



COLLEGE OF AGRICULTURE

DEPARTMENT OF PLANT SCIENCE

MSc. THESIS

**EFFECTS OF PLANTING METHOD AND SEED PRIMING ON GROWTH,
YIELD AND YIELD COMPONENTS OF HOT PEPPER (*Capsicum annum* L.)
AT MERSA, NORTH WOLLO, ETHIOPIA**

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JUNE 2024

WOLDIA UNIVERSITY, ETHIOPIA

Effects of Planting Method and Seed Priming on Growth, Yield and Yield Components of Hot Pepper (*Capsicum annuum* L.) at Mersa, North Wollo, Ethiopia

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**In Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE IN HORTICULTURE**

**By
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SCHOOL OF GRADUATE STUDIES
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I declare that, this thesis is the result of my genuine work, and all sources of information used for writing it have been duly acknowledged. This thesis has been submitted to Woldia University in partial fulfillment of the requirements for the degree of Master of Science in Horticulture and is deposited at the library of the university to be made available to borrowers under the rules and regulations of the library. I solemnly declare that this thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate. Brief quotations from this thesis are allowable without special permission if an accurate acknowledgement of the source is made. Requests for permission to extend quotations from or reproduce this manuscript in whole or in part may be granted by the Head of the Department of Plant Sciences or the Dean of the School of Graduate Studies when, in his or her judgment, the proposed use of the material is for scholarly interests. In all instances, however, permission must be obtained from the author.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
AOSA	Official Seed Analyst Association
ARARI	Amhara Regional Agricultural Research Institute
ATVET	Agricultural Technical Vocational and Educational training
CSA	Central Statistical Agency
EARO	Ethiopian Agricultural Research Organization
EEPA	Ethiopian Export Promotion Agency
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
HARDO	Habru Agricultural and Rural Development Office
ISTA	International Seed Testing Agency
LSD	Least Significant Difference
m.a.s.l	meter above sea level
MARC	Melkassa Agricultural Research Center
MLE	Moringa Leaf Extract
MoA	Ministry of Agriculture
MoARD	Ministry of Agriculture and Rural Development
NMSA	National Meteorological Service Agency
RCBD	Randomly Complete Block Design
SARC	Srinka Agricultural Research Center
SAS	Statistical Analysis System
WHO	World Health Organization

BIOGRAPHICAL SKETCH

Melesech Bekele Anagaw, the author, was born in Southern Achefer worda Amhara Region, in 1992. Her father's name is Bekele Anagaw, and her mother's name is Atalay Alem. She attended Dangila Primary and Junior Secondary School from 1999 to 2011, completing her elementary and junior education there. In 2014, Melesech graduated from Hawassa University with a Bachelor of Science degree in Plant Science. Following her graduation, she worked as a crop science expert for six months in Gozamin Woreda, Ethiopia. Since 2017, she has held the position of Chief Technical Assistant at the Department of Plant Science, Woldia University. Currently, Melesech is in the final year of her studies at Woldia University, pursuing a Master of Science degree in Horticulture.

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Effects of Planting Method and Seed Priming on Growth, Yield and Yield Components of Hot Pepper (*Capsicum annuum* L.) at Mersa, North Wollo, Ethiopia

BY

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ABSTRACT

Hot pepper is widely cultivated as a popular spice and vegetable crop by producers and consumers. Lack of awareness of the advantages of seed priming and planting methods are the predominant factors that reduce the production and productivity of hot pepper. A field experiment was conducted at Mersa College of Agriculture Research Station, Woldia University, in 2021/2022 cropping season under irrigation to evaluate the effect of planting method and seed priming on the growth and yield of hot pepper. A 2x6 factorial combinations were laid out in Randomized Complete Block Design (RCBD) with three replications. Treatments were two planting methods (direct sowing and transplanting) and six levels of seed priming by Moringa Leaf Extracts (MLEs) (0, 2%, 4%, 6%, 8% and 10%. The analysis of variance revealed that priming of hot pepper seeds by Moringa Leaf Extract (MLE) improves the germination percentage, vigor index and speed of germination significantly. The analysis of variance also revealed a significant difference in the interaction effect of planting method and seed priming for most of the growth and yield parameters of hot pepper. Thus, the highest total fruit yield (8.49t ha⁻¹) was obtained from the treatment combination of the transplanting planting method and seeds primed with 10% MLE., However, the highest marketable yield (7.73t ha⁻¹) and the lowest unmarketable (0.70t ha⁻¹) yield were recorded from the transplanting planting method and seeds primed with 8% MLEs. Based on the results of the present work, the transplanting planting method and priming of seeds with 8% MLEs can be recommended for the production of hot pepper at Mersa and other similar agro-ecologies. However, this result was based on one season and location work. Therefore, it is also recommended to repeat the experiment over seasons and locations to make a conclusive recommendation.

Key Words: Germination, Hot pepper, Marketable yield, Moringa, Planting method, Priming

1. INTRODUCTION

1.1. Background and Justification

Hot pepper (*Capsicum annum* L.), commonly known as chili, is the world's third most important vegetable after potatoes and tomatoes in terms of quantity of production. Hot pepper is a tropical spice and vegetable crop that belongs to the nightshade family Solanaceae and the genus *Capsicum* (Kulkarni *et al.*, 2017). It is related to tomatoes, eggplant, potatoes, and tobacco. After tomatoes, the genus *Capsicum* is the world's second-most important vegetable crop (Berhanu *et al.*, 2011). The genus *Capsicum* consists of approximately 22 wild species and five domesticated species. The five domesticated species include *C. annum* L., *C. frutescens* L., *C. Chinenses* L., *C. baccatum* L., and *C. pubescens* R. (Bosland and Votava, 2000).

Hot pepper is produced on all the continents except Antarctica and is historically associated with the voyage of Columbus (Heiser, 1976; Delelegn, 2011). Columbus is given credit for introducing hot pepper to Europe and, subsequently, to Africa and Asia. The exact time of the introduction of pepper, which originated in Latin America, to Africa in general and Ethiopia in particular is not certainly known. However, its history in the country is perhaps more ancient than the history of any other vegetable product. Moreover, hot pepper has been cultivated in Ethiopia for a long time. Currently, it is produced in many parts of the country because, for most Ethiopians, food is tasteless without hot pepper (EEPA, 2003).

Peppers are widely grown in a variety of environmental and climatic conditions. Hot peppers are adapted to hot weather conditions. Day temperatures of 24 to 30°C and night temperatures of about 10 to 15°C are ideal for growth. They are sensitive to freezing temperatures, while temperatures above 32°C can reduce pollination, fruit set, and yield (Smith *et al.*, 1998). The germination and emergence of pepper seeds are slow at room temperature and further delayed by cooler conditions compared to other vegetable seeds. Peppers germinate fast at temperatures between 20 and 25°C and are prevented at temperatures below 15°C. The slow germination and emergence rates of pepper at low temperatures have led to considerable

efforts to devise seed treatments that speed up these processes. They are considered quantitative short-day plants (Demers and Gosselin, 2002).

The crop is now important not only economically but also historically. It is part of the Ethiopian people's daily diet. Peppers are used in a variety of dishes, including 'karia' (green pod), 'berbere' (fine powder made from the dry fruits of hot pepper), grinded mature green fruits blended with other spices, and 'mitmita,' small, pungent fruits. The powder made from dried ripe hot pepper fruits is used as a spice to flavor 'Wot,' an Ethiopian stew served as a daily traditional meal. Salads are made from mature green pods ('karia') (MARC, 2004).

As a food, pepper has little energy value, but it is an excellent source of vitamins A and C and a good source of vitamin B2, potassium, phosphorus, and calcium. The high nutritive value of pepper results in high market demand year-round. Pepper fruits are used in salads, pickles, stuffing, spices, sauce, and as a dried powder. The leaves are used in salads, soups, or eaten with rice (Baliga *et al.*, 2013). Capsaicin, the main component that causes pungency, aids digestion, prevents heart disease, and dilates blood vessels (McCarty *et al.*, 2015). Pepper has also been widely used as a medicine to alleviate pain like arthritis, treat asthenia, coughs, and the common cold, and cure infected wounds (Pawar *et al.*, 2011).

According to FAOSTAT (2017), the world produced 38,415,621 tons of peppers on an area of 3,737,635ha at an average productivity of 10.28t ha⁻¹. According to this report, Nigeria, Egypt, and Ghana all have consistent production that is sold on the global market. The total area under pepper production in Ethiopia was estimated at 14,690.91 hectares, from which 74,007.72 tons were produced in 2021 with an average yield of about 5.04t ha⁻¹ (CSA 2021). This indicates that the productivity of hot pepper in Ethiopia is far below that in the world (10.28t ha⁻¹). The 2020/21 annual pepper production in the Amhara region is 10,159.77 tons from 2,032.53 hectares, with a productivity of 4.99t ha⁻¹ (CSA, 2021) which is still very low as compared to the world average (FAO, 2017). The annual hot pepper production in North Wollo is 119.16 tons from 16.95 hectares, with a productivity of 7.03t ha⁻¹ (CSA, 2021). It is still less as compared to world-average productivity.

This low production and productivity of hot pepper in Ethiopia could be attributed to a lack of crop management procedures, such as inappropriate planting methods, the inability of seed germination, the spread of disease, the use of inferior cultivars, crop rotation, and harvesting methods. Among the factors, inappropriate planting methods and the inability of seed germination are the major ones that reduce production and productivity in the study area (MARC, 2005).

