EFFECTS OF DIFFERENT MULCHING MATERIALS ON PLANT GROWTH, FRUIT YIELD AND QUALITY OF TWO CULTIVARS OF WATERMELON (*Citrullus lanatus* Thunb.)

AUNG KYAW MOE

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A Thesis Submitted to the Post-Graduate Committee of the Yezin Agricultural University as a Partial Fulfillment of the Requirements for the Degree of Master of Agricultural Science (Horticulture)

Department of Horticulture and Agricultural Biotechnology
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The thesis attached hereto, entitled "**EFFECTS OF DIFFERENT MULCHING MATERIALS ON PLANT GROWTH, FRUIT YIELD AND QUALITY OF TWO CULTIVARS OF WATERMELON (*Citrullus lanatus* Thunb.)**" was prepared under the direction of chairperson of the candidate's supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **MASTRE OF AGRICULTURAL SCIENCE (HORTICULTURE).**

……………………………

Dr. Than Than Soe
Chairperson of Supervisory Committee
Lecturer
Department of Horticulture and
Agricultural Biotechnology
Yezin Agricultural University

……………………………

Dr. Maung Maung Tar
External Examiner
Director
Industrial Crop and Horticulture
Division
Department of Agricultural Research

……………………………

Dr. Nang Hseng Hom
Member of Supervisory Committee
Pro-rector (Administration)
Yezin Agricultural University

……………………………

Daw Wai Wai Lwin
Member of Supervisory Committee
Assistant Lecturer
Department of Horticulture and
Agricultural Biotechnology
Yezin Agricultural University

……………………………

Dr. Khin Thida Myint
Professor and Head
Department of Horticulture and Agricultural Biotechnology
Yezin Agricultural University

Date…………………………..

This thesis was submitted to the Rector of Yezin Agricultural University and was accepted as a partial fulfillment of the requirements for the degree of **MASTRE OF AGRICULTURAL SCIENCE (HORTICULTURE).**

…..…………………

Dr. Myo Kywe

Rector

Yezin Agricultural University

Nay Pyi Taw

Date -……………………….

DECLARATION OF ORIGINALITY

This thesis represents the original works of the author, except where otherwise stated. It has not been submitted previously for a degree at any University.

…………………………

Aung Kyaw Moe

Date -……………………….

DEDICATED TO MY BELOVED PARENTS

U KAN NYUNT AND DAW KHIN SHWE

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ABSTRACT

The study was conducted to investigate plant growth, fruit yield and quality attributes of two cultivars of watermelon as affected by mulching materials during the winter seasons of 2014 and 2015 in the field of Department of Horticulture and Agricultural Biotechnology, Yezin Agricultural University. The treatments were laid out in two-factor factorial arrangement in randomized complete block design with four replications. The first factor was mulching materials: rice straw, black polyethylene, silver polyethylene and clear polyethylene and without mulch was control. The second factor was cultivars: namely 855 and Padamya.

The data on main vine length (cm), number of nodes on main vine and number of branches per plant were weekly recorded. Soil moisture content (%) and weed infestation (g) were also measured. At harvest time, single fruit weight (kg), total fruit yield (ton ha^{-1}), skin and pulp firmness (kg cm^{-2}), Brix %, juice content (%) and total titratable acidity (TTA %) and color values of L*, a*, b* were also analyzed. All mulching materials showed significantly higher single fruit weight and total fruit yield than control. The plants without mulch (control) showed the lowest values in single fruit weight and total fruit yield. All mulching materials not only maintained the maximum soil moisture but also suppressed weed infestation. There was an interaction between mulching materials and cultivars on single fruit weight, total fruit yield and also the fruit quality attributes of juice content and color values of L*, a* and b*.

According to the results, mulching practice is efficient for watermelon production and silver polyethylene mulch is the best among them. There were no significant differences in the main growth parameters of single fruit weight and total fruit yield between two cultivars. Moreover, the quality attributes of Brix %, juice content and TTA % of cultivar 855 did not differ from cultivar Padamya. Therefore, cultivar Padamya may be a potential cultivar for local consumption and for export in future along with the cultivar 855.

Keywords: mulching materials, watermelon, growth parameters, yield, fruit quality attributes

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CHAPTER I
INTRODUCTION

Watermelon (*Citrullus lanatus* Thunb.) belongs to the member of the family Cucurbitaceae. It contains about 93 % of water, so its name called “water” melon. The “melon” means the fruit which is large, round, sweet and pulpy flesh. In 2012, total watermelon production area in the world was 3.1 million hectares with the average fruit yield was 30.34 tons per hectare (FAOSTAT 2014).

Watermelon is one of the important cucurbits vegetable fruit crops grown extensively in tropical and subtropical countries of the world. It is a good source of vitamin C, vitamin A and also a good source of several vitamins and minerals such as potassium, copper, Vitamin B5 (pantothenic acid), and vitamin B6 (Bjarnadottir 2016; Szalay, 2014). It is a popular dessert fruit and commercial vegetable fruit in Myanmar. It is usually cultivated in raining season (optimum growing time) and in winter season. The major growing areas of watermelon production in Myanmar are Yangon, Bago, Mandalay and Sagaing regions. Totally 15,262.38 hectares were grown and average fruit yield was 12.02 tons per hectare and total yield was 183,514.83 tons in Myanmar (DOA 2013).

Mulching is a beneficial practice for crop production and it has many advantages which includes: to conserves soil moisture, to control weed, to prevent the plant from direct soil contact with the plant foliages to protect crops from drought and excess moisture or water runs off the impervious mulch as well as improving the physical condition of the soil (Tran 1993; Parmar et al. 2013). Moreover, it can control soil temperature either keeping it cool or keeping it warm, conserve soil fertility and increase soil organic matter content when organic mulch is used and decay takes place.

Various factors affecting on growth, yield and quality of watermelon are the genetic characteristics of the cultivar, growing environment, cultural practices, and pest and disease management (Read 2007). Cultural practices include fertilizer application, irrigation, mulching, and composting and so on.

Mulching is one of the cultural practices that involve placing organic or inorganic materials on the soil around plants to provide a more favorable environment for growth and production. Organic mulches like rice straw, grass clippings, leaves, newspaper and compost tend to return nutrients to the soil through decomposition (Dickerson 2000). This improves the water-holding capacity of the soil and organic matter. It can also provide an ideal environment for earthworms and effective soil organisms.

Inorganic materials or mulches like plastic films and polyethylene provide many advantages for the growers such as increased yields, early crop maturity, high quality produces, and insect and weed control (Ennis 1987). Some inorganic materials of silver reflective mulches are efficient in repelling insects (AVRDC 1990). Various color and thickness of plastic mulches especially create a specific microclimate for plants (Csizinzky et al. 1995). The microclimate factors strongly affect the soil temperature and moisture in the root zone, which in turn may influence plant growth (Aguyoh et al. 1999; Osiru and Hahn 1994).

Although mulching is widely used for watermelon production in developed countries, in Myanmar, its production was usually done in open fields without mulching. The market demand of watermelon becomes higher day by day since people gradually come to know its nutritive values. And thus growers are trying now to increase the production of watermelon by using mulching materials to meet the market demands. However, there is little academic information on watermelon production by the use of different mulching materials in Myanmar. Therefore, the present study was carried out with the following objective;

1. to investigate plant growth, fruit yield and quality attributes of two cultivars of watermelon as affected by different mulching materials

CHAPTER II
LITERATURE REVIEW

2.1 Origin and History of Watermelon

Watermelon, *Citrullus lanatus*, belongs to family Cucurbitaceae and it is originated from southern Africa (Bjarnadottir 2016). The scientific name of the watermelon derived from both Greek and Latin words. The *Citrullus* comes from a Greek word "citrus" which is a reference to the fruit. The *lanatus* is Latin word and the meaning of being wooly, referring to the small hairs on the stems and leaves of the plant (Balakrishnan et al. 2015). Watermelon is an important vegetable fruit and widely cultivated crop. It is found in grassland and bush land, mostly on sandy soils, and often along watercourses or near water, up to 1,785 m above sea level (New World Encyclopedia 2016).

Watermelon refers to both the edible fruit and vine-like plant with a climbing and trailing herb. It is one of the most common types of melon and flowering plant which produces a special type of fruit known as pepo, a type of egigynous berry or false berry that is derived from an inferior ovary (Bjarnadottir 2016). The distribution of watermelon was started from the fifteenth century in South-East Asia. Watermelon is grown in all countries of tropical, subtropical and temperate with a continental climate (Vaughan and Geissler 2009).

Seeds and leaves of watermelon have been found in ancient Egyptian tombs. The genus *Citrullus* contains four species, including *lanatus*, also known as, the watermelon. It is related to cantaloupe melons, zucchinis, pumpkins and cucumbers (Bjarnadottir 2016).

The plants produce male and female flowers separately on the same plant. The female flowers have inferior ovaries. The flesh consists of highly developed placental tissue within the fruit. The watermelon has a thick rind (exocarp) and fleshy center composed of mesocarp and endocarp. It has a smooth exterior green and yellow rind and a juicy, sweet, usually red or yellow, but sometimes orange, interior flesh (New World Encyclopedia 2016).

2.2 Watermelon Production in World

Worldwide watermelon production occurs in over 100 countries. The production covers approximately 3.5 million hectares and almost 90 % of them are in

Asia. The main top ten watermelon producing countries in the world in 2013 were shown in Table 2.1. China is the highest producing country with 72.94 million tons followed by Iran and Turkey, 3.95 million tons and 3.89 million tons respectively (FAOSTAT 2016).

Within South-East Asia countries, Vietnam is the biggest watermelon producer and the annual cultivation area and production are 54,646 hectares and 1.16 million tons respectively in 2013 followed by Thailand, Indonesia, Malaysia, Philippines, Lao and Brunei (FAOSTAT 2016). The cultivation of watermelon in South-East Asia countries in 2013 are shown in Table 2.2.

In Myanmar, watermelon can grow well throughout the year. It plays as the major vegetable fruit crop in Myanmar. The cultivation area was over 15,273 hectare and the production was over 183,514 tons and the average yield was 12.02 tons per hectare (DOA 2013). The yield of watermelon per hectare is still very low comparing to ASEAN and neighbor countries.

In Myanmar, watermelon production was increased year by year and have been exported oversea. Myanmar watermelon is largely exported to China followed by mango and honeydew. China has become the largest market for Myanmar watermelons (FreshPlaza 2016) through the border town of Muse in Shan State. In 2015, Myanmar exported 528,960 tons of watermelon to China worth 56.45 million dollar according to the data from Department of Commerce of Yunnan Province (FreshPlaza 2016). The main production areas of watermelon for export are Mandalay, Sagaing, Bago and Yangon regions. The exportable watermelons were sent to China which is currently the main importing country via Muse border trade.

Table 2.1 Top ten watermelon production countries in the world in 2013

Country	Cultivated area (hectare)	Yield (tons per hectare)	Production (tons)
China, mainland	1,828,250	39.90	72,943,838
Islamic Republic of Iran	146,630	26.92	3,947,057
Turkey	157,585	24.67	3,887,324
Brazil	92,021	23.51	2,163,501
Egypt	60,551	31.29	1,894,738
United States of America	49,910	35.50	1,771,734
Uzbekistan	50,015	31.16	1,558,301
Algeria	56,254	26.67	1,500,559
Russian Federation	134,938	10.52	1,419,953
Vietnam	54,646	21.27	1,162,554

Source; FAOSTAT 2016

Table 2.2 Watermelon production countries in South East Asia in 2013

Country	Cultivated area (hectare)	Yield (tons per hectare)	Production (tons)
Vietnam	54,646	21.27	1,162,554
Thailand	42,000	12.50	525,000
Indonesia	30,065	14.86	446,913
Malaysia	12,009	18.89	226,809
Philippines	6,920	18.78	129,949
Lao	6,349	17.59	111,682
Brunei Darussalam	7	17.00	119

Source; FAOSTAT 2016

2.3 Watermelon Cultivars

There are three classes based on seed developed, which are open-pollinated varieties (OPV), F_1 hybrid and triploid or seedless. Open-pollinated varieties (OPV) are developed through several generations of selection. The selection can be based upon yield, quality characteristics and disease resistance. Open-pollinated varieties have true-to-type seed. Seed cost of open-pollinated varieties is cheaper than F_1 hybrid. F_1 hybrids are developed from two inbred lines that have been selected for several generations and then crossed. F_1 hybrid seeds are exhibit increased uniformity of type and time of harvest compared with open-pollinated seed. F_1 hybrid seeds can exhibit as much as a 20 % to 40 % increase in yields over open-pollinated varieties grown under similar conditions. F_1 hybrid seed can be 5 to 10 times as costly as open-pollinated seed. The availability of F_1 hybrid varieties will change from year to year (George et al. 2000).

