An-Najah National University

Faculty of Graduate Studies

ENHANCE PRODUCTIVITY AND WATER USE EFFICIENCY OF OKRA AND MAIZE BY USING COLD PLASMA TECHNIQUE

By

Shaher Khaldi

Supervisors

Dr. Tawfiq A.H. Qubbaj

Dr. Abdallah Omari

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This Thesis\Dissertation was Defended Successfully on 9/6/2022 and approved by

Dr. Tawfiq Qubbaj Supervisor	Signature
Dr. Abdallah Omari Co-Supervisor	Signature
Dr. Subhi Samhan External Examiner	Signature
Dr. Heba Al-Fares Internal Examiner	Signature

Dedication

To my father and mother who passed during the preparation of this study

To my brothers and sisters

To my wife, sons, and daughters

I give them all my love and appreciation

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Declaration

I, the undersigned, declare that I submitted the thesis entitled:

ENHANCE PRODUCTIVITY AND WATER USE EFFICIENCY OF OKRA AND MAIZE USING COLD PLASMA TECHNIQUE

I declare that the work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: Shahar Mohd Khaldi

Signature:

Date: 9/6/2022

List of Contents

List of Tables

List of Figures

List of Appendices

ENHANCE PRODUCTIVITY AND WATER USE EFFICIENCY OF OKRA AND MAIZE BY USING COLD PLASMA TECHNIQUE

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Shaher Khaldi

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Abstract

Background: The need to increase food productivity pushes toward increasing both the planted area and the unit area's productivity. Cold Plasma treatment is a physicochemical method that can enhance seed germination crop yield and control pathogens held on seed coats.

Amis: This study aims to investigate the effect of cold plasma seeds treatments on some agronomic traits of okra and maize plants, and the effect of cold plasma seeds treatments on crop water needs and irrigation water saving for okra and maize plants.

Materials and methods: The treatment period with cold plasma was 5 minutes for maize, while okra seeds were treated for 5 and 10 minutes. In addition, the assessment of the impact of reducing the irrigation quantity by 50%. The source of plasma treatment was a cold plasma generator device available by Nova plasma company. This experiment was conducted in NARC in Qabatia – Jenin in the north of West Bank in July, August, September and October of 2021.

Results: The results of okra crops show significant differences between plants treated with plasma and those not treated in flowering, SPAD, and total production. The plants treated with plasma show enhanced flowering; consequently, 58 and 60% for the 5 and 10 minutes treatment. While the SPAD value increased by 9%.

In Maize plants, the results indicated that plant diameter; , root moisture content; , plant height and total production have been significantly enhanced. The cold -treated plants have a higher root moisture content of 68% than those not treated 14% for plant diameter 6.48% for plant height; and 20.2% for total production.

In water treatment, reducing the irrigation quantity by 50% showed a significant reduction in the measured parameters between plants irrigated with 50% to those irrigated with 100%. The WUE was enhanced with irrigation compared to raid–fed plants. However, at the same time, WUE in 50% irrigation is higher than 100% irrigation in both crops.

Conclusion: The main conclusion of the results is that cold plasma enhances the productivity and WUE of maize and okra. In Okra, it is recommended to treat the seeds for 10 minutes to achieve higher production

KeyWords: Cold Plasma, Okra, Maize, WUE, yield, growth parameters.

Chapter One

Introduction

1.1 Background

Over the last fifty years, the world population has doubled, from 4 billion in 1974 to around 8 billion nowadays, as well as the food demand. The agricultural development and policies concentrated on the increase of food production. These policies have shifted toward emphasizing external inputs to increase the yield production of food (world meter, 2022).

The world's population growth is causing environmental pollution and increasing agricultural production needs. The world's population will increase to 9.1 billion in 2050, a 34% rise over today's figure. As a result, developing more efficient and sustainable food production methods and adapting them to global climate change is required (FAO, 2020).

Food production needs to be doubled to balance the parallel increase in food demand. The concern is that 1.0 billion people suffer from malnutrition today, and 1.2 billion live in areas under water stress (Bellona, 2009).

The challenges now in the cultivable area which cannot be increased where a potential alternative strategy should be developed to increase crop yield and increase plant growth efficiency and seed survival. (Jiang et al., 2014; de Groot et al., 2018).

Plasma application is a new technology used in industry for tens of years (Cavendish et al., 2017). However, recent interest has been focused on plasma technology applications in biomedical and other disciplines that connect biology and physics (Mohades et al., 2015). The interest in non-thermal plasma applications (also known as "cold" plasma due to its natural neutral gas temperature) continues to grow, as shown by the recent increased number of experiments that applied plasma to plants (Park et al., 2013). Therefore, a modern research sector known as "plasma agriculture" is emerging (Puaˇc et al., 2018).

Since 2010, the articles published on agricultural applications utilizing cold plasmas have increased focusing on significant improvements in plant growth enhancement, seed sterilization and seed germination (Ling et al., 2015). The cold plasma technique can be used in agriculture in two ways: direct application seeds' treatment, where the seeds are involved in the electron collision process inside the device. Such as (DBD) reactor where the seeds are part of the plasma formation process. The seeds play the role of electron receivers (oxidants) . Or indirect, where the electron transformation and movement are inside the device like (CAPJ), and the seeds are not included directly. In the indirect method, noble gas is usually subjected to the electrical field formed by the movement of electrons between cathode and anode (separated by glass or non-electrical conductive material). The subjected noble gas forms an ionized wave. The electrons are received by strong oxidants such as oxygen and the seeds outside the device are subjected to the ionized wave that react with the cells (bacterial or fungal cells). The direct method is commonly applied, and many articles reported the positive impact of this treatment approach in agriculture (Zahoranová et al., 2018). The indirect application method treats water with cold plasma (plasma-activated water) before being applied to crop plants (Yemeli et al., 2020).

The increase of productivity and WUE for the crops is one of the priority goals of researchers around the world. Over the past few years, significant efforts have been made in plant science to increase plant productivity and WUE. However, improving crops' tolerance for biotic and abiotic stresses is limited by the nature of the stress, and it is hard to keep traits stable. (Godoy et al. 2021).

In response to the global food increased demand, the adoption of new agricultural technologies to increase the yield per land unit area is needed. Therefore, improving crop production techniques and enhancing crop resistance to disease is necessary.

Limitations of traditional methods lead to an increased demand for new techniques. One of the methods recently applied by scientists to improve crop productivity is cold plasma technology—nonthermal and environmental friendly, offering many advantages over conventional applied technologies (Flórez et al., 2007).

The influence of magnetic fields as a pre-sowing treatment on various plant species has received increased attention in recent decades. The findings indicate that various types of magnetic fields at various exposure times are also based on the device and the product properties, as reported by (Pietruszewski, 1996). It can enhance seed germination plant growth and increase yield, a feature that positively impacts the producer's profits and results in a more environmental friendly long-lasting agriculture.

This experiment will be based on the preliminary results conducted at NARC headquarter during the summer 2020 and estimated the effect of cold plasma on snake cucumber, squash, cowpea, Okra, and Maize. These results showed a clear and promising influence of the cold plasma seed treatments on biomass and productivity of Okra and Maize.

Therefore, this experiment investigated the impact of cold plasma on the productivity and WUE of Okra and Maize treated seeds grown under the dominant environmental conditions in Jenin district.

1.2 Objectives

1.2.1General Objectives

Enhance productivity and WUE of Okra and Maize using the cold plasma technique.

1.2.2 Specific Objectives

- Investigate the impact of cold plasma seeds treatments on some agronomic traits of okra and maize plants.
- Investigate the impact of cold plasma seeds treatments on crop water needs and irrigation water saving for okra and maize plants.

1.3 Research Question:

The current research hypothesizes that applying the cold plasma technique as a pre-sowing seed treatment will enhance the crop productivity and WUE of okra and maize.

Therefore, The current study focuses on answering the following research questions.:

- Is the crop production and WUE of okra and maize significantly enhanced?
- Does cold plasma contribute to developing a cost-effective, human, and environment-friendly irrigation water management technique and enhance productivity under the irrigated agriculture system.?

Chapter Two

Theoretical Background

2.1 Cold Plasma

As the global demand for food grows very fast, new technologies are needed to produce more food from the limited land and natural resources. Therefore, it is necessary to improve the productivity of crops with the limited available water by implementing new production techniques. Limitations of traditional methods lead to an increase in new technologies. Among these recently increased water use efficiencies is cold plasma technologies. This nonthermal and eco-friendly method offers many advantages over conventional technologies (Thirumdas et al. 2015)

Cold Plasma treatment is a physicochemical method that can enhance seed germination crop yield and control pathogens held on seed coats (Griesser et al., 2011). Thirumdas et al. (2015) reported that seed treatment with cold plasma is a new agricultural high-technique that could increase crop yield. It is different from classical breeding, which utilizes induced mutation. Based on the radiation characterized as non-ionized and are low-level radiation. It could trigger the vitality of seeds without creating mutation; therefore, no breeding risk could occur (Thirumdas et al. 2015). Hertwig et al. (2018) reported that Cold plasma is an ionized gas consisting of UV photons and (RNS, ROS, and RHS), and other compounds.

It is an environmentally safe, modern technology that could increase crop yield (Jiang et al., 2014). A positive impact of low-temperature plasma treatment on the plant growth of different plant crops has been reported (Sera et al., 2012).

Živković, (2004) has demonstrated that the cold plasma treatment can significantly improve *Paulowna tomentosa* seed germination. The cold plasma formed a thin film created by plasma polymerization, which could protect the seeds and promote their germination (Carvalho et al. 2005). Also, Yin Meiqiang (2005) found that magnetic plasma treatment increased germination rate and peroxidase activities in tomatoes.

2.1.1 The Use of Cold Plasma in Agriculture:

For several years, plant physiologists have been interested in the cold atmospheric plasma, which, like bio-stimulants, has the potential to increase plant growth and tolerance to biotic and abiotic stresses (Jiang et al., 2018)

Previous research has demonstrated that plasma discharge combined with the coating of Metarhizium anisopliae and Trichoderma virens seeds provides an alternative to chemical seed dressing (Strejckova et al., 2018). The findings of these studies demonstrated that the use of plasma technology and the combination of plasma and seed bio-treatment has a high potential for value-added processes in seed production technology. Cold plasma applied to seeds has been shown in laboratory and field experiments to enhance germination, and early growth of spring barley, winter rape, and spring poppy seeds with a positive influence on plant production (Strejckova et al., 2018).

According to (Adhikari et al., 2019) plasma-activated liquids, including water, have properties that promote plant growth and development. This is due to the fact that the action of plasma affects the chemical composition of liquids, converting them into mixtures of oxygen and (RONS), which are thought to be signalling facets in different processes of cellular metabolism and facets regulating plant responses to different stresses.

The use of plasma-activated bio-stimulants appears to be an appropriate system for combining the effects of plant nutrition and protection. However, this will not be possible or effective unless the mechanisms underlying plant responses to such treatment are understood (Adhikari et al., 2019).

By converting water into a RONS cocktail, CAP treatment modifies its chemical properties. Plant metabolism, as well as plant growth and development, are significantly influenced by RONs (Mittler et al. 2011).

2.1.2 Effect of Cold Plasma on Seed Germination

Although many researchers have studied the impact of cold plasma on seed germination, the mechanisms of germination enhancement and promoting plant growth are still unclearly identified. Some of the explanations are attributed to a combination of various factors as the following:

- Less water would be required for plant growth, which is essential in countries with limited water resources.
- Changes in wet of seed surface result in water absorption increases (Dobrin et al. 2015).
- Seed dormancy breaking. As nitric oxide is released during plasma, it can break the seed dormancy and lead to faster germination (Šírová, 2011).
- Removal of microorganisms. Cold plasma treatment reduces some bacteria and fungi populations on the seed coat. This treatment has fewer health risks or economic damages (Mitra, 2014)

The mechanisms underlying cold plasma's ability to improve seed germination are still unknown. The initial water imbibition into seeds is critical for seed germination. Previous research has reported an enhancement of seed germination by plasma treatment is due to water uptake increment by seeds (Junior et al., 2016). While Sivachandiran and Khacef (2017) indicated that treated seeds with cold plasma exposed them to a field of electrons, ions, oxygen radicals and UV light. This could lead the seeds to be more hydrophilic and increase seeds' wettability.

Măgureanu et al. (2018) reported that using the fluidized bed DBD generated in air, the effect of nonthermal plasma on tomato seeds resulted in faster seeds germination than untreated seeds. Plasma increased the germination rate slightly and significantly impacted growth parameters. The length and weight of seedlings are significantly greater than those of untreated seeds. Plasma treatment significantly impacts plant roots, which are significantly longer and more branched. Plants grown from treated seeds had a 20–40% increase in weight than control plants (Măgureanu et al. 2018).

Treatments with Cold plasma can effectively promote rooting, root growth, and physiological metabolisms in centipede grass stolon cuttings (Li et al. 2019). With the 300 W producing the greatest stimulating effect. The processes of rooting enhancement may include a rise in stolon cuttings' high water absorption potential, IAA content, and nutrient catabolism during the rooting process. Therefore, cold plasma treatment can be applied to enhance rooting in plant propagation. However, the mechanism of cold plasma in promoting the rooting of centipede grass stolon cuttings is still unclear (Li et al. 2019).

