DIPLOMA THESIS

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BUDAPEST

Comparative Examination of Eggplant (*Solanum melongena* L.) cultivars

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List of Abbreviations:

mg: Milligram

g: Gram

˚C: Celsius degree

FAO: Food and Agriculture Organization of the United Nations

pH: Potential Hydrogen

USDA: United States Department of Agriculture

kcal: Kilocalories

RAE: Retinol activity equivalents

IU: International unit

µg: Micro gram

CGA: Chlorogenic acid

IgE: Immunoglobulin E

kDa: Kilo Dalton

PPOs: Polyphenol oxidase

cm: Centimetre

N: P: K: Nitrogen: Phosphorous: Potassium

CIELAB: Commission Internationale de l´Eclairage

TSS: Total Soluble Solid

ml: Milligram

FRAP: Ferric reducing ability of plasma

nm: Nanometre

L: Litre

UV: Ultra violet

w/v: Weight per volume

CRD: Completely Randomized Design

LSD: Least Significant Difference

ANOVA: Analysis of Variance

1. INTRODUCTION AND OBJECTIVES

Eggplant (*Solanum melongena* L.) also known as Aubergine or Brinjal is a plant species belonging to the family Solanaceae and is one of the most popular vegetables grown in the world. After potato, tomato, pepper and tobacco, eggplant is the fifth most important solanaceous crop in terms of economic importance (Dalia Taher et al., 2017). The edible part of the plant is the purple colored - fruit which is a part of several cuisines around the world.

The plant was well known in both Europe and Asia, since it has been grown for long. Spain and Italy are the top growers of eggplant in the temperate zone and exporting since 1980 (Daunay and Janick, 2007). Cultivation is mainly carried out in greenhouses over open field for protection of plants. Eggplant is cultivated in the agricultural fields as cash crop in the commercial vegetable growing areas and almost every rural household has few brinjal plants in the kitchen garden (Rahman et al., 2016). The skin and seeds of eggplants can be eaten like tomatoes, but are usually consumed cooked like potatoes. The high nutrient content of eggplant makes them appealing food to consume. According to Rahman et al., (2016), eggplant has higher concentration of fiber, folic acid, manganese, thiamine, vitamin B6, magnesium and potassium than the majority of other vegetables, and it contains nearly 92.7 percent water. Because of the valuable nutritional content, each year, there is often an increase in the demand for eggplant. Its well-known flavor and nutritional values might be the reason behind its popularity. According to Sowińska and Krygier (2013), eggplants are a potent treatment for decreasing blood cholesterol and regulating hypertension because they are highly nutritive and low in calories. It is important to provide food with high nutritional values for consumers and the high nutrient content of eggplant makes them appealing food to consume. Therefore, researchers are more interested to produce different types of eggplant variety which contain many nutritional values and also gives good quality yields.

For a processing purposes, the fruit should have high dry matter content and low phenolic content. Bitterness in eggplant is due to the presence of glycoalkaloids which are widely present in plants of Solanaceae family. Typically, foods with a high glycoalkaloids concentration (20mg/100g fresh weight) taste bitter and have an unpleasant flavor. The discoloration in eggplant fruit is attributed to high polyphenol oxidase activity. The cultivars which are suitable for processing are those that are least prone to discoloration (Chen and Li, 1997).

However, production of eggplant at its highest level is often inhibited by threat from biotic and abiotic factors and therefore grafting is the most appealing approach to these problems. It is one of the crops grown in tropical and subtropical climates but they are vulnerable to frost, and temperatures below 16^{0}C limit the growth of young plants (Sowińska et al., 2016). The fruit sets on eggplants will have major issues if there is not enough light (Sun et al., 1990). Inadequate growth temperatures, particularly during blooming and fruit setting can seriously affect the quality and quantity of the fruit. Each stage of developmental requires a specific temperature. Eggplant thrive well and produce fruit best in a temperature range of 21˚C – 29˚C (Chen and Li, 1997).

The various eggplant cultivars produce a variety of fruits in a range of colors, sizes and forms. Egg-shaped eggplant (*Solanum melongena var. esculentum*), long and slender eggplant (*Solanum melongena var. serpentinum*) and dwarf eggplant (*Solanum melongena var. depressum*) are the three botanical varieties or kinds based on the fruit shaped (Maroto, 2002; Rajam and Kumar, 2007).

The aim of the study was to compare the quality characteristics of four eggplant cultivars, 'namely, Blackmoon, Basalto, SV2162EV and Madonna specifically assessing their fruit shape, fruit colour, total sugar content, dry matter content, antioxidant content and polyphenol content for all cultivars.

2. LITERATURE REVIEW

2.1. Origin and Distribution

Eggplant is a member of the Solanaceae family, which has over 3000 species that are evenly spread among 90 genera (Vorontsova and Knapp, 2012). This species is thought to have evolved from its ancestral wild species *Solanum incanum* (Prohens et al., 2013) while *Solanum insanum* is the closest wild relative (Kaushik et al., 2016; Knapp et al., 2013).

Many regions including Laos, Vietnam, Northern Thailand, and Southwest China, where wild plants can still be found, are native to eggplant, including northeast India and Burma (Daunay and Janick, 2007). Its morphology, use, and characteristics were recorded in early agricultural, botanical and medicinal texts from India and Southwest China (Frary et al.,2007).

According to Frary et al., (2007), from Indo-Chinese center of origin and domestication, eggplant made its way to Japan (where the first records are dated from the eighth century A.D) and west probably during the Muslim conquest (the eight to eleventh century). Today, eggplant is grown all over the world having first spread to the entire Mediterranean basin, Central Europe, Africa and later America.

2.2. Eggplant production around the world

The global production of eggplant increased dramatically by over 70 times between 2015 and 2021, from around 513 million tonnes to roughly 586 million tonnes (Figure 1). Despite the fact that the area harvested in the year 2016 was limited, the yield is improving. Asia alone accounted for 94% of global output (Figure 2), with China generating 34 million tonnes, which accounts for 60% of worldwide production, and India producing 12 million tonnes (FAOSTAT, 2021). Europe accounted 1.7 % of global production with Italy as the main producer followed by Spain.

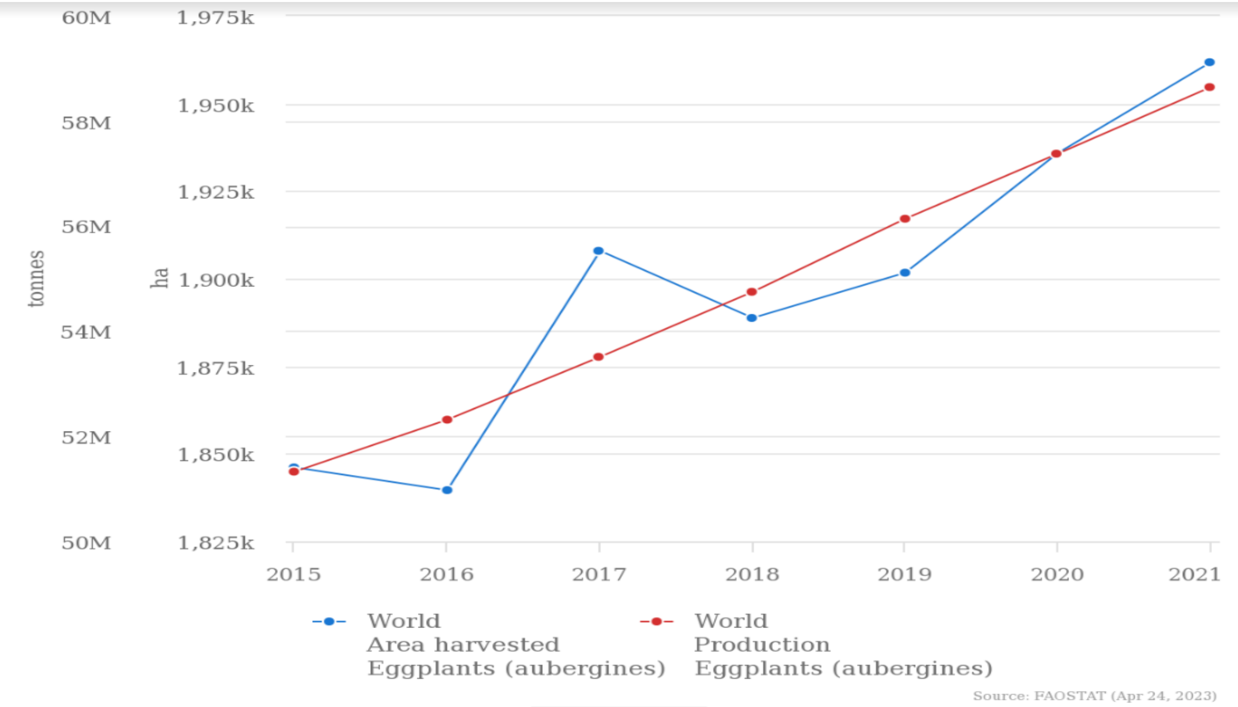

Figure 1: Global production of eggplant (FAOSTAT, 2021)