1. 2. Statement of the Problem

Despite its importance in terms of consumption, it is also very important to farmers in terms of generating income, creating employment opportunities, and ensuring food security. Its average productivity in Ethiopia is about 5.04t ha⁻¹ (CSA, 2021), which is very low as compared to the world's average of 10.28t ha⁻¹ (FAOSTAT, 2017). This low production and productivity of hot peppers in Ethiopia could be attributed to a lack of appropriate planting methods and the inability of seed germination. However, it is important to increase the production and productivity of crops along with desirable attributes through production management practices and priming of seeds for better performance and crop stand establishment.

Accelerating and homogenizing the germination process is necessary for good crop establishment, efficient resource use, and, eventually, increased yields (Subedi *et al.*, 2015). A strong seedling establishment is resistant to environmental stresses and increases biological and crop yields (Hussain *et al.*, 2015). It is a physiological method of controlled hydration and drying that increases the pre-germinative metabolic process to allow for rapid germination (Dawood 2018). Research reports on hot pepper by Khan *et al.* (2009) found that priming seeds was a better treatment than non-primed seeds for improving seedling vigor and seedling establishment. Similarly, Hagroo and Johal (2019) evaluated the impact of priming on physiological seed quality in mature hot pepper seeds and found that primed seeds markedly enhanced seed performance in terms of germination percentage, growth, and yield.

However, the effects of seed priming may vary depending on the priming reagents and rates used, the crops that have been selected, and the factors that they undergo. Different pretreatments have been investigated to improve the rate of pepper seed germination and seedling growth; some of these treatments are chemical, and others are natural products such as MLEs. Moringa leaf extract is considered a natural plant growth regulator because it is a source of Zeatin, which is a natural derivative of Cytokinin, proteins, vitamins E, phenolics, ascorbates, essential amino acids, and several mineral elements, making it a potential natural growth stimulant, as mentioned by Emongor (2012); Rady *et al.* (2013); Howladar (2014) and Rady *et al.* (2015).

Oluwagbenga and Odeghe (2015) mentioned that pepper plant height, number of leaves, fruit weight, and yield were significantly influenced by the application of MLE. Similarly, Aluko (2016) reported that the highest values of pepper plant growth and yield parameters were obtained with MLE foliar application at a concentration of 1:20. Some research reports made in some localities (Bako, Abobo, Awassa, Didessa, Melkassa, etc.), focusing on method of planting, sowing date, fertilizer rate determination, and spacing, have produced valuable recommendations for use and concluded that the transplanting planting method is better than direct sowing of hot pepper (Sam-Aggrey and Bereke, 1985).

Peppers can be established through direct seeding or transplanting, depending on the environment and available resources. Transplanting provides late planting options because seedling establishment requires the least quantity of water. Sometimes, compared to direct-seeded pepper plants, transplanted plants are typically shorter, have more nodes, and have lower total root growth. In general, transplanting might be appropriate in regions with prolonged, reliable, and abundant rainfall. However, the employment of the direct sowing method is crucial in regions with irregular rainfall and a brief rainy season (Gobie, 2019). Therefore, contradicting reports show that selecting the appropriate planting method and the rate of MLE seed priming increases the production and productivity of hot pepper in the study area.

1.3. General Objective

To evaluate the effects of seed priming and planting methods on yield and yield components of hot pepper.

Specific objectives

- ✓ To determine the effect of seed priming on the growth, yield, and yield components of fresh hot pepper
- ✓ To determine the effect of planting methods on the growth, yield, and yield components of fresh hot pepper
- ✓ To determine the interaction effect of planting method and seed priming on growth, yield, and yield components of fresh hot pepper

2. LITERATURE REVIEW

2.1. Origin and Distribution of Hot Pepper

The origin of *Capsicum* species extends from Mexico in the North to Bolivia in the South of Latin America, where it has been part of the human diet since about 7500 B.C. (Purseglove *et al.*, 1981). Pepper was spread all over the world by Spanish and Portuguese explorers. Pepper was introduced to Spain in 1493, England in 1548, and Central Europe in 1585, and it spread to Asia from Europe. In recent times, the crop has been produced in different countries around the world, including India, China, Pakistan, Indonesia, Sri Lanka, Thailand, and Japan in Asia, and Nigeria, Uganda, and Ethiopia in Africa. India and Indonesia have been the largest producers. Currently, China is the major producer and exporter in the world (Delelegn, 2011).

Capsicum annum cultivation is the most widespread of the cultivated species (Berke *et al.*, 2005), and it is thought to have originated in Central and South America. Peru and Mexico could be the second centers of origin, after which it spread into the New World Tropics before being introduced into Asia and Africa in 1493 (Bosland and Votava, 2000). Columbus brought hot peppers to Europe, then to Africa and Asia. The main producers of hot peppers are tropical Asia, tropical Africa, South America (Mexico), and the Caribbean. It is Ethiopia's national spice, believed to have been introduced by the Portuguese in the 17th century (Hafnagel, 1961).

2.2. Ecological Requirement of Hot Pepper

In Ethiopia, the crop is grown in a variety of ecological zones ranging from sea level to 2000 meters above sea level, under both rain fed and irrigated conditions. *Capsicums* thrive in warm, sunny conditions and require a 3-5 month growth period at temperatures ranging from 18 to 30°C; below 5°C, growth is slowed, and frost kills plants at any stage of development. A seedbed temperature of 20–28°C is ideal for germination, which slows at 15°C and stops at 35°C (Weiss, 2002). When seeds are planted during too low soil temperature, germination is slowed, affecting seedling emergence and growth. When the daily air temperature ranges between 18 and 32°C during fruit set, yields increase (Bosland and Votava, 2000).

Pepper is heat-tolerant, but in extremely hot and dry weather, it may produce infertile pollen, reducing fruit set. Excessive transpiration can occur when the temperature exceeds 32°C and the relative humidity is low, resulting in the loss of buds, flowers, and fruits. A temperature drop below 16°C during flowering may result in poor fruit set and seedless fruits (Rice *et al.*, 1990). Pepper grows in almost all soil types, but it prefers well-drained sandy or loamy soils that are rich in lime and have a pH of 5.5–6.8 and a high water retention capacity. Pepper, on the other hand, can tolerate a wider pH range of 4.5 (acidic) to 8.0 (slightly alkaline). Light sands, clay sandy soils, and sandy loams are also suitable for pepper cultivation (Dennis, 2013).

An annual rainfall of 600-1250 mm is appropriate above 1500mm; soils must be free draining because plants cannot tolerate water logging, even for brief periods, especially at the seedling stage. Heavy rain during fruit bloom has a negative impact on pollination, reduces fruit yield, and promotes fungal damage to nearly ripe or ripe fruits (Weiss, 2002). Moisture stress during blooming causes blossoms, immature pods, and flowers to drop, according to Bosland and Votava (2000). Sunscald and dry rot of fruit may become severe if plant growth is slowed by moisture stress, though fruits may become more pungent. Furthermore, moisture stress during rapid vegetative growth and flowering reduces yield by up to 50%, depending on the cultivar. Water stress during flowering and fruit development can result in poorly developed, small, misshapen fruit or blossom-end rot, according to Decoteau (2000), whereas overwatering can promote diseases such as phytophthora and other root-rotting organisms.

2.3. Importance and Production of Hot Pepper in Ethiopia

Hot peppers are consumed as fresh, dried, or processed fruits, as table vegetables, and as spices or condiments (Geleta, 1998), as they increase acceptance of insipid basic nutrient foods. The nutritional value of hot pepper deserves special consideration because it is high in vitamins A, C, and E. Capsaicinoids, an alkaloid ($C_{18}H_{27}NO_3$) produced in glands on the fruit's placenta, are responsible for Capsicum's pungency. Peppers, both hot and sweet; contain more vitamin C than any other vegetable crop (Gobie, 2019). According to Bosland and Votava

(2000) hot peppers are as a tomato and eggplant are high in Vitamins A, C, and a good source of B₂, potassium, phosphorus, and calcium. Pepper has been discovered that as hot peppers mature, their levels of pro-vitamin A (carotene) and ascorbic acid rise. As a result, some countries have increased their production of hot peppers for export markets. Pepper powder accounts for a sizable portion of pepper acreage in the world's top-producing countries. Despite rising production costs, competition, and increased demand, farmers' higher prices for fresh products have helped sustain the vegetative pepper industry. It has also created a need for pepper cultivation to be expanded in areas where it has never been widely grown (Beyene and David, 2007).

In Ethiopia, the planting of red peppers occupies 180,701.46 hectares of land, and the cover of 9,832.28 hectares of green peppers received 1.83t ha⁻¹ red pepper and 6.3t ha⁻¹ green pepper, respectively (CSA, 2021). Ethiopian dry pod hot pepper production has been low, with a national average yield of 0.4 tons of dry fruit yield ha⁻¹ (Fekadu and Dandena, 2006). This variation in yield is attributed to a lack of appropriate planting method and inability of seed germination in the existing agro-ecology as well as irrigation during dry seasons, which can result in flower abortion and low productivity.