Because of its low cost and flexibility, cold plasma (nonthermal) has piqued the interest of researchers in industrial, biotechnology, and biomedical treatment. Recently, cold plasma has been promoted for agricultural application as an alternative to conventional seed treatment because it is less polluted, low in temperature, and, most importantly, does not harm biological materials (Dhayal et al., 2006).

Previous studies on plasma treatment found that it improved the ability of seeds to germinate and plant development. Živković et al. (2004) demonstrated that cold plasma pre-treatment significantly improved Paulownia tomentosa seed germination by 5 to 30% compared to non-treated seeds. Zhou et al (2011) investigated the impact of plasma voltage on tomato yields and found that tomato yields in any plasma voltage treated group was higher than in untreated seed.

The eggplant seeds cold plasma treatment for 5 minutes is found to be the best treatment time. Although the plasma treatment did not increase the seed germination rate, it improved the growth of seeds (Abu Bakar Sidik et al., 2018). Also, the seed germination and seedling growth of radish, tomatoes, and pepper seeds treated with cold plasma for a short exposure time were improved, while seed germination and seedling growth were inhibited with a prolonged exposure time (Sivachandiran and Khacef 2017).

Some studies have concentrated on the content of biologically active compounds. Vida et al (2017) found that purple coneflower (Echinacea purpurea) seedlings grown after cold plasma treatment had significantly higher vitamin C and phenolic acid levels than the control. Thus, optimizing cold plasma conditions in plasma technology prior to seed/fruit growing is critical for maximum biological efficiency.

Cold plasma seed treatment can be used to enhance germination and vegetative seedling growth. The influences of cold plasma seed treatment for different exposure times (5 and 10 minutes) on Cuminum cyminum L. (cumin) seed germination, growth of the seedling and root morphology, antioxidant defence compounds, photosynthetic pigments and nutrient uptake were studied. Seed exposure for 5 and 10 minutes of Cold plasma improved germination percentage and index by enhancing water imbibition and absorption capacity. After cold plasma seed treatment, cumin seedlings have better vegetative biomass growth, proline level content, and antioxidant defence substances. The Seed pre-treatment for 5 minutes of cold plasma also improved nutrient uptake, root growth, volume and surface area. Thus the photosynthesis rate and related pigment contents and cumin vegetative growth were improved (Rasoolia et al., 2021).

2.1.3 Effect of Cold Plasma on Plant Growth and Production:

Škarpa et al. (2020) found that the PAW application improved root electrical capacitor significantly but had no distinct impact on maize plant vegetative growth. PAW reduced chlorophyll fluorescence parameters such as CO_2 assimilation rate and fluctuating fluorescence of dark-adapted leaves, but it did not affect photosystem II electron transport quantum yield. The dry matter of plants treated with PAW contained significantly higher nitrogen, but the contents of other macro-and micronutrients in maize vegetation were unaffected. On the other hand, Jiang et al., (2018) reported a positive impact of Cold plasma treatment on tomato seed germination and seedling growth. Cold plasma treatment enhanced the accumulation of shoot and root biomass raised leaf area and root activity in tomato seedlings. The root length, surface area, and volume growth were also enhanced, resulting in increased nitrogen and phosphorus absorption by cold plasma treatments on seeds (Jiang et al., 2018).

Cold plasma treatment improved seed germination, plant growth, and yield in peanuts (Ling et al. 2016). Cold plasma treatment improved leaf area, thickness, DW the bearing stage, plant height, stem diameter, root DW, mature stage, and yield under field conditions. The enhancement of chlorophyll content, leaf N concentrations, and their interactions may be associated with promoting plant growth and yield and enhanced germination and seedlings growth the most, with the 120 W treatment having the most significant impact.

Cold plasma treatment increases chlorophyll content and improves photosynthetic capacity as well as superoxidase, peroxidase, and polyphenoloxidase activity (Jiang et al., 2014).

Saberi et al (2019) found that cold plasma treatments increased wheat plant tolerance to haze stress by reducing stomatal size, increasing stomatal density, increasing intercellular CO2 concentration, and improving WUE and relative water content.

Compared to the control, 180-second plasma treatment improved photosynthesis rate, chlorophyll content, and stomatal conductance by 34, 32, and 93%. Grain production increased by 58 and 75 % after 180 seconds of cold plasma treatments compared to non-treated seeds.

Cold plasma also improved the yield of oilseed rape, seed germination and vigour, uniformity of seedling emergence, plant growth, and the 100 W treatment produced the best results. Also, relative conductivity and water uptake were enhanced. The cold plasma treatment increased plant growth parameters such as plant height, stem diameter, shoot and root DW at the seedling, bolting, and flowering stages. Moreover, increased crop yield components as the number of pods per plant and one thousand grain weight. In addition, yield/plant was enhanced by 28.20% (Ling et al., 2018).

Jiang et al. 2018 found that cold plasma treatment improved tomato Nitrogen and Phosphorus absorption rate by stimulating the shoot and root mass, rising leaf area and root activity, and improving root length, surface area, and volume. As a result, cold plasma treatment could enhance tomato nutrient absorption.

Jiang et al. 2014 discovered that treating the wheat seeds with 80 W significantly improved seed germination rate. Plant height, root length, and FW all increased significantly at the seedling stage. Also, the plant biomass was increased at the booting stage. Additionally, the chlorophyll, nitrogen, and moisture content were higher than the non-treated, indicating that cold plasma treatment could enhance wheat growth. In summary, cold plasma has promising applications for increasing wheat yield.

2.1.4 Application of Cold Plasma on Maize Plant:

Cold plasma generators (devices as CAPJ) for corn seed treatment were successfully developed. The results show that a three-minute plasma treatment resulted in excellent corn seed germination and growth. Both plasma-treated and untreated seeds germinate at the same rate of 86 percent, but plasma-treated seeds germinate faster. The plasma-treated seed's average root length was nearly 4 cm higher than the control (Abu Bakar Sidik et al., 2018).

Plasma treatments increased the chlorophyll content of maize leaves. The use of plasma was discovered to frequently activate water. Moreover, except for nitrogen, the leaves

PAW application and increased root electronic capacitors in comparison to the weight of the aboveground biomass and the nutrient contents in its dry matter (Škarpa et al., 2020).

The effects of (PAW) generated by nonthermal air plasmas of transitory spark with water electrodeposition or atmospheric glow discharge on maize (Zea mays L.) and barley (Hordeum vulgare L.) seedlings were studied. Plant growth and physiological responses such as plant length, fresh weight, photosynthetic pigment accumulation and photosynthesis percentage, soluble protein proteins, antioxidative, and DNA damage were measured four weeks after plant growth (Yemeli et al., 2020).

2.1.5 Application of Cold Plasma on Okra:

Kumar et al. (2017) studied the effect of cold plasma treatment on okra seeds. He found that 12 minutes of plasma seed exposure can be used as a beneficial pre-sowing treatment to enhance okra's physiological growth and yield. Cold plasma treatment may boost growth and change the rate of germination.
Some of okra's most variable quantitative characteristics are the number of pods plants, days to flowering, and plant height (Singh and Singh, 1977).

Kumar et al. (2017) reported Cold plasma seed treatment enhanced some agricultural characteristics in okra, including harvesting period, 50 percent flowering time, flower amount, fruit set and weight, and okra produce.

The age of the seed had a significant influence on efficiency and yield of okra. In both one and two-year-old seeds, seeds treated with a 12-minute plasma treatment outperformed other plasma treatments and the control (untreated seeds). As a result, seed treatment with 12 minutes of plasma exposure will be a favorable pre-sowing treatment to improve okra physiological growth and yield (Kumar et al., 2017).

Sedara and sedara (2020) studied the effects of different levels of water implementation on the growth, production, and WUE of okra under irrigation water during the dry period. They discovered that an Okra crop irrigated at 60FIT(complete irrigation treatment) has the highest yield, growth, and WUE, saving up to 40 percent of water to additional land that should be irrigated. Farmers can plant and schedule drip irrigation during the dry season if the drip irrigation and evaporation amounts are recognized.

2.2 Maize

Maize (Zea mays L.), known as corn, represents nearly 72% starch, 10% protein, and 4% fat and has a power density of 365 Kcal/100 g. It is widely grown. Maize is a major annual cereal crop globally; it belongs to the Poaceae family. The word "maize" is derived from the Spanish word "maize," which perfectly represents the plant. Mays is a Taino word that means "life-giver" and Zea is an ancient Greek word meaning "sustaining life." Zea, silk maize, Makka, barajovar, and other names have been given to the plant (Kumar & Jhariya, 2013).

Maize can be turned into a variety of food and industrial goods, such as starch, sugar substitutes, oil, juices, paste, industrial drinking, and fuel ethyl alcohol (Ranum et al. 2014).

Maize has a variety of health benefits. It contains B-complex vitamins, which are beneficial to the skin, hair, heart, brain, and digestion. They are also thought to improve joint motility, which helps to alleviate rheumatoid arthritis symptoms. The occurrence of vitamins A, C, and K, as well as beta-carotene and selenium, aids thyroid and immune function. Potassium is an important nutrient discovered in maize with hypotensive characteristics. Maize silk has numerous benefits. Many countries around the world, including India, China, Spain, France, and Greece, use it to treat kidney stones, urinary tract infections, jaundice, and fluid retention. It may also aid in the reduction of blood pressure, the support of liver function, and the production of bile. It works well as a moisturizer for injuries, swelling, and skin diseases. A silk, roots, and leaves concoction is used to treat bladder problems, nausea, and puking, while a cob concoction is used to treat stomach pains. (Kumar & Jhariya, 2013).

Maize is a great source of phytonutrients, which are essential for health (Kopsell et al., 2009). Maize grains, particularly the yellow variety, contain high carotenoid pigments. Because humans cannot involve in developing flavonoids, they play a significant role in the diet. These pigments are also beneficial in the prevention of cancer. (Michaud et al., 2000).

The consumption of maize complex carbohydrates reduces the risk for breast cancer, arteriosclerosis, and adiposity complications (Rouf Shah et al., 2016).

Maize is an important component of human nutrition because its kernels can be consumed whole, ground into flour, or even used to extract oil.

Exhibiting particular physicochemical properties, the increasing food and other industrial sectors' demands for Corn yield and quality improvements have propelled the agricultural industry.

t is considered a regular feature food in several regions of the world. It is the world's third most important crop after rice and wheat (Sandhu et al., 2007). Worldwide maize production was estimated 967 million tons . Because it has the largest amount possibility of any cereal, it is known as the "Queen of Cereals." The USA is the world's largest maize production, responsible for nearly 35% of worldwide corn production. The cultivated area of maize in the west bank is about 6982 dunom. Each dunom produce 1-1.5 ton (MOA, 2021).

Maize is widely used in cattle feed. Grits, cornstarch, starch, semolina, tortilla chips, and snacks, and breakfast cereals are among the many products. Maize flour is used to make chapattis, or flatbreads, which are popular in a few Northern Indian states (Mehta & Dias, 1999). Because of the growing interest in the Natural compounds and phytoconstituents deduced from maize, as well as their health characteristics, have recently become an important topic of study.

2.3 Okra

Okra (*Abelmoschus esculentus* L.) belongs to the meliaceae and is a heat-tolerant vegetable crop that produces fruits during high summer temperatures. Okra contains modest amounts of vitamins A and C, vitamin b12, folic acid, and nicotinic acid, as well as calcium, potassium, and phosphorus (Eke et al., 2008).

Okra is mainly grown for its capsules, which are eaten fresh, frozen, or dehydrated. It has a high concentration of pectin, vitamins, fiber, calcium, magnesium, and potassium. Okra mycelium is used to either replace or improve blood volume. Oil concentrations in okra seeds range from 20 to 40%, with the large percentage being linoleic acid, a poly - unsaturated fatty acid necessary to human nutrition. Okra is a nutrient-dense food, with roughly half of its caloric intake coming from carbohydrate in gum tissue and pectin, which decreases cholesterol level and thus the risk of heart attack. It also contains a lot of complex carbs, minerals, and vitamins, all of which are beneficial to human health (Mihretu et al. 2014).

According to APEDA, (2011) the total area and production of okra is 1148.0 thousand ha and 7896.3 thousand tons. The primary producers are India, Nigeria, Sudan, Pakistan, Ghana, Egypt, Benin, Saudi Arabia, Mexico, and Cameroon. India has the most land and produces the most, followed by Nigeria. Egypt has the highest productivity (12.5 tons/ha), followed by Saudi Arabia (13.3 tons/ha).

The area cultivated with okra in the west bank is about 5167 dunum (1723 irrigated and 3444 dunum rain-fed). The irrigated okra produces 600-800 kg/du, while the rain-fed produce 200-250 kg/du (MOA 2021). Enhanced genotypes combination of good farming techniques are required to increase okra production and quality.

Population result in growth water demand and a lower average share, which may cause a reduction in agriculture land due to increased social and industrial water needs, climate change, and deterioration in the quantity and quality of water.

Water deficit is amongst the most serious factors that affect crop production and success in agriculture and the ongoing increase in the drought problem caused by global climate change, which impact food production (Ahmed, 2016).

Because agriculture is one of the most water-intensive and demanding industry sectors, substantial attempts are being taken to decrease water intake in farming production by enhancing water management (UNEP 2006).