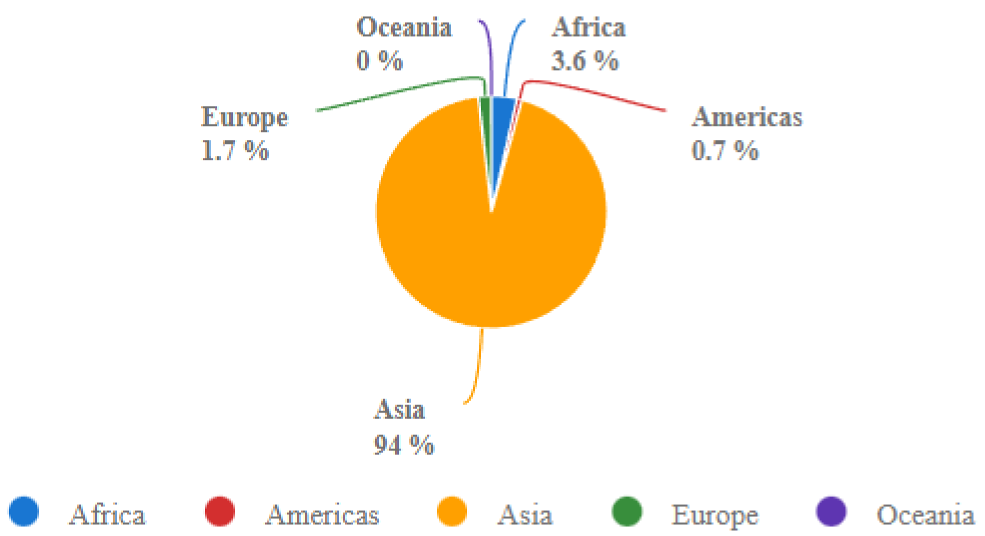

Figure 2: Production of Eggplant by region (FAOSTAT, 2021)

2.3. Plant morphology

Eggplant is a bushy plant that can grow as 120cm (Chen and Li, 1997). Its leaves are enormous, huge, elliptical, somewhat lobed (as shown in Figure 3), and its flowers are large, violet or white colored and solitary or in clusters of two or more. Despite being a perennial plant, it is economically grown as an annual crop. The fruits are berries and are of variable shape (round, intermediate, long and snake-shaped) and size according to different cultivars (as shown in Figure 3).

Root system of eggplant is characterized by tap root (Figure 3), which arises from the upper portion of the primary root, which gives the eggplant root system its distinctive appearance. The main stem is monopodial, has leaves and branches but no blooms. Every major stem node often has two axillary buds. 1-5 andromonoecious cymes make up the inflorescence, while the majority of modern cultivars have solitary hermaphrodite blooms. The standard kind of flower is 5-merous (5 sepals, 5 petals and 5 stamens), however 6,7, and 8-merous flowers are sometimes seen in globous and round fruited types (Frary et al.,2007).

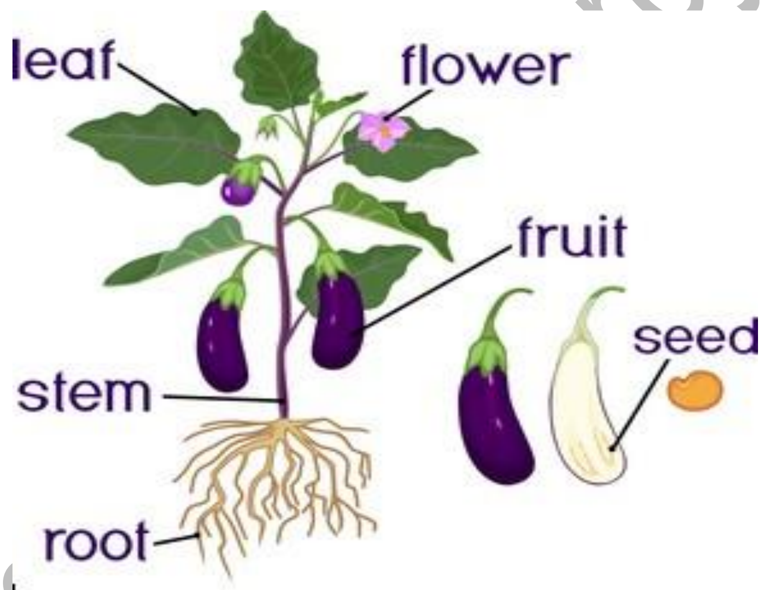

Figure 3: Different parts of Eggplant plants (HTTP 1)

2.4. Ecological requirement

The Eggplant is a photo neutral plant (Chen et al., 2002). They are vulnerable to frost and temperatures below 16^0C limit the growth of young plants (Sowińska et al., 2016). Although eggplants can tolerate mild dryness and substantial rainfall, high temperature and excessive rainfall accelerate the vegetative phase (Chen et al., 2002). The outcome of the commercial production of eggplant is influenced by climatic and soil conditions, as well as blooming and fruit set. Each stage of developmental requires a specific temperature. Eggplant thrive well and produce fruit best in a temperature range of 21^0C – 29^0C (Chen and Li, 1997).

The key factor in the success of vegetable cultivation is irrigation. Physiological and climatic factors, as well as the soil moisture regime, affect the eggplants need for water (Kirnak et al., 2002). Eggplants develop a robust root system in soil rich in organic matter, fertile, deep, well-drained, and has a pH range of 5.5-6.8. Due to the development of root rot, waterlogging and soils with a high clay concentration should be avoided (Chen et al. 2002).

2.5. Bioactive compounds in eggplant

Although secondary plant metabolites are not necessary for basic plant processes; however, both traditional and modern medicine depends on these bioactive chemicals because of their antioxidant qualities which make them a valuable source of medications and pharmaceuticals. Phenolics and Carotenoids are the main phytochemicals that help maintain human health (Singh et al., 2015).

2.5.1. Phenolic compounds

According to Helmja et al., (2007), the best source of phenolic acids among cultivated Solanaceae species is eggplant. The amount of phenolic acids in eggplant varies depending on the season of harvest (Garca-Salas et al., 2014). From spring to summer, the majority of the phenolic compounds dropped, indicating that high temperatures an adverse influence in phenolic content. The wild relative *S.indicum* has more total phenolic compounds than *S.melongena*; however there are no significant differences between the phenolic acid profiles of wild type and those of cultivated eggplant (Raigon et al., 2008). The phenolic acid content of commercial eggplant lines has recently been increased by the use of *S.incanum* in breeding programs (Prohens et al., 2013).

Significant phenolic compounds in eggplant include flavonoids. Different flavonoids profiles can be found in eggplant leaves and fruits. According to Piao et al., (2014) kaempferol accumulates in the leaves while quercetin, apigenin and isorhamnetin are minor compounds in eggplant fruit (Huang et al., 2007).

Depending on the pH, anthocyanins which are water soluble compounds and members of the flavonoids group impart a red, purple or blue colour in plants (leaves, stems, roots, flowers and fruits). Anthocyanins are naturally occurring pigments in eggplant. Dranca and Oroian (2016), reported that anthocyanins are concentrated in the fruit peel and range in concentration from 80-850 mg/kg peel depending on agronomic and genetics parameters, intensity and type of light, temperature, processing and storage. One of the main anthocyanins of eggplant peel is Delphinidin glucosides which is a derivative of delphinidin anthocyanins and impart a dark purple colour (Li and Ding, 2012; García-Salas et al., 2014).

2.5.2. Carotenoids

The majority of the vegetables and fruits that are yellow and orange contain carotenoids. Carotenoids levels are affected by various factors, such as developmental stages of the plant, stress conditions, post-harvest conditions or cooking treatment (Gürbüz et al., 2018). Carotenoids levels are highest during the early stages of eggplant fruit maturity, then decrease during fruit ripening, and post-harvest storage at 0^0C protects carotenoids levels (Zaro et al., 2014 b).

2.6. Nutritional values

Eggplant is an excellent source of iron, calcium, phosphorus, potassium, and vitamin B group. Its fresh weight is 92.7 percent moisture, 1.4 percent protein, 1.3 percent fiber, 0.3 percent fat, 0.3 percent minerals, and the remaining 4 percent is made up of different carbs and vitamins (A and C) (Khan 1979; Lawande and Chavan 1998). Proteins and lipids are present in trace amounts. The main sugars are glucose and fructose, which range in concentration from 0.8% to 1.5%. Sucrose and maltose are present, but in little amounts (Rodriguez et al., 1999). Organic acids are found at relatively low quantities (about 0.1%) and are more abundance in the outer pulp (near the peel) than in the inner flesh (Zaro et al., 2014a). In comparison to other vegetables, eggplant has a low energy density (25 and 19 cal per 100 g of raw and cooked fruit, respectively)

Eggplant is a crop with a high yield that thrives well in hot and humid climates. Therefore, it typically remains affordable while other vegetables crop price increases. As a result, eggplant is a particularly significant supplier of nutrients (

Table **2**) in the diets of low - income consumers, (Hanson et al., 2006). This plant is gaining popularity because of its good source of antioxidants (anthocyanins and phenolic acids), which are beneficial to human health (Gajewski et al., 2009). Eggplant has also anti-mutagenesis, anti-cancer and vision enhancement properties (Philpott et al., 2009). Not only antioxidants, it also has minerals, vitamins, nutritional fibre and protein.