2.4. Response of Hot Pepper to Seed Priming

The critical stages during the growth of crops are uniform seed germination, early seedling growth, and a uniform plant stand. Low crop yields are attributed to uneven seed germination and seedling growth. Therefore, the quality of seed can be improved through priming in addition to the field management techniques for better seed germination (Pawar1 and Laware, 2018). Seed priming is a physiological technique of seed hydration and drying to enhance the pre-germinative metabolic process for rapid germination, seedling growth, and final yield under normal as well as stressed conditions (Kamithiet *al.*, 2016). The primed seeds show faster and uniform seed germination due to different enzyme activation, metabolic activities, biochemical processes of cell repair, protein synthesis, and improvement of the antioxidant defense system as compared to unprimed seeds (Tavili *et al.*, 2011).

Seed priming is a general term that refers to several different techniques used to hydrate seeds under controlled conditions while preventing the completion of germination for the purpose of advancing seed germination (Rehman *et al.*, 2011). During priming, seeds are able to imbibe or partially imbibe water and achieve elevated (critical) seed moisture content (Sarkar *et al.*, 2018). Seeds may be kept in this condition for a period that may range from less than one day to several weeks (Soleimanzadeh, 2013). Seeds remain incomplete in germination; therefore, they are desiccation-tolerant and can still be dried for long-term storage. Primed seed germinates faster and more uniformly than non-primed seed, especially in cool soils (Lemrasky and Hosseini, 2012).

According to Tuk *et al.* (2022), the effects of different priming methods on pepper seed vigor can be maintained, and to reduce the decline in the longevity of primed seeds during storage, the change in primed seed vigor across different storage processes must be monitored and studied. This information is vital to the environment, agriculture, and economy. It has a variety of beneficial effects, including nutrient uptake, water use efficiency, photo- and thermo-dormancy maturity, and crop yield. Seedlings sprouted from primed seeds and germinated quickly and uniformly. Furthermore, the seed-priming treatments promote overall plant growth (Safari *et al.*, 2018). Seed priming can boost growth at both the early and late stages of development. Plant growth promotion can have an impact on yield (Rhaman *et al.*, 2020).

Seed priming generally improves germination percentage and rate, emergence, seedling growth and uniformity, and yields of peppers, especially under suboptimal (cool) temperatures (Govinden-Soulange and Levantard, 2008). According to Pawar and Laware (2018), various techniques can be used to increase crop yield, with seed priming being the simplest and most appropriate technique for synchronizing seed germination, increasing emergence, and establishing the farm. Seed priming can help farmers reduce fertilizer use, increase crop yield through synchronized seed germination, and induce systemic resistance in plants. This technique is used to improve germination speed, vigor, seedling establishment, and yield (Mehri, 2015).

Rapid germination and emergence are important to ensure a good stand and adequate yields. Pepper seed emergence is slowed down by low temperatures, and seed emergence from soil may be prevented altogether by temperatures below 15 °C (Tombegavani *et al.*, 2020), while emergence accelerates in soils between 24 and 30°C. To overcome such germination problems, pepper seed requires a special enhancement, among which seed priming is one (Bosland and Votava, 2012).

The use of MLEs via seed priming has been proven to enhance the emergence and establishment of seedlings and improve crop development and growth, leading to increased yields in unfavorable and normal environmental circumstances (Khan *et al.*, 2022). Nwangburuka *et al.* (2012) explained that, depending on the seed type, pre-treatment of seeds before storage with moringa reduces the possibility of fungal infection and also maintains the viability and vigor of the seed for a particular time period. For resource-constrained farmers working in low-input agricultural systems where yield potential is constrained by inherently challenged agronomic settings, seed priming can be very helpful (Carrillo-Reche *et al.*, 2018). In both favorable and unfavorable environmental conditions, seed priming with MLEs has been shown to boost crop development and growth, increase seedling emergence and establishment, and result in higher yields (Khna *et al.*, 2020).

2.5. Effect of Moringa Leaf Extract on Seed Priming

Plant water extracts have reportedly been found to significantly increase the production of field crops in recent years (Khan *et al.*, 2020). The development, growth, and productivity of field crops, particularly when grown in unfavorable conditions, have been improved by a variety of crop water extracts that alter physiological and biochemical processes such as stomatal conductance, signal transduction, phytohormone metabolism, absorption of water and nutrients, antioxidant defense systems, and photosynthesis (Cheng and Cheng, 2015). The scientific community is mainly interested in moringa tree leaf extracts, which are a natural source of various antioxidants, minerals, vitamins, and growth-promoting compounds, among the majority of naturally occurring plant growth stimulants (Khan *et al.*, 2020). Due to the

existence of various allelochemicals, *Moringa oleifera* is also thought to be a potential allelopathy crop (Khna *et al.*, 2017).

Farmers with limited resources operating in low-input agricultural systems whose yield potential is constrained by inherently pressured agronomic settings may benefit especially from seed priming (Carrillo-Reche *et al.*, 2018). In both unfavorable and typical environmental conditions, seed priming with MLEs has been shown to boost crop development and growth, improve seedling emergence and establishment, and increase yields (Khan *et al.*, 2020). By priming with MLE, the highest shoot and root lengths, root-shoot ratios, and seedling fresh and dry weights were obtained (Afzal *et al.*, 2012). Compared to conventional seed priming methods, moringa (*Moringa oleifera* Lam.) leaf extract (MLE), a newly found plant growth enhancer, boosts rangeland grass seedling emergence as well as seedling vigor and growth (Nouman *et al.*, 2012b).

2.6. Response of Hot Pepper to Planting Methods

Capsicum is either transplanted or directly seeded in the field, depending on the environmental condition of the area. Both types of planting have their own distinctive advantages, one over the other, but results show contrasting features under different geographical locations and cultures of production (Bosland and Votava, 2012). According to research results from different parts of Ethiopia using a standard Bako local variety, direct-sown plots were more vigorous than transplanted ones, but the stand percent of the former was seriously affected by erosion (Gobie, 2019). In the same report, direct-sown plants were shown to be affected by lodging due to their bearing more fruits than transplanted ones. In spite of the low stand percent, direct sowing was reported to be by far better than transplanting. Direct-sown plots had plants superior in pod weight, pod length, earliness in flowering and pod formation, and total and marketable yields.

Similarly, direct-sown plants were reported by Leskovar and Othman (2021) to have a stronger taproot than transplants, which form extensive lateral roots because of the early containerization or shock after being uplifted from bed. The authors further reported that direct

sowing reduces labor required for transplanting and hence the cost of production, with transplant shock avoided. Considering all these factors, it was concluded that direct sowing of hot peppers would be better than transplanting. In the same way, in Yugoslavia, the production of sweet pepper by direct sowing resulted in a higher yield and improved quality of pods than transplanting, which accounted for its higher plant density per unit area (Markovic *et al.*, 1989).

Transplanting is used for more precise control of plant population and spacing, thinning costs are avoided, and seed is used more efficiently than in direct planting (Xu *et al.*, 2019). Bosland and Votava (2012) reported that transplanting also affords late planting opportunities for seedlings raised in greenhouses and consumes less water during seedling establishment. In some cases, transplanted plants tend to be shorter, have more branches, and have lower total root growth than direct-seeded pepper plants (Gobie, 2019). Transplanted plots would enable a good (uniform) stand in the field. However, there could be a risk of pests destroying plants if no extra seedlings are there for replacement (Bosland and Votava, 2012). The seedlings could also be late in both flowering and fruit bearing and result in a high unmarketable yield due to bleaching and shriveling. Local experience had shown that transplanting was inferior in total fruit yield but required less weeding and cultivation than direct sowing (Xu *et al.*, 2019).

Leskovar and Othman (2021) indicated that when grown under environmental stress, transplants started flowering at least 16 days earlier and produced more than plants grown from direct seeding. However, similar investigations indicated that yields were similar or improved with direct sown rather than transplanted crops. Yigermal *et al.* (2021), on the other hand, reported that transplants exhibited significantly higher and earlier yields than direct-sown pepper plants. Furthermore, they observed that direct-sown plants maintained more balanced root, stem, leaf, and fruit dry matter partitioning than transplants, which allocated more dry weight (per unit of root growth) to stems, leaves, and fruits.

Direct seeding has been seen as a cost-effective approach of creating stands because transplanting would involve additional expenditures for nursing the transplants in nurseries as

well as the large labor costs of transplanting (Ketema *et al.*, 2013; Palma and Laurance, 2015). Direct planting, on the other hand, should take into account the high cost of seeds and poor seedling survival, especially for high-value vegetable crops that are frequently hybrids rather than open pollinated cultivars. Transplantation is an effective method for accelerating growth, increasing yield, and achieving early maturity (Ketema *et al.*, 2013).

2.7. Effect of Seed priming and Planting Method on growth and yield of hot pepper

Primed seeds are physiologically close to germination stage, they show an enhanced germination rate, early and uniform germination, improved growth attributes, faster emergence and better establishment of crop stand (Farooq *et al.*, 2006). It improves the mean performance of a seed lot by reducing the variation due to staggered emergence within a seed lot. This also allows the ‘poor’ seeds to catch up with the ‘good’ ones during the pre-sprouting germination events. Thus, it results in lesser emergence time, vigorous seedling growth, and uniform crop stand of direct-seeded vegetable crops. It alleviates the stress at the germination stage and ultimately results in the successful seedling establishment under an abiotic stress environment (Ashraf and Foolad, 2005). Drought-induced root development inhibition has been widely documented in tolerant genotypes, but not in sensitive ones (Piro *et al.*, 2003). As a result, a well-developed root system appears to be a potential strategy for improving plant growth, particularly under soil conditions with limited water and nutrient inputs.