Triploid or seedless watermelon is the third type. These are developed by creating watermelon plants with double the usual chromosome number and crossing them with normal watermelon plants. The resulting plants have one-and-a-half times the normal chromosome number. Triploid watermelons are referred to as seedless. They are not truly seedless. Triploid seeds can be more expensive than F_1 hybrid seeds (George et al. 2000; Shrefler et al. 2015).

Watermelons can also be grouped according to fruit shape (round to oblong), rind color or pattern (light to dark green in color with or without stripes), and fruit size. The fruit shape of watermelons range from round to oblong. Fruit rind can be light to dark green in color with or without stripes. Flesh pulp colors can be red, dark red or yellow. The groups are often named for a popular variety with these characteristics. For example, oblong watermelons with dark stripes on a light background in the 25 to 35 lb (12 to 16 kg) range are called Jubilee types after the popular Jubilee variety. Varieties of similar shape and size as Jubilee with a light green rind are called Charleston Gray types. Round watermelons in the range of 20 to 30 lb (9 to 14 kg) with a striped rind are called Crimson Sweet types. Small oblong melons about 15 to 25 lb (7 to 12 kg) with a dark green rind and light yellow stripe with dark red flesh are called All-sweet types. The blocky shape, which is between a Jubilee and Crimson Sweet type, are referred to as Royal Sweet or Mirage types. Round watermelons of 10 lb (5 kg) or less are called icebox types (George et al. 2000; Shrefler et al. 2015).

2.4 Health Benefits of Watermelon and Nutritional Facts

Watermelon consists mostly of water 91% and it contains 7.5 g of carbohydrate in 100 g. The carbohydrates are mainly simple sugars, such as glucose, fructose and sucrose. Watermelon contains nearly no protein or fat with very low in calories and a small amount of fiber (0.4 g). It has several health benefits, including lower blood pressure, improved insulin sensitivity and reduced muscle soreness after exercise and improved metabolic health. It is a very good source of vitamin C, several vitamins and minerals such as potassium, copper, Vitamin B5 (pantothenic acid), vitamin B6 and vitamin A (USDA 2016; Bjarnadottir 2016; Szalay; 2014). The nutritional facts of watermelon were listed in Appendix 14.

Watermelon is the richest dietary source of both citrulline and lycopene. The highest amount of citrulline is found in the white rind of watermelon. In the human body, citrulline is transformed into the essential amino acid arginine. Both citrulline and arginine play an important role in the synthesis of nitric oxide (NO), which helps to lower blood pressure. Arginine is also important for many organs, such as the lungs, kidneys, liver, immune and reproductive systems, and facilitate the healing of wounds. Watermelon is the best fresh source of lycopene which is a powerful antioxidant. Fresh watermelon is a better source of lycopene than tomato (Bjarnadottir 2016; Mangels et al. 1993).

2.5 Use of Mulches

Mulching is a practice which involves organic and inorganic mulch to provide a more favorable environment for plant growth and production. Organic mulch is used traditionally in small and home gardens. It is derived from natural materials that decompose over time. It can suppress annual weed germination and emergence. It can enhance crop growth, fairly easy to apply and reduce soil moisture losses. Inorganic mulches are mostly plastic mulches. They are made of either linear, low-density polyethylene or high-density polyethylene. High-density polyethylene is lighter and stronger than the same thickness of low-density polyethylene. Some plastic mulches are long lasting, ultraviolet, light-stabilized mulch are guaranteed to last up to five years. They allow water and air penetration while controlling weeds. These tear-resistant mulches can be reused year after year to warm the soil, control weeds, harvest rainfall and reduce evaporation of moisture from the soil (Dickerson 2012).

Mulches create a microenvironment by retaining soil moisture and changing root-zone temperatures and the quantity and quality of light reflected back to the plants which alter plant growth and development (Csizinszky et al. 1995). Plastic mulches affect plant microclimate by modifying the soil energy balance and restricting soil water evaporation, thereby affecting plant growth and its yield (Tarara 2000).

2.5.1 Organic mulch

Organic mulches include straw, hay, and fresh-cut forage or cover crops, chipped brush, wood shavings, tree leaves, cotton gin waste, rice hulls, and other crop residues. It can provide many important benefits as organic matter, nutrients, moisture conservation, soil protection, moderation of soil temperature and beneficial microorganisms. It can also improve soil tilth and drainage, reduce soil compaction, and attract earthworms (Dickerson 2012). Organic mulching improves physical, chemical and biological properties of soil, as it releases nutrients to the soil and ultimately facilitates the growth and yield of crops (Dilipkumar et al. 1990). Organic mulching possesses an advantage for increased crop production through its positive effect on the soil environment which enhances crop growth and yield (Lal et al. 1980). Straw, hay, and fresh-cut forage or cover crops are widely used as organic mulches (Schonbeck 2012). Compost and manure have also been used as organic mulches (Abd EI-Kader et al. 2010). Organic mulches decompose over time, improving soil structure and quality, and returning nutrients to the soil (Nwe 2009).

2.5.1.1 Straw mulch

Straw is defined here as the stalks and other residues left after harvest of a mature grain. It is similar to hay in texture, potential for soil protection and moisture conservation, weed suppression, and application methods. It has favorable effect on soil moisture, yield and water use efficiency (Sun et al. 2014). It is clean, persistent and effective in keeping the fruit of growing crops. Straw has lighter colored and it has reflective effect. Straw has higher carbon to nitrogen (C:N ratio) and it can delay crop growth because it has soil cooling effect. However it can be beneficial for cool weather crops like potato. Straw mulch is more suitable for summer crop production. Rice straw, wheat straw and buckwheat straw can be used as straw mulch (Abdul-Baki and Teasdale 1994; Tindall et al. 1990; Tindall et al. 1991).

Rice straw is a byproduct of the rice harvest and it is the cheapest, fairly lightweight and easiest way to mulch vegetable beds. The mulch breaks down slowly and it can be reused in next season. There are numerous advantages by mulching rice straw. They can reduce emergence of weed, can reduce water loss by evaporation, can keep soil moisture, can moderate soil temperature during hot weather and can prevent soil erosion by water runoff (Kramer 2013; Li et al. 2013). Therefore, rice straw mulch can be used for watermelon, cucumber, kale, spinach, lettuce, mustard, water cress, and so on.

2.5.1.2 Hay mulch

Hay is often used as mulch on horticultural crops. Grasses, rye, sorghum, etc can be used as hay mulches that can keep fruit like melons out of direct contact with soil. It is fairly easy to apply in small scale plantings. Hay mulch can reduce emergence of weed seedlings. It can moderate soil temperature during hot weather and can conserve soil moisture and prevent soil crusting and erosion. It can add significant amounts of organic matter and slow-release nutrients, especially potassium, K (Lamont 1999).

2.5.1.3 Living mulch

Living mulches system is growing of perennial or annual cover crops and vegetables between crop rows in the field for all or part of the growing season in order to extent weed control. Living mulches suppress weeds growth, reduce soil erosion, enhance soil fertility, and improve water infiltration. Living mulches can compete with the crop for moisture and nutrients, resulting in lower yields. However, in wide-spaced crop plantings, living mulch can be used between the rows of perennial plants, while the area near crop rows are kept free of competing vegetation and mulched with straw or other organic materials. Living mulches can be used in orchards, vineyards, berries, windbreaks, and field nursery trees to control erosion and provide traction (Sullivan 2003).

2.5.1.4 Other organic mulches

Crop residues like cotton gin waste, rice hulls, peanut hulls, and buckwheat hulls can be used as mulch. Their ability to suppress weeds may vary, depending on texture and possibly chemical properties. Sawdust, chipped brush, wood shavings, barks mulches are most often used on perennial crops and ornamental perennials. These mulches have high C:N ratio and relatively long lived. They can provide calcium (Ca), micronutrients, and small amounts of N, P, and K. They can transform stable humus when fully decomposed. Some growers use compost as mulch. They can provide slow-release nutrients, P, K, and some micronutrients in the soil and improve soil structure. Tree leaves mulches are sometimes used in vegetable production. They are rich in calcium (Ca) and micronutrients, contain small to moderate amounts of N, P, and K, and decompose gradually to form leaf mold (Lamont 1999).

2.5.2 Inorganic mulch

Plastic mulches have been used commercially for the production of vegetables since the early 1960's, and their usage is still increasing throughout the world (Lamont 1991). The greatest benefit from plastic mulch is that the soil temperature in the planting bed is raised, promoting faster crop development and earlier harvest. Plastic mulch is commonly used in conventional production of watermelon to conserve soil moisture, to prevent weed emergence, and fruit rots. Plastic mulches provide many other positive advantages, such as increasing yields, earlier crops harvesting, higher crop quality, insect and weed control (Lament 1993). A variety of vegetables can be grown successfully by using plastic mulches but watermelon, muskmelons, tomatoes, peppers, cucumbers, squash, eggplant and okra have been shown the most significant responses (Lamont 1991). The color of mulches can affect the temperatures below and above the mulch through the absorption, transmission and reflection of solar energy (Dickerson 2012; Lamont 1999). Most plastic mulches vary in thickness from 0.75 to 1.5 mil and may be smooth or embossed (McCraw and Motes 1991). Plastics mulch come in rolls 2,000 to 4,800 feet long depending on the thickness and 3 to 5 feet wide.

2.5.2.1 Black polyethylene mulch

Black polyethylene mulch is the standard plastic mulch and widely used in the commercial vegetable production especially for weed control (Gordan et al. 2010). The black plastic film does not allow sunlight to pass through onto the soil. Hence, it arrests weed growth completely. Black plastic alters the plant's growing environment by generating warmer soil temperatures (Dodds et al. 2003; Hanna et al. 2003) and holding more soil moisture (Ham et al. 1991; Lament 1993) than bare soil. It can absorb most incident solar radiation, including visible, infrared and ultraviolet light (Dickerson 2012). Soil temperatures under black plastic during the daytime can be increased as much as 5ºF higher at a 2 inch depth and 3ºF higher at a 4 inch depth than bare soil at the same depths (Lamont 1999). Black plastic mulch is used for the production of watermelon, cucumber, eggplant, pepper, chilli, and tomato.

2.5.2.2 Clear polyethylene mulch

Clear plastic has soil solarization process resulted in improved crop growth and control of soil-borne pests and pathogens under various condition (Katan 1981). Clear plastic absorbs a little solar radiation but transmit 85 to 95% solar radiation which transmission is depending on the thickness and degree of opacity of polyethylene (Dickerson 2012). The underside of clear plastic mulch is covered with condense water droplets. This allows solar light in with short-wave radiation, but blocks the heat outgoing by long-wave infrared radiation (Taber 1993). The incoming solar radiation can grow weeds which is a major problem under clear plastic mulch. If clear plastic mulch is used, an herbicide, soil fumigant, or solarization is requires for controlling weeds (Lamont 1999). Clear plastic mulches are generally used in the cooler regions because it can provide greater warming benefits (Vincent 2012). Under clear plastic mulch, soil temperatures can reach 8-14 ºF higher at the 2 inch depth and 6-14 ºF higher at the 4 inch depth than bare soil at the same depths during the daytime. It is used primarily on production of watermelon, melons, cucumbers, eggplants and sweet corn (Nwe 2009).

2.5.2.3 Silver or Aluminum polyethylene mulch

Reflective silver or aluminum mulches also give cooler soil temperatures. These mulches reflect UV wavelength that tend to repel aphids, whiteflies and leaf hoppers which can serve as vectors for various viral diseases (Dickerson 2012; Lamont et al. 1990). Mulch color effects on internodes length suggested as a role of surface reflected light (particularly far-red to red light (FR:R) ratio) on tomato plant development (Decoteau et al. 1989). The higher FR: R ratio will cause a taller plant (Lamont et al. 1990). Gordon et al. (2010) suggested that plastic mulch gave higher plant height, fresh weight, early crop maturity and total yield than other mulches. They are used on production of watermelon, melons, tomato, chilli, cucumber and so on. Sharma and Narendra (2004); Aruna et al. (2007) were also stated that silver plastic mulches increased average fruit weight in tomato and Angrej-Ali and Gaur (2007) also found in strawberry.