Okra is a well-known and widely used species of the Malvaceae family that contains two types of fiber: soluble fibers and insoluble fibers. The soluble fiber lowers serum cholesterol and the risk of heart disease, while the insoluble fiber keeps the intestinal track healthy. Okra plant pods should be harvested when they are young; they are ready to pick when about 10 cm long. Okra contributes significantly to healthy human food by supplying carbohydrates, protein, fat, minerals, and vitamins are typically lacking in basic foods (Abid et al., 2002).

Okra demands an adequate supply of water and comparatively moist soil all through the planting season to produce a high production. Okra's flowering and fruiting stages are the most important delicate of the entire growing season. Water shortage at this stage reduces okra yield. Therefore, controlling irrigation is required to increase okra yield (Al-Harbi et al. 2008), because the crop is sensitive to both over and under irrigation.

2.4 C3 &C4 plants physiology

C4 crops are adapted to conditions in which the stomata of the leaves are nearly closed through the day. This occurs at hot temperatures and in direct sun; (partly) closing the stomata in these conditions inhibits water loss. Because C4 plants use a different mode of carbon fixation, they can connect a greater amount of Co_2 than C3 plants. That is, C4 plants require fewer open stomata to obtain the Co_2 levels process of photosynthesis. In contrast to its leaves, which use the C4 photosynthesis process pathway, this same husk encompassing the ear of maize (*Zea mays*) had also spaced evenly vessels with an amount of stems mesophyll cells and has been defined as able to operate an incomplete C3 photosynthetic pathway. (Dengler and Nelson, 1999).

Mncube et al, (2017) indicated that Okra and Maize are C4 plants. Sinclair and Horie, (1989) reported that the C4 photosynthesis process pathway in the maize (*Zea mays*) leaf converts CO2 into sugars, dividing enablers into two distinct cycles within the leaf. The isolation of these two cycles is assisted by two major photosynthesizing types of cells within the leaf: bundle sheath cells, that also bind around the vascular tissue and are constrained by mesophyll cells, forming a wreath-like structure is known as Kranz physiology; and mesophyll cells. Crops, such as maize, have greater chlorophyll content N use efficiency than C3 crops and generally have a lower leaf N content limit for the highest photosynthesis rate; however, photosynthesis's reaction to leaf N uptake is much greater in C4 crops than in C3 crops.

Ghannoum, (2009) indicated that a slight increase in the N content of maize leaf tissue can significantly boost carbon assimilation prices. Moreover, even though Crops dominate in warm, arid regions prone to drought, these have long been believed that C4 photosynthesis is much more resistant to drought than C3 photosynthesis. Besides that, in comparing to C3 crops, a lower photosynthetic rate blended with CO2-concentrating process results in greater WUE in C4 crops. Nonetheless, new research shows that C4 photosynthesis is just as susceptible to abiotic stresses as C3 photosynthesis.

2.5 Plasma in Palestine

In Palestine, there are no previous studies on the impact of cold plasma on plants under the local dominant environmental conditions. Therefore this study is considered the first study carried out in Palestine that examines the impact of cold plasma on plant crops yield and growth. However, cold plasma is a new technology that increases plant productivity and have positive impact on plant physiological processes As a result it enhances WUE (Hatfield and Dold, 2019).

2.6 WUE

Worldwide, it is approximated that 70% of groundwater is used in agriculture to watering 25% of the world's farmland (399 million ha), which deliver % of the world's food, in the same time approximately 50 percent to 70 percent of water is wasted in conventional irrigation methods due to conveyance, evaporation, field application, and distribution losses (Thenkabail et al, 2011). The demand for freshwater resources is increasing, with the increase of population and the changes in livelihood standards proportionally. This trend is likely to continue as the world's population grows, resulting in increased demand for food and fiber, as well as the predicted negative effects of climate change. There is also a growing awareness of the importance of supplying sufficient water to maintain other ecosystem systems there appears to be broad agreement that watered agriculture, in general, will require less water in the future.

The agricultural sector consumes approximately 83 percent of water, Drip irrigation and efficient water management practices can help to reduce these losses (Dahiya et al., 2005).

An increased effectiveness in using limited water resources is required, a concept is known essentially as WUE or simply irrigation efficiency.

WUE is frequently defined from an engineering standpoint to use a volume or hydrogeology strategy, this is defined as the proportion of irrigation that the plant uses productive way or advantageous. When discussing field-scale irrigation water management, this definition is most commonly used. It should be noted, however, that WUE can also be evaluated at the watershed or alluvium scale (Qureshi et al., 2011).

On the other hand, irrigation WUE can be viewed from a plant physiological standpoint, particular, the yield or financial impact of a watered crop or pasture is compared to the quantity of water actually occurred by the crop or pasture. Throughout fact, rather than WUE, this is usually referred to as irrigation water productivity (Han et al., 2018).

WUE relates to the quantity of carbon absorbed as biomass or grain produced per unit of water used by the crop (WUE). Many of the most challenging questions is how plants will react to climatic changes, with temperature, rainfall, and carbon dioxide (CO_2) levels all influencing their WUE. WUE tends to increase at the canopy level until the leaf is revealed to temperatures above the optimal temperature for growth (i.e., heat stress), where at point it begins to decrease. Water deficiencies (drought stress) cause varying WUE reactions in leaves. The physiological parameters controlling CO2 and H2O gradients are directly related to WUE response at the leaf level, such as leaf: air vapor pressure deficits between the leaf and the air that surrounds it. A few techniques exist for checking genetic information for improved WUE under climate projections. The dynamics of crop water use and biomass production must account for soil moisture removal rate, water vapor from the leaves, and growing season pattern as we keep moving from the leaf to the canopy. WUE at the leaf level can be enhanced by adding practices such as crop residue management, mulching, row spacing, and irrigation that decrease soil evaporation of water and deflect more water into transpiration. Climate change will have an impact on growing plants, but we can enhance WUE through different crops and cultural traditions to mitigate the effects of climate change (Hatfield and Dold, 2019).

WUE is the result of a wide range of plant and environmental operations that work together over the life of a crop to determine both yield and water use. (Naroua et al., 2014)

In addition, water is a significant factor restricting crop output in arid regions Two new agricultural water management techniques that have gained popularity in crop production are drip irrigation and plastic film mulching (Zhang et al 2018).

Increasing the WUE by adjusting irrigation frequency to match regional evapotranspiration. Related management techniques could be implemented in the other arid areas with similar soil and climatic factors (Zhang et al 2018).

Palestine is suffering from severe and continuous water shortage. This shortage is growing annually. At the same time, the Palestinians suffer from the deny of access to the water sources where they have access only to 15% of the Palestinian water resources. Agriculture sector accounts only for 45% of 145 MCM of water used by all sectors (MOA, 2014).

On the other hand, the weak management of available water increases the water dilemma in Palestine. The farmers are using time-based irrigation rather than a volumetric base. The Irrigation efficiency is estimated to be around 50% (Alhaj Hussein and nofal, 2015). For the above, enhancing WUE for the crops is a crucial step in Palestinian development.

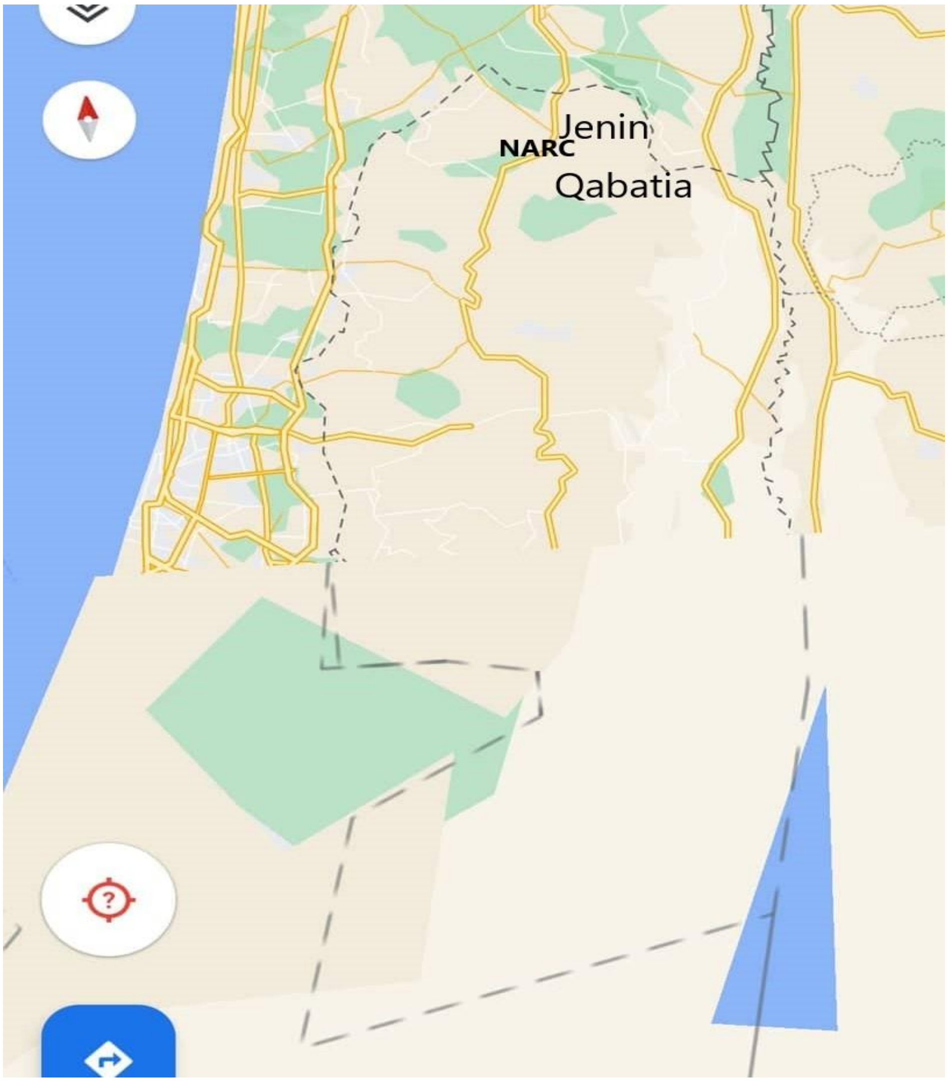
Chapter Three

Methodology

The experiment was conducted at the (NARC) station field located in Jenin- Qabatia.it was carried out during the summer of 2021. The soil in the experimental location is deep, the texture is clay loam, with more than 4 m depth.

Figure 3.1

The Experiment A rea on NARC staion field in Jenin Qabatia



3.1 Experimental Design and Layout

The experiment has split-plot design with three replicates for each treatment, as shown in figure (3.2)

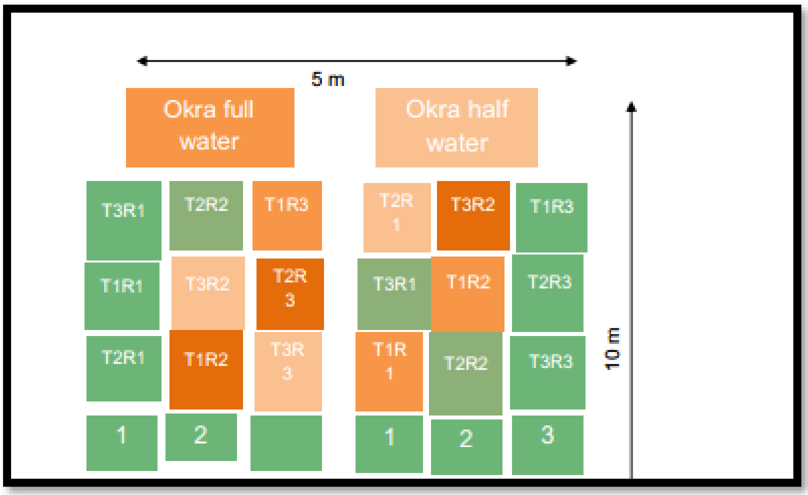
Main plot (irrigation schedule):

Treatmetn1:Non Stressed irrigation (100% of the crop water requirements)

Treatment 2:Stressed irrigation (50% of the crop water requirements) (100 m^3/du)

Figure 3.2

Experiment Design on Okra



Sub plot (cold Plasma seed treatment):

- Treatment1: 5 minutes plasma treatment.
- Treatment 2: 10 minutes plasma treatment.
- Treatment 3: control (without cold plasma treatment).
- Each Treatment consisted of three replicates witch distribution randomization (R1,R2,R3)

Maize scheme:

The experiment is designed in Figure (3.3) as

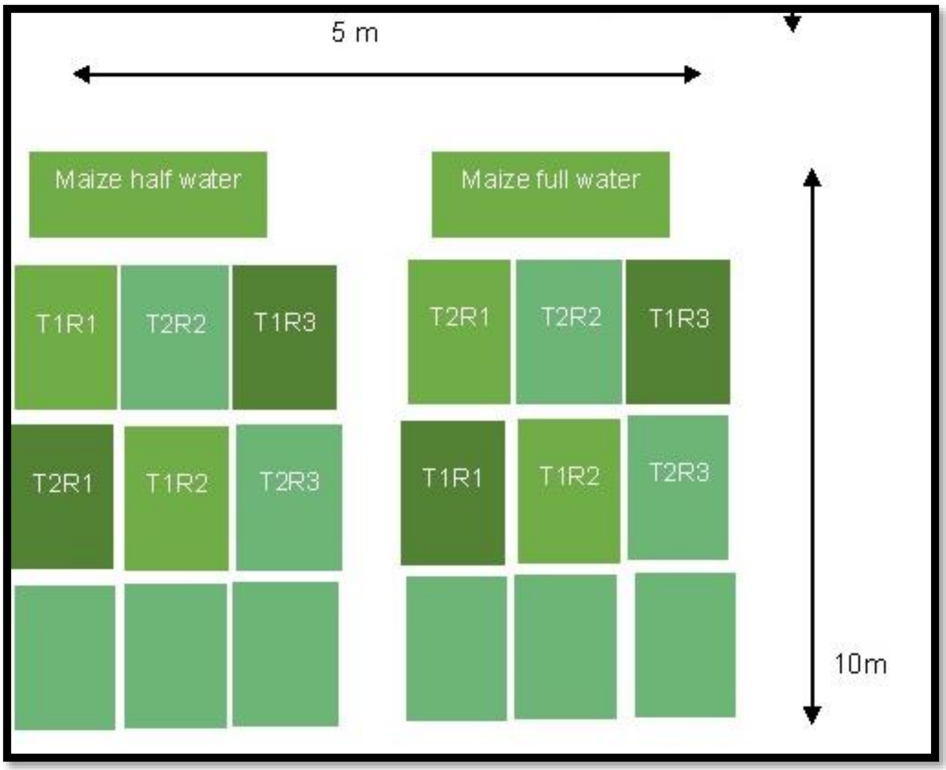
Main plot (irrigation schedule):

Treatmetn1:Non Stressed irrigation (100% of the crop water requirements)

Treatment 2:Stressed irrigation (50% of the crop water requirements) (100 m^3/du /season).