3. MATERIALS AND METHODS

3.1. Description of the Study Site

This study was conducted at Mersa College of Agriculture research station, Woldia University, North Wollo Zone of Amhara National Regional States of north eastern Ethiopia in 2021/2022 cropping season. The site is 491 km away from Addis Ababa to the north and 30 km away from Woldia town to the south (HWAO, 2010 unpublished). The site is situated at 11°39'0" to 11° 41' 0" N latitude and 39° 38' 30" to 39° 40' 30" E longitude with an altitude of 1625 m.a.s.l (MoA, 1998) (Fig. 3.1). According to the weather record from the National Meteorological Service Agency (NMSA, 2022) the minimum and maximum monthly rain fall and the minimum and maximum temperature of the area based on the last 22 years (2000-2022) records were 7.33 mm and 252.52mm and 5.16°C and 24.41°C, respectively. The dominant soil type of the study area is clay loam and classified as vertisol with slightly acidic to slightly alkaline. The common crops grown in the area are Sorghum; Teff; Onion, Hot pepper and Tomato. (HARDO, 2019 unpublished).

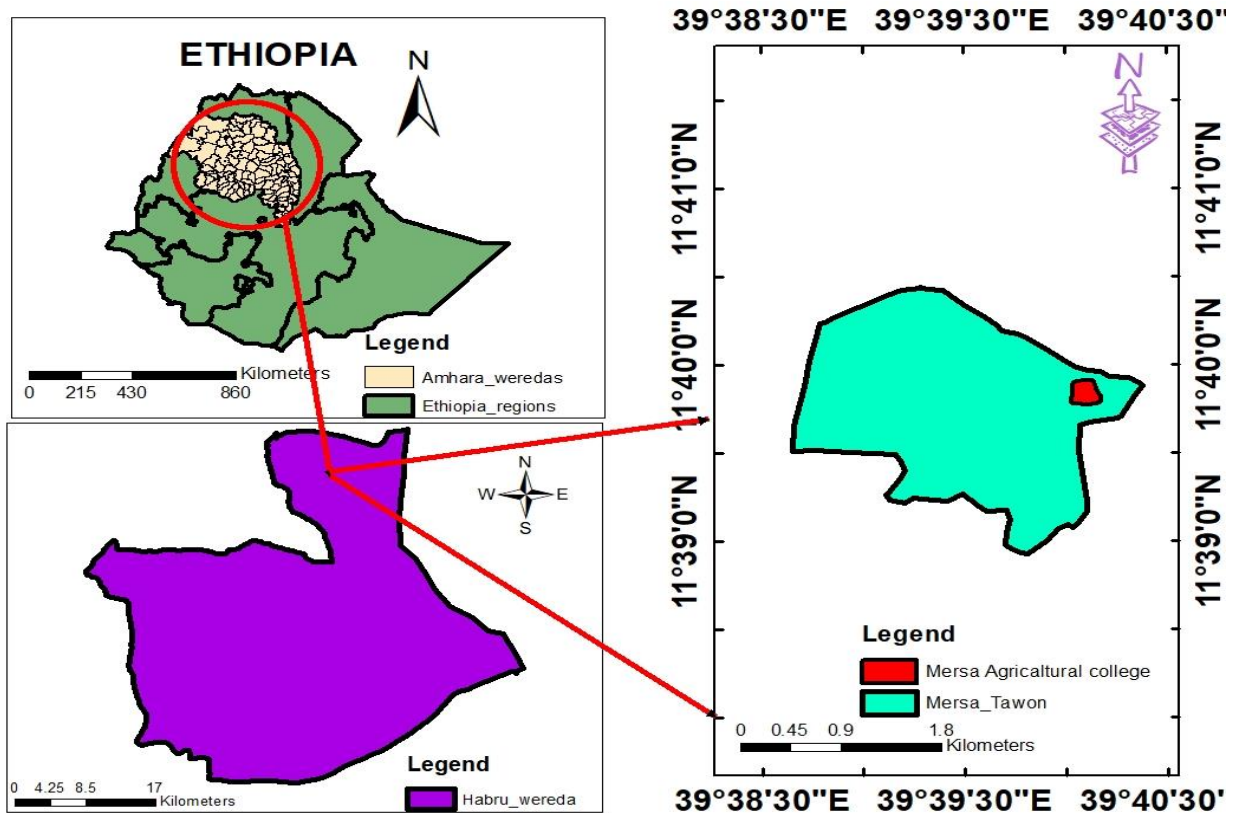


Figure 1. Location map of the study area

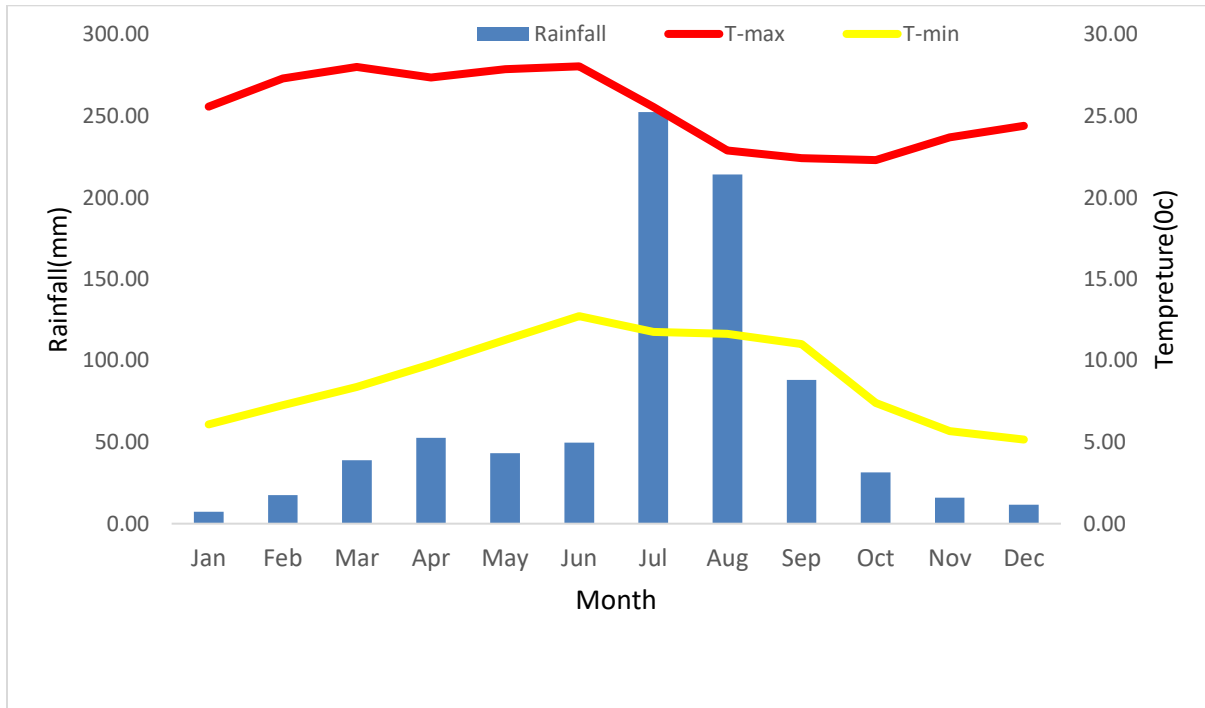


Figure.2: Mean monthly average rainfall, maximum and minimum temperature of 22 years' weather data (2000–2022) at Mersa district, northeastern Ethiopia

3.2. Experimental materials

Marakofana pepper variety obtained from the Melkassa Agricultural Research Center was used as the test crop (MARC, 2003). Larger, more potent pods that are a highly desired dark red color characterize Marakofana peppers. It is highly favored by local consumers due to its pungency, appealing color, and high powder yield. Marakofana is a high-yielding variety that thrives in environments with annual precipitation ranging from 600 to 1337 mm and altitudes between 1200 and 2000 meters above sea level. Its productivity varies according to the country's agro ecological conditions and agronomic practices. The marketable dry pod yield potential of Marakofana was between 1.5 and 2.0 t/ha, according to MARC (2005). It reaches maturity in a period of 110–130 days (Sirba *et al.*, 2021).

3.3. Treatments and Experimental Design

Each of the 12 treatments included two by six factorial combinations of the seed treatment. Seed priming with MLE at untreated (0%, 2%, 4%, 6%, 8%, and 10% and the planting method direct sowing and transplanting. Three replications of a Randomized Complete Block Design (RCBD) were used. With a 1 m and a 1 m separation between adjacent plots and replications, the gross plot was 3 m x 3.5 m, measuring 10.5 m², and the net plot was 2.7 x 2.8, measuring 7.56 m². The plots had five rows, each 70 cm apart, with 30 cm separating the plants in a row, for a total of 50 plants per plot in a full stand. Details of treatment combinations are depicted in Table 1 below.

