (%)	9.36
LSD (0.05)	5.560

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

There is a significance difference among different sweet potato germplasm in case of tuberous roots diameter (Appendix IV). Germplasm 3 (G_3) showed the highest value (59.62 mm) for tuberous root diameter while germplasm 15 (G_{15}) showed the lowest value (6.410 mm) compared to another germplasm (Table 9). G_5 (51.15 mm) is statistically similar with G_{14} (47.19 mm). Again, G_{13} (13.14 mm) is statistically similar with G_{10} (16.36 mm). According to Egbe *et al.* (2012), root diameter varies with different varieties. This finding is parallel with the findings of Mau *et al.* (2019). Mangani *et al*. (2015), Taha (1961), Rumhungwe *et al*. (2016) and Khan *et al*. (2011) also recorded variations in tuberous root diameters.

4.5 Yield characters

4.5.1 Number of tuberous roots/plant

Table 10. Number of tuberous roots/plant variations among fifteen sweet potato germplasm

Treatments	No. of tuberous roots/plant
G_1	6.067 f
G_2	7.000 bc
G_3	7.133 abc
G_4	7.300 a
G_5	7.200 ab
G_6	6.433 e
G_7	6.933 c
G_8	7.000 bc
G_9	7.200 ab
G_{10}	5.200 h
G_{11}	6.400 e
G_{12}	6.333 e
G_{13}	5.900 f
G_{14}	6.700 d
G_{15}	5.433 g
CV (%)	1.99
LSD (0.05)	0.2181

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Number of tuberous roots/plant varied significantly among different sweet potato germplasm (Appendix V). The highest value (7.300) was found for number of tuberous roots/plant in germplasm 4 (G_4), and the lowest value (5.200) was recorded in germplasm 10 (G_{10}) (Table 10). G_4 (7.300), G_9 (7.200), G_5 (7.200) and G_3 (7.133) were found statistically identical and showed highest value for number of tuberous roots/plant. Tuberous root number per plant extensively varies due to genetic variation in different genotypes (Mau *et al.*, 2019). Similar finding is supported by Egbe *et al.* (2012), Villordon *et al.* (2009). Mangani *et al*. (2015), Haque *et al*. (2015), Ganga *et al*. (2014), Mahmud *et al*. (2014), Datta *et al*. (2015), Liao *et al*. (2015), Khan *et al*. (2012), Kaspar *et al*. (2013) and Iheagwara (2013) also reported same findings.

4.5.2 Weight of a single tuberous root

Table 11. Variation in weight of a single tuberous root among fifteen sweet potato germplasm

Treatments	Weight of single tuberous root (g)
G_1	132.8 e
G_2	142.0 c
G_3	149.1 b
G_4	116.2 g
G_5	137.6 d
G_6	136.2 de
G_7	157.4 a
G_8	103.6 i
G_9	116.6 g
G_{10}	65.53 k
G_{11}	110.8 h
G_{12}	124.1 f
G_{13}	77.97 j
G_{14}	136.1 de
G_{15}	80.33 j
CV (%)	1.81
LSD (0.05)	3.609

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

A significance difference was recorded in fifteen sweet potato germplasm in case of a single tuberous root weight (Appendix V). Germplasm 7 (G_7) showed the highest value (157.4 g) for weight of a single tuberous root while germplasm 10 (G_{10}) showed the lowest value (65.53 g) compared to another germplasm (Table 11). G_5 (137.6 g), G_6 (136.2 g) and G_{14} (136.1 g) were found statistically similar. Weight of a single tuberous root greatly depends with the sweet potato varieties (Egbe *et al.*, 2012). This finding is similar to the findings of Awal *et al*. (2007) and Datta *et al*. (2015).