Figure 3.3

Experiment Design on Maize



Sub plot (cold Plasma seed treatment):

- Treatment1: 5 minutes plasma treatment.
- Treatment 2: control (without cold plasma treatment).
- Each Treatment consisted of three replicates witch distribution randomization (R1,R2,R3)

3.2 Cold Plasma Treatments

The experiment is based on the use of Cold plasma technique. The seeds are subjected to non–thermal plasma (nonionized waves) using a cold plasma generator device manufactured by Nova plasma company (Hevel Megiddo, 2021) . The device was made up of two parallel plates that were linked to the output of the radiofrequency power source. Each plate had a metal suspension shell that was filled with insulating materials between the plate and the metal shell. The distance between the two polar plates ranged from 1.5 to 10 cm. When the seed was transported through the cavity between the two polar plates, it was exposed to non-ionizing radiation (Jiang et al., 2014).

Two crops (Okra and Maize) are planted in the open field after receiving the plasma treatment.

Sweet Maize seeds of Royal ""F1 hybrid ""variety. Okra crop variety is a local variety used by the farmers. The treatment was following the standard protocol of Kumar et al. 2017 and Abu Bakar Sidik et al. 2018.

The cold plasma treatment conditions for seeds (running parameters and conditions) are:

- Plasma configuration – Two parallel plates (DBD configuration).
- Plasma gap ~3cm
- Plasma gas – Air.
- Pressure = -98.5mB
- frequency ~ 700KHz

3.2.1 Okra Seeds Treatment

Okra Seeds received two cold plasma treatments. Each consisted of three replicates (R1,R2,R3).

T1 is 5 minutes plasma treatment

T2 is 10 minutes plasma treatment.

3.2.2 Maize Seeds Treatment

Seed treatment with plasma for 5 minutes. With three replicates (R1,R2,R3).

3.3 WUE

To investigate the interaction effects of cold plasma on water saving on the cold plasma treated okra and maize crops. Two levels of irrigation water were applied. The first experiment set was irrigated with 100 % of the crop water requirements. The second experiment set received 50 % of the water requirements for each okra and maize cold plasma treated and non-treated (control).

The crop water requirements for experimental period of the two crops were identified following the modified Penman – Montieth equation of FAO. The calculations were carried out via FAO – CROPWAT software.

Monthly climatic data of Qabatia for the growth period is used for the calculations.

The annual water requirements are:

- 400 m^3/ du for Maize and 196 m^3/du for Okra.

The irrigation net is a drip irrigation with 4 L/h drippers.
WUE was calculated based on the following formula (Bramley et al, 2013):

WUE = GY/ Total water used

Where:

WUE is (kg/m^3);

GY is Fruit Yield (kg) from given irrigation ,

and Total Water used (m^3) for each irrigation treatment.

3.4 Okra Experiment

In total, 600 okra seeds were selected randomly, treated with cold plasma and planted in a split-plot design (with three replication). The treatments were:

> it was 7 days irrigation interval for okra. the irrigation started with 400 l/du for full irrigation and 196 l/du for deficit irrigation water for four weeks and then 800 l/du for full irrigation and 400 l/du for deficit irrigation for four weeks and 1200 l/du for full irrigation and 600 l/du for deficit irrigation for four weeks.

3.5 Maize Experiment

In total, 600 Maize seeds were selected randomly, treated and planted in a split-plot design (with three replication). The treatments were:

Sub plot (cold Plasma seed treatment):

- Treatment1: 5 minutes plasma treatment.
- Treatment 2: control (without seed treatment with plasma).

Main plot (irrigation schedule):

Two treatments for this factor:

- Treatmetn1:Full irrigation (100% of the crop water requirements) (400 m^3/du /season.)
- Treatment 2:deficit irrigation (50% of the crop water requirements) (196 m^3/du /season).
- The irrigation started with 400 l/du for full irrigation and 200 L/du for deficit irrigation water during 3 days irrigation interval for maize for three weeks and then 1200 l/du for full irrigation and 600 l/du for deficit irrigation water for three weeks and 2000 l/du for full irrigation and 1000 l/du for deficit irrigation for seven weeks .

3.6 Parameters

To achieve the study objectives different parameters of plant growth, production and yield components were considered. These parameters are:

3.6.1 Plant Physiological Parameters

Plant samples were collected to measure the following parameters:

.- RWC.
- Relative chlorophyll using Soil Plant Analysis Development (SPAD).
  Konica Minolta, Tokyo, Japan. Chlorophyll Meter – SPAD Plus.
- Plant Height.
- Stem Diameter.
- Leaves Moisture Contenowth Parameters

The plants growth parameters were collected at the end of the experiment as plant height, fresh and DW, stem diameter, leaf and root moisture content, and crop production.

3.7 Statistical Analysis

The results were statistically analyzed by Genistat program V12 to calculate the means, standard deviation and Anova tables.

3.8 Seed Sowing and Germination:

The sowing of the seeds in nursery was on 30 June 2021. The transplant was incubated for two weeks.

Figure 3.4

The plants in the nurse 10/7/2021

Figure 3.5

the plants during vegetative growth 20/8/2021

Chapter Four

Result and Discussion

The results of this study are grouped according to the crop,where the results of okra are separated from maize. The last part of the results are the water use efficiency.

4.1 Okra Crop

The results of okra crop are presented as

4.1.1 Effect of Cold Plasma on Okra Physiological Parameters

4.1.1.1 Effect of Cold Plasma on RWC:

No Significant difference ($P \leq 0.05$) was found due to different plasma treatments on RWC content in September. Also, no significant difference ($P \leq 0.05$) was found in September for water use treatment on RWC content. whereas significant differences ($P \leq 0.05$) were found due to plasma treatments on RWC content in October, and also significant difference ($P \leq 0.05$) was found for water use treatment on RWC content in October.(Table 4.1).

Table 4.1

A analysis Variance of RWC Content in Okra

		RWC/September		RWC/October	
Source of Variation	d.f.	m.s.	F pr.	m.s.	F pr.
Plasma	2	23	0.22	95.5	<.001
Water	1	31.5	0.15	262.8	<.001
Plasma. Water	2	3.1	0.80	1	0.67
Residual	12	13.3		2.6	
Total	17				

significant differences between treatments at $p < 0.05$ level. m.s: mean square, Fpr.: F. probability, d.f. : degree of freedom (n-1), Residual: the difference between the observed value and the mean value that the model predicts for that observation.

The results of RWC in okra showed no significant difference ($P \leq 0.05$) between the treatments and the control in September, while in October, there were significant differences.

During October, the average leaf RWC content was higher due to seeds plasma treatments for 5 or 10 minutes compared to control (80%, 82%, and 74%, respectively). In September, the average leaf RWC content was higher in seeds plasma-treated plants compared to control (69%, 70%, and 67%, respectively). The average leaf RWC in the non-stressed water treatment during October and September was higher with 82%, 70% than the stressed water treatment with 75%, 67%. (Table 4.2)

The peak of vegetative growth as indicated by (Mohammed et al, 2022) is after 50 – 60 days of planting. This occurred in September. While in October, it is in the mid stage (Ma et al, 2018). the RWC is affected by any water stress, and the plasma could reduce this effect. This resulted in enhanced RWC for plants treated with plasma are agreed with the results found on winter wheat treated with cold plasma under stress haze conditions, where Haze stress had several adverse effects on wheat plant physiological and yield. By reducing stomatal size, increasing stomatal density, increasing intercellular CO2 concentration, and improving water use efficiency and relative water content, cold plasma treatments increased tolerance to haze stress RWC, chlorophyll, and WUE in wheat plants (Saberi et al., 2019). Wheat is a C3 plant, while okra is a C4 plant (Mncube et al, 2017), therefore it has higher water use efficiency. The results indicate that okra response to plasma is significantly increase RWC

Table 4.2

The mean of RWC Content in Okra

Treatment	RWC/September%	RWC/October%
Plasma (5 min seed exposure)	68.5ns	79.6ab
Plasma (10 min seed exposure)	70.4ns	82.1a
Control	66.5ns	74.2b
Water Use		
Stressed Water (98 m^3/du /season)	67.2ns	74.8b
Non Stressed Water (196 m^3/du /season)	69.8ns	82.4a
CV	5.3	2.1
LSD plasma	4.5	2
LSD water	3.7	1.6

Different letters indicate significant differences (a) and (b) tests at $p < 0.05$ level and (ns) not significant. CV: Coefficient of Variation. LSD: Least Significant Difference.

4.1.1.2 Effect of Cold Plasma on (SPAD) Parameter

the SPAD meter measures the difference between the transmittance of a red (650 nm) and an infrared (940 nm) light through the leaf, generating a three-digit SPAD value (Uddling et al., 2007).

Significant differences (P≤0.05) were found due to plasma treatment in SPAD and also Significant differences (P≤0.05) was found for water use treatment. (Table 4.3)

Table 4.3

Analysis of Variance of SPAD in Okra

		SPAD%	
Source of Variation	d.f.	m.s.	F pr.
Plasma	2	0.002	<.001
Water	1	0.001	0.007
Plasma. Water	2	0.0001	0.418
Residual	12	0.0001	
Total	17		

The average of plasma (5+10 min seed exposure) treatment in SPAD was higher with 65%,64% than the control with 61%. also the average of non-stressed water treatment in SPAD was higher with 65% than the stressed water with 63%. (Table 4.4).

Cold plasma treatment increases chlorophyll content and improves photosynthetic capacity as well as superoxidase, peroxidase, and polyphenoloxidase activity (Jiang et al. 2014). Jiang et al. 2018 found that cold plasma treatment improved tomato Nitrogen and Phosphorus absorption rate by stimulating the shoot and root mass, rising leaf area and root activity, and improving root length, surface area, and volume. As a result, cold plasma treatment could enhance tomato nutrient absorption.

In the same time the quantity of water have significant impact on chlorophyll content. This effect is caused by the reduction in stomatal aperture as reported by (Zhu et al, 2016). The water stress cause stomatal closure, and stomatal resistance to CO_2 exchange, which affects the chlorophyll content. The results of this study agree with the findings of (Enneb et al, 2021), who reported a reduction in chlorophyll content in Faba bean (vicia faba L.) plants due to water stress.

Table 4.4

The mean of SPAD in Okra

Treatment	SPAD (%)
Plasma (5 min seed exposure)	65a
Plasma (10 min seed exposure)	64ab
Control	61b
Water Use	
Stressed Water (98 m^3/du /season)	63b
Non Stressed Water (196 m^3/du /season)	65a
CV	2.1
LSD plasma	0.017
LSD water	0.014

4.2 Plant Growth Parameters

4.2.1 Effect of Cold Plasma on Plant Height :

The analysis of variance revealed that no significant difference (P≤0.05) was found for plasma treatment on plant height, whereas a significant difference (P≤0.05) was found in plant height due to different water treatments (Table 4.5).

Table 4.5

Analysis Variance of Plant Height in Okra

		Plant Height (cm)	
Source of Variation	d.f.	m.s.	F pr.
Plasma	2	28.5	0.18
Water	1	648	<.001
Plasma. Water	2	3.4	0.79
Residual	12	14.4	
Total	17		

The plants irrigated with 50% of the water requirements could suffer water stress during growth; therefore, the plant height has been affected, as shown in Tables 8 and 9. significant differences between 50% and 100% irrigation water amount were observed.

The average plant height of cold plasma treatments was higher (66 cm, 65cm) than the control (62cm). The average of the non-stressed water was higher (71cm) compared to the stressed water (59 cm). (Table 4.6).

The results show no significant differences between plants with plasma treatment and non-treated plants. This is explained by (Škarpa et al. (2020), who found that plasma affected the stomatal activity, leaf area, and CO_2 assimilation but didn't affect the above-ground biomass. And also Ling et al.(2016) reported that Cold plasma treatment improved plant height.