2.5.2.4 White polyethylene mulch

White plastic mulch is reflected light back into the atmosphere or the plant canopy resulting in slightly cooler soil temperature about -2ºF at 1-inch depth. These mulches can be used to establish crops when reduced soil temperature might be beneficial. Coextruded white on black plastic mulch helps cool the soil while controlling weeds. The light with white mulches can help by reflecting the light back into the plant canopy for some greenhouse crops that have limited light. Depending on the degree of opacity of white mulch, it may require the use of fumigant or herbicide because of potential weed growth (Dickerson 2012; Lamont 1999). White plastic mulch has been shown to generate cooler soil temperatures than black plastic (Díaz-Péréz and Batal 2002; Lament 1993). White plastic is preferred during the summer growing season in warmer regions of the world compared with black plastic because it has the ability to maintain soil moisture while having cooler temperatures than black plastic (Csizinszky et al. 1995; Lamont et al. 1990).

2.5.2.5 Red polyethylene mulch

Red plastic mulch has been shown to increase tomato yields, quality and reduce the severity of early blight in others. It can increase yields of honeydews, muskmelons and zucchini (Decoteau et al. 1989; Kasperbauer 1992). Moreover, it also can increase soil temperatures (Dickerson 2012; Lamont 1999).

2.5.2.6 Yellow polyethylene mulch

Yellow color mulch attracts certain insects like green pea aphids (*Myzus persicae*) and striped (*Diabrotica undecimpunctata*) and spotted (*Acalymma trivitatum*) cucumber beetles. So, these mulches might be used in the field as “catch crops” to pull insects away from other crops (Dickerson 2012; Mitchell et al. 2002; Lamont 1999).

2.5.2.7 Other polyethylene mulches

There are many other plastic color mulches. They are blue, orange, green, pink and gray. They have different radiation patterns that are reflected back into the canopies of various crops affect plant growth and development. They have also been shown to influence insect behavior. Thus, they are mainly used to repel and attract the insects (Jensen 2004). Blue-colored mulches have been shown to increase zucchini and honeydew yields. However, more researches are needed to be conducted to determine the effects of these colors on plant growth, yields, earliness and pest resistance (Dickerson 2012).

2.6 Effect of Mulching Materials on Soil Temperature

Temperature during plant growth and after harvest has significant effect on crop quality. Optimum temperature during growth is required for proper eating quality and harvesting quality. Temperature and light has positive impact on optimum plant productivity and harvest index (Kays 1999). Plastic mulches have long been used by gardeners, home and commercial, in the belief that they will materially raise soil temperatures (Owlcroft Company 2016). Temperature and moisture in soil are very interdependent factors. Water content has an influence on soil temperature due to its higher heat capacity in relation to that of soil particles (Brady and Weil 2008).

Soil temperature is increased 5 to 10ºC by the application of plastic mulches compared to bare soil (Elmer and Ferrandino 1990). Locher et al. (2005) revealed that use of dark colored mulch is the safest solution because even in case of high air temperature and solar radiation, the soil does not warm to a harmful degree. They observed that in case of light colored mulches (clear, violet, light green) the soil temperature increased 2.5 to 2.9ºC higher than control. They also mentioned that dark colored mulches (black, dark green, red) increased soil temperature 1.4 to 2.1ºC compared to the control. The soil temperature under highly reflective silver mulches will be several degrees (5 to 8ºF) cooler when compared to black plastic mulch (Jensen and Malter 1994).

The rise of soil temperature is often used as an explanation for increased production of crops grown on plastic mulch (Grubinger et al. 1993; Davis 1994). Plastic mulches modify the soil temperature regime (Ham et al. 1993). Changes in root zone temperature can affect the uptake and translocation of essential nutrients, therefore influencing root and shoot growth (Tindall et al. 1990). Increase in soil temperatures can affect the crop. Higher solar heating of the soi1 can improve plant health by controlling soil-borne pathogens (Katan et al. 1976).

Mulches color can affect the temperatures below and above the mulch, and microenvironment around the plant through the absorption, transmission and reflection of solar energy (Kramer 2013; Boucher 2012; Dickerson 2012; Lamont 1999; Lippert and Wilding 1964). The rise of soil temperature is derived mostly from the suppression of latent heat losses through soil evaporation (Hanada 1991). Bonanno and Lamont (1987) found that transparent and black plastic film created favorable conditions for increasing temperature in the soil.

Black plastic mulch exchanged large quantities of energy with the atmosphere and caused relatively small changes in soil temperature, while transparent polyethylene film transmitted radiation to the soil surface which was absorbed and converted to sensible heat (Hopen 1964). Clear plastic mulch is often used for soil sterilization. This film is fixed over wet soil to trap solar heat which kills weeds and soil pathogens. The soil temperature under clear polyethylene film was higher than brown, green, black and white polyethylene mulch (Ban et al. 2009; Argall and Stewart 1990). Transparent films produced a considerable build up of heat in the soil during the day because of a better transmissivity of short wave infrared radiation that provided the maximum of heat (Ballif and Dutil 1981). In cool climates, plain black plastic was used for mulching to improve soil temperature and it is still predominates mulch.

In hot areas, white plastic is often used to reduce excessive soil temperatures. An alternative way, clear plastic mulch provides substantially greater soil heating than black, but weed can exist or spread everywhere under mulch and that cannot be controlled (Owlcroft Company 2016).

2.7 Effect of Mulching Materials on Soil Moisture

Water is essential for crop growth and development. Moisture retention is definitely the most common reason for which mulch is applied to soil. Mulch is used to protect the soil moisture losses and surface runoff. Organic and inorganic mulches have been shown to improve the moisture retention of soil. This extended water holding ability enables plants to survive during low rainfall periods.

Mulch enables the soil moisture levels to maintain for longer periods. Covering the ground with mulch saves water by preventing surface evaporation (McMillen 2013). Mulching reduces water use and it can provide soil moisture level to maintain for longer periods. Mulch such as straw increases water retention and prevents soil evaporation (Steiner 1989; Li and Xiao 1992; Baumhardt and Jones 2002; Kar and Singh 2004). This is also ensures a more even moisture distribution throughout the soil profile, which further improves water use. Organic mulches will decompose over time and it adds humus to the soil, which increases water holding capacity (Unger 1974).

Plastic mulches can improved soil moisture by decreasing moisture evaporation from the soil surface. Times and amounts of irrigation can be reduced by using plastic mulch (Lamont 1999). The different types of mulches lead to increasing the soil moisture due to decreased evaporation from soil surface compared to bare soil. The soil moisture was always higher under black mulch than under transparent mulch (Maged 2006). Palada et al. (2003) found that plastic mulching resulted in 33-52 % more efficient use of irrigation water in bell pepper compared to bare soil.

2.8 Effect of Mulching Materials on Weed Infestation

Weed is a major problem in crop production and it is time consuming and expensive task. Mulching can reduce weed incidence significantly by inhibiting light penetration to the soil surface resulted in higher water use efficiency. It can also reduce soil erosion by minimizing the impact of raindrops and water runoff (Bhatt and Khera 2006; Sauvage 1995; Khera and Singh 1995; Verma et al. 1979).

Mulching materials including organic or inorganic mulches can be applied for weed control. Organic mulches can suppress annual weeds and it can offer other important benefits, such as organic matter, nutrients, moisture conservation, soil protection, and moderation of soil temperature. Straw and other organic mulches effectively block emergence of most weeds germinating from seed with a greater thickness (Schonbeck 1998). Nkansah et al. (2003) reported grass straw, rice straw, rice husk and saw dust mulches significantly reduced fresh weed weigh.

Plastic mulches can prevent weed growth and it also increases soil moisture retention and temperature. Black plastic mulch is effective for both soil warming and weed competition reducing. As black plastic mulch prevents light entering to the soil, annual and perennial weeds emergence and growth can be prevented. However, thin black plastic mulch will not control all weeds (Lamont 1999). Clear plastic mulch provides greater soil warming, but it cannot reduce the weed competition (Lamont 2005). Weed emergence and growth can be a serious problem under clear plastic unless proper herbicides are used.

2.9 Effect of Mulching Materials on Crop Growth, Yield and Fruit Quality

Growth, yield and nutrient uptake are affected by plastic mulch and initial nitrogen levels in the soil (Wein and Minotti 1987). Karp et al. (2006) reported that mulching treatment significantly influenced nutrient content of leaves and lower chlorophyll contents in control plants compared with plants grown on different mulches.

Plastic mulches can offer a barrier against weeds, moisture loss, nutrient loss, erosion, insect and disease injury while encouraging plant establishment and an earlier crop of potentially higher quality (Mugalla et al. 1996). The combined effects of soil temperature, soil moisture and weed suppression not only work to improve crop growth but also facilitate to get high yield and increase fruit size (Scheerens and Brenneman 1994).

Plastic mulches have the potential to alter soil temperature, crop water use, improve crop quality and in some cases reduce weed competition, thereby improving crop development and increasing yields (Lamont 2005, Ngouajio and Ernest 2005). It conserved 47.08% of water and increased yield by 47.67% in tomato when compared to control (Friake et al. 1990). Plastic mulches can prevent fruit crops from direct touching the soil and that can reduce the incidence of fruit rots (Lamont 1991).

The two main benefits of using black and clear plastic mulches are earlier plant growth and crop production. Earlier crop production can result in higher market price and good yield. Black plastic mulch can facilitate crop production as much as one to two weeks. Clear plastic mulch has been resulted to be crop earliness as much as three weeks (Lamont 1999). It has repellent effect on aphids (Jones 1991) and help in reducing the appearance of viral disease in cantaloupe (Orozco-Santos et al. 1995). Aphids were less severe on clear plastic mulch than on bare soil and black plastic mulch. Low numbers of whiteflies on the white and clear plastic mulches during early cycle of culture delayed virus symptom development (Summers et al. 2004). Farias-Larios and Orzoc-Santos (1997) concluded that clear plastic mulch could be a practical management tool for reducing insect populations, virus incidence and increasing soil temperature for watermelon production and enhancement of fruit quality.

Organic mulching possesses an advantage for increased crop production through its positive effect on the soil environment which enhances crop growth and yield (Lal et al. 1980). It can also serve the purpose of increasing beneficial insect predators. The densities of natural predators have been shown to be higher in living mulch as compared to synthetic mulch (Frank 2004).

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site

The field experiments were conducted at the Department of Horticulture and Agricultural Biotechnology, Yezin Agricultural University (YAU), Nay Pyi Taw. The experimental site is situated at 19° 38′ N latitude and 96° 51′ E longitude. The soil type is sandy loam with a pH 5.9. The experiments were carried out in winter seasons of 2014 and 2015.

3.2 Experimental Design and Layout

The treatments were laid out in two factors factorial arrangement in Randomized Complete Block (RCB) design with four replications. The first factor was mulching materials: rice straw, black polyethylene, silver polyethylene and clear polyethylene mulch and without mulch was used as a control. The second factor was cultivars: namely 855 and Padamya. The experimental orientation was from East to West.

The experimental area was 48 m × 40 m and each plot size was 12 m × 4 m. The tested cultivars of watermelon were 855 and Padamya. The seed source of 855 was Known You Seed Company Limited and that cultivar was currently in market demand for local and export. Padamya cultivar is introduced and provided by East West Seed Company Limited.

3.3 Preparing for Seedlings

The seeds were sown in plastic bags of 4.5 cm in diameter and 9 cm in height. The bags were filled with a mixture of garden soil, burnt rice husk and well decomposed farm yard manure with the ratio of 2:1:1 by volume. Single seed of watermelon was sown in a seed bag. The seeds were germinated at 10 days after sowing (DAS) for 855 cultivar and 11 DAS for Padamya cultivar in the first experiment and 9 DAS for 855 cultivar and 12 DAS for Padamya cultivar in the second experiment. The seedlings were transplanted in the field when they were at 12 days old age of seedlings.

Plate 1. Experimental field

Plate 2. Experimental plots

(A) Control (no mulch)

(B) Rice straw mulch

(C) Black polyethylene mulch

(D) Silver polyethylene mulch

(E) Clear polyethylene mulch

Plate 3. Experimental plots of watermelon mulched with different materials

3.4 Characteristics of Cultivar

Cultivar 855 is a hybrid variety of Known You Seed Company Limited. It is one of the most popular and commercial watermelon cultivars currently used in Myanmar. It is oblong-shaped, broad dark stripes over green rind, with the average of 7 kg in weight, uniform fruit, with deep-red and juicy flesh. It usually takes around 90 days from sowing to harvest.

Cultivar Padamya is also a hybrid and it is the newly introduced to Myanmar from East-West Seed Company Limited. The seedling vigor is moderate to strong and large fruits with the average of 5 kg in weight, uniform fruit, mostly oblong, sweet and deep red flesh. The rind is thinner than 855 cultivar and it will take 90 days from sowing to harvest.