4.5.3 Tuberous root yield/plant

Table 12. Differences of tuberous root yield/plant among fifteen sweet potato germplasm

Treatments	Root yield/plant (g)
G_1	805.6 f
G_2	993.7 b
G_3	1064. a
G_4	847.9 e
G_5	990.6 b
G_6	876.6 d
G_7	1091. a
G_8	725.2 g
G_9	839.3 e
G_{10}	340.8 i
G_{11}	709.0 g
G_{12}	785.9 f
G_{13}	460.1 h
G_{14}	911.8 c
G_{15}	436.6 h
CV (%)	2.11
LSD (0.05)	28.01

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Tuberous root yield/plant showed significant difference among different sweet potato germplasm (Appendix V). The germplasm 7 (G_7) showed the highest value (1091.0 g) for tuberous root yield/plant and germplasm 10 (G_{10}) showed the lowest result (340.8 g) compared to another germplasm (Table 12). G_7 (1091.0 g) is found statistically similar with G_3 (1064.0 g) and showed the highest value. Again, G_{13} (460.1 g) is found statistically similar with G_{15} (436.6 g). Variation in the yield of storage roots per plant occur due to cultivar, location, and time (Caliskan *et al.*, 2007). Shayanowako *et al.* (2014), Ganga *et al*. (2014), Mahmud *et al*. (2014), Mangani *et al*. (2015), Kaspar *et al*. (2013) and Haque *et al*. (2015) also reported the similar finding.

4.5.4 Tuberous root yield/ha

Table 13. Tuberous root yield/ha variations among fifteen sweet potato germplasm

Treatments	Root yield/ha (t/ha)
G_1	44.77 f
G_2	55.20 b
G_3	59.07 a
G_4	47.10 e
G_5	55.03 b
G_6	48.70 d
G_7	60.60 a
G_8	40.27 g
G_9	46.60 e
G_{10}	18.93 i
G_{11}	39.40 g
G_{12}	43.67 f
G_{13}	25.57 h
G_{14}	50.63 c
G_{15}	24.23 h
CV (%)	2.10
LSD (0.05)	1.546

In column having similar letter(s) are statistically similar and those dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

Significant variation is observed among different sweet potato germplasm in case of tuberous root yield/ha (Appendix V). The highest result (60.60 t/ha) was found for tuberous root yield/ha in germplasm 7 (G_7) while the lowest result (18.93 t/ha) was found in germplasm 10 (G_{10}) compared to another germplasm (Table 13). G_7 (60.60 t/ha) is found statistically identical with G_3 (59.07 t/ha) and showed the highest value. Again, G_{13} (25.57 t/ha) is found statistically similar with G_{15} (24.23 t/ha). According to Bacusmo *et al.* (1988), different sweet potato cultivars were experimented at 4 places in the USA and the storage root yield was recorded 9.46 to 25.56 t/ha. Due to genetic variation in the cultivars of sweet potato, there are differences in tuberous root yield/ha (Mamun *et al*., 2016). Mbithe *et al*. (2016), Holtan *et al.* (2003), Gichuki *et al.* (2003), Joseph *et al*. (2005) and Lachman and Hamouz (2005) also agreed with the findings.

4.6 Color of 15 sweet potato germplasm

Color characteristics were marked by visual observation on the basis of the directions of the Union for the protection of Plant Varieties (UPOV).

Table 14. Color of fifteen sweet potato germplasm

Germplasm	Skin color	Flesh color	Flesh color after baking
G_1	Purple red	Yellow	Yellow
G_2	White	Purple	Purple
G_3	Orange	Orange	Orange
G_4	White	White	Gray
G_5	Orange	Orange	Orange
G_6	Medium purple	Orange	Orange
G_7	White	White	Gray
G_8	White	White	Gray
G_9	Purple red	Purple	Purple
G_{10}	Medium purple	Orange	Orange
G_{11}	Purple red	Purple	Purple
G_{12}	White	White	Gray
G_{13}	Purple red	Orange	Orange
G_{14}	Purple red	Purple	Purple
G_{15}	Purple red	Purple	Purple

4.6.1 Color of skin

i. Purple red: G_1, G_9, G_{11}, G_{13}, G_{14} and G_{15} were observed purple red color while G_6 and G10 found to have medium purple color (Plate 17).

ii. White: Five germplasm, namely, G_2, G_4, G_7, G_8 and G_{12} were showed white skin color (Plate 17).

iii. Orange: Two germplasm, viz. G_3 and G_5 were orange in color (Plate 17).