Jiang et al. 2014 discovered that Plant height, increased significantly at the seedling stage of wheat. Also, the plant height, leaf area, and leaf thickness of the treated plant were increased at the booting stage. Some of okra's most variable quantitative characteristics are the number of pods plants, days to flowering, and plant height (Singh and Singh, 1977).

Table 4.6

The mean of Plant Height (cm) in Okra

Treatment	Plant Height (cm)
Plasma (5 min seed exposure	66.1ns
Plasma (10 min seed exposure)	65.9ns
Control	62.2ns
Water Use	
Stressed Water (98 m^3/du /season)	58.8b
Non-Stressed Water (196 m^3/du /season)	70.8a
CV	5.9
LSD plasma	4.8
LSD water	3.9

4.2.2 Effect of Cold Plasma on Stem Diameter Parameter

No Significant differences ($P \leq 0.05$) were found for plasma treatment in stem diameter, whereas Significant differences ($P \leq 0.05$) were found in different applied irrigation water amount treatments. (Table 4.7).

Table 4.7

Analysis of Variance of Stem Diameter in Okra

Source of Variation	d.f.	m.s.	F pr.
Plasma	2	0.44	0.10
Water	1	0.71	0.05
Plasma. Water	2	0.007	0.95
Residual	12	0.160	
Total	17		

The average of plasma (5+10 seed exposure) for stem diameter with 6.37+6.16 cm was higher than the control with 5.83 cm. and also the average of non-stressed water treatment of stem diameter was higher with 7cm than the stressed water with 6cm. (Table 4.8)

According to (Henselová et al., 2012) the plasma treatment increased leaf photosynthesis. This leads to increased phloem sap movement and plant growth, resulting in maximum seed fill and the final yield. Therefore, the impact resulted in more active leaves rather than stem diameter increase. While Ling et al. (2016) found

Cold plasma treatment improved stem diameter at the mature stage.and Jiang et al. (2014) discovered that Plant height in wheat, increased significantly at the seedling stage, and also increased at the booting stage.

Table 4.8

The mean of stem diameter in Okra

Treatment	Stem Diameter cm
Plasma (5 min seed exposure)	6.3ns
Plasma (10 min seed exposure)	6.1ns
Control	5.8ns
Water Use	
Stressed Water (98 m^3/du /season)	5.9b
Non-Stressed Water (196 m^3/du /season)	6.3a
CV	6.6
LSD plasma	0.50
LSD water	0.41

4.2.3 Effect of Cold Plasma Leaf Moisture Content

No Significant differences ($P \leq 0.05$) were found for plasma treatment in vegetative moisture and also no Significant differences ($P \leq 0.05$) was found for water use treatment.(Table 4.9)

Table 4.9

Analysis of Variance Leaf Moisture Content in Okra

	Leaf Moisture Content %		
Source of Variation	d.f.	m.s.	F pr.
Plasma	2	48.1	0.44
Water	1	14.6	0.61
Plasma. Water	2	30.1	0.59
Residual	12	54.9	
Total	17		

The leaves water content is neither directly affected by the plasma treatment nor by water quantity. The reduction in water quantity didn't reach severe levels that stomata is closed, The plants were able to transfer water to leaves, which means the leaves content of water is not affected but RWC which reflects the total stress is affected as explained by (Ma et al, 2018) . The plasma has affected the plant activities, but has no direct effect on water content, these results agree with (Škarpa et al, 2020).

4.2.4 Effect of Cold Plasma on Roots Moisture Content Parameter

The root moisture was calculated based on the difference between wet and DW according to:

$$\text{Root Moisture Content} = \frac{FW-DW}{DW} * 100\%$$

The results indicated that no significant differences ($P \leq 0.05$) were found for plasma treatment in roots moisture content, and also, no significant differences ($P \leq 0.05$)) were found for water use treatment. (Table 4.10).

Table 4.10

Analysis Variance of Roots Moisture Content in Okra

		Roots Moisture %	
Source of Variation	d.f.	m.s.	F pr.
Plasma	2	29.4	0.29
Water	1	23.8	0.31
Plasma. Water	2	4.9	0.80
Residual	12	21.8	
Total	17		

The roots water content is not affected by plasma treatment part of the plants which has improved the root absorption, but the water content is not directly affected as reported by (Jiang et al. 2018).

4.3 Yield and yield Components Parameters

4.3.1 Effect of Cold Plasma on Yield:

Significant differences ($P \leq 0.05$) were found for plasma treatment in production, and also Significant differences ($P \leq 0.05$) were found for water use treatment. (Table 4.11) in appendix a.

The results show that yield of plants with plasma treatment has significantly increased depending on the period of seed exposure to plasma. The yield production was 21.5, 23 g/ plant for 5 and 10 minutes plasma treatment consequently, while plants with no plasma treatment average yield was 17.5 g/ plant.(Table 4.12).

Regarding the irrigation quantity, the plants which received irrigation showed significant increase in production. The production was (21.7 g/plant), (19.5 g/plant) for plants with 100% and 50% irrigation consequently.

This increase in yield production results from both, satisfying the plant water requirements (Adejumo et al, 2018; Sedara and Sedara, 2020) and the effect of plasma treatment as reported by (Škarpa et al, 2020), Cold plasma treatment was found to stimulate seed germination, plant growth, and yield in Okra. These beneficial effects of cold plasma treatment could be attributed to improvements in the seeds' wettability, permeability, and water uptake. As a result, cold plasma treatment can be used to increase the growth and production of Okra.

Ling et al. (2016) found that Cold plasma treatment improved yield under field conditions. And also Ling et al. (2018) reported that The cold plasma treatment increased crop yield such as pod numbers per plant and 1000 seed weights. In addition, yield / plant enhanced by 28.20% (Ling et al., 2018). Kumar et al. (2017) reported that cold low-pressure plasma seed treatment in okra improved some agronomic attributes such as harvesting time, fruit number and weight, and okra yield.

The effect of water quantity on yield is described in many studies. However, Ma et al (2018) reported the enhanced yield responding to water. Enneb et al (2021) reported the negative effect of water stress on production. The results agree with these reports. In addition it agrees with the findings of Zhang et al (2018).

4.3.2 Effect of Cold Plasma on Flowering in Okra

The cold plasma seed treatment affected flowering in Okra. Where the number of flowers has increased significantly, the results indicated a significant ($P \leq 0.05$) increase in flowering during September 2021 and October 2021, whereas no significant differences ($P \leq 0.05$) were found for different irrigation water amount treatment in September and also in October 2021 . (Table 4.13) in appendix a.

The impact of plasma treatments, either for 5 minutes plasma seeds treatment or 10 minutes plasma seeds treatment on flowering intensity in September was significantly higher with 60 and 58%, respectively, than the control with 53 %. In October, the average plasma (5+10 min seed exposure) treatment showed higher flowering with 86+85% than the control with 82%. non-treated plants as plasma-treated plants have significant differences. But at the same time, the changes in irrigation quantities didn't significantly affect the flowering even though the average flowering for plants having non-stressed water was 58% compared to 56% for plants with stressed water quantity. In October, the flowering was higher with 86% for plants with non-stressed water than

83% for plants with stressed water quantities. As the results showed, the flowering is not affected significantly by changing irrigation quantities. (table 4.14) in appendix a.

Plants treated with plasma have enhanced N concentrations as indicated by Ling, L et al (2016). In addition to nitrogen, phosphorus absorption is enhanced by plasma treatment, as Jiang et al. (2018) reported. The enhanced absorption of macro nutrient positively influences flowering. This was confirmed by (Jiang et al. 2018), who examined the shoot root relation and found enhancement of phosphorus absorption, which is the major factor affecting the flowering. The enhanced nutrient absorption increased the flowering, as shown in the results. Some of okra's most variable quantitative characteristics are the number of pods plants, days to flowering, and plant height (Singh and Singh, 1977). Kumar et al. (2017) reported that cold low-pressure plasma seed treatment in okra improved some agronomic attributes such as harvesting time, 50% flowering time, flower number, fruit number and weight.

The flowering and fruiting stages of okra are the most delicate of the entire growing season. Water shortage at this stage reduces okra yield. Therefore, controlling irrigation is required to increase okra yield (Al-Harbi et al. 2008), because the crop is sensitive to both over and under irrigation.

4.4 Results of Maize Crop

4.4.1 Plant Physiological Parameters

4.4.1.1 Effect of Cold Plasma on RWC Content:

In RWC, no significant differences ($P \leq 0.05$) were found due to the plasma treatment. But at the same time, decreasing the irrigation quantity has significantly affected RWC content in August. In September, the differences are not significant as a result of water (Table 4.15) in appendix a.

The average of plasma treatment in RWC content in August and September was higher with 83%, 72% than the control with 81%, 67%. The average of non-stressed water in RWC content in September and October with 90%, 73% were higher than the stressed water supplied with 74%, 66% (Table 4.16) in appendix a.

The results of RWC in maize show that during August, the plants are in vegetative growth. Therefore, it is affected highly by water quantity (more sensitive to water stress). There are significant differences ($P \leq 0.05$) between non-stressed and stressed water during this period. This is because plants have a higher response to water during vegetative growth, as reported by (Admasu et al, 2017). This agreed with the general pattern as published by allen et al, 1998) (FAO 56). In August, the maize plants were in the vegetative growth period according to the growth stage periods (Allen et al, 1998). During this growth stage, plants start to accumulate nutrients in the produced kernels, which lowers RWC (Çakir, 2004).

4.4.1.2 Effect of Cold Plasma on SPAD:

Significant differences ($P \leq 0.05$) were found for plasma treatment in SPAD and also Significant differences ($P \leq 0.05$) was found for water use treatment.(Table 4.17) in appendix a.

The average plasma treatment for SPAD was higher with 65% than the control with 61 % and the average of non-stressed water with 64% higher than the stressed water with 62%. (Table 4.18) in appendix a.

These results are compatible to the findings of (Škarpa et al., 2020) who reported a significant enhancement in chlorophyll content of maize leaves due to cold plasma treatment due to the activated water in the leaves (Indirect plasma application).. SPAD is enhanced as the results show due to the direct treatment of seeds as shown in the table. The water quantity treatment show positive influence, where the chlorophyll content in the leaves increased significantly. This is due to the enhancement of the leaves area as explained by (Saberi et al., 2019) . In addition to the increase in leaves nitrogen content (Scarp et al., 2020).

Significant effect of water quantity on chlorophyll content is discussed by (Thakur and Shinde, 2020). They reported that water stress cause lack of essential factors for chlorophyll synthesis, and decomposition of photosynthetic pigments in pea. The results agree with their findings. Also it agrees with the findings of (Enneb et al, 2021), and the results of (Saberi et al., 2019).

4.4.2 Plant Growth Parameters

4.4.2.1 Effect of Cold Plasma on Roots Moisture Content:

Significant differences (P≤0.05) were found for plasma treatment in moisture roots and also Significant differences (P≤0.05) were found for water use treatment in moisture roots. (Table 4.19) in appendix a.

The average of plasma treatment for roots moisture was higher with 68% than the control with 57%, and also, the average non-stressed water treatment for roots moisture was higher with 67% than the stressed water with 57%. (Table 4.20) in appendix a.

These results agree with (Yemeli et al., 2020). Where, the plasma-enhanced plant growth and physiological parameters, therefore it is expected to have significant increase in root moisture content. As explained by (Škarpa et al., 2020) who reported an increase in root moisture content due to enhanced electrical capacity of the roots due to plasma treatment.

In the same time (Çakir, 2004) reported the positive effect of satisfying the plant water requirements on the physiological parameters in the same time this is confirmed by (Ma et al, 2018).

4.4.2.2 Effect of Cold Plasma on Leaf Moisture Content:

No Significant differences (P≤0.05) were found due to plasma treatment in leaf moisture content. While Significant differences (P≤0.05) were found for water use treatment in leaf moisture content. Table (4.21) in appendix a.

The average of plasma treatment for leaf moisture content was higher with 65% than stressed water with 62%. Also, the average non-stressed water treatment for leaf moisture was higher with 68% than the stressed water with 59%. (Table 4.22) in appendix a.

The results show no significant differences in leaves moisture content due to plasma treatment. In contradiction to Ma et al. (2018) who found significant effect of plasma on leave moisture content.

The quantity of applied water has significantly enhanced leaves moisture content. These results agree with (Jiang et al. 2014) who reported direct impact of water quantity to the leaves moisture in wheat. Maize and wheat are from the same family, for that, it is expected to have significant effect of water quantity on leaves moisture content, which is indicated by the results.

In addition Ma et al.(2018), reported that water stress affects maize growth characteristics in relation to water. This explains the reduction in leaf moisture content by reducing irrigation from 100% to 50% of plant water requirements.

4.4.2.3 Effect of Cold Plasma on Kernels' Moisture Content:

Significant differences ($P \leq 0.05$) was found for plasma treatment in kernels moisture also Significant differences ($P \leq 0.05$) was found for water use treatment.(Table 4.23) in appendix a.

The average of plasma treatment for kernels moisture was higher with 60% than the control with 54%, and also, the average non-stressed water treatment for kernels moisture was higher with 58% than the stressed water with 57%.(Table 4.24) in appendix a.