Nowadays, farmers would like to get lower seed price with good fruit shape and quality. Although fruit shape and quality are similar to cultivar 855, seed price of Padamya is two times lower than that of cultivar 855. Selection of new cultivars acceptable for consumers is very important because varieties are being changed and market trends are also changing (George et al. 2000).

3.5 Cultural Practices

The experimental fields were thoroughly prepared with double row sowing practice which was conventionally used by farmers. The raised beds were 990 cm in length, 90 cm in width and 20 cm in height. The plant spacing was 90 cm and plot spacing was 540 cm for tendril running.

The farmyard manure, FYM, (5 tons per hectare) and lime (500 kg per hectare) were added as a basal 5 days ahead of transplanting. The fertilizers were applied at the rate of 250 kg Urea, 150 kg T-Super and 150 kg Murate of Potash per hectare (Parmar et al. 2013). Full dose of T-Super fertilizer was applied as basal in all treatments. Urea and Muriate of Potash fertilizers were used for four times in split application, one for basal and three for side dressings which were applied at 30 days after sowing (DAS), 45 DAS and 60 DAS. All chemicals were applied at recommended rates. Foliar fertilizers were weekly sprayed starting from 45 DAS. Furadan was added as a basal application to prevent the soil-borne diseases infestation. Insecticides and fungicides were weekly applied to control pests and diseases.

The plants were trained and pruned by removing the side shoots only leaving three main vines up to 60 DAS. Fruit thinning were done leaving only one fruit. Irrigation was applied thoroughly to the experimental beds before transplanting and plants were watered as soon as transplanting. Watering were practiced every 5-day intervals in the first experiment and one liter per plant for every day in the second experiment. Weeding were done only the plants for control (without mulch) if necessary.

3.6 Preparation of Mulching

Inorganic mulches of polyethylene such as black, silver, clear and organic mulch of rice straw (13,500 kg per hectare) were applied as the mulching materials on sowing beds prior to transplanting (Sun et al. 2014). Without mulch was treated as control. The experimental plots were designed with different mulching materials according to the treatments.

3.7 Data Collection

Ten sample plants were selected from each treatment to collect data. The crop growth parameters of main vine length (cm), number of nodes on main vine and number of branches per plant were weekly recorded. Soil moisture content (%) and weed infestation (g) were also recorded. At harvest time, single fruit weight (kg), total yield (tons per hectare) and fruit quality attributes of skin and pulp firmness (kg cm^{-2}), Brix %, juice content (%), total titratable acidity (TTA %) and color values of (L*,a*,b*) were also measured and analyzed.

3.8 Measurement of Fruit Quality Attributes

3.8.1 Measurement of skin and pulp firmness (kg cm^{-2})

Skin and pulp firmness ($kgcm^{-2}$) were measured by puncturing into the fruit for three places at the equatorial portion of fruit by using hardness tester (9300 M-5 kg, Tokyo, Japan). The fruits were cut into cross section to determine the pulp firmness. The firmness tester is a fruit destructive device that incorporates a penetrometer as a force-sensing component with a tip of 3 mm in diameter. The maximum force applied to skin or pulp of the fruit is defined as firmness value that is measured by the penetrometer gauge (Soe 2008).

3.8.2 Measurement of total soluble solid (TSS or Brix %)

The total soluble solid (TSS) content was determined by using a pocket refractometer (ATAGO PAL-1) by squeezing the juice from the pulp of watermelon. The reading value is expressed as Brix % and three times were recorded and average was calculated.

3.8.3 Measurement of total titratable acidity (TTA %)

Total titratable acidity (TTA %) of watermelon pulp juice was determined by the acid base titration method. Watermelon juice of 10 ml and 90 ml of water were titrated with 0.1 N NaOH and using 2 to 3 drops of phenolphthalein as an indicator (i.e., the solution has colorless for 30 second). Total titratable acidity was expressed as percentage of malic acid by using the following equation (AOAC 1990).

$$\text{TTA\%} = \frac{\text{(ml) NaOH x 0.1 N NaOH x 0.067 x 100}}{\text{10 ml of watermelon juice}}$$

Whereas, 0.067 = constant value for malic acid in ripe watermelon

3.8.4 Measurement of color values (L*, a*, b*)

The fruits were cut into cross-section and the flesh color was measured at three places by using colorimeter (KONICA MINOLTA CR-10). Color values were recorded and analyzed. L*a*b* is the most widely used for color measurement. As a result, single value can be used to describe the red/green and the yellow/blue attributes. When a color is expressed in L*a*b*, L* indicates lightness; a* denotes red/ green value; and b* is the yellow/blue value (McGuire 1992).

Where,

L = Difference in lightness and darkness (+ = lighter, - = darker)

a = Difference in red and green (+ = redder, - = greener)

b = Difference in yellow and blue (+ = yellower, - = bluer)

3.9 Statistical Analysis

The collected data were statistically analyzed by using the Statistix 8 software program and treatment means were compared by using least significant difference (LSD) test at 5% level.

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Growth Parameters

4.1.1 Main vine length (cm)

Effects of different mulching materials on main vine length of two cultivars of watermelon are described in table 4.1. The main vine length of watermelon was highly significantly different among the mulching materials between two cultivars. The main vine length of cultivar 855 was longer than that of cultivar Padamya. Among the mulching materials, the plants treated with silver polyethylene mulch gave the longest main vine length of 329.18 cm. All mulched plants were significantly longer in main vine length than control. The plants without mulch resulted in the shortest main vine length of 261.24 cm. There was no interaction between mulching materials and cultivars combination.

These results are similar to the findings of Parmar et al. (2013), who reported that silver coating on black plastic mulch increased main vine length among different mulching materials. Moreover, Maughan and Drost (2016) and Nunez (2010) also stated that silver reflective plastics mulches are very effective in reducing aphid and thrips populations.

As all treated plants showed longer main vine length than control, it may be due to the fact that mulches can more or less conserve soil moisture near root zone and can minimize the soil surface evaporation losses.

4.1.2 Number of branches per plant

Effects of different mulching materials on number of branches per plant of two cultivars of watermelon are mentioned in table 4.1. The number of branches per plant was significantly different among the mulching materials between two cultivars. Among the mulching materials, the plants treated with silver polyethylene mulch showed the highest number of branches per plant (38.52). The lowest number of branches per plant (17.47) was observed in control followed by clear polyethylene mulch (25.23). There was no significant difference in number of branches per plant of rice straw (28.84) and black polyethylene (31.82) mulched plants. The number of branches per plant for cultivar 855 was significantly more than that of cultivar Padamya. There was an interaction between mulching materials and cultivars. This indicated that the responses of number of branches per plant to watermelon cultivars were influenced by mulching practices (Appendix 7-a).

These results are similar to the findings of Parmar et al. (2013) and Hamid et al. (2012). They reported that silver plastic mulch produced more number of branches per plant compared to control.

It may be due to the fact that the plants treated with silver polyethylene mulch can maintain soil moisture, which can result in favorable microclimate condition for more branches per plant.

4.1.3 Number of nodes on main vine

Table 4.1 shows the effects of different mulching materials on number of nodes on main vine of two cultivars of watermelon. The number of nodes on main vine was highly significantly different among the mulching materials between two cultivars. Among the treatments, the plants treated with silver polyethylene mulch showed the highest number of nodes on main vine (37.29) followed by clear polyethylene mulch (35.92). The lowest number of nodes on main vine was observed in control (32.92). The cultivar 855 resulted in higher number of nodes on main vine than cultivar Padamya. There was no interaction between mulching materials and cultivars combination.

The result of this study was similar to the findings of Parmar et al. (2013) who reported that plants treated with silver plastic mulch increased number of nodes per vine among the mulching materials. Moreover, Rajablarijani et al. (2012) also stated that the plants treated with plastic mulches considerable produced more number of nodes relative to control plants.

It can be assumed that the plants with mulching materials resulted in higher number of nodes on main vine due to favorable soil moisture for node development while the plants without mulch cannot maintain soil moisture, which is a constraint for node development.

4.1.4 Single fruit weight (kg)

Effects of different mulching materials on single fruit weight of two cultivars of watermelon are described in table 4.1. Single fruit weight of watermelon was significantly influenced by the mulching materials. Among the mulching materials, silver polyethylene mulched plants were recorded to have the highest single fruit weight (6.45 kg) followed by clear polyethylene mulched ones (5.97 kg). The lowest single fruit weight was observed in control (3.80 kg). There was no significant difference in single fruit weight of cultivars 855 and Padamya. The interaction was occurred between the mulching materials and tow cultivars. This indicated that the responses of single fruit weight of two cultivars were influenced by mulching practices (Appendix 7-b).

Similar results have been reported by Ansary and Roy (2005); Arancibia and Motsenbocker (2008) and Parmar et al. (2013). They stated that all mulching treatments, especially the silver polyethylene mulches, significantly increased the average fruit weight.

Soil moisture and temperature may be the important factors for crop growth and development. In this study, silver polyethylene mulch resulted in higher single fruit weight. It may be due to high soil moisture content under mulch that results in favorable microclimate conditions for fruit development. Moreover, it can be assumed that silver polyethylene mulch has insect repellent action and it can suppress insects and pests infestation which can enhance fruit development.

4.1.5 Total fruit yield (tons per hectare)

Effects of different mulching materials on total fruit yield of two cultivars of watermelon are presented in table 4.1. The total fruit yield of watermelon was significantly influenced by mulching materials. The plants mulched with silver polyethylene gave significantly highest total fruit yield (23.20 ton ha^{-1}) followed by clear polyethylene mulched plants (21.20 ton ha^{-1}). However, the plants without mulch produced the lowest total fruit yield (13.64 ton ha^{-1}). There was no significant difference in total fruit yield of the cultivar 855 and Padamya. The interaction was found between mulching materials and cultivars. This revealed that the responses on total yield of watermelon cultivars were influenced by mulching practices (Appendix 8-a).

This result agreed with that of Dean et al. (2004) and Cenobio et al. (2007). They stated that the total fruit yield was significantly higher in mulched plants especially in silver polyethylene mulch. Maughan and Drost (2016) and Nunez (2010) also stated that silver reflective plastic mulches are very effective in reducing aphids and thrips populations.

The microclimate condition around the plant would be greatly influenced by mulches and that can provide favorable temperature and moisture for crop growth and yield. In this study, all mulches especially silver polyethylene mulch produced larger fruit and higher total fruit yield than control. It can be assumed that the application of mulch on soil surface can support the favorable microclimate condition (i.e. soil moisture and soil temperature) for fruit development to attain higher total fruit yield. Moreover, silver polyethylene mulch has insect repellent action and it can also suppress weed growth resulted more fruit development and total fruit yield.

4.1.6 Soil moisture content (%)

Effects of different mulching materials on soil moisture content of two cultivars of watermelon are shown in table 4.1. There were highly significant differences in soil moisture content among the mulching materials. The soil moisture contents were significantly lowest (16.68 %) in treatments without mulch (control) followed by rice straw mulch (19.68 %). Soil moisture contents were significantly highest in the treatments with silver and black polyethylene mulches.

The treatments with polyethylene mulches significantly maintained soil moisture contents than did others (rice straw and without mulch). These results are similar to the findings of Maged (2006), who stated that different types of mulches maintained soil moisture by reducing evaporation from soil surface compared to bare soil. Palada et al. (2003) also stated that soil moisture was always higher under black mulch than transparent mulch.

It may be assumed that polyethylene mulches can improve soil moisture by decreasing moisture losses from soil because they completely covered around the root environment. That fact is favorable for plant growth due to effective use of water. The plants treated with no mulch and rice straw mulch cannot maintain soil moisture because they did not completely cover around the root zone and thus there were more moisture losses and not enough moisture for plant growth and development.

4.1.7 Weed infestation (g)

Effects of different mulching materials on weed infestation of two cultivars of watermelon are demonstrated in table 4.1. The weed infestations were significantly different between mulched and un-mulched plants. The weed infestation of control plants were significantly more than the mulched plants. However, there were no significant differences in weed infestation among the mulching materials of inorganic mulch (polyethylene) and organic mulch (rice straw).

According to the results, the plants treated with different mulching materials significantly suppressed the weed growth. Similar results were found by Hatami et al. (2012). They stated that polyethylene mulch had a significant effect on weed infestation. Grassbaugh et al. (2004) also reported that black polyethylene was completely eliminated weed growth. Moreover, organic mulches such as rice straw not only effectively block emergence of weed germination from seeds but also provide organic matter and nutrients for plant growth (Schonbeck 1998).