Table 3.2. Possible treatment combinations

Planting method	Seed priming	Treatment combinations
Direct sowing (DS)	Control (un primed); P1	DS x P1
	Priming with 2% MLE; P2	DS x P2
	Priming with 4% MLE; P3	DS x P3
	Priming with 6% MLE; P4	DS x P4
	Priming with 8% MLE; P5	DS x P5
	Priming with 10% MLE; P6	DS x P6
Transplanting (Tr)	Control (un primed); P1	Tr x P1
	Priming with 2% MLE; P2	Tr x P2
	Priming with 4% MLE; P3	Tr x P3
	Priming with 6% MLE; P4	Tr x P4
	Priming with 8% MLE; P5	Tr x P5
	Priming with 10% MLE; P6	Tr x P6

*MLE: Moring Leaf Extract

3.4. Treatment Description and Procedures

3.4.1. Preparation of Moringa leaf Extract

Moringa leaf extract was prepared by collecting young, disease-free leaves from Moringa trees grown on the main campus of Woldia University. These leaves was washed and then frozen for two days in the refrigerator (Muhammad, 2015). The leaves were ground in a manual juicer to extract the leaf juice. The juice was collected and filtered by passing through cheesecloth to remove all the green matter. After that, the extract was stored at room temperature. The concentrations was prepared from the crude extract. About 20, 40, 60, 80, and 100 ml of the crude extract were taken and diluted with 980 ml, 960 ml, 940 ml, 920 ml, and 900 ml of distilled water, respectively, to reach concentrations of 2%, 4%, 6%, 8%, and 10%, according to Bashir *et al.* (2014). The extraction was carried out a day prior to its application and kept in the refrigerator to avoid being contaminated by some harmful microorganisms and other unfavorable environmental conditions.

3.4.2. Seed priming

A pure, fresh, and healthy Marakofana pepper variety seed was obtained from the Melkassa Agricultural Research Center for the experiment. Half of the seeds was subjected to seed priming, which was started six days prior to the actual sowing date. The seeds were put into the solution in a 10:1 solution-to-seed ratio by weight (Wein, 1997). After 6 days of priming, seeds were removed from the solution, washed, and allowed to dry for two consecutive hours under shade without being subjected to desiccation (Basra *et al.*, 2002). The seeds was sown either on nursery beds or directly in the field on their respective plots, allocated based on the design. Similarly, the non-primed (dry) seeds were sown on their respective plots on the same day after the preparations were completed.

3.4.3. Methods of planting

In this experiment, two methods of planting were used for hot peppers: direct sowing and transplanting. Direct sowing comprised half of the treatments that did not require the raising of seedlings. For the direct method of planting, seeds were sown on well-ploughed, pulverized, and friable soil. In a row spaced 70 cm apart and 30 cm apart within a row, seeds were placed in a pit and then covered with a thin layer of fine soil to form a depth of 2 cm (Matta and Cotter, 1994). Emerging seedlings were counted and thinned after ensuring good emergence. The first thinning was done when plants reached 5–10 cm in height, and the second thinning was done eight days later (ARARI, 2005). Weaker, diseased, and thinner seedlings were removed during thinning, leaving only one plant per hill.

For the transplanting method treatments, seedlings were raised in a nursery adjacent to the experimental area on two seedbeds of 1 m width and 5 m length on the same day of which the direct sowing was done. On the nursery beds, treated seeds with the aforementioned treatments were drilled in rows at a distance of 8 cm. All management practices (watering, weeding, pest control, etc.) were applied as required until the seedlings reached the transplanting stage. The seedlings were transplanted into the experimental plots when seedlings reached a height of 15 cm (Sam-Aggrey and Brerke-Tsehai, 1985). Only uniform

and healthy seedlings with good growth were selected for transplanting. Prior to lifting, plots was watered to facilitate easy lifting of the seedlings.

3.4.4. Germination test

For each treatment, about 25 hot pepper seeds were placed in Petri dishes composed of soft material, which was moistened several times with 5 ml of distilled water for up to seven days. Each priming treatment was replicated three times in a Completely Randomized Design (CRD). The Petri dishes were placed in the biology laboratory at room temperature. The unprimed seed was used as a control. Upon germination, seedlings were counted for up to two weeks. The number of normal seedlings was interpreted according to International Seed Testing Agency (ISTA) criteria for normal seedlings (Bekendam and Grob, 2003). The germination parameters were determined as follows.

Total Germination Percentage (TG %)

The total number of treated seeds germinated in the total number of days was determined as a proportion of the seed numbers shown as a percentage for each procedure (Othman *et al.*, 2006).

TG (%) = Number of germinated seeds

$$\text{Total number of seeds set for germination} \times 100$$

Speed of Germination

The method provided by Czabator (1962) was used to determine the speed of germination with the following formula:

$$\text{Speed of germination} = N1/d1 + N2/d2 + N3/d3 + \dots + Nn/dn$$

Where N is the number of germinated seeds and d is the number of days.

Germination Index (GI)

As defined by the Official Seed Analyst Association (AOSA, 1983), the germination index (GI) was calculated as follows:

$$\text{Germination Index} = Gt/Tt$$

Where Gt is the number of seeds germinated on day t and Tt is the number of germinated seeds at time Ti.

Vigor Index (VI)

The index of vigor (VI) was determined using the equation from Baki and Anderson (1970) from maximum germination and the length of seedlings. $VI = TG (\%) \times \text{seedling length (mm)}/100$, where TG = total germination.

3.5. Data Collection and Measurement

The data collection was made on the middle rows, leaving border rows in order to avoid border effects. Data on different plant growth characteristics, yield, and yield components was recorded. The detailed methodologies adopted were as follows.

3.5.1. Phenological Data

Days to 50% flowering: Days to flowering were recorded starting from the date of sowing until 50% of the population within the middle rows of each plot showed their first flowering.

Stand count: The number of plants in the middle rows of each plot was recorded at the time of first fruit harvesting.

3.5.2. Vegetative Growth Parameter

Number of branches: Among the plant population within the middle rows, 5 randomly selected sample plants were used to assess the number of primary, secondary, and tertiary branches in each treatment plot.

Plant height: The plant height measurement was taken from 5 random sample plants from the central rows of each plot. Measurements were taken in centimeters from the soil surface to the topmost growth point at the last harvesting time.

3.5.3. Yield and Yield Related Parameter

Number of Fruits per plant: The fruit (pod) number (both marketable and unmarketable fruits) would be counted from 5 randomly taken plants from the central rows of a plot at each harvest and summed up at the final stage of the experiment.

Fruit diameter: the fruit width (diameter) of random sample of 5 marketable fruits from each plot bulk were measured in cm at each harvest using caliper and mean values would be calculated after the final harvest data was obtained.

Fruit length: The length of fruit a random sample of 5 marketable fruits from each plot bulk were measured in cm at each harvest using a caliper and mean values would be calculated after the final harvest data was obtained.

Number of seed per pod: Seeds from 5 randomly picked marketable fruits at successive harvests would be counted and the means of seed number per pod would be calculated.

Fresh fruit weight: Freshly collected fruit from 5 sample fruits would be weighed and recorded immediately after each harvest before losing weight due to evaporation. After the final harvest, the mean fruit weight (g) per plot would be calculated.

Total fresh fruit yield (t ha⁻¹): The weight of fresh fruits harvested at each successive harvesting from the central rows was recorded, and at the end of the experiment, all the recorded data were summed up for the estimation of yield per hectare. The total fresh fruit yield is a summation of both marketable and unmarketable fruit yields obtained at the end of the experiment.

Marketable fruit yield (t ha⁻¹): The marketable yield was subjectively determined. During each harvest, the marketable yield from each plot was assessed based on quality ratings by experienced laborers on the farm. The color of the fruit, shininess, presence of surface defects due to insect or disease damage, fruit firmness, and fruit size would be taken as visual parameters for a marketable rating.

Un-marketable fruit yield per plot (t ha⁻¹): the weight of diseased, cracked, fruits with physiological disorder and very small-sized pepper fruits were determined from each plot at final harvest by using weighing balance and expressed as t ha⁻¹.

3.6. Data Analysis

Prior to analysis, all the data were checked for normality and subjected to Analysis of Variances (ANOVA) using Statistical Software (SAS version 9.3) based on Gomez and Gomez (1984). The differences among treatment means were compared using the Least Significance Difference test (LSD) at 5% probability level. Moreover, simple Pearson's correlation analysis was used to reveal the magnitudes and directions of the relationships between selected growth, yield and yield component variables of the crop.

4. RESULTS AND DISCUSSION

4.1. Laboratory Experiment

4.1.1. Germination percentage and vigor index

Analysis of variance revealed that the germination percentage of hot pepper seeds was significantly ($p < 0.01$) affected by the rates of seed priming with MLE (Appendix Table 1). Thus, the highest germination percentage (94.67%) was recorded from the hot pepper seeds that were primed with the rates of 8 and 6% MLE, but it was statistically similar to the germination percentage of seeds that were primed with the rates of 2%, 4%, and 10% MLE. While the lowest germination percentage (80%) of hot pepper seeds was recorded from the controlled or unprimed hot pepper seeds (Table 4.1), This might be due to the fact that MLE facilitates the germination percentage of seeds due to the presence of Zeatin, a plant growth regulator hormone that is involved in several plant germination, growth, and development processes and helps the seeds germinate and increase the germination percentage as compared to unprimed seeds.

Table 4. 1. The germination percentage and the vigor index of hot pepper seeds

Treatment (dose in ml)	Germination percentage (%)	Vigor index
0	80 ^b	0.24 ^e
2	88 ^a	0.35 ^d
4	92 ^a	0.37 ^d
6	94.67 ^a	0.47 ^b
8	94.67 ^a	0.57 ^a
10	88 ^a	0.44 ^c
LSD	7.0	0.03
Significance level	**	**
CV (%)	4.13	4.05

Means with the same letter(s) within a column are not significantly different each other at 5% level of significance

4.1.2. Vigor index

Analysis of variance revealed that the vigor index of hot pepper seeds was highly significantly ($p < 0.01$) affected by the rates of seed priming by MLE (Appendix Table 1). Thus, the highest vigor index (0.57) was recorded from the hot pepper seeds, which were primed with the rate of 8 MLE, while the lowest germination percentage (0.24) of hot pepper seeds was recorded from the controlled or unprimed hot pepper seeds (Table 4.1). This might also be due to the presence of a seed enhancer compound called Zeatin, which is an important compound that helps to facilitate the germination rate, helps them to have vigorous seeds, and results in better vigorousness of hot pepper seeds.