Results show that cold plasma treatment enhanced the maize kernel's RWC. This increase is caused by the enhancement of physiological activities as a result of to the plasma treatment (Yemeli et al., 2020). However this enhancement in RWC in the kernel as indicated by the results agree with the findings of (Ghasemzadeh, 2022), who reported an increase in maize Kernel's RWC caused by plasma treatment.

The relationship between the kernel's RWC and irrigation is positive as the growth parameters of maize is affected by any water stress (Yemeli et al, 2020). Maiorano et al. (2014) reviewed the kernel water content during growth phases of the kernel. In these phases the water stress during the first stage affect severely the growth of the kernel. The results of this study indicate this effect and agree with these findings of (Maiorano et al, 2014).

4.4.2.4 Effect of Cold Plasma on Stem Diameter

Significant differences ($P \leq 0.05$) was found for plasma treatment in stem diameter and also Significant differences ($P \leq 0.05$) was found for water use treatment in stem diameter.(Table 4.25) in appendix a.

The average of plasma treatment for stem diameter was higher with 8cm than the control with 7cm. Also the average non-stressed water treatment for stem diameter was higher with 8cm than the stressed water with 7cm. (Table 4.26) in appendix a.

The average of plasma (5+10 seed exposure) for stem diameter with 6.37+6.16 cm was higher than the control with 5.83 cm. and also the average of non-stressed water treatment of stem diameter was higher with 7cm than the stressed water with 6cm. (Table 4.8)

These results agree with (Yemeli et al., 2020). Where the results indicate the positive effect of plasma treatment on the physiological characteristics, as reported by (Yemeli et al., 2020). In the same time, the results don't agree with (Henselová et al., 2012) who referred non significant effect on stem. The results indicate a significant increase in stem diameter due to plasma treatment. This agrees with the findings of (Ling et al. 2016). Who reported improved stem diameter in practice.

The results of water quantity show significant increase in stem diameter due to water quantity. This agree with (Jiang et al. 2014) and (Ling et al, 2018) The effect of water quantity on stem diameter is concluded by (Ma et al, 2018).

4.4.2.5 Effect of Cold Plasma on Plant Height:

Significant differences ($P \leq 0.05$) were found for plasma treatment in plant height and also Significant differences ($P \leq 0.05$) were found for water use treatment in plant height (Table 4.27) in appendix a.

The average of plasma treatment for plant height was higher with 115cm than the control with 108cm and also the average of non-stressed water higher with 117cm than the stressed water with 106cm.(Table 4.28) in appendix a.

Plasma treatment positively affects maize plants' growth as reported by (Škarpa et al., 2020). This positive effect result in increased plant height as the result show. The results agree with (Yemeli et al., 2020).

The results indicated the positive proportional of the plant height to the water quantity. These results agree with the findings of (Yemli et al, 2020), (Zhu et al, 2016), (Yan et al, 2016) and others.

The water quantity significantly increase the plant height. This enhancement is a result of satisfying the plant water requirements as reported by (Zhu et al, 2016). Yan et al. (2016) discussed the effect of water shortage on maize growth parameters, they reported the effect of water stress on plant height.

4.4.3 Yield and Yield Components

4.4.3.1 Effect of Cold Plasma on Production:

Significant differences ($P \leq 0.05$) were found for plasma treatment in production and also Significant differences ($P \leq 0.05$) were found for water use treatment. (Table 4.29) in appendix a.

The average of plasma treatment for production was higher with 181g/plant than the control with 150g/plant and also the average of non-stressed water was higher with 204g/plant than the stressed water with 127g/plant.(Table 4.30) in appendix a.

The maize production reflects the accumulated effects of irrigation quantity and plasma on plant parameters during different growth stages.

The positive enhancements on plant parameters resulted in production incensement. In this study, the results showed a significant increase in the production ($p<0.05$) resulting from plasma treatment and a significant decrease ($p<0.05$) by reducing the irrigation quantity to 50% compared to 100% irrigation.

The results of plasma effect on production are in the same trend of the findings of different studies such as (Zahoranová et al, 2018) who reported a significant increase of maize production due to plasma treatment. Ling et al (2018) reported the same impact on brassica, and the findings of (Zhou et al, 2020) regarding the positive impact of plasma on maize production.

The results of water quantity reflect the correlation between the yield and the water quantity. Huang et al (2006) described deeply the water use efficiency of maize and the response to water stress. The results have the same pattern. They are computable to (Ghasemzadeh, 2022) and agree with (Maiorano et al, 2014) and (Yan et al, 2016).

4.4.3.2 Effect of Cold Plasma on Flowering Parameter:

Male Flowers :

No significant differences ($P \leq 0.05$) were found for plasma treatment in mid-August 2021 and late August 2021. Significant differences ($P \leq 0.05$) was found for water use treatment in mid and late August 2021 (Table 4.31) in appendix a.

The average of plasma treatment for male flowering in mid and late August was higher with 34%, 82% than the control with 30%, 77% (Table 32).

And the average of non-stressed water for male flowering in mid and late August was higher with 42%, 85% than the stressed water with 23%, 73%. (Table 4.32) in appendix a.

Female Flowers

no significant differences ($P \leq 0.05$) was found for plasma treatment in late August 2021 whereas there was Significant differences ($P \leq 0.05$) in September .

no Significant differences ($P \leq 0.05$) was found for water use treatment in late August 2021 whereas there was Significant differences ($P \leq 0.05$) in September. (Table 4.33) in appendix a.

The average of plasma treatment for female flowering in September and August was higher with 82%, 33% than the control with 78 %, 25% and also the average of non-stressed water in September and August was higher with 85%, 32% than the stressed water with 74%, 26%. (Table 4.34) in appendix a.

The results (Tables 4.31;4.32;4.33;4.34) showed that plasma treatment is not affecting the number of flowers. No significant differences ($p < 0.05$) are found between plasma-treated plants and control. However water quantity has more effect on the number flowers than plasma as the results show (Table 4.31;4.33). Significant differences ($p < 0.05$) is found between 100% and 50% irrigation quantity.

These results indicate the effect of water stress on the plant parameters as discussed by (Çakir, 2004; ma et al, 2018), who reported the response of maize to water stress. However the results neither agree with (Škarpa et al., 2020). Who reported an increase in maize flowering, nor with (Yemeli et al., 2020) who reported an increase in maize flowering due to the treatment of seeds with cold plasma.

The results show an increase in flowering. But not significant increase, therefore, it is expected that the fruit set is higher, as a result of plasma effect on physiological activities as reported by (Yemeli et al., 2020).

The quantity of water is affecting the flowering of maize as described by (Çakir, 2004). The results agree with these findings, where it is significantly increased the total male and female in the non stressed plants.

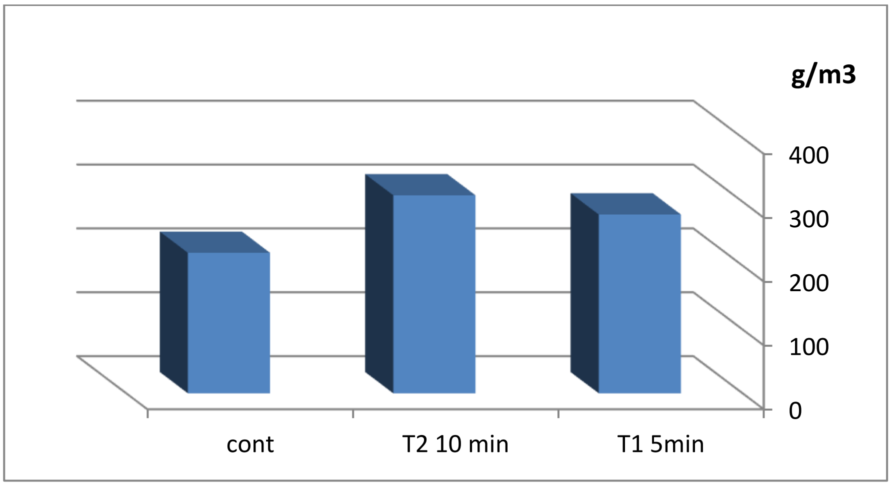
4.5 WUE

4.5.1 WUE on Okra

The WUE for plants with 100% irrigation (5 minutes plasma 280g/m^3) is lower than those of 50% irrigation (10 minutes plasma 310g/m^3). In the same time WUE is enhanced compared to control (no plasma, no irrigation 220g/m^3) as shown in figure (4.1).

Figure 4.1

WUE with Different Applied Irrigation Water Amount in Okra (g/m^3).



WUE connect the yield to the quantity of applied water (Bramley et al, 2013).

However the response of plant to water is well explained and yield to water relationship is published as in (stone et al, 2006). The results of WUE is following the same curve as Soomro et al (2014) reported that okra has the same pattern of response to water.

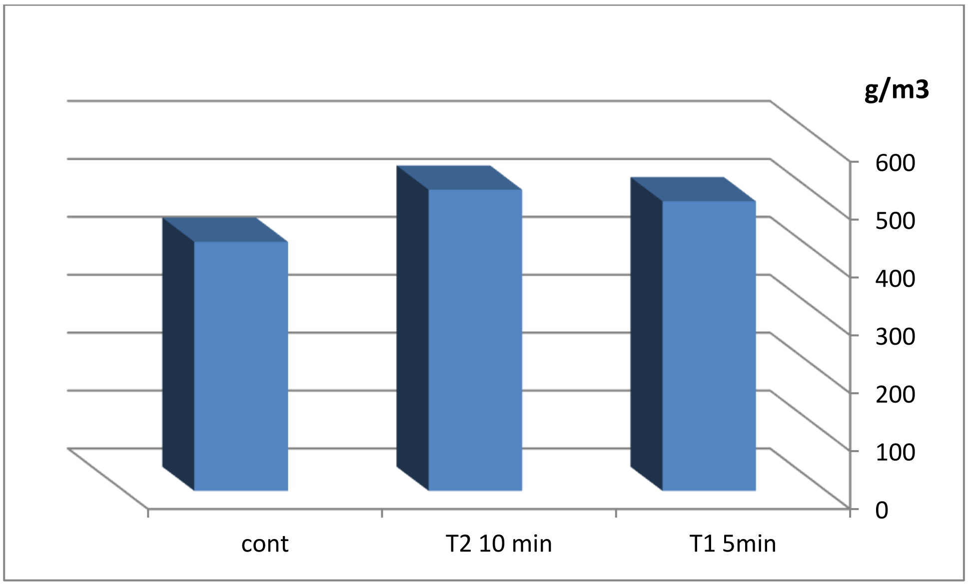
The slope of the curve in the mid region (50%) is higher than at 100% irrigation. This clearly mean that at 50% irrigation the plant water requirements is not fully satisfied, and any additional unit of water will give an increase in the yield. The rate of yield increase (slope of the curve) is decreasing as approach 100%. This explains the reason of reduced WUE at 100% irrigation compared to 50% irrigation.

The effect of plasma treatment on WUE is shown in figure (4). Under fixed irrigation quantity (50% of water requirements). WUE increased with plasma treatment.

The results show that with 5 minutes of seed exposure to plasma WUE increased to reach 500 (g/m^3) (fig.4.2). Increasing the time of plasma treatment to be 10 minutes of seed exposure to plasma enhanced further the WUE, it increased significantly to be 520 (g/m^3) compared to 430 (g/m^3) in the control. the stressed water was increased for plasma treatments compared with the control. In total T1 35%, T2 36%, and the control 29% .

Figure 4.2

WUE of Plasma Treated Okra Plants under Stressed Water (g/m^3).



In general, the plasma seed treatments enhanced the WUE in Okra crop; however, the seeds treatment for 10 minutes had higher enhanced WUE compared to 5 minutes treatment. This agreed with the findings of Saberi et al.(2019), who reported an enhancement effect of cold plasma on crop WUE. This enhancement is due to the effect of cold plasma, which resulted in reduced stomata size and density, and enhanced intercellular CO_2 concentration (Saberi et al, 2019) .

4.5.2 WUE on Maize

There is only one plasma treatment for the maize crop, 5 minutes treatment. Therefore. The WUE is calculated under the two irrigation quantities and compared to the non-treated plants.

Under the 100% irrigation, the WUE is significantly increased due to the plasma treatment, as shown in the figure. 4.3. WUE increased in the 100% irrigated plants from 1450 (g/m^3) in plasma non-treated plants to 1730 (g/m^3) for plants treated. While under 50% irrigation, WUE for plasma-treated was 2170 (g/m^3) compared to 1770 (g/m^3) (figure. 4.3).

Figure 4.3

WUE with Non-Stressed Water in Maize (g/m^3).