Nutritional studies of eggplant revealed that the nutrient makeup of eggplant varies depending on a number of parameters, including genotype-variety and environmental factors including phenolics content, dry matters, amino acids, and minerals (Ayaz et al., 2015).

Table 2: Nutritional value of eggplant (USDA report 11209)

Nutrient		Unit	Value (per 100g)
Proximates	Water	g	92.3
	Energy	kcal	25.0
	Protein	g	0.98
	Total lipid (fat)	g	0.18
	Carbohydrates, by difference	g	5.88
	Fibre, total dietary	g	3.00
	Sugar, total	g	3.53
Minerals	Calcium, Ca	mg	9.00
	Iron, Fe	mg	0.23
	Magnesium, Mg	mg	14.0
	Phosphorous, P	mg	24.0
	Potassium, K	mg	229.0
	Sodium, Na	mg	2.00
	Zinc, Zn	mg	0.16
Vitamins	Vitamin C	mg	2.20
	Thiamine	mg	0.039
	Riboflavin	mg	0.037
	Niacin	mg	0.0649
	Vitamin B6	mg	0.084
	Folate, DFE	µg	22.0
	Vitamin B12	µg	0.00
	Vitamin A, RAE	µg	1.00
	Vitamin A, IU	IU	23.0
	Vitamin E (α-tocopherol)	mg	0.30
	Vitamin D (D2+D3)	µg	0.00
	Vitamin K (Phylloquinone)	µg	3.50
Lipids	Fatty acids, total saturated	g	0.034
	Fatty acids, total monosaturated	g	0.016
	Fatty acids, total polysaturated	g	0.076
	Cholesterol	mg	0.000

2.7. Health benefits

In addition to its nutritional and agronomic value, eggplant also has a large number of therapeutic advantages. The plant has also been used in traditional medicine to treat many diseases. For example, in some regions of Asia, the vegetative aerial parts of S. *americanum/nigrum* were traditionally used as a purgative, to relieve urination, to improve sex desire, and to heal skin issues (Meyer et al., 2014).

According to numerous studies, eggplant extracts are incredibly effective at treating a range of conditions, including burns, warts, inflammatory infections, gastritis, stomatitis, and arthritis (Im et al., 2016). Fruit skin contains the main phenolic component chlorogenic acid (5-O-caffeoyl-quinic acid; CGA), which has anti-obesity, anti-inflammatory, anti-diabetic, and cardio-protective properties (Plazas et al., 2013). The anthocyanin present in eggplant has a significant role against diabetes, neuronal problems, cardiovascular disorders, and cancer as well (Naeem and Ugur, 2020). According to Basuny et al., (2012) the eggplant peel can be used in pharmaceuticals because of the ability of anthocyanins to lower cholesterol levels.

The fibre in eggplant supports good digestion and helps in the removal of toxic pollutants from the body, lowering the incidence of colon and stomach cancer (Fraikue, 2016). In diabetic rats, the Africa eggplant (*Solanum kumba*) was proven to lower blood glucose levels. These results suggest that a diet rich in eggplant may help to lower the blood sugar levels, blood pressure and levels of oxidative stress in those with type 2 diabetes (Nwanna et al., 2016).

2.8. Allergens in eggplant

Food allergens are proteins that initiate IgE- mediated immunoreactions. In recent years, allergic reaction to eggplant have been reported mainly from the Asian regions (Pramod SN and Venkatesh, 2004; Pramod SN and Venkatesh, 2008; Lee J et al., 2004). The major symptoms experienced in eggplant allergy include skin rashes, angioedema, and wheezing (Harish Babu and Venkatesh, 2009). IgE binding proteins of various molecules masses are particularly abundant in the peel. However, their identification has proved to be difficult due to the very low protein content (1% of fresh weight) and multitude of proteins (Harish Babu and Venkatesh, 2009). After conducting a thorough examination, Harish Babu et al., 2016 discovered the first allergens in eggplant peel and reported that the 64 and 71 kDa allergens in eggplant peel are Polyphenol oxidase (PPOs).

2.9. Variety

The term "eggplant" now refers to three Old World crops of the genus *Solanum*, subgenus *Leptostemonum*: *Solanum melongena* L. (eggplant), *S. aethiopicum* L. (scarlet eggplant), and *S. macrocarpon* L. (Gboma eggplant), *Solanum aethiopicum*. The *S. melongena* complex has a variety of morphological intermediates, ranging from small-fruited spiny plants to large-fruited non-spiny plants. The species arrived in Europe in the eleventh century, when Arabs pioneered eggplant cultivation in the Iberian Peninsula (Daunay, Janick 2007). Although eggplant is thought to be an Asian vegetable, most of its wild relatives are from Africa (Weese and Bohs, 2010). Wild eggplants grow tiny, bitter, multi-seeded fruits that are virtually invariably inedible, and the plant is quite spiky.

The eggplant variety is quite diverse. Eggplant comes in a variety of shapes and sizes, ranging from oval and round to oblong or pear-shaped. Many parameters can be considered to differentiate the variety. The shape and colour depend on the variety. As well as, the size of the plant, yield and time of ripening are all different between the eggplant cultivars.

Scarlet eggplant is a shrub-like plant with glabrous foliage that is primarily cultivated in Africa. One of the common species use in horticulture area is *Solanum integrifolium* L. from Aculeatum group. Gilo, on the other hand, is the most significant in *the S aethiopicum* L. group complex (Gürbüz et al., 2018). *S. aethiopicum* L. produces big edible fruit, whereas S. macrocarpon L. makes small non-edible fruit. It's only cultivated for its big, glabrous, nutritious foliage.

Martin and Rhodes (1979) used the classification proposed by Choudhury (1976), which separated the eggplant cultivars into three botanical varieties on the basis of the shape of the fruit:

1. *S. melongena* var. *esculentum* Dunal (Nees) – round, oval or egged-shaped fruits,
2. *S. melongena* var. *serpentinum* L. – long slender fruits,
3. *S. melongena* var. *depressum* – small, miniature fruits, dwarf, and early types.

Twenty-Eight (28) traditional Spanish eggplant cultivars were grouped into four groups: "round", "semi-long", "long", and "listada de Grandia" in a study by Prohens et al., 2005. The Globe eggplant is the most popular kind of eggplant grown in US; it is the large variety with glossy, deep-purple skin and spongy fruit. Other commonly cultivated varieties include white eggplants, Thai eggplants, Black Beauties, Ichiban, Rosa Bianca, and Little Fingers.

According to Sekara et al., 2007 there are thirty three (33) Sanskrit names for eggplant appear in ancient Indian literature, although Hirst, 2014 states that there are currently between 15-20 common varieties (Figure 4).

a) Western eggplants, also known as dark purple eggplants, are common in America and Europe but were just recently introduced to Asia. Although less vigorous, plants are extremely productive. Fruits are typically huge and come in two basic shapes: oval and elongated (200-600 g) (Sekara et al., 2007).

b) Italian, baby, or finger eggplants are little, slender, or spherical; they are typically sweeter and more tender than bigger varieties. They also have thinner skins and fewer seeds than larger varieties (Sekara et al., 2007).

c) Oriental eggplants, which are indigenous to tropical Asia, are highly well-liked in the Philippines, Japan, China, India, and Thailand. Plants are active and emerge early. Fruits may be spherical or thin in shape, purple, violet green, with or without stripes. Oriental eggplants are divided into the following groups (Sekara et al., 2007):

- Chinese eggplants: they often tall, violet, purple, and bluish-white, with exceptionally few seeds. They are also sensitive and tasty, and the plants are vigorous and prolific.

- Japanese eggplants: they are longer or oblong, harder and heavier, sweet-tasting, violet to inky-purple.

- Thai eggplants: they have a thick skin, are dense, mildly delicious, and have numerous seeds. Fruit-bearing plants are exceedingly appealing and are frequently planted as ornamentals.

- Indian eggplants: they are small, oval, violet to purple, sometimes with stripes or medium-sized.

San José et al. (2013) investigated the chemical composition of seven occidental eggplant cultivars from various origins; they analyzed fruit of various shapes (long, oval, semi long) and colors (dark purple, purple, purple stripes, and white) with the goal of identifying eggplant cultivars for breeding to produce fruits with improved nutritional quality. Raigón et al. (2008), conducted a study to obtain information among different varieties of eggplant about compounds with nutritional interest including phenolics.