It can be assumed that the plants without mulch showed the highest weed infestation due to favorable condition for weed germination and weed growth. Moreover, inorganic mulches especially polyethylene can block light entering through the mulch, which can suppress weed growth and reduce weed competition. It may be due to the fact that the growth of weeds could be retarded in the absence of light under the polyethylene mulches.

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Table 4.1 Combined analysis of effects of different mulching materials on crop growth parameters of two cultivars of watermelon

Treatments	Main vine length (cm)	Number of Branches per plant	Number of nodes on main vine	Single fruit weight (kg)	Total yield (tons per plant)	Soil Moisture (%)	Weed infestation (g)
Mulching							
Control	261.24 c	17.47 d	32.92 c	3.80 c	13.64 c	16.68 d	270.94 a
Straw	302.06 b	28.84 bc	34.71 bc	5.38 b	19.30 b	19.68 c	88.19 b
Black	304.58 b	31.82 b	34.33 bc	5.36 b	19.01 b	33.26 a	68.69 b
Silver	329.18 a	38.52 a	37.29 a	6.45 a	23.20 a	34.07 a	61.06 b
Clear	304.14 b	25.23 c	35.92 ab	5.97 ab	21.20 ab	31.21 b	89.38 b
LSD $_{0.05}$	22.87	6.42	2.00	0.88	3.20	1.91	36.25
Cultivar							
855	311.21 a	30.27 a	36.17 a	5.36	19.04	26.77	112.62
Padamya	289.27 b	26.49 b	33.90 b	5.44	19.51	27.19	116.18
LSD $_{0.05}$	13.30	2.88	0.96	0.51	1.86	1.07	19.34
Pr>F							
Mulching	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
Cultivar	0.002**	0.012*	0.001**	0.746	0.609	0.431	0.713
Mulching x Cultivar	0.633	0.001**	0.099	0.003**	0.005**	0.001**	0.001**
CV %	28.23	34.74	12.37	28.86	29.65	9.91	62.65

Means in the same column followed by the same letters are not significantly different at P≤0.05.

* = significant at 5% level

** = significant at 1% level

4.2 Fruit Quality Attributes

4.2.1 Fruit skin and pulp firmness (kg cm^{-2})

Effects of different mulching materials on skin and pulp firmness of two cultivars of watermelon are shown in table 4.2. There were highly significant differences in skin and pulp firmness among the mulching materials. The highest skin and pulp firmness (3.86 and 0.47 kg cm^{-2}) were observed in the fruits treated with rice straw mulch. However, there were no significant differences in skin and pulp firmness in other treatments. The skin firmness was also significantly affected by different cultivars while pulp firmness was not. There was an interaction between the mulching materials and watermelon cultivars. This indicated that the responses on skin and pulp firmness to watermelon cultivars were influenced by mulching practices (Appendix 8-b and 9-a).

The skin and pulp firmness of rice straw were highest among the mulching materials. According to Tindall et al. (1991), straw mulch can delay crop growth than plastic mulch due to soil cooling effect. Therefore, it can be assumed that the firmness of skin and pulp may be partly due to soil cooling effect and partly due to less soil moisture content in this study.

4.2.2 Total soluble solid (TSS or Brix %)

Table 4.2 shows Effects of different mulching materials on total soluble solid (TSS or Brix %) of two cultivars of watermelon. The Brix % of watermelon was significantly different among the mulching materials. The highest and the same value of Brix % (9.50) was observed in the fruits treated with black and silver polyethylene mulches followed by clear polyethylene mulched plants (9.07). The lowest Brix % (8.54) was observed in control fruits followed by rice straw mulch (8.83). There was no significant difference in Brix % of fruits between two cultivars. No interaction was occurred between mulching materials and cultivar combination.

According to the findings of Ansary and Roy (2005), the maximum total soluble solid were observed in the fruits treated with silver polyethylene mulch while the minimum sugar content was observed in control.

In this study, all polyethylene mulched fruits, especially black and silver polyethylene mulched ones, were sweeter than those of other treatments. It can be assumed that polyethylene mulches can absorb and maintain high temperature, which might improve sugar level or Brix % of watermelon.

4.2.3 Juice content (%)

Effects of different mulching materials on juice content (%) of two cultivars of watermelon are shown in table 4.2. The juice content of watermelon was significantly influenced by mulching materials but there was no significant difference in the two cultivars of watermelon. Among the mulching materials, the fruits treated with silver polyethylene mulch showed the highest juice content (74.41 %) followed by black polyethylene mulch (72.92 %). Other treatments did not significantly differ from each other. There was an interaction between mulching materials and cultivars. This indicated that juice content of watermelon responses to cultivars were influenced by mulching practices (Appendix 9-b).

According to the findings of Moreno et al. (2009), there was no significant difference in the juice content of tomato among the mulching treatments. However, in this study, silver and black polyethylene mulched fruits resulted in the highest juice content.

It can be assumed that the plants mulched with polyethylene may have higher soil temperature and soil moisture, which can enhance plant growth and fruit development with high juice content.

4.2.4 Total titratable acidity (TTA %)

Effects of different mulching materials on total titratable acidity (TTA %) of two cultivars of watermelon are described in table 4.2. The TTA % was highly significantly different among the mulching materials. The fruits treated with rice straw mulch showed the highest TTA % (0.14) while the lowest and the same TTA % of (0.12) was observed in black polyethylene mulch and control. However, no significant differences of TTA % were observed between two cultivars. There was an interaction between mulching materials and watermelon cultivars. This indicated that the responses of TTA % to watermelon cultivars were influenced by mulching practices (Appendix 10-a).

In this study, the fruits treated with black polyethylene mulch showed the lowest TTA % with the highest Brix %. It can be assumed that the decrease in TTA % of fruits may be due to conversion of the malic acid to sugar level and lycopene biosynthesis resulted in becoming less TTA % (Rathore et al. 2007).

4.2.5 Color values (L*, a*, b*)

Effects of different mulching materials on pulp color values of L*, a* and b* of watermelon are shown in table 4.2. Customers always determine fruit quality by color. Therefore, color is one of the most important quality attributes of fruit. The value of L* (lightness) was not significantly different among the mulching materials. However, significant differences in the values of a* (redness) and b* (yellowness) were observed among the mulching materials between two cultivars. The highest a* value was observed in the fruits treated with no mulch (35.32) followed by silver polyethylene mulch (34.24). The lower a* values occurred in mulching materials of clear (32.85) and black (32.93) polyethylene mulches. The highest b* value (17.13) was observed in the fruits treated with silver polyethylene mulch followed by clear polyethylene one (16.80). The lowest b* value occurred in the fruits without mulch (15.94). The color values of a* and b* of cultivar 855 were significantly higher than those of the cultivar Padamya. An interaction was observed between mulching materials and watermelon cultivars. This indicated that the responses of pulp color values of L*, a* and b* to watermelon cultivars were influenced by mulching practices (Appendix 10-b, 11- a and b).

The brightness (L* value) of pulp color in watermelon was not affected by different mulching materials. But the significant differences in redness and yellowness (a* and b* values) in the pulp of watermelon were observed to be affected by different mulching materials and cultivars.

It might be due to the fact that the red color intensity of watermelon was attributed to the increased synthesis of lycopene and deep red fleshed watermelon has a high concentration of lycopene (Magda 2016 and Perkins-Veazie and Collins 2004). Lycopene is the major pigment in the red variety of watermelon (Lewinsohn et al. 2005).

Table 4.2 Combined analysis of effects of different mulching materials on quality attributes of two cultivars of watermelon

Treatments	Skin Firmness (kg cm^{-2})	Pulp Firmness (kg cm^{-2})	Brix %	Juice content %	TTA %	Color development		
						L*	a*	b*
Mulching								
Control	3.55 b	0.41 bc	8.54 b	68.65 b	0.12 c	39.86	35.32 a	15.94 b
Straw	3.86 a	0.47 a	8.83 b	69.34 b	0.14 a	39.80	33.80 bc	16.40 ab
Black	3.66 b	0.38 c	9.50 a	72.92 a	0.12 c	40.22	32.93 c	16.41 ab
Silver	3.62 b	0.43 ab	9.50 a	74.41 a	0.13 b	39.26	34.24 ab	17.13 a
Clear	3.57 b	0.43 ab	9.07 ab	69.04 b	0.13 b	39.98	32.85 c	16.80 a
LSD $_{0.05}$	0.12	0.05	0.63	3.08	0.006	1.20	1.15	1.13
Cultivar								
855	3.73 a	0.43	9.00	70.99	0.13	41.46 a	34.67 a	17.16 a
Padamya	3.58 b	0.42	9.17	70.75	0.12	38.19 b	32.99 b	15.92 b
LSD $_{0.05}$	0.08	0.03	0.41	1.90	0.004	0.76	0.78	0.58
Pr>F								
Mulching	<0.001**	0.005**	0.013*	<0.001**	0.001**	0.570	0.001**	0.042*
Cultivar	0.001**	0.572	0.394	0.809	0.20	0.001**	0.001**	0.001**
Mulching x Cultivar	0.003**	0.028*	0.667	0.001**	0.001**	0.001**	0.001**	0.001**
CV %	6.18	16.89	16.83	6.01	3.36	2.21	1.80	2.82

Means in the same column followed by the same letters are not significantly different at $P \leq 0.05$.

* = significant at 5% level

** = significant at 1% level

CHAPTER V
CONCLUSION

This study revealed that all growth parameters of main vine length, number of branches per plant, number of nodes on main vine, single fruit weight and total fruit yield were significantly influenced by different mulching materials. Moreover, all of the mulching materials not only maintained the maximum soil moisture but also suppressed weed infestation. The fruit quality attributes of skin and pulp firmness, Brix %, juice content, total titratable acidity, color values of a* and b* were significantly different among the mulching materials.

All mulching materials showed significantly higher single fruit weight and total fruit yield than control. The plants without mulch (control) were observed to be the lowest in single fruit weight and total fruit yield. The plants treated with silver polyethylene mulch resulted in the highest value in main vine length, number of nodes on main vine, number of branches per plant, single fruit weight and total fruit yield. Moreover, their fruit quality attributes of Brix %, juice content and color values of a* and b* were higher than those of others. There were interactions between mulching materials and cultivars on single fruit weight, total fruit yield and also quality attributes of juice content and color values of L*, a* and b*.

According to the results, mulching practice is efficient for watermelon production and silver polyethylene mulch is the best among them. There were no significant differences in the main growth parameters of single fruit weight and total fruit yield between two cultivars. Moreover, the quality attributes of Brix %, juice content and TTA % of cultivar 855 did not differ from cultivar Padamya. Therefore, cultivar Padamya may be a potential cultivar for local consumption and for export in future along with the cultivar 855.

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APPENDICES

Appendix 1. Effects of different mulching materials on growth parameters of two cultivars of watermelon (2014-winter season)

Treatments	Vine length (cm)	Number of nodes on main vine	Number of branches per plant	Single fruit weight (kg)	Total yield (ton per hectare)	Soil moisture (%)	Weed infestation (g)
Mulching							
Control	266.80 b	33.35 a	16.70 c	3.83 c	13.75 c	18.06 d	359.38 a
Straw	307.02 a	36.17 ab	31.49 ab	4.95 bc	17.75 bc	21.59 c	144.50 b
Black	324.21 a	35.99 ab	36.47 ab	5.24 abc	18.35 abc	32.65 ab	84.00 c
Silver	338.30 a	38.36 a	40.21 a	6.55 a	23.48 a	34.14 a	83.87 c
Clear	319.71 a	36.97 a	26.46 bc	6.21 ab	21.84 ab	30.15 b	116.13 b
LSD $_{0.05}$	34.54	2.91	10.89	1.46	5.40	2.94	29.85
Cultivar							
855	377.10	32.80 a	33.45	4.78	17.13	26.86	161.90
Padamya	364.39	31.23 b	31.03	5.07	18.18	27.77	153.25
LSD $_{0.05}$	24.96	1.38	5.49	0.62	2.24	2.00	17.62
Pr>F							
Mulching	0.003**	0.024*	0.001**	0.006**	0.009**	<0.001**	<0.001**
Cultivar	0.300	0.027*	0.367	0.341	0.342	0.351	0.317
Mulching x Cultivar	0.007**	0.002**	<0.001**	0.002**	<0.001**	<0.001**	<0.001**
CV %	10.50	6.99	24.73	21.51	21.02	10.58	19.35

Means in the same column followed by the same letters are not significantly different at P≤0.05.