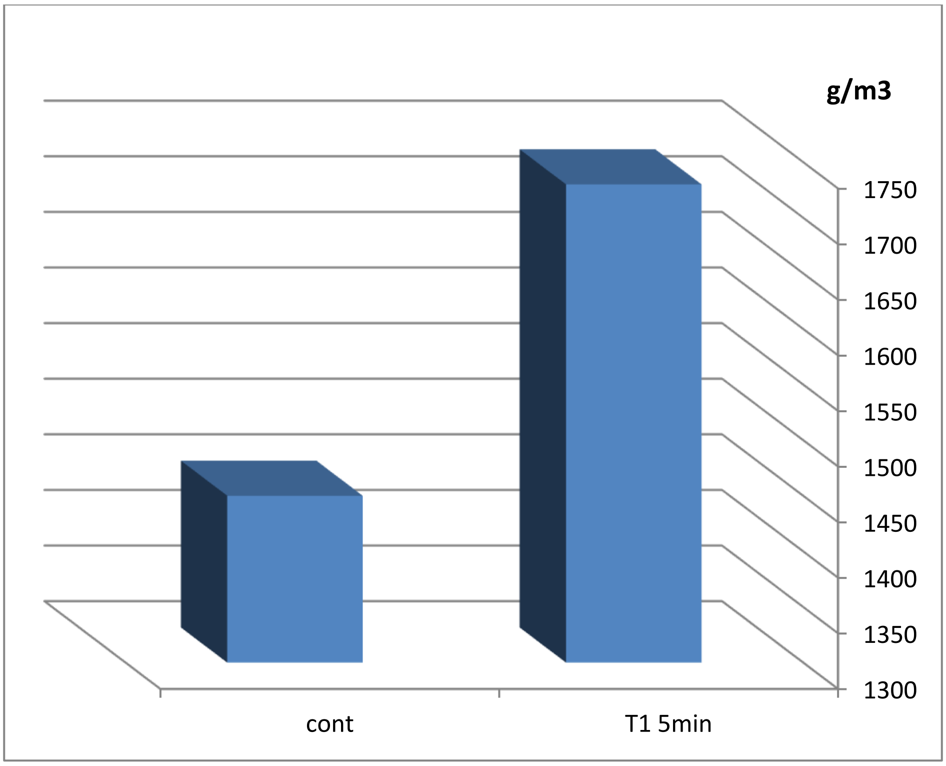
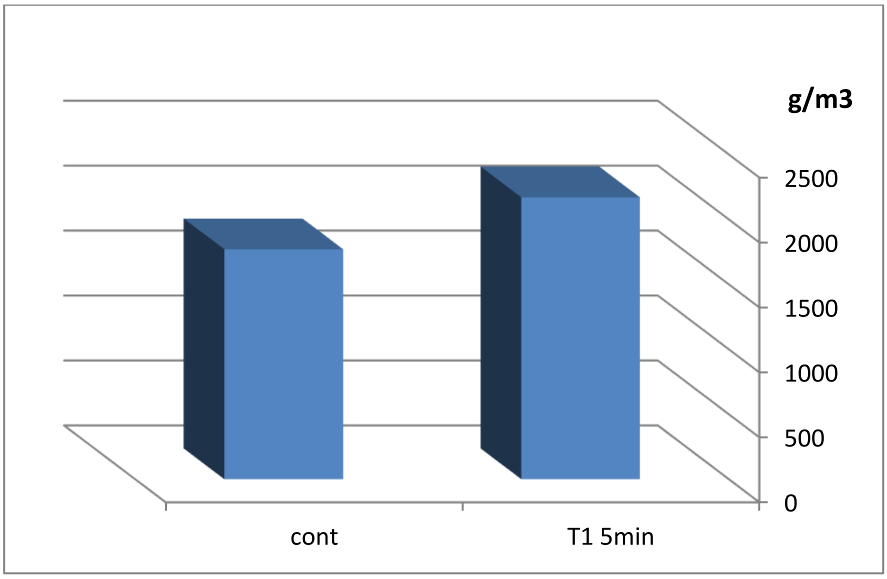


Figure 4.4

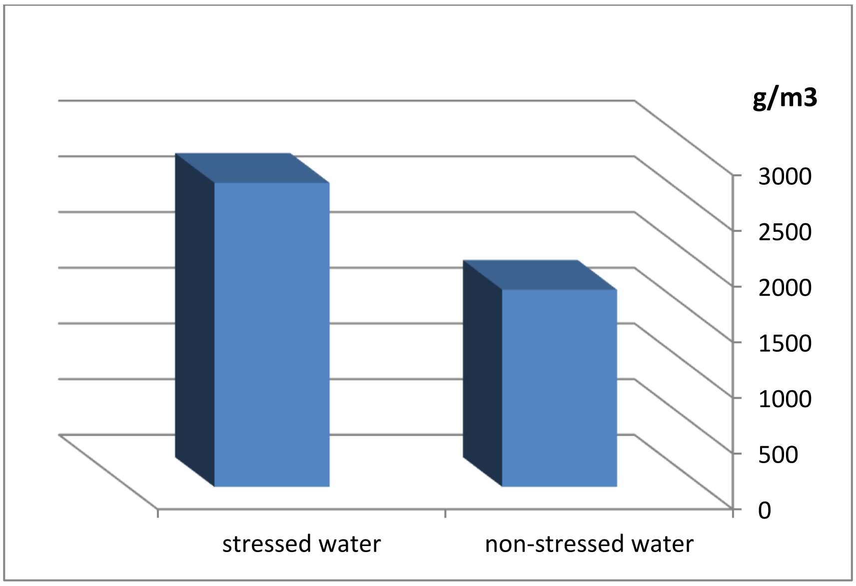
WUE with Stressed Water in Maize (g/m^3).



The effect of irrigation without plasma treatment is shown in (figure 4.5) where WUE has increased as the irrigation quantity decreased from 100% to 50%.

Figure 4.5

WUE for Non-Stressed and Stressed Water g/m^3



These results have a similar trend of Okra; therefore, reducing the quantity of irrigation will end at a pint of higher slope in the yield water curve, which means higher WUE (Bergamaschi et al. 2006).

Maize is a C4 plant, therefore, it has a higher water Use efficiency. According to Huang (et al, 2006) maize highly responds to water quantity. The results on maize WUE is similar to the findings of Yan et al (2016).

The WUE for non-stressed water was decreased for plasma treatments compared with the control and increased for stressed water in maize. in total non-stressed water 45% and stressed water 55%.(Fig.4.6) in Appendix b

The WUE for non-stressed water was decreased for plasma treatments compared with the control and increased for stressed water. In total non-stressed water 36% and stressed water 64% as shown in (Fig 4.7) in Appendix b.

The photosynthetic water-use efficiency measures how much photosynthesis occurs per stomatal conductance and transpiration rate unit. Plants adjust the relationship between water, transpiration, photosynthesis, and WUE through stomatal changes to adapt to stress conditions to maximize CO2 assimilation. These mechanisms also prevent water content loss, lowering tissue damage levels. The amount of photosynthesis rate and stomatal conductance increased after plasma treatment. it increasing stomatal conductance increases transpiration rate, but the plant can have higher levels of photosynthesis per mole of water in plasma treatments. Saberi et al (2019) showed that cold plasma treatments of Wheat plants' tolerance to haze stress were improved by limiting stomatal size, increasing stomatal density, increasing intercellular CO2 concentration, and improving WUE and relative humidity water content.

Plants irrigated at 100% had the highest flowering parameter (in September 58%, October 83%), plant height (70.8 cm), RWC content (in September 69.83 %, October 82.48%), stem diameter parameter (6.32 cm), SPAD content (65%) and total yield (143g/ plant). While, plants irrigated at 50% had the lowest flowering (in September 56%m October 86%), plant height(58.8 cm), RWC content (in September 67.21%, October 74.84%), stem diameter parameter (5.92 cm), SPAD content (63%), and total yield (130g/ plant). This is due to the availability of water for the plants' physiological functions, and non-stressed water provides a consistent supply of water to the entire root area on a continuous basis, reducing "drench and dry-out" stresses (Barzegar et al. 2016).

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

- Seed treatment with cold plasma significantly enhances both okra and maize crops growth and production under the local Palestinian conditions.
- The duration of plasma treatment has significant role in the increase of Okra crop productivity. Plasma treatment with 10-minutes treatment shows a higher effect than 5–minutes.
- Different response of Okra and Maize to cold plasma treatment was seen in some morphological parameters. Where significant differences in flowering and RWC were seen in Okra. While the response of Maize was significant in plant height and plant stem diameter.
- Irrigation quantity significantly affects the yield of Okra, and Maize crops. Where irrigating okra with 196 m^3 resulted in an increase of production with 11% compared to 98m^3 (50% of the irrigation quantity). In maize the production increase by 38% when irrigation increased to be 400 m^3 compared to the production when irrigation is 200 m^3 (50% irrigation quantity).
- Reducing irrigation quantity from 100% to 50% increases WUE while the total production decreases by 28% on Okra and 10% on Maize.

5.2 Recommendations

- It is recommended to implement demonstrations under farmers conditions for plasma treatment of Okra and Maize.
- The positive results encourage plasma treatment and test the effect on other different vegetable crops.
- The economic impact of cold plasma treatment under Palestinian conditions should be conducted for Okra and Maize crops.
- The interaction of irrigation quantity with plasma treatment requires further research.
- It is recommended to examine the production under different scenarios of irrigation deficit.

List of Abbreviations

Abbreviation	Meaning
WUE	Water Use Efficiency
DBD	Dielectric Barrier Discharge
CAPJ	Cold Plasma Jet
PAW	Plasma-Activated Water
NARC	National Agricultural Research Center
RWC	Relative Water Content
SPAD	Soil Plant Analysis Development
RNS, ROS, and RHS	Reactive Nitrogen Species, Oxygen, and Hydrogen
CAP	Cold Activated Plasma
RONS	Nitrogen Reactive Species
FAO	Food and Agriculture Organization
MOA	Ministry Of Agriculture
FW	Fresh Weight
TW	Turgid Weight
DW	Dry Weight
du	Dunum
l	litter

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Appendices

Appendix A

Tables

Table 4.11

Analysis Variance of Yield Production in Okra

	Production		
Source of Variation	d.f.	m.s.	F pr.
Plasma	2	543	<.001
Water	1	231	0.01
Plasma. Water	2	439	0.26
Residual	12	291	
Total	17		

Table 4.12

The mean of the Yield Production of Okra

Treatment	**Production/g/plant**
Plasma (5 min seed exposure)	21.5ab
Plasma (10 min seed exposure)	23a
Control	17.5b
Water Use	
Stressed Water (98 m^3/du /season)	21.7b
Non-Stressed Water (196 m^3/du /season)	24a
CV	7.9
LSD plasma	67.9
LSD water	55.4

Table 4.13

Analysis Variance of the Number of Flowers/Plant in September and October in Okra

		Flowering September%		**Flowering October %**	
Source of Variation	d.f.	Mean Square (MS)	F pr.	Mean Square (MS)	F pr.
Plasma	2	0.006	0.04	0.002	0.05
Water	1	0.001	0.40	0.003	0.08
Plasma. Water	2	0.0004	0.78	0.0001	0.86
Residual	12	0.0016		0.0009	
Total	17				

Table 4.14

the mean of Flowering during September and October in Okra

Treatment	**Flowering in September (%)**	**Flowering in October (%)**
Plasma(5 min seed exposure)	60ns	86a
Plasma(10 min seed exposure)	58ns	85ab
Control	53ns	82b
Water Use		
Stressed Water (98 m^3/du /season)	56ns	83ns
Non-Stressed Water (196 m^3/du /season)	58ns	86ns
CV	7.2	3.7
LSD plasma	0.051	0.039
LSD water	0.041	0.032

Table 4.15

Analysis Variance of RWC Content in Maize

		RWC/August		**RWC/September**	
Source of Variation	d.f.	m.s.	F pr.	m.s.	F pr.
Plasma	1	16.0	0.49	89.3	0.30
Water Use	1	797.4	0.001	137.9	0.20
Plasma. Water	1	7.4	0.63	45.9	0.45
Residual	8	31.4		73.8	
Total 11	11				

Table 4.16

the mean of RWC Content in Maize

Treatment	RWC %/August	RWC %/ September
Plasma (5 min seed exposure)	83.1ns	71.9ns
Control	80.8ns	66.5ns
Water Use		
Stressed Water (200 m^3/du / season)	73.8b	65.8ns
Non-Stressed Water (400 m^3/du/ season)	90.1a	72.6ns
CV	6.8	12.4
LSD plasma	7.4	11.4
LSD water	7.4	11.4

Table 4.17

Analysis Variance of SPAD Diameter in Maize

		SPAD	
Source of Variation	d.f.	m.s .	F pr .
Plasma	1	0.0029	0.01
Water	1	0.0016	0.04
Plasma. Water	1	0.0001	0.54
Residual	8	0.0003	
Total	11		

Table 4.18

the mean of SPAD Diameter in Maize

Treatment	SPAD (%)
Plasma (5 min seed exposure)	65a
Control	61b
Water Use	
Stressed Water (200 m^3/du / season)	62b
Non-Stressed Water (400 m^3/du / season)	64a
CV	2.8
LSD plasma	0.023
LSD water	0.023

Table 4.19

Analysis of Variance of Root Moisture Content in Maize

Roots Moisture Content%			
Source of Variation	d.f.	m.s.	F pr.
Plasma	1	399.5	<.001
Water	1	292.6	<.001
Plasma. Water	1	93.2	0.006
Residual	8	6.8	
Total	11		

Table 4.20

the mean for Roots Moisture Content in Maize

Treatment	Roots Moisture Content %
Plasma (5 min seed exposure)	68.1a
Control	56.6b
Water Use	
Stressed Water (200 m^3/du / season)	57.4b
Non-Stressed Water (400 m^3/du / season)	67.3a
CV	4.2
LSD plasma	3.4
LSD water	3.4

Table 4.21

Analysis of Variance of Leaf Moisture Content in Maize

Leaf Moisture Content			
Source of Variation	d.f.	m.s.	F pr.
Plasma	1	32.85	0.07
Water	1	265.17	<.001
Plasma. Water	1	8.02	0.33
Residual	8	7.77	
Total	11		