The number of eggplant varieties has grown dramatically as a consequence of extensive selection and breeding over several hundred years. Cultivars with purple, oval fruits are widely grown in Europe and the Americas, although the fruit colors, forms, and sizes vary greatly in Southeast Asia (Doganlar et al. 2002). Sekara (2010) recommended the 'Epic' F1 hybrid for field production in temperate climate zones because it achieved a mean marketable yield of 40 t/ha: early production (first four harvests) accounted for 13.5% of total yield and was represented by first- and second-class fruits (86% and 10%, respectively).

Figure 4: Different eggplant varieties (Fraikue, F. B 2016, Hirst, 2014, Se̱kara et al, 2007)

3. MATERIALS AND METHODS

3.1. Place and Timing of the Experiment

The experiment was conducted at the Experimental Plant and Educational Institution (Vegetable sector) of the Hungarian University of Agriculture and Life Sciences in Hungary, Soroksar from March to October, 2022 (Figure 5). The soil for the experiment was characterized by sandy soil.

Figure 5: Eggplant cultivation in the Experimental Farm

3.2. Plant materials and management practices

The cultivar used for the experiment were Madonna, Basalto, Blackmoon and SV2162EV. Each cultivar was replicated four times in which ten plants were planted for each replicate. Seeds of eggplant were sown on 17th March 2022 and potting was done on 27th April (Figure 6). The seed pots were kept in a polyhouse. On 27th May, tilling was done before the seedlings were transplanted onto the main field.

Figure 6: Seedling preparation

3.3. Cultivars and description of the eggplant fruits used in the study

Madonna: Madonna is a Monsanto Seed Company cultivar and is a popular variety with uniform, elongated drop-shaped fruits. The plants have foliage, strong growth, and produce deep purple fruits weighing an average of 300g (HTTP 2). It is ideal for growers looking for a vigorous and open plant habit with a high yield potential for indoor and outdoor cultivation (Kappel, Noémi, and Maryam Mozafarian. 2022)

Blackmoon: Blackmoon is a F1 hybrid which has a purple colour fruit grown on large bush plant. The fruits are oval or round and average 5 inches by 6 inches, in size (HTTP 3). They are excellent for canning and cooking. They are susceptible to root knot nematode (Molinari ,2016). The surface is very shiny, the flesh is green green. The plants are slightly sprawling, reaching a height of 65-70 cm (HTTP 2).

Basalto: Basalto is an early variety with oval, round fruits. The fruits are bright, deep purple in color. The plant has a very vigorous growth (HTTP 2).

SV2162EV: SV2162EV is a relatively new, early variety with oval, dark purple fruits. The plant has good leaf coverage, which helps both outdoor and indoor cultivation (HTTP 2).

3.4. Cultivation during the experiment

Eight weeks after sowing, the seedlings were ready for transplanting to open field. The seedlings were transplanted with a spacing of 80 × 25 cm (Figure 7). A drip irrigation system was used. Nutrient solution of N:P: K at a concentration of 14:11:25 were mixed into the irrigation water and applied twice in a week. Weed monitoring was performed using tractor during the cultivation period (Figure 8). Eggplant are also prone to falling over when overloaded with fruits, so supporting them will prevent from potential injury and fruit loss and so cord support system was used. A pest Brown marmorated stink bug (*Halyomorpha halys*) was discovered in the field (Figure 9).

Figure 7: Transplanting of eggplant

Figure 8: Weeding

Figure 9: Brown marmorated stink bug (*Halyomorpha halys*)

3.5. Measurements

3.5.1 Length (cm) and width (cm) of the fruit

The length (cm) and width (cm) of the four cultivars were measured by using Ruler scale. Each fruit of the four replicates of the cultivars were measured. The length was measured from the stalk of the fruit (as shown in Figure 10).

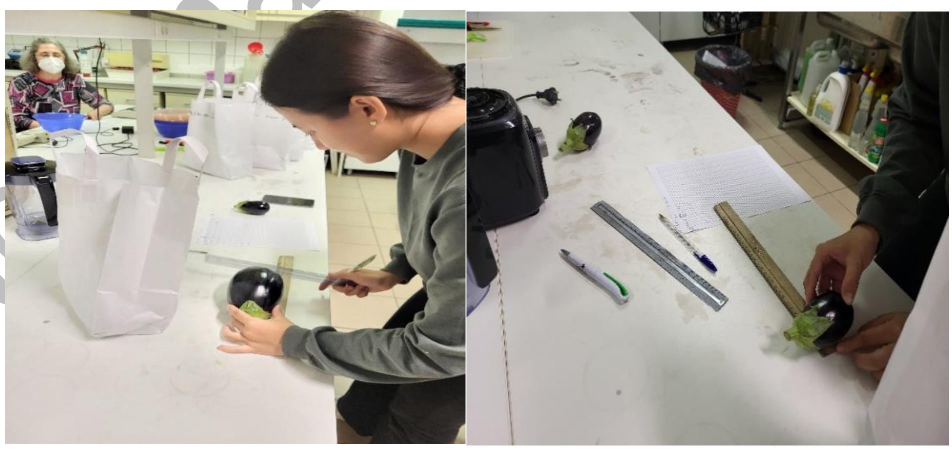

Figure 10: Measurement of length and width of the fruit (cm)

3.5.2 Fruit colour measurement

The colour of the eggplant was determined by using a colorimeter Minolta Chroma meter CR-400 (Minolta Corporation, Ltd., Osaka, Japan (Figure 11). Fruit chromaticity was expressed in L*, a*, b* colour space coordinates with a Commission Internationale de l'Eclairage (CIELAB). L* (lightness), a* (red/green chromatic coordinates), and b* (yellow/blue chromatic coordinates) measurements were taken to assess fruit colour.

Figure 11: Colour measurement

3.5.3 Total Soluble Solid (Brix°)

The peeled fruit sample was sliced into pieces and blended using a blender. The fruit skin was refrigerated for later analysis of antioxidant. The blended sample was placed in sterile cutted gauze laps, and the sugar content (TSS%) was measured using Atago pocket Refractometer PAL -1 Brix 0-53% Digital hand from the fruit juice (Figure 12). Each sample's juice was cleansed with distilled water before being placed in the refractometer. Each sample measured three times for reach repetition.

Figure 12: Brix measurement

3.5.5. Dry matter content (%)

After storing the pulverised sample for 3-4 weeks, the dried sample was placed in a petri dish and the dry matter content was measured using an analytical balance.

3.5.6 Determination of antioxidant and polyphenol content

3.5.6.1 Preparation of the extract

The fruit peel that had been stored in the refrigerator was taken and crushed with a grinder. Approximately 2g of each of the pulverized sample was taken in a plastic test tube (Figure 13). The sample was treated with 6ml of extracting solution, which comprised of 60ml of distilled water, 39.9ml of methanol and 0.1ml of concentrated HCl, and then filtered using Whatman's filter paper.

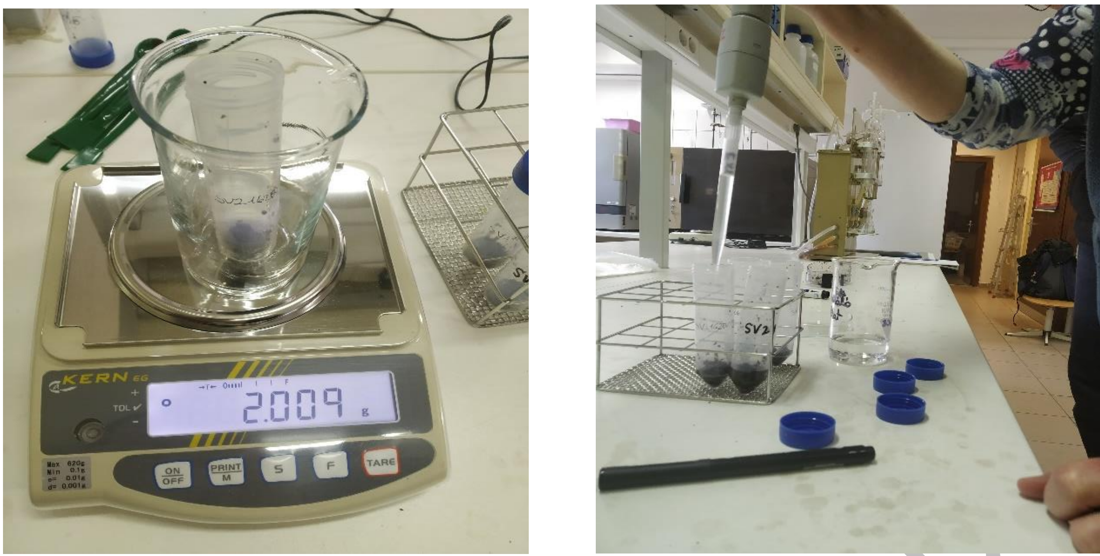

Figure 13: Extract preparation

3.5.6.2 Preparation of FRAP reagent

The FRAP reagent is composed of 25ml of pH 3.6 acetate buffer, 2.5ml of $FeCl_3$ solution, and 2.5ml of TPTZ (Triazine) solution. The FRAP reagent was kept in a glass wrapped with aluminum foil.