4.6.2 Color of flesh

i. Yellow: G_1 found to have yellow flesh color (Plate 18).

ii. Purple: G_2, G_9, G_{11}, G_{14} and G_{15} were observed purple flesh color (Plate 19, Plate 26, Plate 28, Plate 31 and Plate 32 respectively).

iii. Orange: Five germplasm, viz. G_3, G_5, G_6, G_{10} and G_{13} found to have orange flesh color (Plate 20, Plate 22, Plate 23, Plate 27 and Plate 30 respectively).

iv. White: G_4, G_7, G_8 and G_{12} were white in color (Plate 21, Plate 24, Plate 25 and Plate 29 respectively).

4.6.3 Color of flesh after baking

i. Yellow: G_1 was observed to have yellow flesh color (Plate 33).

ii. Purple: Five germplasm, i.e., G_2, G_9, G_{11}, G_{14} and G_{15} were observed purple colored (Plate 33).

iii. Orange: G_3, G_5, G_6, G_{10} and G_{13} were found orange in color (Plate 33).

iv. Gray: Four germplasm, viz. G_4, G_7, G_8 and G_{12} were gray (Plate 33).

Plate 17. Skin color of fifteen sweet potato germplasm studied

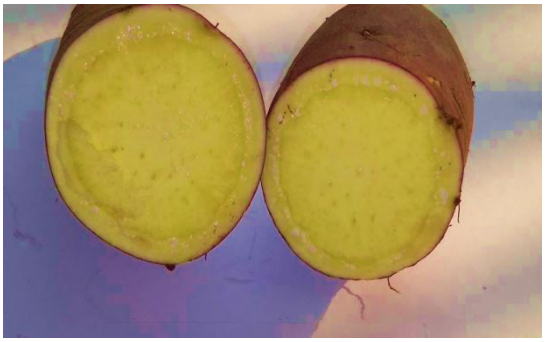


Plate 18. Flesh color of the germplasm 1

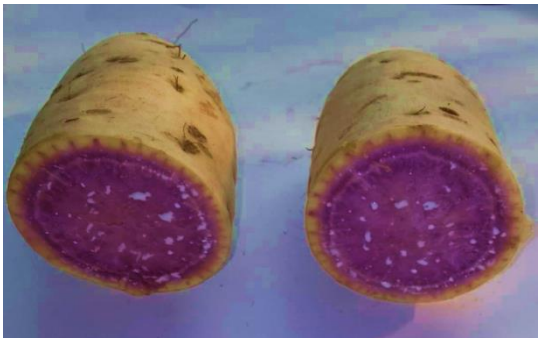


Plate 19. Flesh color of the germplasm 2

Plate 20. Flesh color of the germplasm 3

Plate 21. Flesh color of the germplasm 4

Plate 22. Flesh color of the germplasm 5

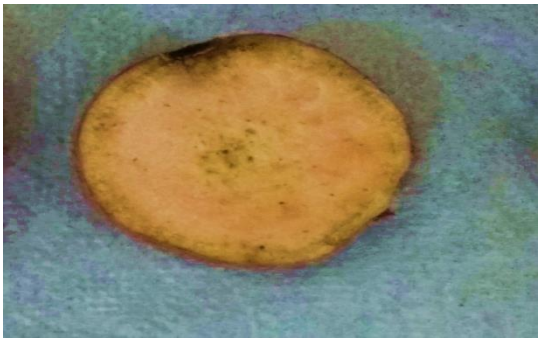


Plate 23. Flesh color of the germplasm 6

Plate 24. Flesh color of the germplasm 7

Plate 25. Flesh color of the germplasm 8

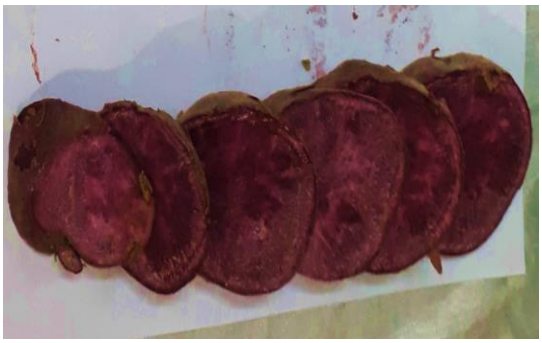


Plate 26. Flesh color of the germplasm 9