Table 4.22

the mean of Leaf Moisture Content in Maize

Treatment	Leaf Moisture Content %
Plasma (5 min seed exposure)	65.1ns
Control	61.8ns
Water Use	
Stressed Water (200 m^3/du / season)	58.7b
Non-Stressed Water (400 m^3/du / season)	68.1a
CV	4.4
LSD plasma	3.7
LSD water	3.7

Table 4.23

Analysis Variance of Kernels' Moisture Content in Maize

	kernels' Moisture Content %		
Source of Variation	d.f.	m.s.	F pr.
Plasma	1	110.4	0.01
Water	1	5.3	0.05
Plasma. Water	1	0.03	0.95
Residual	8	10.7	
Total	11		

Table 4.24

the mean of Kernels' Moisture Content in Maize

Treatment	kernels' Moisture Content %
Plasma (5 min seed exposure)	60.4a
Control	54.3b
Water Use	
Stressed Water (200m^3/du / season)	56.7a
Non-Stressed Water (400 m^3/du / season)	58.0a
CV	5.7
LSD plasma	4.368
LSD water	4.368

Table 4.25

Analysis Variance of Stem Diameter in Maize

Stem Diameter cm			
Source of Variation	d.f.	m.s.	F pr.
Plasma	1	3.34	0.01
Water	1	2.37	0.03
Plasma. Water	1	0.03	0.75
Residual	8	0.36	
Total	11		

Table 4.26

the mean of Stem Diameter in Maize

Treatment	Stem Diameter cm
Plasma (5 min seed exposure)	8a
Control	7b
Water Use	
Stressed Water (200 m^3/du / season)	7.08b
Non-Stressed Water (400 m^3/du / season)	7.97a
CV	8
LSD plasma	0.8
LSD water	0.8

Table 4.27

Analysis Variance of Plant Height in Maize

Plant Height			
Source of Variation	d.f.	m.s.	F pr.
Plasma	1	122.8	0.01
Water	1	312.1	0.001
Plasma. Water	1	1.6	0.73
Residual	8	13.5	
Total	11		

Table 4.28

the mean of Plant Height in Maize

Treatment	Plant Height (cm)
Plasma (5 min seed exposure)	114.6a
Control	108.2b
Water Use	
Stressed Water ((200 m^3/du / season)	106.3b
Non-Stressed Water (400 m^3/du / season)	116.5a
CV	3.3
LSD plasma	4.9
LSD water	4.9

Table 4.29

Analysis Variance of Production in Maize

		Production	
Source of Variation	d.f.	m.s.	F pr.
Plasma	1	6.90	0.002
Water	1	45.24	<.001
Plasma. Water	1	0.14	0.54
Residual	8	0.35	
Total	11		

Table 4.30

the mean of Production in Maize

Treatment	Production/ g/plant
Plasma (5 min seed exposure)	181a
Control	150b
Water Use	
Stressed Water (200 m^3/du / season)	127b
Non-Stressed Water (400 m^3/du / season)	204a
CV	7.2
LSD plasma	0.79
LSD water	0.79

Table 4.31

Analysis Variance of Male Flower in Mid and Late August in Maize

		Male Flowering mid-August		Male Flowering late-August	
Source of Variation	d.f.	m.s.	F pr.	m.s.	F pr.
Plasma	1	0.005	0.37	0.007	0.25
Water	1	0.110	0.002	0.040	0.02
Plasma. Water	1	0.0002	0.85	0.0008	0.69
Residual	8	0.005		0.005	
Total	11				

Table 4.32

the mean of Male Flowers in Mid and Late August in Maize

Treatment	Male Flowering mid-August %	Male Flowering /late August %
Plasma (5 min seed exposure)	34ns	82ns
Control	30ns	77ns
Water Use		
Stressed Water (200 m^3/du/ season)	23b	73b
Non-Stressed Water (400 m^3/du/ season)	42a	85a
CV	23.8	8.9
LSD plasma	0.10	0.09
LSD water	0.10	0.09

Table 4.33

Analysis Variance of Female Flowering in August and September in Maize

		Female Flowering/ September %		Female Flowering/ August %	
Source of Variation	d.f.	m.s.	F pr.	m.s.	F pr.
Plasma	1	0.0052	0.037	0.016	0.14
Water	1	0.0352	<.001	0.010	0.24
Plasma. Water	1	0.0002	0.631	0.001	0.60
Residual	8	0.0008		0.006	
Total	11				

Table 4.34

the mean of Female Flowering in August and Late September in Maize

Treatment	Female Flowering/ September(%)	Female Flowering/ August(%)
Plasma (5 min seed exposure)	82a	33ns
Control	78b	25ns
Water Use		
Stressed Water (200 m^3/du / season)	74b	26ns
Non-Stressed Water (400 m^3/du / season)	85a	32ns
CV	3.6	28
LSD plasma	0.03	0.10
LSD water	0.03	0.10

Table 4.35

The Results of Soil Analysis.

Irrigation		Nitrogen N%	phosphorous P(ppm)	potassium k(ppm)	salinity EC(ds/m)	acidity PH
Non-Stressed Water Okra	T1	0.21	560	21.6	0.59	7.37
	T2	0.28	500	24	0.63	7.42
	T3	0.27	360	24	0.82	7.34
Stressed Water Okra	T1	0.18	400	19.2	0.6	7.2
	T2	0.24	300	21.6	0.6	7.48
	T3	0.28	110	16.8	0.57	7.34
Non-Stressed Water Maize	T1	0.28	520	19.2	0.4	7.62
	T2	0.27	134	14.4	0.5	7.26
Stressed Water Maize	T1	0.29	130	14.4	0.51	7.6
	T2	0.21	280	16.8	0.63	7.4

Appendix B

Figures

Figure 4.6

WUE in Maize with Non-Stressed and Stressed Water

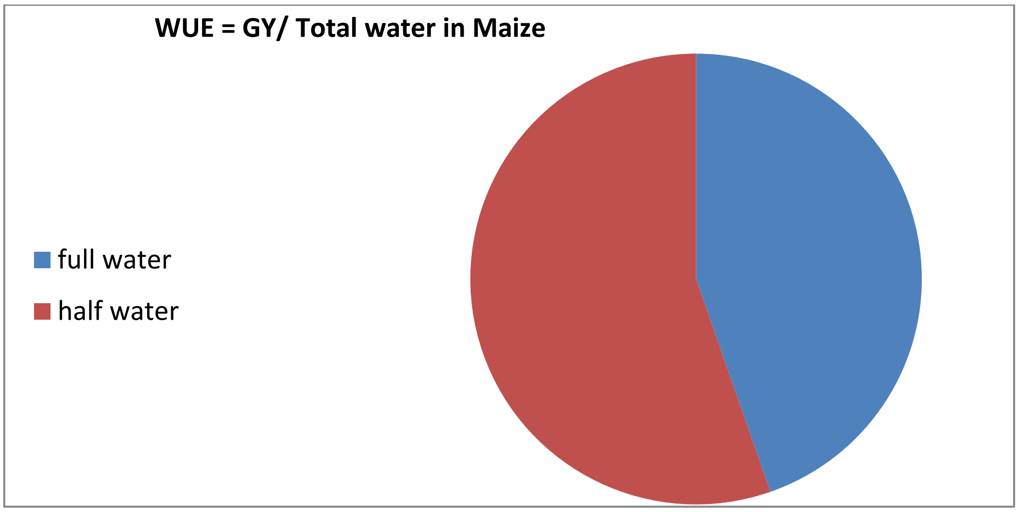
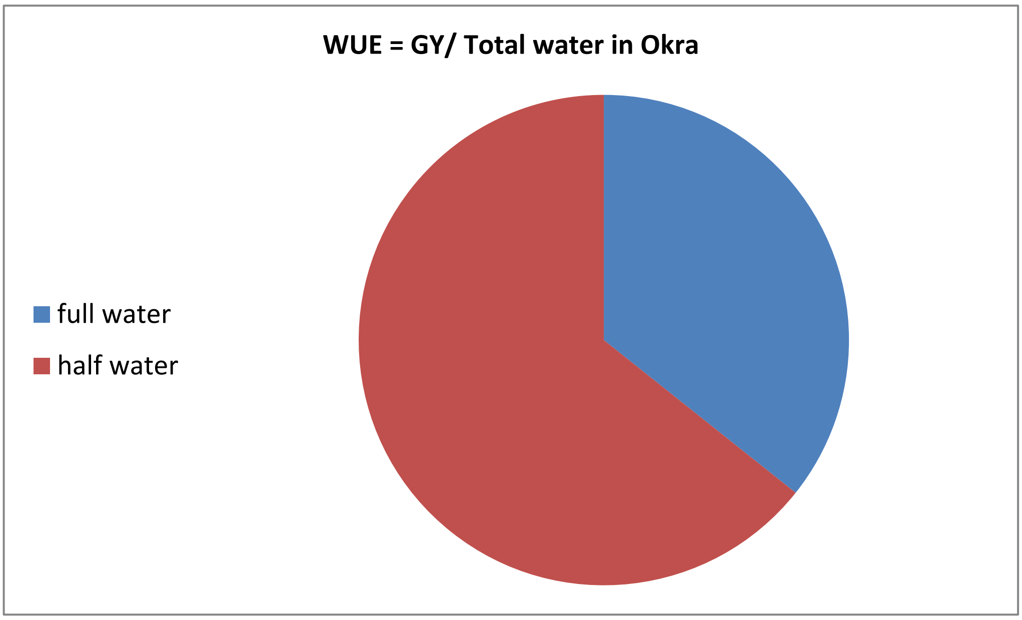


Figure 4.7

WUE in Okra with Non-Stressed and Stressed Water



جـــامعـــــة النجاح الوطنية

كليـــة الدراســـــات العليـــا

تعزيز الانتاجية وكفاءة استخدام مياه الري لنباتي البامية والذرة باستخدام تقنية البلازما الباردة

إعداد

شاهر محمد عبد الكريم خالدي

إشراف

د. توفيق القبج

د. عبد الله العمري

قدمت هذه الرسالة استكمالا لمتطلبات الحصول على درجة الماجستير في الإنتاج النباتي، من كلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

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إعداد

شاهر محمد عبد الكريم خالدي

إشراف

د. توفيق القبج

د. عبد الله العمري

الملخص

خلفية الدراسة: الحاجة إلى زيادة إنتاجية الغذاء تدفع الى زيادة المساحة المزروعة وإنتاجية وحدة المساحة. معالجة البلازما الباردة هي طريقة فيزيائية كيميائية يمكنها تعزيز إنبات البذور وانتاج المحصول والتحكم في مسببات الأمراض الموجودة على طبقات البذور.

أهداف الدراسة: تهدف هذه الدراسة إلى معرفة تأثير معاملات بذور البلازما الباردة على بعض الصفات الزراعية لنبات البامية والذرة ، وتأثير معاملات بذور البلازما الباردة على احتياجات المحاصيل من المياه وتوفير مياه الري لنبات البامية والذرة.

المنهجية: كانت فترة العلاج بالبلازما الباردة 5 دقائق للذرة بينما تمت معالجة بذور البامية لمدة 5 و10 دقائق. بالإضافة الى. تقييم أثر تقليل كمية الري بنسبة 50٪. كان مصدر المعالجة بالبلازما جهاز مولد البلازما البارد المنتج من قبل شركة Nova plasma. أجريت هذه التجربة في (المركز الوطني للبحوث الزراعية) في قباطية – جنين شمال الضفة الغربية في شهري تموز وآب وأيلول وتشرين الأول من عام 2021.

أظهرت نتائج محصول البامية اختلافات معنوية بين النباتات المعالجة بالبلازما وتلك التي لم تعالج في نسبة الازهار وقيم SPAD والإنتاج الكلي. تظهر النباتات المعالجة بالبلازما تحسن في نسبة الازهار؛ 58 و 60٪ للبذور المعالجة بالبلازما الباردة لمدة 5 و 10 دقائق. بينما زاد قيم SPAD بنسبة 9٪.

النتائج: أظهرت النتائج في نباتات الذرة أنه قد تم تحسين قطر النبات ؛ محتوى رطوبة الجذر ؛ ارتفاع النبات والناتج الكلي بشكل كبير. تحتوي النباتات المعالجة بالبلازما على نسبة رطوبة أعلى بنسبة 68٪ من غير المعالجة. 14٪ لقطر النبات. 6.48٪ في ارتفاع النبات. و 20.2٪ كإجمالي الإنتاج.

في معالجة مستوى الري ، أظهر تقليل كمية الري بنسبة 50٪ انخفاضًا معنويًا في المعاملات المقاسة بين النباتات المروية بنسبة 50٪ لتلك المروية بنسبة 100٪. تم تحسين WUE بالنباتات المروية مقارنة بالنباتات التي كانت نصف مرويه. ولكن في نفس الوقت ، فإن WUE في 50٪ ري أعلى من 100٪ في كلا المحصولين.

الاستنتاجات: الاستنتاج الرئيسي للنتائج هو أن البلازما الباردة تعزز الإنتاجية و WUE للذرة والبامية., في البامية يوصى بمعالجة البذور لمدة 10 دقائق لتحقيق إنتاج أعلى

الكلمات المفتاحية: البلازما الباردة ، البامية ، الذرة ، المحصول ، عوامل النمو.

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