3.5.6.3 Determination of antioxidant content

The antioxidant was determined by using FRAP method. The filtered sample was placed in a cuvette with the FRAP reagent, distilled water and treated for five minutes. After five minutes, the color changes to blue, and the absorbance of the sample was measured at 593nm using spectrophotometer (Figure 14).

Figure 14: Sample reading

3.5.6.4 Determination of polyphenol

The polyphenol content was determined by Folin-Ciocalteu method. The chemistry of this reaction implies the transfer of electrons from phenolic compounds to phosphomolybdicphosphotungstic complexes in alkaline conditions and produces reduced complexes in blue color that are measured spectrophotometrically at a wavelength of 765 nm (Singleton et al., 1999; Waterhouse, 2002; Ainsworth and Gillepsie, 2007).

Aliquots of sample extract were mixed with 125 L of the Folin-Ciocalteu reagent and 500 L of distilled water. The mixture was shaken and left to incubate at room temperature for 6 minutes. Then 1250 L Sodium carbonate (Na_2CO_3) 20% (w/v) and an aliquot of distilled water to form a total volume of 3ml were added. The mixture was incubated for 2 hours at room temperature in the dark. The absorbance was read at 760 nm using UV spectrophotometer versus prepared blank.

3.6 STATISCAL ANALYSIS

The Experiment was arranged in a completely randomized design (CRD) with four replications and ten plants in each replication. Data were statistically analysed using Statistic 8 software (Tallahassee, FL, USA). Data were subjected to the one-way analysis of variance (ANOVA) and means were separated using the least significant difference (LSD) test at $p < 0.05$.

4. RESULTS

4.1 Length and width of the fruit

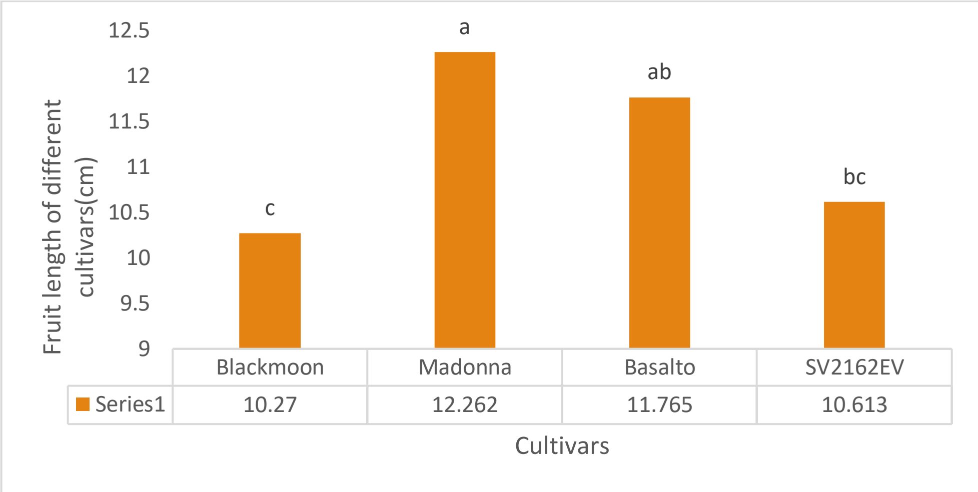

Figure 15: Length of fruit (cm)

Different letters indicating significant difference according to Tukey's test ($p<0.05$)

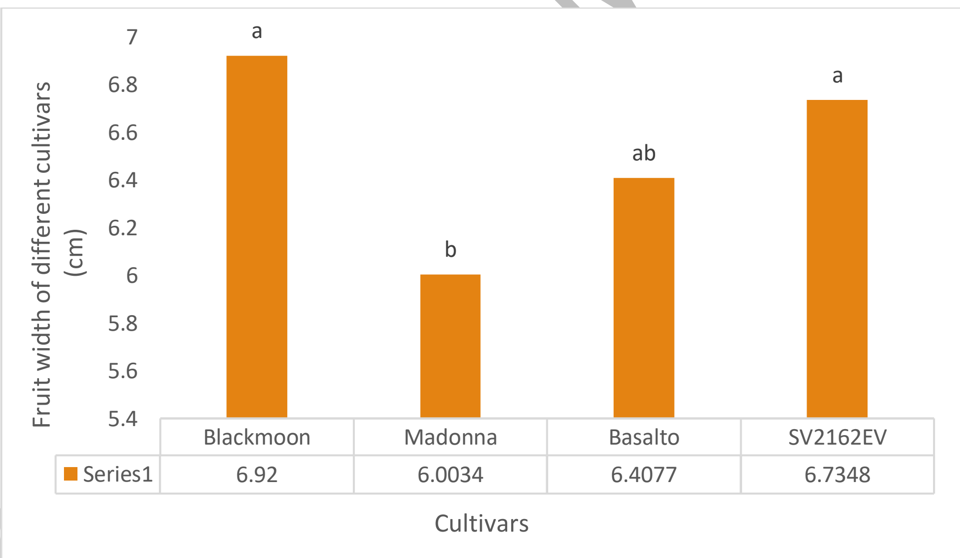

Figure 16: Width of fruit (cm)

Different letters indicating significant difference according to Tukey's test ($p<0.05$)

Figure 15 shows the fruit length measure in centimetre (cm) of different cultivars of eggplant. The Madonna cultivars recorded the highest length of a mean value of 12.26 cm followed by Basalto cultivars recording a mean value of 11.76 cm. SV2162EV cultivars recorded a mean value of 10.613 cm, with Blackmoon cultivars recorded the lowest fruit length of a mean value of 10.27 cm. Figure 16 there was a sharp reversal values among the eggplant cultivars in regards to the fruit width. Blackmoon cultivars recorded the highest width mean value of 6.92 cm followed by SV2162EV cultivars recorded a width mean value of 6.73 cm. Basalto and Madonna cultivars recorded width mean values of 6.4 cm and 6 cm respectively.

4.2 Total Soluble Solid (Brix°)

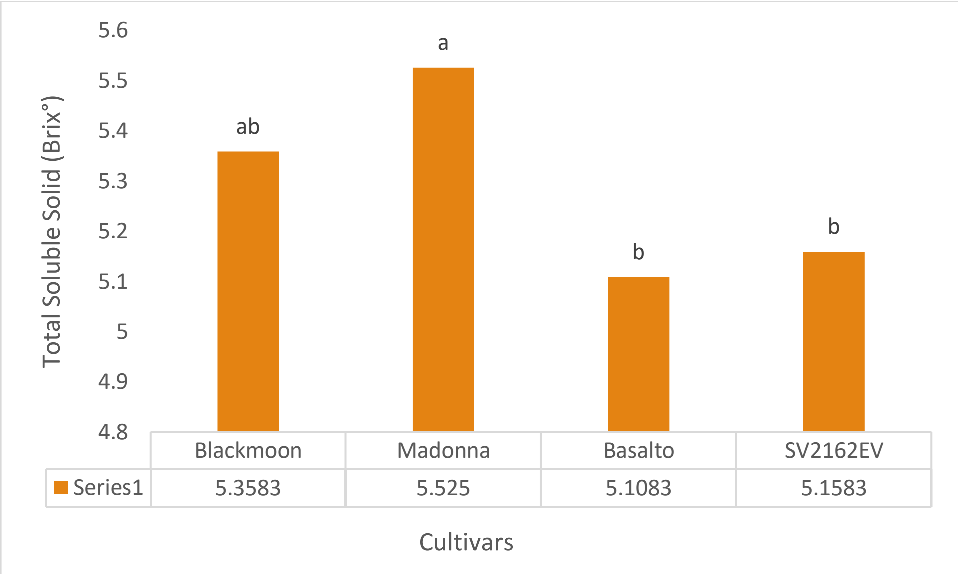

Figure 17: Total Soluble Solid content (Brix°)

Different letters indicating significant difference according to Tukey's test ($p<0.05$)

Figure 17 shows the sugar content (Brix) of different cultivars of eggplant. The highest Brix° value was in Madonna with 5.52 Brix° and the lowest in Basalto and SV2162EV with 5.10 Brix° and 5.15 Brix° respectively. As shown in the figure, Madonna and Blackmoon has the highest Brix value as compared to Basalto and SV2162EV and they had significant difference.

4.3 Dry matter

Figure 18 illustrated the dry matter content of eggplant cultivars Blackmoon, Madonna, Basalto and SV2162EV. The mean values of dry matter content of eggplant cultivars range from 7 – 8.5 %. From the figure, it can be seen that the dry matter content of eggplant cultivars is non-significant.