Plate 27. Flesh color of the germplasm 10

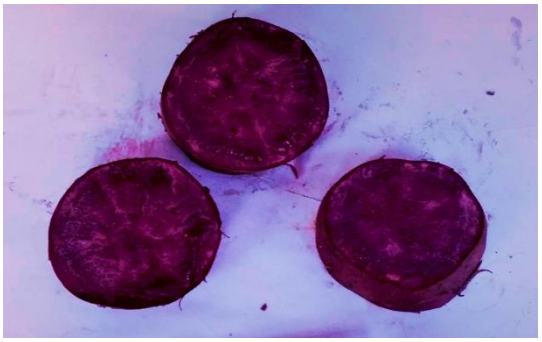


Plate 28. Flesh color of the germplasm 11

Plate 29. Flesh color of the germplasm 12

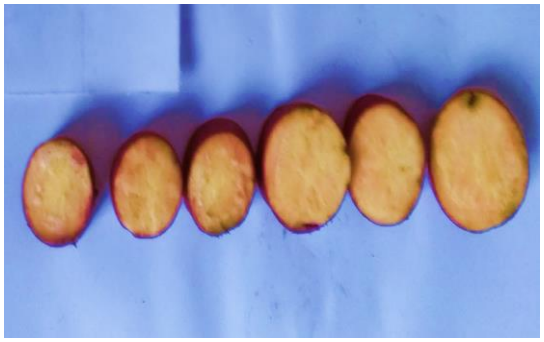


Plate 30. Flesh color of the germplasm 13

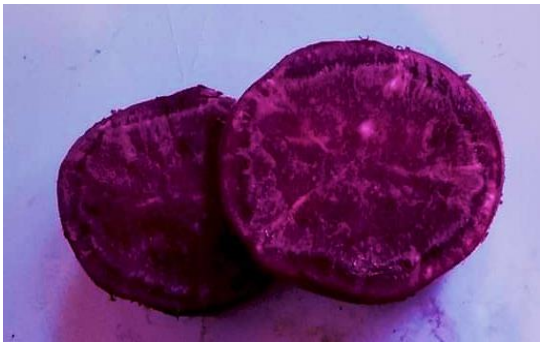


Plate 31. Flesh color of the germplasm 14

Plate 32. Flesh color of the germplasm 15

Plate 33. Flesh color of sweet potato after baking

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

An experiment was conducted to study morpho-physiological traits of fifteen sweet potato germplasm from two sources. The field experiment was accomplished at Horticulture Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The duration of the experiment was from September 2018 to March 2019. Fifteen different sweet potato germplasm were used as single factor. The germplasm were recorded as- germplasm 1, germplasm 2, germplasm 3, germplasm 4, germplasm 5, germplasm 6, germplasm 7, germplasm 8, germplasm 9, germplasm 10, germplasm 11, germplasm 12, germplasm 13, germplasm 14 and germplasm 15. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

By following the instructions of Union for the Protection of Plant Varieties (UPOV), different morphological parameters were classified. Vegetative growth, reproductive growth and yield related different parameters were analyzed statistically. In this chapter, the summary of all the results has been stated, concluded and finally recommended.