* = significant at 5% level

** = significant at 1% level

Appendix 2. Effects of different mulching materials on quality attributes of two cultivars of watermelon (2014-winter season)

Treatments	Skin firmness (kg cm^{-2})	Pulp firmness (kg cm^{-2})	Brix %	Juice content (%)
Mulching				
Control	3.62 b	0.44 a	8.48 b	64.77 c
Straw	3.97 a	0.46 a	8.48 b	70.07 b
Black	3.74 b	0.36 b	9.83 a	75.72 a
Silver	3.67 b	0.43 ab	9.26 ab	74.73 a
Clear	3.66 b	0.45 a	8.91 ab	69.67 b
LSD $_{0.05}$	0.18	0.07	0.93	4.25
Cultivar				
855	3.78	0.39	8.07	74.26
Padamya	3.78	0.41	7.81	71.38
LSD $_{0.05}$	0.02	0.04	0.60	2.40
Pr>F				
Mulching	0.003**	0.051	0.030*	<0.001**
Cultivar	0.919	0.155	0.373	0.020*
Mulching x Cultivar	0.001**	<0.001**	<0.001**	<0.001**
CV %	0.77	12.5	2.49	2.64

Means in the same column followed by the same letters are not significantly different at P≤0.05.

* = significant at 5% level

** = significant at 1% level

Appendix 3. Effects of different mulching materials on some growth parameters and quality attributes of two cultivars of watermelon (2014-winter season)

Treatments	Number of female flowers per plan	Number of male flowers per plant	Male to female flowers (sex ratio)	Fruit girth (cm)	Fruit length (cm)	Pulp weight (kg)	Rag weight (kg)
Mulching							
Control	3.48 b	19.20 c	5.50 b	65.53 c	77.06	2.75 c	1.08 b
Straw	4.55 a	29.03 b	6.64 b	70.74 b	80.56	3.67 bc	1.28 b
Black	4.90 a	31.06 ab	6.56 b	72.06 b	80.54	3.81 bc	1.43 b
Silver	5.26 a	34.12 ab	6.77 ab	77.33 a	83.67	4.94 a	1.61 ab
Clear	4.64 a	36.43 a	8.15 a	74.60 ab	85.86	4.22 ab	1.99 a
$LSD_{0.05}$	1.06	6.45	1.51	4.44	9.49	1.04	0.56
Cultivar							
855	4.99 a	29.98	6.07 b	72.80	80.34	3.77	1.01 a
Padamya	4.14 b	29.95	7.38 a	71.31	82.74	4.19	0.88 b
$LSD_{0.05}$	0.70	4.21	1.13	2.74	4.18	0.58	0.22
Pr>F							
Mulching	0.025*	<0.001**	0.024*	<0.000**	0.398	0.001**	<0.001**
Cultivar	0.020*	0.99	0.026*	0.270	0.246	0.836	<0.001**
Mulching x Cultivar	0.007**	<0.001**	0.011*	<0.001**	0.512	0.007**	<0.001**
CV %	21.34	20.03	21.85	5.77	11.13	24.76	26.58

Means in the same column followed by the same letters are not significantly different at $P \leq 0.05$.

* = significant at 5% level

** = significant at 1% level

Appendix 4. Effects of different mulching materials on growth parameters of two cultivars of watermelon (2015-winter season)

Treatments	Vine length (cm)	Number of nodes on main vine	Number of branches per plant	Single fruit weight (kg)	Total yield (ton per hectare)	Soil moisture (%)	Weed infestation (g)
Mulching							
Control	255.68 c	32.48 b	18.23 c	3.77 b	13.53 b	15.31 c	182.50 a
Straw	297.09 ab	33.26 ab	26.18 b	5.82 a	20.86 a	17.78 b	31.87 b
Black	284.94 bc	32.66 b	27.18 b	5.48 a	19.67 a	33.87 a	53.38 b
Silver	320.07 a	36.22 a	36.83 a	6.39 a	22.93 a	34.00 a	38.25 b
Clear	288.58 ab	34.88 ab	24.00 bc	5.74 a	20.57 a	32.27 a	62.63 b
LSD $_{0.05}$	32.55	3.01	7.58	1.08	3.89	1.98	53.02
Cultivar							
855	245.31 a	39.53 a	27.08 a	5.94	20.93	26.68	63.35
Padamya	214.16 b	36.57 b	21.95 b	5.81	20.83	26.61	79.10
LSD $_{0.05}$	10.73	1.38	2.36	0.85	3.17	0.98	35.58
Pr>F							
Mulching	0.008**	0.075	<0.001**	<0.001**	<0.001**	<0.001**	<0.001**
Cultivar	<0.001**	<0.001**	<0.001**	0.761	0.950	0.886	0.366
Mulching x Cultivar	<0.001**	0.0678	0.008**	<0.001**	0.009**	<0.001**	0.004**
CV %	9.24	8.61	22.11	20.23	18.02	7.45	81.33

Means in the same column followed by the same letters are not significantly different at $P \leq 0.05$.

* = significant at 5% level

** = significant at 1% level

Appendix 5. Effects of different mulching materials on quality attributes of two cultivars of watermelon (2015-winter season)

Treatments	Skin firmness (kg cm^{-2})	Pulp firmness (kg cm^{-2})	Brix %	Juice content (%)	TTA %	Color development		
						L*	a*	b*
Mulching								
Control	3.48 b	0.38 c	8.60 b	72.52 ab	0.12 c	39.86	35.32 a	15.94 b
Straw	3.76 a	0.48 a	9.17 ab	68.62 c	0.14 a	39.80	33.80 bc	16.40 ab
Black	3.59 b	0.40 bc	9.17 ab	70.12 bc	0.12 c	40.22	32.93 c	16.41 ab
Silver	3.58 b	0.44 ab	9.67 a	74.10 a	0.13 b	39.26	34.24 ab	17.13 a
Clear	3.49 b	0.42 abc	9.23 ab	68.41 c	0.13 b	39.98	32.85 c	16.80 a
$LSD_{0.05}$	0.16	0.06	0.86	3.19	0.01	1.20	1.15	1.13
Cultivar								
855	3.69 a	0.47 a	9.92 b	67.72	0.13	41.46 a	34.67 a	17.16 a
Padamya	3.38 b	0.43 b	10.53 a	70.13	0.12	38.19 b	32.99 b	15.92 b
$LSD_{0.05}$	0.12	0.04	0.53	2.89	0.00	0.76	0.78	0.58
Pr>F								
Mulching	0.014*	0.023	0.193	0.003**	0.001**	0.570	0.001**	0.042*
Cultivar	<0.000**	0.030*	0.027*	0.097	0.200	0.001**	0.001**	0.001**
Mulching x Cultivar	<0.000**	0.034*	0.595	<0.000**	0.001**	0.001**	0.001**	0.001**
CV %	4.46	10.96	9.47	1.76	3.36	2.21	1.80	2.82

Means in the same column followed by the same letters are not significantly different at P≤0.05.

* = significant at 5% level

** = significant at 1% level

Appendix 6. Effects of different mulching materials on some growth parameters and quality attributes of two cultivars of watermelon (2015-winter season)

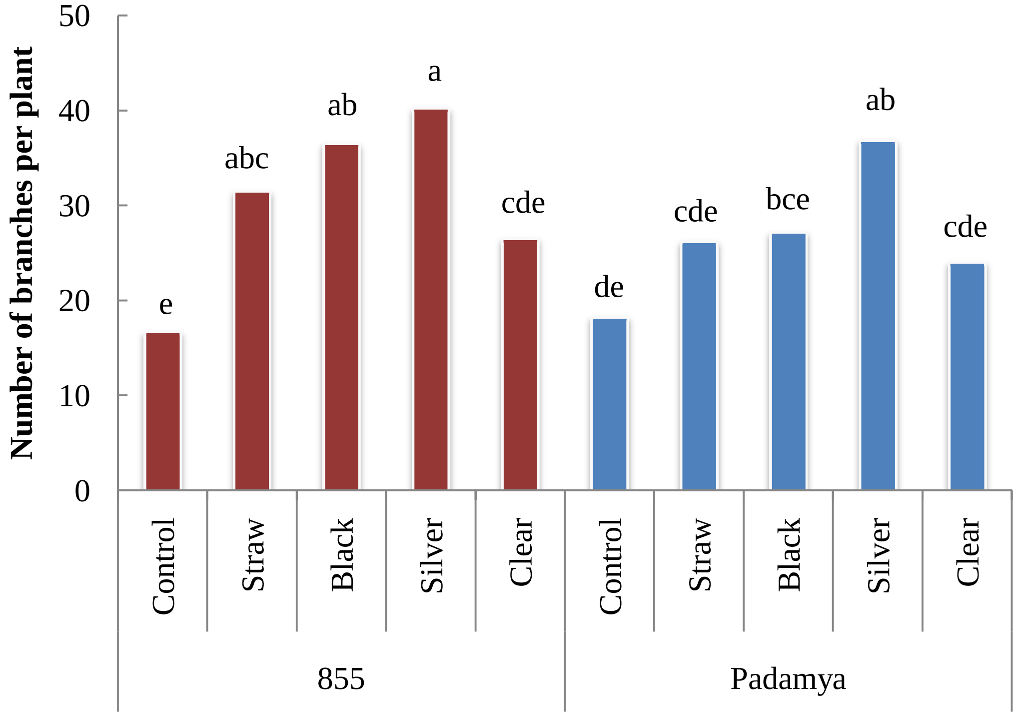
Treatments	Number of female flowers per plant	Number of male flowers per plant	Male to female flowers (sex ratio)	Fruit girth (cm)	Fruit length (cm)	Pulp weight (kg)	Rag weight (kg)
Mulching							
Control	3.07 b	21.47 b	7.10	58.46 b	68.69 b	2.83 b	0.94 b
Straw	3.99 a	28.88 a	7.37	63.53 ab	76.68 a	4.37 a	1.45 a
Black	3.94 a	28.07 a	7.31	61.01 b	71.48 ab	4.22 a	1.26 ab
Silver	4.73 a	34.41 a	7.70	62.56 b	76.28 a	4.81 a	1.58 a
Clear	4.75 a	34.12 a	7.30	68.18 a	76.75 a	4.51 a	1.23 ab
$LSD_{0.05}$	0.85	6.57	1.47	5.45	7.51	0.85	0.41
Cultivar							
855	3.64 b	29.30	8.20 a	60.09 b	70.44 b	4.74	1.20 a
Padamya	4.55 a	29.48	6.52 b	65.41 a	77.51 a	5.09	0.72 b
$LSD_{0.05}$	0.47	4.70	1.22	2.95	3.39	0.75	0.32
Pr>F							
Mulching	0.002**	0.002**	0.946	0.016*	0.118	<0.001**	0.036*
Cultivar	<0.001**	0.940	0.010**	0.001**	<0.001**	0.014*	<0.001**
Mulching x Cultivar	<0.001**	0.023*	0.294	<0.001**	0.0750	0.035*	<0.001**
CV %	18.75	23.46	23.68	6.95	10.19	22.21	27.09

Means in the same column followed by the same letters are not significantly different at P≤0.05.

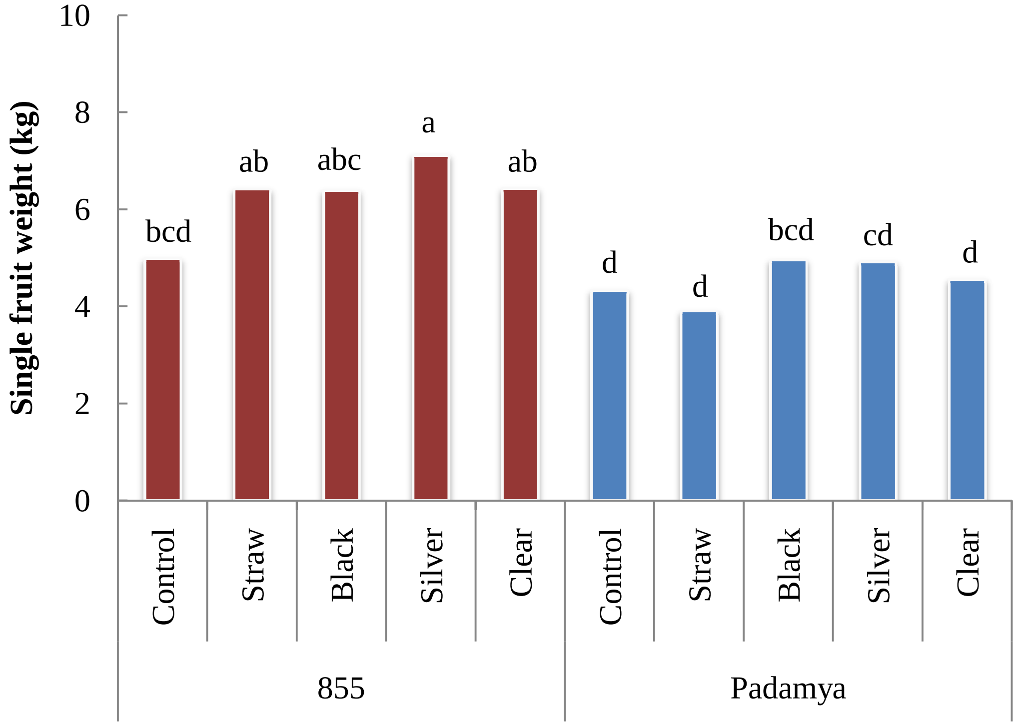
* = significant at 5% level

** = significant at 1% level

Appendix 7.