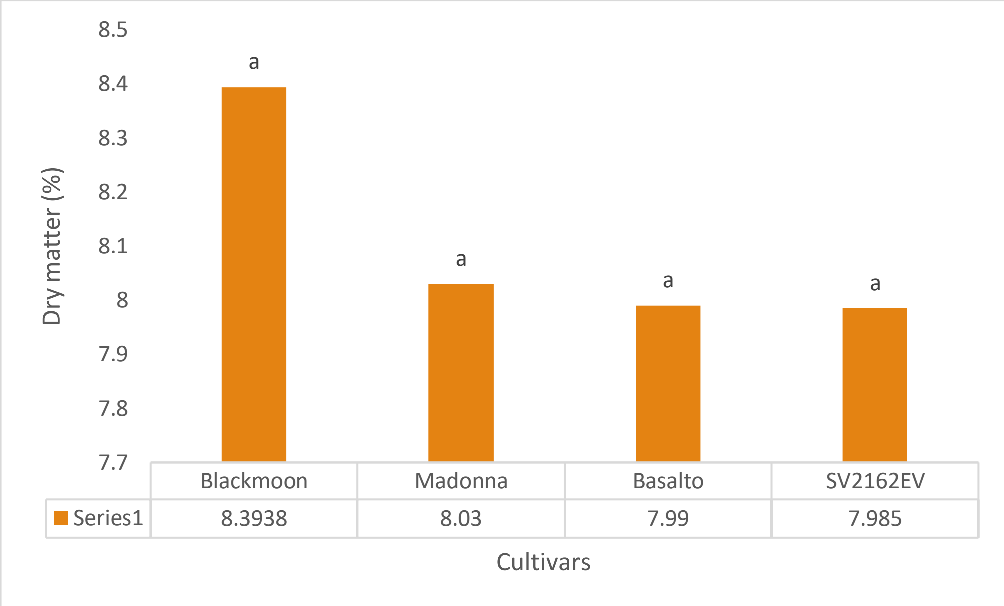

Figure 18: Dry matter (%)

Different letters indicating significant difference according to Tukey's test (p<0.05)

4.4 Fruit skin colour

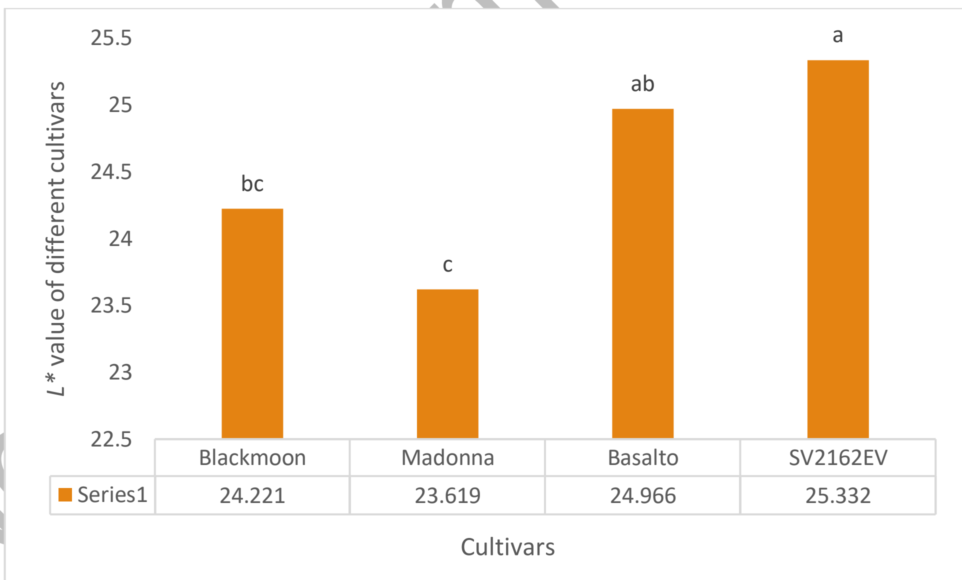

Figure 19: Mean of *L** value

Different letters indicating significant difference according to Tukey's test (p<0.05)

The significant difference in L* value was found in all the cultivars as shown in the figure. The *L* value* was range between 22.5 – 25.5. The cultivar with the greatest L* value is SV2162EV, whereas the cultivar with the lowest is Madonna.

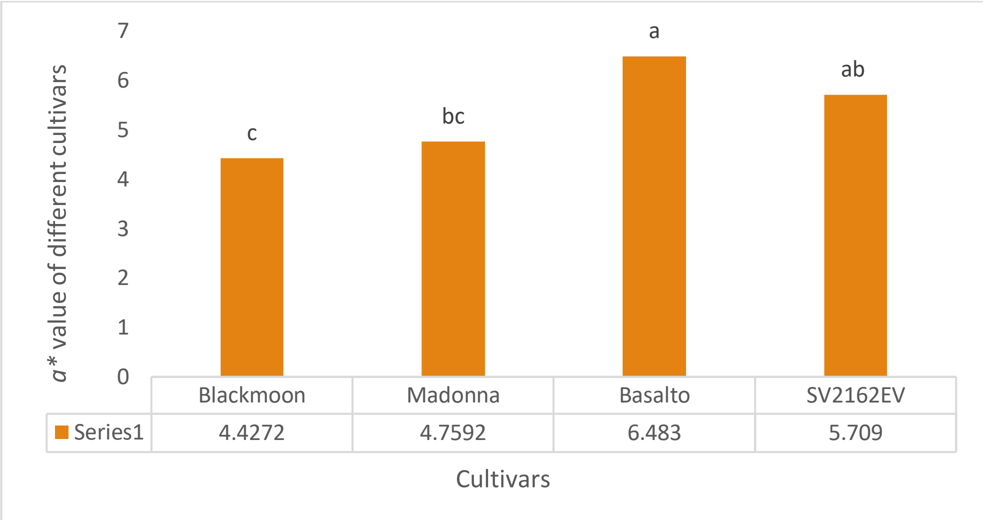

Figure 20: Mean of *a** value

Different letters indicating significant difference according to Tukey's test ($p<0.05$)

Statistical analysis showed a significant difference effect on *a** value of fruit skin colour as shown in the Figure 20. Blackmoon and Madonna have nearly identical values, however Basalto has the highest a* value of 6.4, followed by SV2162EV of 5.7.

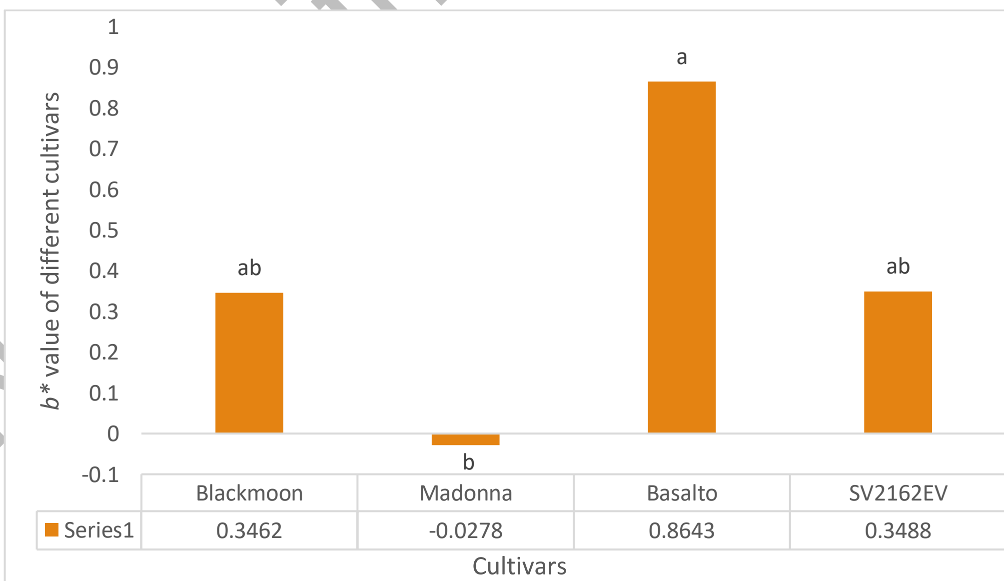

Figure 21: Mean of *b** value

Different letters indicating significant difference according to Tukey's test ($p<0.05$)

Although there is a difference with other cultivars, there was no significant difference in b^* value between Blackmoon and SV2162EV. Basalto had the maximum b^* value led by Blackmoon and SV2162EV, while Madonna appears to have the lowest with negative values.