Leaf length (6.133 cm), leaf width (9.76 cm), length of internode (4.333 cm), petiole length (12.87 cm) and flower stalk length (8.633 cm) for germplasm 1 were found. Tuberous root length (19.40 cm), tuberous root diameter (44.17 mm), number of tuberous roots/plant (6.067), weight of a single tuberous root (132.8g), tuberous root yield/plant (805.6g), tuberous root yield/ha (44.77 t/ha) were observed. Mature leaf blade color was green and young leaf was light green. Petiole pigmentation was present. Number of leaf lobe was 5. Depth of leaf lobing was very shallow. Pubescence of tip was dense. Root shape was irregular. Deep type of eye depth was found on tubers. Skin color of tuberous root was found purple red and flesh color noted yellow. After baking, the flesh color was observed yellow.

Leaf length (6.500 cm), leaf width (10.60 cm), length of internode (4.433 cm), petiole length (15.40 cm) and flower stalk length (11.20 cm) for germplasm 2 were found. Tuberous root length (19.13 cm), tuberous root diameter (45.02 mm), number of tuberous root/plant (7.000), weight of a single tuberous root (142.0 g), tuberous root yield/plant (993.7 g), tuberous root

yield/ha (55.20 t/ha) were observed. Mature leaf blade color was green and young leaf was light green. Anthocyanin coloration of petiole was found strong. Number of leaf lobe was 5. Depth of leaf lobe was deep. Pubescence of tip was medium. Long elliptic storage root shape was found. Depth of eye on tubers was deep. White type of skin color was recorded in tuberous root. The flesh color was purple. After baking, the flesh color found purple.

Leaf length (6.500 cm), leaf width (10.70 cm), length of internode (4.033 cm), petiole length (12.70 cm) and flower stalk length (7.367 cm) were found for germplasm 3. Tuberous root length (18.47 cm), tuberous root diameter (59.62 mm), number of tuberous root/plant (7.133), weight of a single tuberous root (149.1 g), tuberous root yield/plant (1064.0 g), tuberous root yield/ha (59.07 t/ha) were observed. Young leaf blade color was light green and mature leaf was green. Anthocyanin coloration of petiole was found weak. 5 lobes were found in leaves. Depth of leaf lobe was moderate. Sparse type pubescence of tip was recorded. Long oblong type storage root shape was observed. Depth of eye on tubers was deep. Orange colored skin was found in the tubers. Flesh color was also found orange before and after baking.

Leaf length (5.933 cm), leaf width (10.83 cm), length of internode (3.333 cm), petiole length (11.50 cm) and flower stalk length (6.967cm) were found for germplasm 4. Tuberous root length (14.60 cm), tuberous root diameter (41.26 mm), number of tuberous root/plant (7.300), weight of a single tuberous root (116.2 g), tuberous root yield/plant (847.9 g), tuberous root yield/ha (47.10 t/ha) were observed. Color of mature leaf was green and young leaf light green. Anthocyanin coloration of petiole was absent. Number of leaf lobe was 5. Sparse type tip pubescence was observed. Depth of leaf lobe was shallow. Storage shape was observed long elliptic. Deep eye depth was found on root tubers. The skin color of tubers was recorded as white. The flesh color was observed white too. After baking, the flesh color became gray.

Leaf length (5.967 cm), leaf width (9.900 cm), length of internode (3.467 cm), petiole length (10.33 cm) and flower stalk length (14.07 cm) were observed in germplasm 5. Tuberous root length (18.80 cm), tuberous root diameter (51.15 mm), number of tuberous root/plant (7.200), weight of a single tuberous root (137.6 g), tuberous root yield/plant (990.6 g), tuberous root yield/ha (55.03 t/ha) were observed. Color of mature leaf was green and young leaf was light green. Pigmentation of petiole was weak. 5 lobes were present in leaves. Depth of lobing of leaf was moderate. Pubescence of tip was observed sparse type. Long elliptic root shape was observed. Depth of eye on tubers was recorded as deep. Root skin and flesh each color was found orange. Flesh color remained orange after baking.