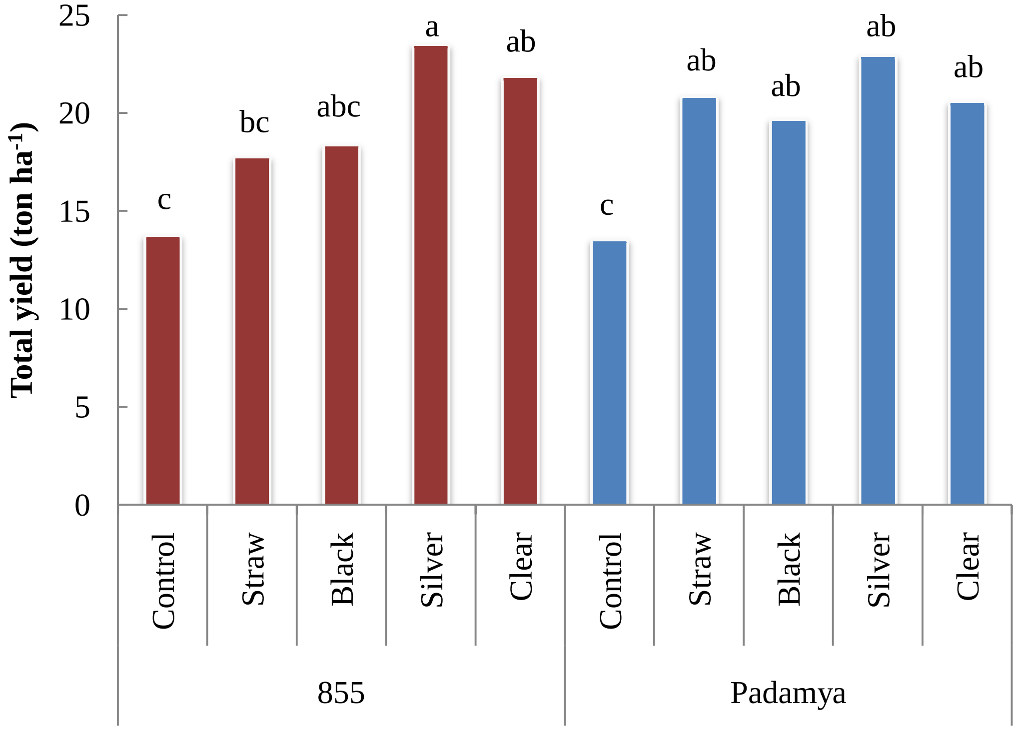


(a) **Effects of different mulching materials and cultivars on number of branches per plant of watermelon**

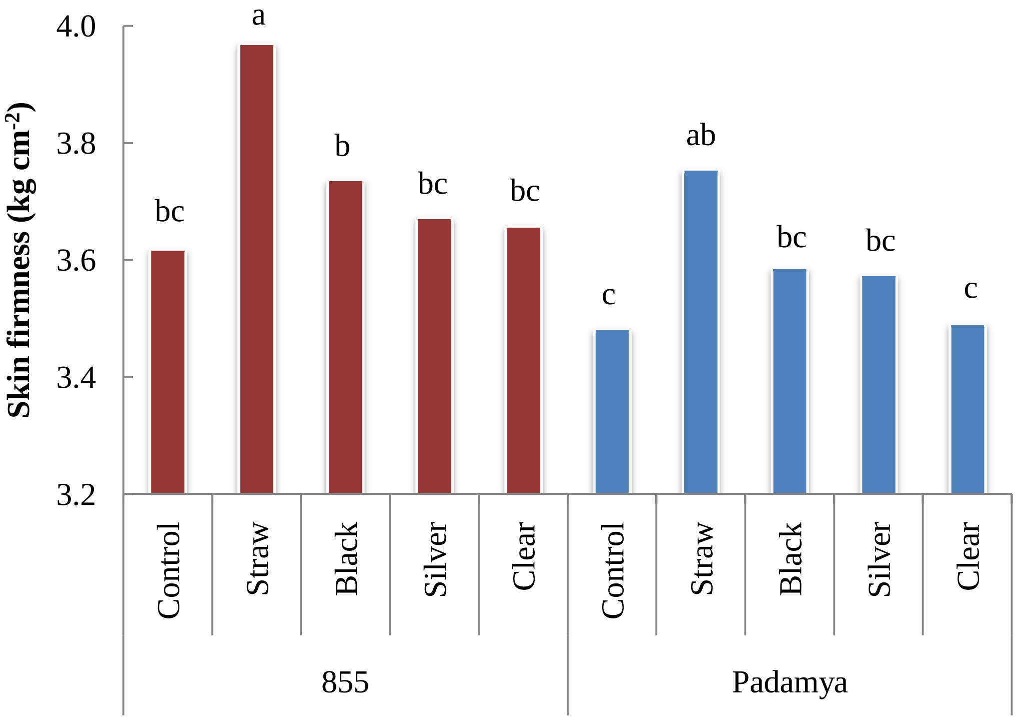


(b) **Effects of different mulching materials and cultivars on single fruit weight of watermelon**

Appendix 8.

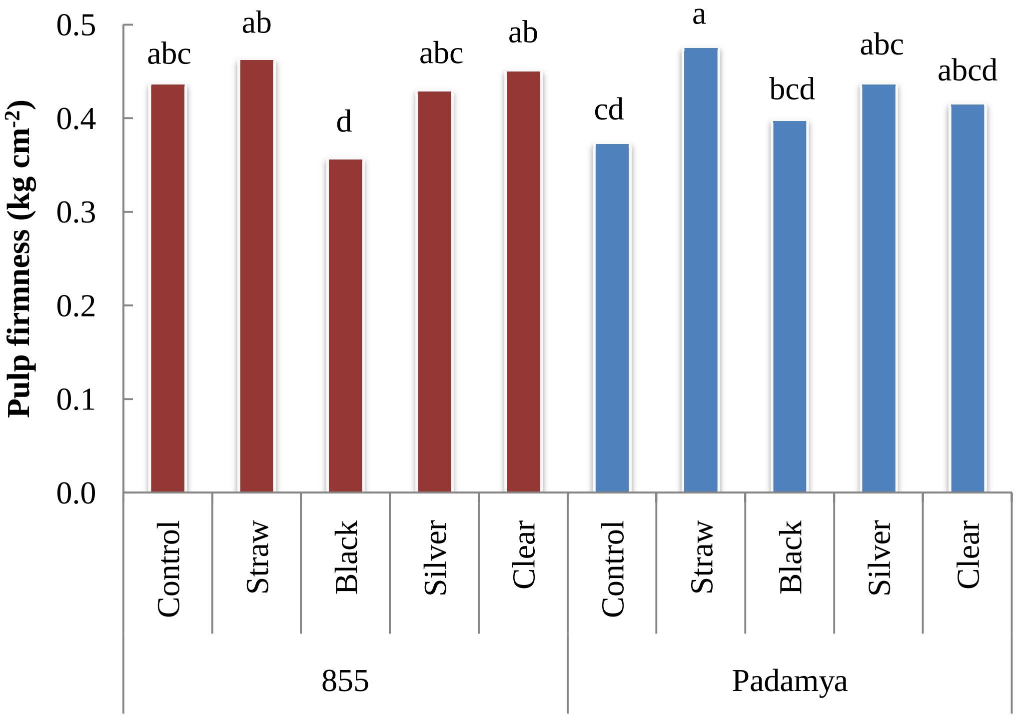


(a) Effects of different mulching materials and cultivars on total fruit yield of watermelon

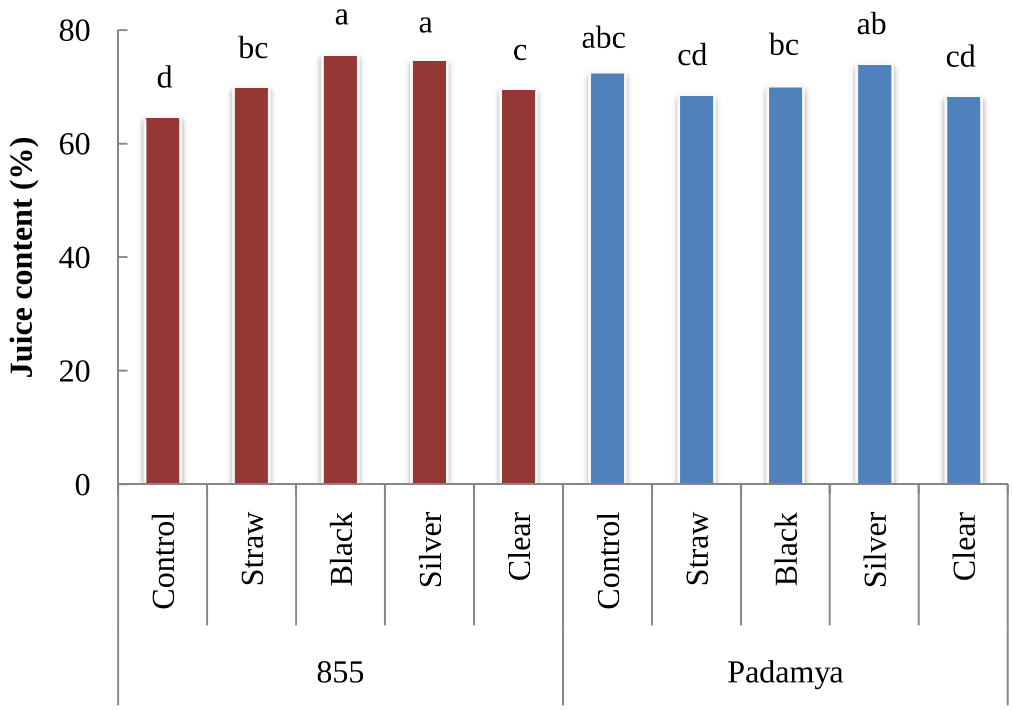


(b) Effects of different mulching materials and cultivars on skin firmness of watermelon

Appendix 9.