4.5 Antioxidant content

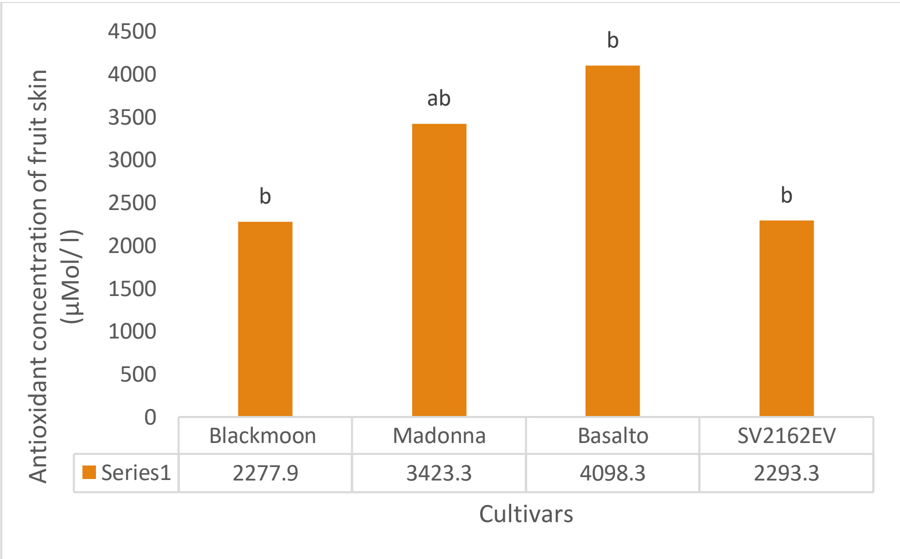

Figure 22: Antioxidant content of fruit skin (µMol/ l)

Different letters indicating significant difference according to Tukey's test (p<0.05)

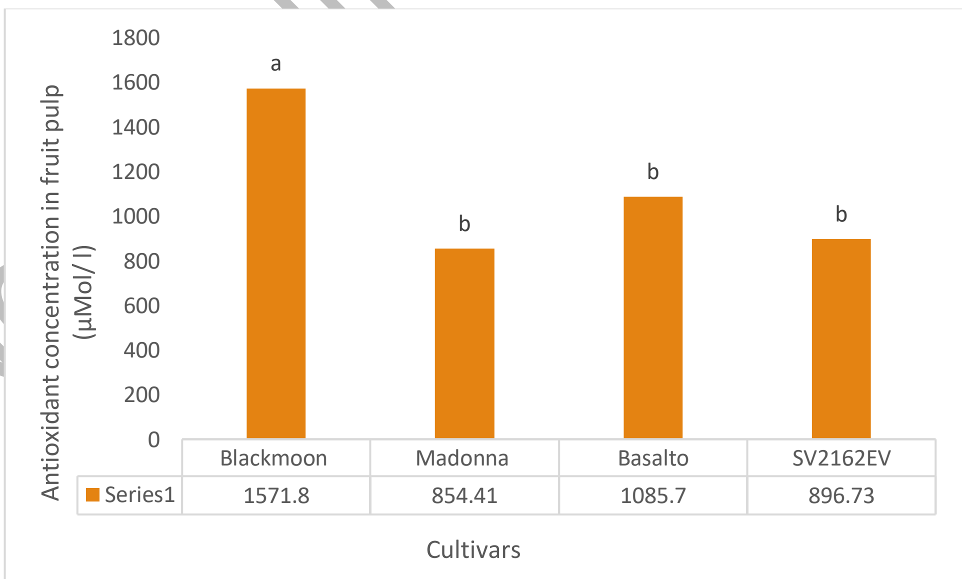

Figure 23: Antioxidant content of fruit pulp (µMol/ l)

Different letters indicating significant difference according to Tukey's test (p<0.05)

With statistical analysis, the antioxidant content in the fruit skin ranges from 2000 – 4500 µMol/ l. In the Figure 22, Madonna recorded the highest antioxidant in fruit skin with a value of 3423.3 µMol/ l. In regards of fruit pulp, Blackmoon showed the highest antioxidant (1571.8 µMol/ l) while the other cultivars showed the least antioxidant (Figure 23). There is no significant difference among the cultivars.

4.6 Polyphenol content

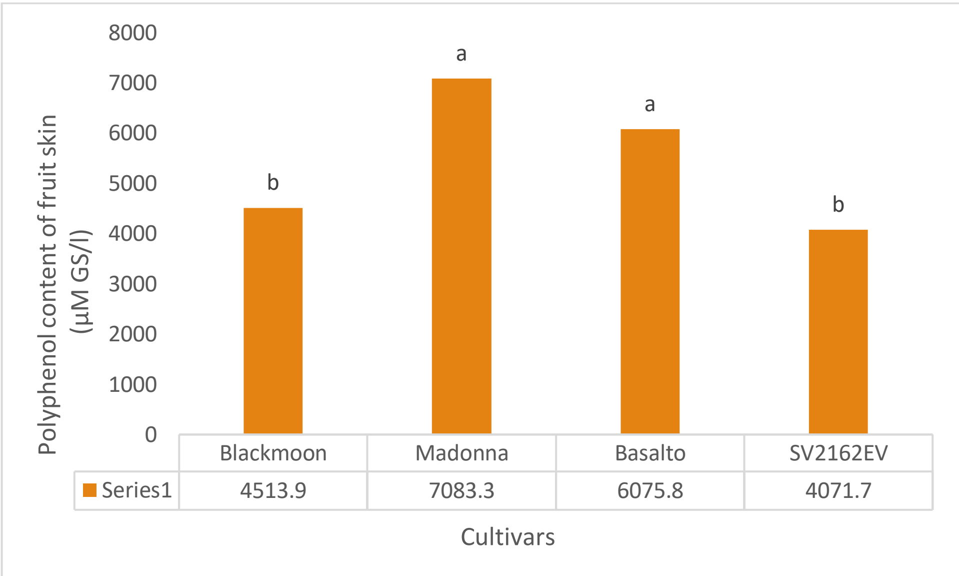

Figure 24: Polyphenol content of fruit skin (µM GS/l)

Different letters indicating significant difference according to Tukey's test ($p<0.05$)

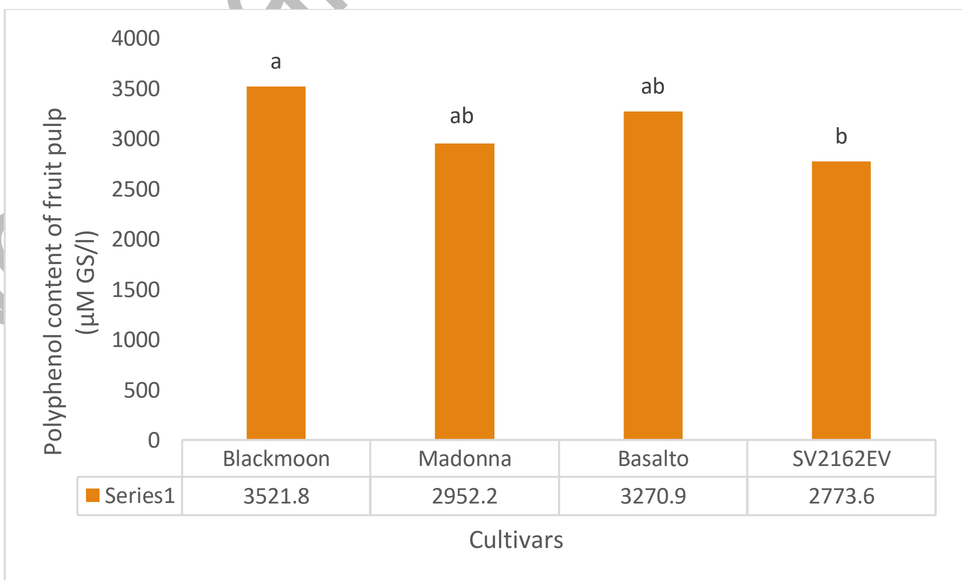

Figure 25: Polyphenol content of fruit pulp (µM GS/l)

Different letters indicating significant difference according to Tukey's test ($p<0.05$)

The result of a mean values of eggplant cultivars (skin and pulp) were shown in Figure 24 and Figure 25. The highest mean values of polyphenol content (skin) was observed in Madonna cultivars with a value of 7083.3 mg and the lowest value was in SV2162EV with a value of 4071.7 µM GS/l. Regarding the pulp, Blackmoon recorded the highest mean value of 3521.8 mg followed by Basalto, Madonna and the lowest mean value was in SV2162EV with a value of 2773.6 µM GS/l. The polyphenol content in the fruit pulp of Madonna and Basalto showed no significant difference. Blackmoon had the lowest polyphenol concentration in the skin whereas Madonna had the highest however in the fruit pulp Blackmoon has the most content while Madonna has the least.