Leaf length (6.300 cm), leaf width (10.17 cm), length of internode (3.467 cm), petiole length (11.17 cm) and flower stalk length (7.667 cm) were recorded for germplasm 6. Tuberous root length (15.47 cm), tuberous root diameter (25.26 mm), number of tuberous root/plant (6.433), weight of a single tuberous root (136.2 g), tuberous root yield/plant (876.6 g), tuberous root yield/ha (48.70 t/ha) were recorded. Mature leaf was green but young leaf was purplish brown color. There was no pigmentation on petiole. There was no leaf lobe found in this germplasm. Pubescence of tip was recorded as medium. The shape of root was recorded as long elliptic. Depth of eye on tubers was found deep. The skin color was found medium purple and flesh color was orange. Flesh color also found orange after baking.

Leaf length (7.500 cm), leaf width (10.90 cm), length of internode (3.500 cm), petiole length (9.167 cm) and flower stalk length (6.933 cm) were recorded for germplasm 7. Tuberous root length (17.43 cm), tuberous root diameter (44.37 mm), number of tuberous root/plant (6.933), weight of a single tuberous root (157.4 g), tuberous root yield/plant (1091.0 g), tuberous root yield/ha (60.60 t/ha) were recorded. The color of mature leaf was green and young leaf was light green. Pigmentation of petiole was weak. Number leaf lobe was 5. Depth of leaf lobe was very shallow. Medium type pubescence of tip was observed. Irregular root shape was observed. Depth of eye on tubers was deep. White color was recorded both in skin and flesh of sweet potato tubers. White colored raw flesh turned into gray after baking.

Leaf length (6.467 cm), leaf width (10.93 cm), length of internode (4.100 cm), petiole length (7.067 cm) and flower stalk length (10.17 cm) were observed in germplasm 8. Tuberous root length (16.47 cm), tuberous root diameter (37.09 mm), number of tuberous root/plant (7.000), weight of a single tuberous root (103.6 g), tuberous root yield/plant (725.2 g), tuberous root yield/ha (40.27 t/ha) were recorded. Mature leaf was green and young leaf was light green color. Pigmentation of petiole was weak. Number of leaf lobe was 3. Depth of leaf lobe was moderate. Pubescence of tip was observed sparse. The storage root shape was found irregular. Deep eye depth found on tubers. Both skin and flesh color were found white. The flesh color was observed gray after baking.

Leaf length (10.77 cm), leaf width (11.23 cm), length of internode (6.400 cm), petiole length (7.567 cm) and flower stalk length (11.50 cm) were observed in germplasm 9. Tuberous root length (12.23 cm), tuberous root diameter (31.30 mm), number of tuberous root/plant (7.200), weight of a single tuberous root (116.6 g), tuberous root yield/plant |(839.3 g), tuberous root yield/ha (46.60 t/ha) were found. The color of young leaf was light green and mature leaf was

green. Anthocyanin coloration in petiole was absent. Number of leaf lobe was 5. Depth of leaf lobe was deep. Dense tip pubescence was found. Types of storage root shape were oblong. Depth of eye on tubers was shallow. Purple red skin color and purple colored flesh were observed. Flesh color was found purple after baking.

Leaf length (7.367 cm), leaf width (10.00 cm), length of internode (6.433 cm), petiole length (8.433 cm) and flower stalk length (6.633 cm) were observed in germplasm 10. Tuberous root length (15.37 cm), tuberous root diameter (16.36 mm), number of tuberous root/plant (5.200), weight of a single tuberous root (65.53 g), tuberous root yield/plant (340.8 g), tuberous root yield/ha (18.93 t/ha) were recorded. The color of young leaf was light green and mature leaf was green. Anthocyanin coloration of petiole was absent. There was no leaf lobe found in leaf. Medium type tip pubescence was found. Storage root shape was found long elliptic. Depth of eye on tubers was observed deep. Medium purple skin color and orange flesh color were recorded. The flesh color recorded as orange after baking.