4.1.3. Speed of germination and germination index

Analysis of variance revealed that the speed of germination of hot pepper seeds was highly significantly ($p < 0.01$) affected by the rates of seed priming by MLE but germination index of hot pepper seeds was not show significant difference on different levels MLE. Thus, the fastest germination of hot pepper seeds was recorded from the hot pepper seeds that were primed with 8% and 10% MLE and the latest were recorded from the controlled one. This might be due to the fact that priming of hot pepper seeds by 8 and 10% MLE helps to germinate fast due to the highest water imbibitions, which helped them to have the fastest germination speed. Among the germination indexes, the germination index of hot pepper seeds was not influenced by MLE.

Table 4. 2. The speed of germination and the germination index of hot pepper seeds

Treatment (dose in ml)	Speed of germination	Germination index
0	0.12 ^c	0.19
2	0.20 ^b	0.24
4	0.26 ^a	0.21
6	0.23 ^{bc}	0.24
8	0.27 ^a	0.26
10	0.27 ^a	0.22
LSD	0.05	0.15
Significance level	**	Ns
CV (%)	10.13	7.43

Means with the same letter(s) within a column are not significantly different each other at 5% level of significance

4.2. Field Experiment

4.2.1. Phenological and growth parameters

4.2.1.1. Days to 50% flowering

Analysis of variance revealed that the number of days needed to attain 50% flowering of hot pepper was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming. However, their interactions did not show a significant difference on the days to 50% flowering (Appendix Table 1). Thus, the maximum period (63.50 days) to attain 50% flowering of hot pepper was recorded from the unprimed plot and plots, which were treated with 2% MLE. However, it was also statistically similar with the number of days recorded from the plots, which were treated with 4% MLE, which took 60.00 days to attain 50% flowering. While the shortest period (52.00 days) to attain 50% flowering was recorded from the plots that were treated with 10% MLE, it was statistically similar with days to 50% flowering recorded from the plots that were treated with 8% MLE, which took 55.00 days to 50% flowering. Among planting methods, the maximum period (65.56 days) to attain 50% flowering was recorded from directly sown plots. While the shortest time (52.06 days) to attain 50% flowering was recorded from transplanting methods of planting (Table 4.3).

The results of the present study showed that increasing the rate of MLE reduces vegetative growth, which fastens the flowering of pepper. This might be due to the greater efficiency of seed priming to improve cell water saturation, which acts as a co-factor in the activities of numerous enzymes and results in earlier flowering than those unprimed seeds, which delayed flowering and emergence. It might also be due to the fact that plants from unprimed seed may take more days to emerge than from primed seed, which may result in an above-ground age difference. In line with this finding, seed priming can improve the establishment of many plants, which can lead to rapid growth, early flowering, and higher yields (Harris *et al.*, 2002). The results were also in agreement with the findings of Harris *et al.* (2007), who reported that priming of seeds by different media resulted in faster emergence, better and more uniform stands, less need for re-sowing, more vigorous plants, better drought tolerance, earlier

flowering, earlier harvest, and higher grain yield. Raun *et al.* (2002) reported that priming the rice seed improved its germination index.

Table 4. 3. The main effects of planting method and seed priming on days to 50% flowering and number of seeds per pod of hot pepper grown at Mersa

Treatment	Days to 50% flowering	Number of seeds per pod
Planting method		
Direct sowing	65.56 ^a	106.05b
Transplanted	52.06 ^b	113.72a
LSD	2.37	2.17
Significance level	**	**
% of MLE		
0	63.50 ^a	100.00d
2	63.50 ^a	107.00c
4	60.00 ^{ab}	105.67c
6	58.83 ^{bc}	113.83b
8	55.00 ^{cd}	106.17c
10	52.00 ^d	126.65a
LSD	4.09	3.76
Significance level	**	**
CV (%)	5.82	2.86

Means with the same letter(s) within a column are not significantly different each other at 5% level of significance

4.2.1.2. Number of seeds per pod

Analysis of variance revealed that the number of seeds per pod was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming. However, their interactions did not show a significant difference in the number of seeds per pod (Appendix Table 1). Thus, the maximum number of seeds per pod (126.65) of hot pepper was recorded from the plots, which were primed with 10% MLE, while the lowest number of seeds per pod (100.00) was recorded from the controlled plot or unprimed plot. Among planting methods, the highest number of seeds per pod (113.72) was recorded from transplanting methods of planting. While the minimum number of seeds per pod (106.50) was recorded from directly sown plots (Table 4.3). This might be due to the development of the longest fruit size on plots, which were treated with 10% MLEs, and the transplanting planting method, which might help them accumulate more seeds per pod and result in a higher number of seeds per pod.

4.2.1.3. Plant Height

Analysis of variance revealed that plant height was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming and significantly ($p < 0.05$) affected by their interaction (Appendix Table 1). Increasing the rates of seed priming with MLE increases the plant height significantly. Thus, the tallest plant height (65.47cm) was recorded from the treatment combination of seeds treated with 10% MLE and the transplanting planting method, but it was statistically similar to the plant height obtained from the treatment combination of seeds primed with 8% MLE and the transplanting planting method. While the shortest plant height (47.47cm) was recorded from plots that were directly sown with unprimed seeds, it was statistically similar to the plant height obtained from unprimed seeds and transplanted plots (Table 4.4).

The tallest height of the primed seeds might result from the fact that primed seeds imbibed water, which broke dormancy and revived seed metabolism and resulted in seed germination quickly, which in turn resulted in the tallest plant height. Moringa leaf extract is a source of essential amino acids and several mineral elements, such as K and Ca, which are considered potential natural growth stimulants (Howladar, 2014; Rady *et al.*, 2015). In line with this, Mohammadi (2009) and Bakare and Ukwungwu (2009) have reported that seed priming causes an increase in plant height. This can be explained based on emergence. Plants from unprimed seed may take more days to emerge than from primed seed, which may result in an above-ground age difference, and this above-ground age difference may cause a difference in plant height.

The results were in agreement with the findings of Al-Soqueer (2004), who stated that plant height and the number of leaves per plant increased across the primed seeds compared to the non-primed. Similarly, Farooq *et al.* (2005) also reported priming had a positive effect on plant height, that is, plant height increased with increasing rates of MLE as compared to the unprimed seeds. Improvement in plant height due to priming seems to be the result of earlier, uniform, and vigorous seedlings that gave an energetic start (Basra *et al.*, 2004; Farooq *et al.*, 2006b & 2007).

4.2.1.4. Number of branches per plant

The analysis of variance revealed that the number of branches per plant was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming and by their interaction (Appendix Table 1). Thus, the maximum number of branches (8.13) was recorded from the treatment combination of transplanting planting method and seeds primed with 10% MLE, but it was statistically similar to the number of branches recorded from the treatment combination of transplanting planting method and seeds primed with 8% MLE. While the lowest number of branches per plant (4.37) was recorded from the unprimed and direct sowing planting methods (controlled plot), However, it was statistically similar with the number of branches recorded from the treatment combination of the direct sowing planting method and seeds primed with 2%, 4%, and 6% (Table 4.4).

This might be due to the early emergence of primed seeds, which resulted in early growth and an increase in the number of branches as compared to unprimed seeds. It might also be due to priming, which enhances water imbibitions, leading to enzyme activation, translocation, and utilization of reserved food materials, which in turn increases the ability to divide them into different branches and increase their number. The result was in agreement with results reported by Shah *et al.* (2011), who stated that primed seeds gave a higher number of branches per plant. Similarly, Basra *et al.* (2003) reported that priming increases the number of tillers and leaves in different crops. The authors correlated these improvements with faster and more uniform emergence, better seedling vigor, and the growth of primed seeds, which is in line with this finding. The strong and vigorous seedlings resulted in a higher number of productive branches (Reddy, 2004).

4.2.1.5. Stand count

The analysis of variance revealed that the stand count was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming and by their interaction (Appendix Table 3). Thus, the maximum number-stand count (42.33) was recorded from the

treatment combination of the transplanting planting method and seeds primed with 8% MLE. While the lowest number of stand counts (29.00) was recorded from controlled plot, it was statistically similar to the number of stand counts recorded from the treatment combination of direct sowing planting method and seeds primed with 10% MLE (Table 4.4).

Transplanted and primed hot pepper seeds resulted in a higher number of stands per plot than those unprimed and directly sown seeds. This might be due to the fact that plants that were transplanted and primed have an ability to survive better in field conditions than those directly sown and unprimed ones, which might have no uniform emergence and establishment and reduce the final number of plants in the field during harvesting, resulting in a lower number of stands. This result was in line with the finding of Haileslassie *et al.* (2015), who reported that primed seeds and transplanted hot peppers resulted in higher population survival up to the final harvest.