5. CONCLUSION

5.1. Length and Width of the fruit

The findings of the study revealed a significant variation in fruit shape, width and length among all the cultivars. All of the fruits produced in this trial varied in shape from round to oblong. Madonna had the longest berry form (Figure 15) whilst Blackmoon had the greatest fruit width (Figure 16). Sifola et al (1995) reported that the round shaped fruit irrigated with saline water led in a decrease in fruit length. According to Zawma et al., (2020), increase in fruit size can be attributed to fruit growth; which is largely determined by rapid cell enlargement, cell division and reduced intercellular space. Also, Zawma et al (2020) stated that an increased in fruit size can also be attributed by a rise in photosynthetic processes and the production of further carbohydrates by significant varieties of plants and leaves. Fruit shape in eggplant is genetically determined and extremely inheritable (Gisbert et al., 2011b; Muoz-Falcón et al., 2008). According to Muoz-Falcón et al. (2008), the surrounding environment had no effect on fruit form.

Overall, the fruit shape index (length/width ratio) of the cultivars, showed Madonna as the best with a 2.04 cm (ratio length/width) followed by Basalto cultivars with 1.83cm (ratio length/width). This results obtained corresponds to the experiment of Muñoz-Falcón et al., (2008) which tested local varieties and their hybrids for the improvement of eggplant production in the open field and greenhouse cultivation, and grouped the cultivars fruit shape into 3 categories which is long (with a ratio length/width greater than 4), round to obovate (ratio length/width in the range 0.8-1.5) or semi-long (ratio length/width in the range 1.5-3). Madonna and Basalto were regarded as the best because they exceeded the range which was stipulated by Muñoz-Falcón et al., (2008) in his experiment.

5.2. Total Soluble Solid (Brix°)

The experiment result showed significant difference in Brix value between Madonna and other cultivars all of which are non-grafted plants. According to Arvanitoyannis et al., (2005) non-grafted plants showed a higher rating of fruit taste. The cultivars were cultivated from March to October when the summer temperatures were high, which is in agreement with Toshiyuki and Yusuke (2008) statement that temperature changes alter the chemical makeup, such as sugar concentration of harvested goods. When the temperature rises, the plant loses water, causing changes in its chemical makeup. According to Masayuki Oda et al. (1996), water stress on plants often increases soluble solids and sugar content of fruits but decreases growth and fruit output.

The total sugar content of eggplant fruit cultivars ranges from 4.8 – 5.6 Brix°. Madonna recorded highest sugar content among all the cultivars with a value of 5.5 Brix° followed by Blackmoon with a value of 5.35 Brix°, Basalto and SV2162EV recorded the lowest which are nearly same Brix value of 5.1. Kaur et al. (2001) examined the TSS of eggplant fruits and reported a greater variance in TSS concentration (7.17 to 27.86 mg/100 g) than the current research.

5.3. Dry matter content

The dry matter content of most vegetables is between -4% and 10%, which is relatively low. In 2015, Voytsekhovskiy et al. reported that the dry matter content of eggplant ranged from 6 to 13%. According to the graph, the dry matter content values for the four cultivars; Black Moon, Madonna, Basalto, and SV2162EV were statistically insignificant and fell in the range of 7.7 and 8.4% as seen in Figure 18. This result correlates with the range (6 to 13%) of dry matter content of eggplant reported by Voytsekhovskiy et al., (2015); Shabetya, Zinchenko, 2014; and Shabetya, Mozgovska, 2017).

In addition, Zhuchenko (2001) reported that, the dry matter content of eggplants is affected by the climatic conditions of cultivation. Thus, with the results observed in Figure 18 it can be assumed that the cultivars were grown within the ideal growing season between March and October as reported by Caruso et al., (2017).

5.4. Fruit colour

Eggplant cultivars display different colours from white, green, to dark violet at full maturity, due to a combination of different patterns of anthocyanin and chlorophyll presence or absence. Peel colour is the most important fruit quality attribute because pigments that bestow colour are connected with not only visual appeal but also nutritional, health, and flavor benefits (Brand et al., 2014).

The L*, a*, b* colour parameters, measured on the eggplant fruits ranged from 23.619–25.332(L*), 4.4272 to 6.483 (a*), and −0.0278 to 0.8643 (b*) for the studied cultivars. Focusing on the colour parameter *L** in Figure 19, considerable variations were discovered between the cultivars, with SV2162EV having the lightest colour (1.713-fold higher value) and Madonna possessing the darkest hue. In Figure 20 it was noted that significant differences were also detected for the colour parameter *a** across all the cultivars, with Basalto exhibiting a reddish colour (2.0558 - fold greater value) and Black moon having a greener colour tone. Additionally, the *b** colour parameter data (Figure 21) showed Basalto cultivar exhibiting a lot more yellowish colour (0.8365 - fold higher value), whereas Madonna had a blueish colour. Blackmoon and SV2162EV did not significantly differ in the *b** colour parameter.

The fruit colour results obtained from all the colour parameters for Basalto cultivars could be as a result of growing conditions such as inadequate light, temperatures or diseases are likely to contribute to fruit colour defaults. In addition, Daunay et al. (2004) reported that when fruit turns physiologically ripe, anthocyanins and chlorophylls fade and give rise to yellow pigments.

5.5. Antioxidant content

The antioxidant content of the fruit skin and pulp was found to be non-significant. However, Madonna and Blackmoon had the highest antioxidant content in fruit skin and pulp with a mean value of 3423.3 µMol/ l and 1571.8 µMol/l respectively. This shows that the antioxidant level is higher in skin as compared to pulp. This is in accordance with the findings of Morales-Soto et al., 2014, who discovered that the antioxidant capacity of the edible component, which consists solely of the pulp, is significantly lower than that of the skin and/or seeds. There is a considerable association between high antioxidant activity and phenolic content (Huang et al. (2004)). Their findings correspond with the current study, that the polyphenol concentration of the fruit skin and pulp was highest in Madonna and Blackmoon.

5.6. Polyphenol content

According to Mukhtar et al., (2021), polyphenolic compounds are a broad class of secondary metabolites with the ability to be effective antioxidants due to their structure. Antioxidants have a positive impact on health and preventing disease. In this study, the polyphenol content of the skin and pulp was found to be significant ($p<0.05$) among the cultivars. Eggplant peels possess higher mean values of polyphenol content compared to the pulp. The mean values of eggplant cultivars in the peel ranged from 1000 to 8000 µM GS/l, whereas the pulp ranged from 500 to 4000 µM GS/l. The peel of Madonna cultivars showed significantly higher phenolic content as compared to other cultivars and SV2162EV has the lowest. Regarding the fruit pulp, Basalto has the greatest mean polyphenol content and SV2162EV has the lowest, but no significant difference was found between Madonna and Basalto. Although Blackmoon had the lowest polyphenol concentration in the skin and Madonna had the highest, Blackmoon had the greatest level in the fruit pulp and Madonna has the lowest.

The variation in the level of polyphenol content of the eggplant cultivars as shown in the Figure 24 and Figure 25 may be related to factors like growing conditions, variety or cultivar type and stages of fruit development. Many previous research studies which has done the work in different criteria have shown such variation in the quantities of total phenolic compounds in different varieties of eggplant fruits. For example, based on phenotypic appearance, Okmen et al., (2009) evaluated and compared the total phenolic content. According to Zaro et al., 2014b the level of phenolic acids which is found in the eggplant fruit depend on the maturity level and further García-Salas et al., 2014 stated that it also influenced by the cultivars ability to adapt to abiotic condition.

6. SUMMARY

Eggplant (*Solanum melongena* L.) is one of the most popular vegetables grown in the world and its cultivation is increasing globally. As a result, production has increased in recent years. It is important to provide food with high nutritional values for consumers and the high nutrient content of eggplant makes them appealing food to consume. Therefore, researchers are more interested to produce different types of eggplant variety which contain many nutritional values and also gives good quality yields.

From oval and round to oblong or pear-shaped, eggplant come in all different shapes and sizes. Many parameters can be considered to differentiate the variety. The shape and colour depend on the variety. And also, the size of the plant, yield and time of ripening are all different between the eggplant cultivars. Cultivars with purple, oval fruits are commonly grown in Europe and the Americas.

The study's goal was to examine the quality attributes of four eggplant cultivars, namely Blackmoon, Basalto, SV2162EV, and Madonna, especially measuring their fruit shape, fruit colour, total sugar content, dry matter content, antioxidant content and Polyphenol content for all cultivars.

In our findings, Madonna and Basalto had the highest fruit shape index. The Brix value turned out to be higher in Madonna and Blackmoon; nonetheless, there was a little difference between them. In term of skin colour, the significant difference among the cultivars were found in all the values *L*, a*,* and *b** colour dimension. Basalto cultivar showed the least colour effect. However, the dry matter content did not show significant difference between the cultivars. The antioxidant content was highest in Madonna and Blackmoon. And the polyphenol concentration in the fruit pulp varies significantly between cultivars, with Blackmoon having the highest content and showing strong antioxidant potential. These findings suggested that total polyphenol content may be somewhat responsible for antioxidant activity.

In conclusion the four cultivars varied depending on the physiological parameters selected in the experiment. The results indicated that there is a significant variation in most of the measurements. Overall, Madonna and Blackmoon cultivars performed better. However, more research is required to improve the colour of the fruit.

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