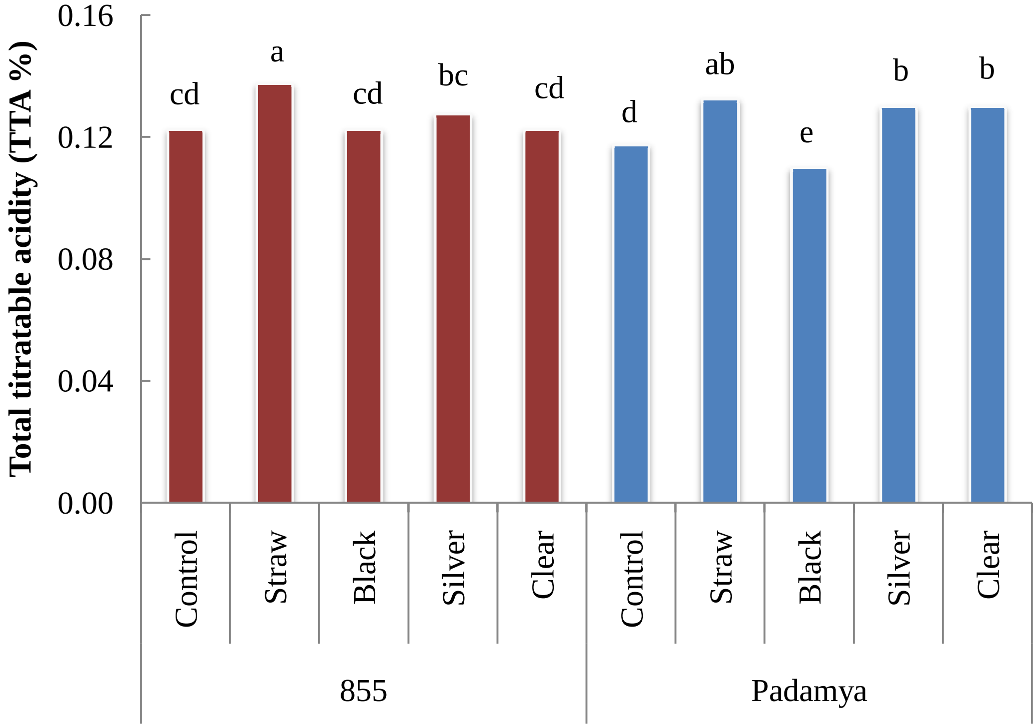


(a) **Effects of different mulching materials and cultivars on pulp firmness of watermelon**

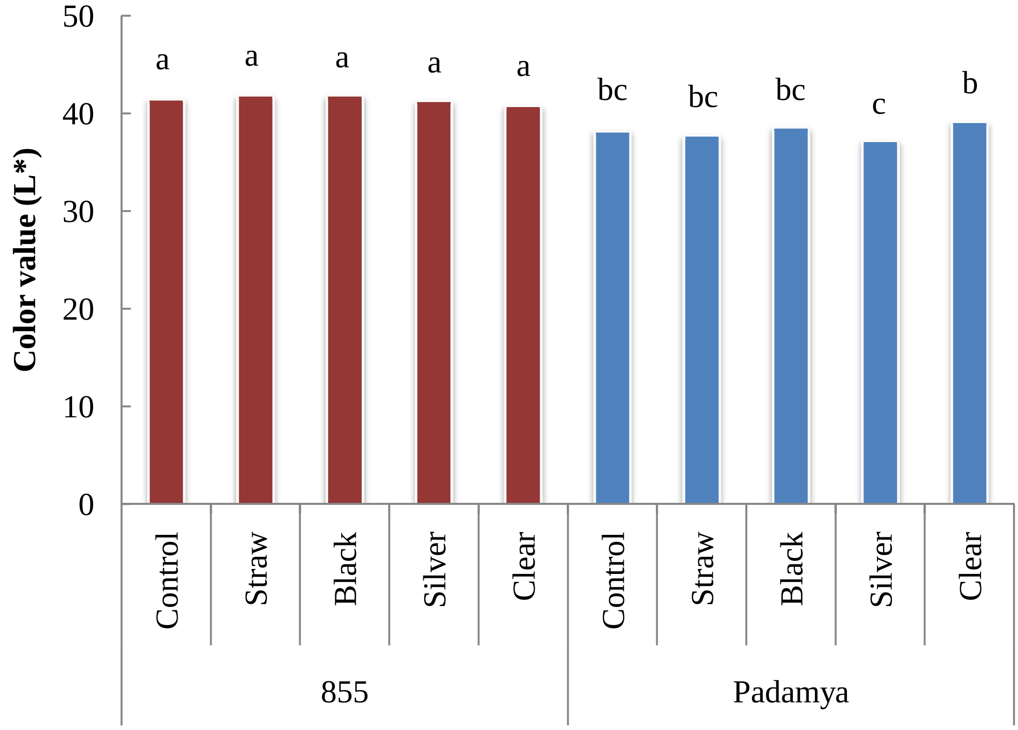


(b) **Effects of different mulching materials and cultivars on juice content of watermelon**

Appendix 10.

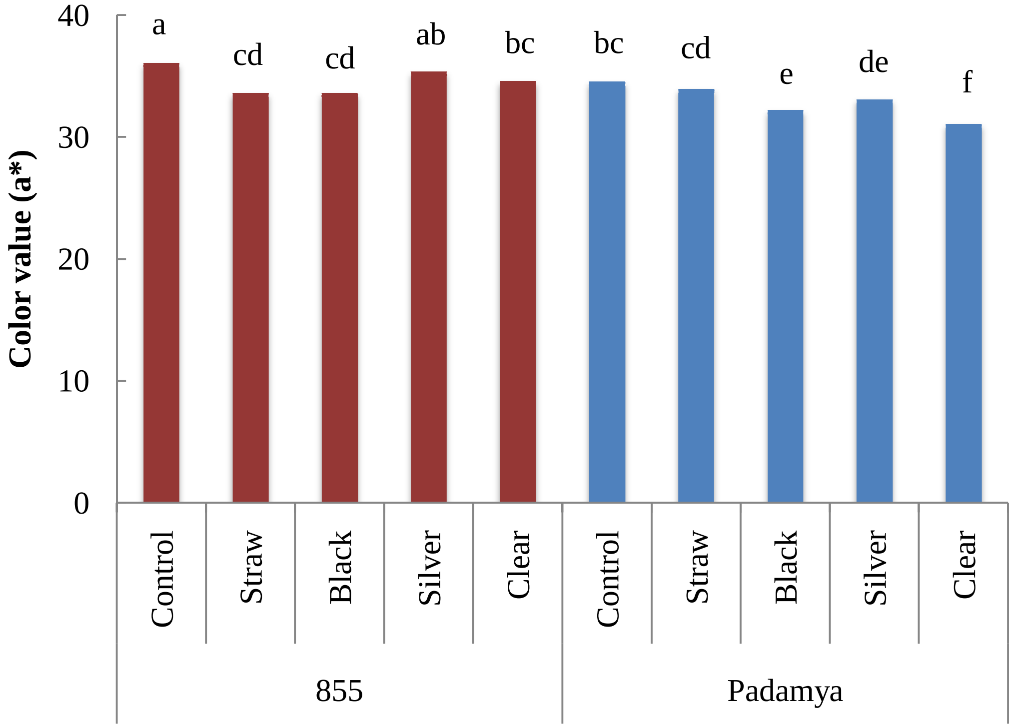


(a) **Effects of different mulching materials and cultivars on total titratable acidity (TTA %) of watermelon**

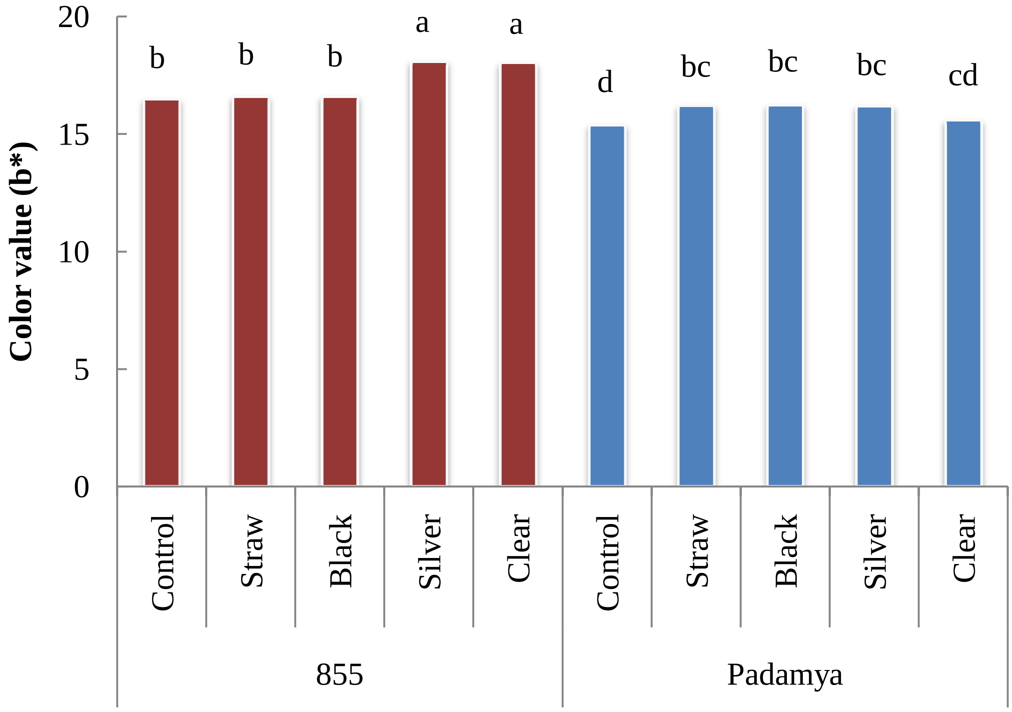


(b) **Effects of different mulching materials and cultivars on pulp color L* value of watermelon**

Appendix 11.



(a) **Effects of different mulching materials and cultivars on pulp color a* value of watermelon**



(b) **Effects of different mulching materials and cultivars on pulp color b* value of watermelon**

Appendix 12. Monthly weather data during the experimental periods

Month	First experiment				Second experiment			
	Year	Rainfall	Temperature (˚C)		Year	Rainfall	Temperature (˚C)	
		Mm	Minimum	Maximum		Mm	Minimum	Maximum
October	2014	114.00	20.0	36.2	2015	83.06	20.0	36.5
November	2014	45.00	14.5	28.5	2015	0.00	15.5	35.5
December	2014	0.00	13.0	35.0	2015	7.11	13.7	34.5
January	2015	0.00	12.5	32.0	2016	0.00	11.5	34.5
February	2015	0.00	12.5	32.0	2016	0.00	12.5	33.4

Source: Department of Agricultural Research (DAR), Yezin

Appendix 13. Germination condition of two cultivars of watermelon

Experiment	Cultivar	Germinated seed by Days				Days to germinate	Germinated Seeds	Total Seeds	Germination %
		5 DAS	7 DAS	9 DAS	12 DAS				
First	855	25	200	318	350	10	350	450	77.78
	Padamya	0	69	256	307	11	307	423	72.58
Second	855	166	391	417	417	9	417	441	94.56
	Padamya	0	18	232	393	12	393	419	93.79

Appendix 14. Nutritional value per 100 g of watermelon

Nutritions	Unit	Value per 100 g
Water	g	91.45
Energy	kcal	30.00
Protein	g	0.61
Total lipid (fat)	g	0.15
Carbohydrate, by difference	g	7.55
Fiber, total dietary	g	0.40
Sugars, total	g	6.20
Minerals		
Calcium, Ca	mg	7.00
Iron, Fe	mg	0.24
Magnesium, Mg	mg	10.00
Phosphorus, P	mg	11.00
Potassium, K	mg	112.00
Sodium, Na	mg	1.00
Zinc, Zn	mg	0.10
Vitamins		
Vitamin C, total ascorbic acid	mg	8.10
Thiamin	mg	0.03
Riboflavin	mg	0.02
Niacin	mg	0.18
Vitamin B-6	mg	0.05
Folate, DFE	µg	3.00
Vitamin A, RAE	µg	28.00
Vitamin A, IU	IU	569.00
Vitamin E (alpha-tocopherol)	mg	0.05
Vitamin K (phylloquinone)	µg	0.10
Lipids		
Fatty acids, total saturated	g	0.02
Fatty acids, total monounsaturated	g	0.04
Fatty acids, total polyunsaturated	g	0.05

Source: USDA National Nutrient Database for Standard Reference, 2016

A B

Plate 4. Amount of seeds in a bag (A) cultivar 855 and (B) cultivar Padamya

A B

Plate 5. Seed characteristic of (A) cultivar 855 and (B) cultivar Padamya

A B

Plate 6. Germination condition of (A) cultivar 855 and (B) cultivar Padamya (3 days after seed soaking)

A B

Plate 7. Seedling of (A) cultivar 855 and (B) cultivar Padamya (9 days after seed sowing)

A B

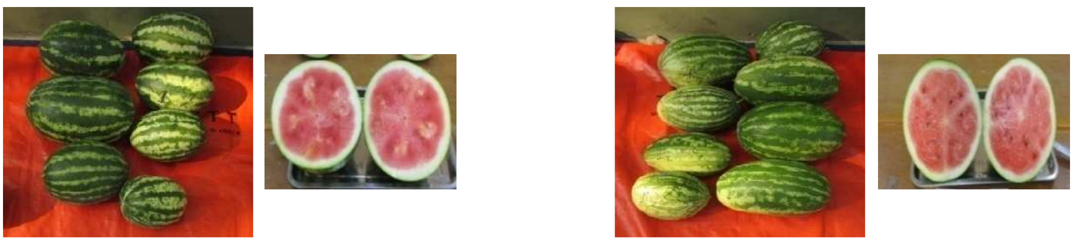
Plate 8. Fruit shape and size of (A) cultivar 855 and (B) cultivar Padamya

Without mulch (Control)

Rice straw mulch

Black polyethylene mulch

Silver polyethylene mulch



Clear polyethylene mulch

Cultivar 855 **Cultivar Padamya**

Plate 9. Fruit shape and pulp color of two cultivars of watermelon

Black polyethylene

Clear polyethylene

Silver on black polyethylene

Yellow polyethylene

White polyethylene

Red polyethylene

Plate 10. Different color of polyethylene