4.2.1.6. Number of fruit per plant

Analysis of variance revealed that the number of fruit per plant was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming and by their interaction (Appendix Table 2). Thus, the highest number of fruits per plant (52.07) was recorded from the treatment combination of the transplanting planting method and priming seeds with 10% ml of MLE. While the lowest number of fruits per plant (28.57 fruits) was recorded from the treatment combination of unprimed seeds and direct sowing planting method (Table 4.4), The higher number of fruits per plant obtained from primed seeds and transplanted planting methods might be due to the presence of a higher number of branches on transplanted and primed seeds, which in turn increases the number of fruits per plant. On the other hand, the number of branches in unprimed and directly sown plots was low; as a result, the number of fruits produced per plant was reduced, resulting in the lowest number of fruits per plant on unprimed and directly sown plants.

Vigorous seedlings produced by seed priming can produce a higher leaf area index, a higher durable leaf area, and uptake nutrients efficiently from the soil, which helped them translocate synthesized food to the sinks (fruits) and increase their number of fruits, as reported by Sharma

et al. (2014), which is also in line with this finding. It was determined through the increased activity of enzymes involved in sucrose metabolism that those branches translocated the synthesized food to sinks, helped them develop more fruits per plant, and resulted in a higher number of fruits per plot. Harris *et al.* (2002) also reported that more fruits per plant are obtained from primed plots due to having higher branches, which is similar to this finding.

Table 4. 4. Interaction effects of planting method and seed priming on growth and yield of hot pepper grown at Mersa

Treatments		Parameters			
MLE (% ml)	Planting method	PH (cm)	NBPP (No.)	NFPP	Stand count
0	Direct sowing	47.47 ^e	4.37 ^g	28.57 ⁱ	29.00 ^f
	Transplanted	47.97 ^e	5.23 ^{def}	37.80 ^f	33.67 ^{bcd}
2	Direct sowing	48.27 ^e	4.77 ^{fg}	30.93 ^h	31.60 ^{de}
	Transplanted	50.73 ^{bcd^e}	5.80 ^d	40.07 ^e	32.93 ^{cde}
4	Direct sowing	50.50 ^{cde}	4.80 ^{efg}	30.97 ^h	34.00 ^{bc}
	Transplanted	52.50 ^{bcd}	6.47 ^c	42.90 ^d	34.00 ^{bc}
6	Direct sowing	48.50 ^{de}	4.90 ^{efg}	32.30 ^g	34.00 ^{bc}
	Transplanted	54.60 ^b	7.27 ^b	46.70 ^c	33.33 ^{bcd^e}
8	Direct sowing	52.97 ^{bc}	5.20 ^{def}	33.03 ^g	34.00 ^{bc}
	Transplanted	61.63 ^a	7.87 ^a	49.73 ^b	42.33 ^a
10	Direct sowing	54.67 ^b	5.43 ^{de}	36.13 ^f	31.00 ^{ef}
	Transplanted	65.47 ^a	8.13 ^a	52.07 ^a	35.67 ^b
LSD		4.08	0.64	1.84	2.33
Significance level		*	**	**	**
CV (%)		4.63	6.14	2.96	3.01

Means with the same letter(s) within a column are not significantly different each other at 5% level of significance

PH: plant height; NBPP: number of branch per plant; NFPP: number of fruit per plant

4.3. Yield and Yield related parameters

4.3.1. Fruit diameter

Analysis of variance revealed that fruit diameter was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming and significantly ($p < 0.05$) affected by their interaction (Appendix Table 2). Thus, the widest fruit diameter (4.63cm) was recorded from the treatment combination of the transplanting planting method and priming seeds with 10% ml of MLE; while the narrowest fruit diameter (0.97cm) was recorded from the plots, which were directly sown with unprimed seeds (Table 4.5).

This might be due to the fact that MLE is a rich source of plant growth regulator hormones such as Zeatin, ascorbic acid, Ca, and K (Foidl *et al.* 2001), which are involved in several plant growth and development processes and help the fruits develop wider as compared to unprimed seeds. Seed priming with growth regulators improves plant vigor and increases different plant yield parameters (Afzal *et al.*, 2002). Cytokinin often plays its role by interacting with other plant hormones like auxin and abscisic acid (Iqbal *et al.*, 2006). In line with this result, Iftikhar (2009) also observed increased emergence and vigorous plant development in maize seeds primed with MLEs due to the presence of Ca, K, ascorbic acid, and cytokinin hormone.

4.3.2. Fruit length

Analysis of variance revealed that fruit length was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming and by their interaction (Appendix Table 2). Thus, the longest fruit length (12.30cm) was recorded from the treatment combination of the transplanting planting method and priming seeds with 10% ml of MLE. While the shortest fruit length (5.77cm) was recorded from the plots, which were directly sown with unprimed seeds (Table 4.5), This might be due to the fact that MLE is a rich source of zeatin, which is a plant promoter hormone that enhances root, shoot, and fruit development and might result in the tallest fruit length as compared to unprimed seeds. This might also be due to the

accumulation of more dry matter content due to healthy crop growth, which leads to an increase in fruit length (Aravindkumar *et al.*, 1991). The results are in agreement with Raza *et al.* (2013) and Sharma *et al.* (2014), who found a higher yield from primed seeds than unprimed seeds.

4.3.3. Fruit weight

Analysis of variance revealed that fruit weight was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming and by their interaction (Appendix Table 2). Thus, the heaviest fruit weight (29.63g) was recorded from the treatment combination of the transplanting planting method and priming seeds with 10% ml of MLE. While the lightest fruit weight (14.37g) was recorded from the plots, which were directly sown with unprimed seeds. However, it was statistically similar to the fruit weight obtained from the treatment combination of the direct sowing planting method and seeds primed with 2%, 4%, 6%, 8%, and 10% MLE (Table 4.5). This shows that the rates of MLE do not have a statistical influence on the fruit weight. The highest fruit weight from primed seeds and transplanted plots might be due to an increase in growth and cell division by influencing the synthesis and activity of auxin and cytokinin due to the presence of Zeatin in MLE.

In line with this result, Siddik *et al.* (2015) showed that Zeatin improves morphological characteristics such as plant height, leaf number per plant, number of branches per plant, and fresh and dry weights of fruits in pepper. Priming increases the nitrate reductase enzyme activity, which will improve N nutrition in plants and increase the fruit weight and dry matter of plants (Singh *et al.*, 2015). In line with this finding, priming of pepper seeds increased the dry and fresh weights of fruit (Eisvand *et al.*, 2015). Similar to this finding, Farooq *et al.* (2006) and Bakht *et al.* (2010) also reported that primed seeds produced a larger fruit weight.

Table 4. 5. The interaction effects of planting method and seed priming on yield components of hot pepper grown at Mersa

Treatments		Parameters		
MLE (% ml)	Planting method	FD (cm)	FL (cm)	FW (g)
0	Direct sowing	0.97 ^h	5.77 ^h	14.37 ^e
	Transplanted	2.17 ^{de}	7.30 ^{ef}	17.20 ^{de}
2	Direct sowing	1.07 ^{gh}	5.90 ^h	15.47 ^e
	Transplanted	2.30 ^d	8.03 ^{de}	18.80 ^{cd}
4	Direct sowing	1.30 ^{fgh}	6.07 ^h	16.03 ^{de}
	Transplanted	2.93 ^c	8.43 ^{cd}	21.57 ^c
6	Direct sowing	1.63 ^{efg}	6.50 ^{gh}	16.00 ^{de}
	Transplanted	3.30 ^c	8.93 ^c	24.77 ^b
8	Direct sowing	1.77 ^{def}	6.83 ^{fg}	16.27 ^{de}
	Transplanted	4.00 ^b	10.20 ^b	26.13 ^b
10	Direct sowing	2.23 ^d	7.57 ^{ef}	17.13 ^{de}
	Transplanted	4.63 ^a	12.30 ^a	29.63 ^a
LSD		0.59	0.74	3.03
Significance level		*	**	**
CV (%)		10.76	4.87	8.25

Means with the same letter(s) within a column are not significantly different each other at 5% level of significance

FD: Fruit diameter; FL: Fruit length; FW: Fruit weight

4.3.4. Marketable fruit yield

Analysis of variance revealed that marketable yield was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming and significantly ($p < 0.05$) affected by their interaction (Appendix Table 3). Thus, the highest marketable yield (7.73 t ha^{-1}) was recorded from the treatment combination of transplanting planting method and seeds primed with 8% ml of MLE, but it was statistically similar to the marketable yield obtained from the treatment combination of transplanting planting method and seeds primed with 10% ml of MLE. While the lowest marketable yield (3.47 t ha^{-1}) was recorded from the treatment combination of the direct sowing planting method with unprimed seeds (Table 4.6). This might be due to the fact that plots that were transplanted have better growth performance, which might help them to have a good fruit yield, which is attractive and preferred on the

market, and increase the marketable fruit yield of hot pepper as compared to unprimed and directly sown plots, which have the lowest marketable yield.

4.3.5. Unmarketable fruit yield

Analysis of variance revealed that unmarketable yield was significantly ($p < 0.05$) affected by the main effects of seed priming and highly significantly ($p < 0.01$) affected by the interaction of planting method and seed priming. However, the main effect of the planting method did not show a significant difference in the unmarketable yield of hot pepper (Appendix Table 3). Thus, the highest unmarketable yield (1.33 t ha^{-1}) was recorded from the treatment combination of direct sowing planting method and unprimed seeds, but it was statistically similar to the unmarketable yield obtained from the treatment combination of transplanting planting method and seeds primed with 10% ml of MLE. While the lowest unmarketable yield (0.70 t ha^{-1}) was recorded from the treatment combination of the transplanting planting method and seeds primed with 8% of MLE (Table 4.6).