Leaf length (9.833 cm), leaf width (11.53 cm), length of internode (7.200 cm), petiole length (7.267 cm) and flower stalk length (10.63 cm) were recorded for germplasm 11. Tuberous root length (9.533 cm), tuberous root diameter (30.20 mm), number of tuberous root/plant (6.400), weight of a single tuberous root (110.8 g), tuberous root yield/plant (709.0 g), tuberous root yield/ha (39.40 t/ha) were found. Mature leaf was green and young leaf was light green color. Pigmentation of petiole was absent. 5 lobes were found in the leaves. Depth of leaf lobing was deep. Pubescence of tip was found dense. Ovate type storage root shape was found. Shallow eye depth was found on tubers. Purple red skin color and purple colored flesh were observed. Flesh color was observed purple after baking.

Leaf length (7.967 cm), leaf width (9.667 cm), length of internode (6.400 cm), petiole length (9.933 cm) and flower stalk length (6.433 cm) were observed in germplasm 12. Tuberous root length (19.57 cm), tuberous root diameter (40.13 mm), number of tuberous root/plant (6.333), weight of a single tuberous root (124.1 g), tuberous root yield/plant (785.9 g), tuberous root yield/ha (43.67 t/ha) were observed. Young leaf was light green and mature leaf was green in color. Anthocyanin coloration of petiole was very weak. 3 leaf lobes were found. Depth of leaf lobe was moderate. Medium tip pubescence was observed. Irregular root shape was found in this germplasm. Depth of eye on tubers was found deep. Both skin and flesh color were observed white. After baking, the flesh color was found gray.

Leaf length (6.667 cm), leaf width (9.967 cm), length of internode (0.9333 cm), petiole length (7.633 cm) and flower stalk length (6.533 cm) were found in germplasm 13. Tuberous root length (18.33 cm), tuberous root diameter (13.14 mm), number of tuberous root/plant (5.900), weight of a single tuberous root (77.97 g), tuberous root yield/plant (460.1 g), tuberous root yield/ha (25.57 t/ha) were observed. Mature leaf was green and young leaf was light green in color. There was no pigmentation in the petioles. Number of leaf lobe was found 5. Depth of leaf lobe was shallow type. Pubescence of tip was observed dense. Storage root shape was found irregular. Deep eye depth was found on tubers. Purple red skin color and orange flesh color were recorded. The flesh color was observed orange after baking.

Leaf length (11.20 cm), leaf width (11.33 cm), length of internode (2.300 cm), petiole length (7.100 cm) and flower stalk length (6.900 cm) were recorded for germplasm 14. Tuberous root length (15.63 cm), tuberous root diameter (47.19 mm), number of tuberous roots/plant (6.700), weight of a single tuberous root (136.1 g), tuberous root yield/plant (911.8 g), tuberous root yield/ha (50.63 t/ha) were measured. Color of young leaf was light green and mature leaf was green. Pigmentation of petiole was absent. 5 lobes were found in leaves and depth of leaf lobe was found deep. Sparse type pubescence was recorded on tip. Long elliptic storage root shape was observed. Depth of eye on tubers was observed shallow. Purple red skin color was found. Purple colored flesh was observed before and after baking.

Leaf length (10.83 cm), leaf width (11.40 cm), length of internode (2.233 cm), petiole length (8.633 cm) and flower stalk length (6.567 cm) were found in case of germplasm 15. Tuberous root length (11.53 cm), tuberous root diameter (6.410 mm), number of tuberous roots/plant (5.433), weight of a single tuberous root (80.33 g), tuberous root yield/plant (436.6 g), tuberous root yield/ha (24.23 t/ha) were observed. Color of mature leaf was green and immature leaf was light green in color. Anthocyanin coloration of petiole was absent. Number of leaf lobe was 5 and depth of lobing was deep. Pubescence of tip was observed medium. Obovate type storage root shape was observed. Shallow eye depth was found on tubers. The skin color of this germplasm was found purple red. Purple colored raw flesh and purple flesh was observed after baking.

5.2 Conclusion

After observing and analyzing all the data, it can be concluded that, there were significant differences among fifteen sweet potato germplasm studied in terms of different growth and yield related parameters.

The highest value (19.57 cm) of tuberous root length was found in G_{12} while the lowest value (9.533 cm) from G_{11}. G_7 showed the highest value for weight of a single tuberous root (157.4 g), tuberous root yield/plant (1091.0 g) and tuberous root yield/ha (60.60 t/ha). On the other hand, the lowest value for number of tuberous roots/plant (5.200), weight of a single tuberous (65.53 g), tuberous root yield/plant (340.8 g) and tuberous root yield/ha (18.93 t/ha) were observed in G_{10}. Furthermore, from fifteen different sweet potato germplasm, purple red skin color was found in G_1, G_9, G_{11}, G_{13}, G_{14} and G_{15}; white skin color was recorded for G_2, G_4, G_7, G_8 and G_{12}; orange skin color was observed in G_3 and G_5. Again, purple color flesh was found in G_2, G_9, G_{11}, G_{14} and G_{15}; white color flesh of G_4, G_7, G_8 and G_{12}; orange color flesh observed in G_3 and G_5.

5.3 Recommendation

Sweet potato varieties with various colors and high yield can be produced in our country to ensure food security and get extra nutrition in our food. Different colored sweet potato can also be grown and used as the natural source of food color and can extract pigment from them. The study was conducted just for one season. So, further experiment can be done to justify the results of this study.

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APPENDICES

Appendix I. Different physical attributes and chemical formation of soil of the research field

Attributes of soil	**Results**
Agro-ecological Zone	Madhupur Tract
Organic mater	85%
pH	5.8-6.5
Available phosphorous	20 ppm
Exchangeable K	0.42 meq / 100 g soil
Total N	46%

Source: Soil Resource and Development Institute (SRDI), Dhaka

Appendix II. Average precipitation, temperature, relative humidity and sunshine of the study area from September 2018 to March 2019

Month	**Total rainfall (mm)**	**Temperature (^{0}C)**		**Relative humidity (%)**	**Sunshine (hr)**
		Maximum	**Minimum**		
September, 2018	180.3	33.1	24.2	81	5.4
October, 2018	170.2	32.2	22.8	79	5.3
November, 2018	32.4	28.9	20.2	78	5.6
December, 2018	13.4	25.4	13.8	68	5.4
January, 2019	7.1	24.5	12.6	68	5.7
February, 2019	30.2	27.6	16.2	65	5.6
March, 2019	66.4	33.2	21.4	64	5.4

Source: Sher-e-Bangla Agricultural University Weather Station

Appendix III. Analysis of variance of the data on leaf length, leaf width, length of internode, petiole length and flower stalk length of fifteen sweet potato germplasm

Source of variation	Degrees of freedom (df)	Mean Square				
		Leaf length	Leaf width	Internode length	Petiole length	Flower stalk length
Replication	2	0.084	0.600	1.336	5.550	3.942
Treatment	14	11.195*	1.226*	9.478*	19.012*	16.992*
Error	28	0.062	0.129	0.214	0.202	0.039

* : Significant at 0.05 level of probability.

Appendix IV. Analysis of variance of the data on tuber length and tuber diameter of fifteen sweet potato germplasm

Source of variation	Degrees of freedom (df)	Mean Square	
		Tuberous root length	Tuberous root diameter
Replication	2	4.323	12.709
Treatment	14	28.761*	670.213*
Error	28	2.318	11.050

* : Significant at 0.05 level of probability.

Appendix V. Analysis of variance of the data on number of roots/plant, weight of single root, root yield/plant and root yield/ha of fifteen sweet potato germplasm

Source of variation	Degrees of freedom (df)	Mean Square			
		No. of roots/plant	Weight of single root	Root yield/plant	Root yield/ha
Replication	2	0.082	7.470	2117.155	6.368
Treatment	14	1.314*	2233.568*	154727.697*	477.180*
Error	28	0.017	4.656	280.394	0.854

* : Significant at 0.05 level of probability