This might be due to the fact that plots that were directly sown might have no best-performing ability due to a lack of uniform germination and seedling performance on the field, which in turn might result in yellow-colored and deformed fruit settings that are not preferred on the market, reduce the marketable fruit yield of the fruit, and increase the unmarketable yield. It might also be due to subjective judgment based on shrunken-shaped fruits, small-sized and discolored fruits due to a lack of uniform germination and seedling performance on the field, those that lacked uniformity, or physiological disorders (bleaching) during the fruit set or due to the climatic conditions of the growing environment during harvesting, which increase the unmarketable yield.

4.3.6. Total fruit yield

Analysis of variance revealed that total yield was highly significantly ($p < 0.01$) affected by the main effects of planting method and seed priming and their interactions (Appendix Table 3). Thus, the highest total yield (8.49 t ha^{-1}) was recorded from the treatment combination of

transplanting planting method and seeds primed with 10% ml of MLE, but it was statistically similar to the total yield obtained from the treatment combination of transplanting planting method and seeds primed with 8% ml of MLE. While the lowest total yield (4.65t ha⁻¹) was recorded from the treatment combination of directly sowing planting method and seeds primed with 6% MLE, it was statistically similar to the total yield obtained from the treatment combination of direct sowing planting method and seeds primed with 2%, 4%, 6%, 8%, and 10% MLE (Table 4.6).

This might be attributed to a moringa extract concentration of 10%, which caused an increase in pepper growth parameters, i.e., leaf area, chlorophyll content, and number of leaves per plant, as shown, which maximized photosynthesis and increased sink capacity through supply of photo assimilates from leaves and translocation to build high-quality fruit and yield, as reported by Thomas and Howarth (2000). The authors also reported that the application of MLE, whereas it is rich with zeaten like cytoknin, may induce cytoknin biosynthesis in the maximum number of photosynthetic active leaves, and that is obvious from the number and area of leaves per plant maintaining the chlorophylls in higher concentrations, which reflect on plant yield. Similarly, Azooz *et al.* (2004) also reported that the different concentrations of moringa extract were capable of enhancing the photosynthetic apparatus in treated plants, which led to an increase in plant productivity and fruit dry matter.

Moringa leaf extract contains a plant growth hormone called Zeatin, which has been reported to increase yields by 25–30% for nearly any crop, as mentioned by Jason (2013). In line with this result, Ozobia (2014) reported that moringa extract as a foliar application improved eggplant yield and the physical characteristics of the fruit. Similarly, Bakht *et al.* (2010) also reported that priming agents affect the yield of crops, which is also in agreement with this result. The results were also in conformity with some studies carried out in hot pepper (Dabrowska *et al.*, 2005), in maize (Harris *et al.*, 2007), in wheat (Rashid *et al.*, 2002), and in okra (Sharma *et al.*, 2014). They reported that the increase in fruit yield might be due to early emergence, higher total emergence, an increase in fruit weight, and more fruit per plant. Furthermore, many studies by Muhammad *et al.* (2013) and Bashir *et al.* (2014) on tomatoes, Oluwagbenga and Odeghe (2015) and Aluko (2016) reported the same results on pepper.

Table 4. 6 The interaction effects of planting method and seed priming on the yield of hot pepper grown at Mersa

Treatments		Parameters		
MLE (% ml)	Planting method	MY (t ha ⁻¹)	UMY (t ha ⁻¹)	TY (t ha ⁻¹)
0	Direct sowing	3.47 ^f	1.33 ^a	4.80 ^e
	Transplanted	4.90 ^{cd}	1.00 ^{cd}	5.90 ^{cd}
2	Direct sowing	3.57 ^f	1.20 ^{ab}	4.77 ^e
	Transplanted	5.10 ^{cd}	0.86 ^{de}	5.96 ^{cd}
4	Direct sowing	3.77 ^{ef}	1.20 ^{ab}	4.97 ^e
	Transplanted	5.80 ^c	0.82 ^{de}	6.63 ^c
6	Direct sowing	3.67 ^f	1.00 ^{cd}	4.67 ^e
	Transplanted	6.73 ^b	0.87 ^{de}	7.60 ^b
8	Direct sowing	3.83 ^{ef}	0.83 ^{de}	4.67 ^e
	Transplanted	7.73 ^a	0.70 ^e	8.43 ^{ab}
10	Direct sowing	4.67 ^{de}	1.13 ^{bc}	5.37 ^{de}
	Transplanted	7.20 ^{ab}	1.29 ^{ab}	8.49 ^a
LSD		0.92	0.17	0.90
Significance level		*	**	**
CV (%)		9.80	10.10	7.90

Means with the same letter(s) within a column are not significantly different each other at 5% level of significance

MY= Marketable yield, UMY=Unmarketable yield, TY= Total yield

4.4. Correlation analysis

Correlation coefficients were calculated to show the relationship of different growth and yield component parameters on growth and yield of hot pepper as influenced by seed priming and planting method. Accordingly, fruit weight, marketable and total fruit yield of hot pepper was highly significantly and positively correlated with most of the growth parameters including plant height, number of branches, number of fruits, fruit diameter, and fruit weight indicating that better performance of growth characteristics of pepper increased marketable and total fruit yield by improving these parameters. On the other hand, unmarketable fruit yield of hot pepper was negatively correlated with number of fruits, fruit diameter and marketable fruit yield (Table 4.7).

This association indicates that an increased photosynthetic area in response to planting space had noticeably contributed to enhance fruit yield, which could be through the production of more assimilates and finally translocate to the fruits (Marschner, 1995). In line with this result, Hyder *et al.* (2007) also showed that plant height has positively correlation with marketable and total fruit yield. Furthermore, Abdisa *et al.* (2011) also indicated fruit weight of pepper had positively strongly association with plant height, leaf number and leaf length. This study is in agreement with Alee mullah *et al.* (2000), who reported that fruit yield and quality of pepper was mainly dependent on the environment and or their inherent characteristics, which affects the traits simultaneously in same direction and sometimes-in different directions.

Table 4.7. Pearson's correlation analysis among growth, yield and yield related parameters of hot pepper planted at Mersa, North Wollo Ethiopia.

	FL	PH	NB	NF	FD	FRL	FW	MY	UMY	TY	SC	NSP P
FL	1.00											
PH	-0.64**	1.00										
NB	-0.80**	0.83*	1.00									
		*										
NF	-0.87**	0.78*	0.96**	1.00								
		*										
FD	-0.86**	0.83*	0.94**	0.95**	1.00							
		*										
FRL	-0.80**	0.86*	0.93**	0.94**	0.93**	1.00						
		*										
FW	-0.75**	0.80*	0.94**	0.93**	0.94**	0.93**	1.00					
		*										
MY	-0.79**	0.82*	0.93**	0.94**	0.92**	0.92**	0.91**	1.00				
		*										
UMY	0.34*	0.07ns	0.03ns	-	-	0.04ns	0.09ns	-	1.00			
				0.06ns	0.04ns			0.03ns				
TY	-0.74**	0.83*	0.93**	0.92**	0.91**	0.92**	0.92**	0.99*	0.11ns	1.00		
		*						*				
SC	-0.50**	0.60*	0.64**	0.61**	0.59**	0.59**	0.57**	0.59*	0.06ns	0.59*	1.00	
		*						*		*		
NSPP	-0.62**	0.68*	0.67**	0.69**	0.72**	0.75**	0.68**	0.66*	-0.10ns	0.64*	0.21ns	1.00
		*						*		*		

FL=Fruit Length ;PH=Plant Height ;NB=Number Of Branch ;NF=Number f Fruit ;FD=Fruit Diameter ;FRL=Fruit Length ;FW=Fruit Weight ;MY=Marketable Yield ;UMY=Un Marketable Yield ;TY=Total Yield ;SC=Stand Count ;NSPP=Number Of Seed Per Pod

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Hot pepper is a widely cultivated tropical spice and vegetable crop in Ethiopia and is rapidly becoming a popular vegetable crop among producers and consumers. It is a high-value and income-generating vegetable crop for most farmers in Ethiopia. In Mersa, hot pepper is produced in the same way as in other parts of the country for home use, in both irrigation and rain-fed conditions. The high yield production of these crops is important, but it may encounter several obstacles that reduce the growth and yield of the crops. The enhancement of pepper production and productivity can be related to different growth factors. Although several constraints are associated with hot pepper production, seed germination and seedling growth may be affected by different factors, like the planting method.

This problem can be overcome through several techniques that involve the treatment of the seed before sowing it into the soil. One of the techniques is seed priming, which involves hydrating the seed in numerous ways. Hence, lack of awareness of the advantages of seed priming and planting methods is among the key factors that affect the growth and yield of hot peppers. Thus, the use of appropriate planting methods and seed priming has made an undeniable contribution to increased hot pepper yields. However, there are no research recommendations pertaining to seed priming and planting methods with due consideration of the environmental condition of the study area.

The findings of the research showed significant differences between the planting method and seed priming for most of the hot pepper growth and yield-related parameters. Accordingly, the growth and yield component parameters of hot pepper increased as the rate of seed priming increased from 2% to 10% MLE. A further increase in the seed priming rate of MLE did not show a significant difference in the marketable and total fruit yield of hot pepper.

Thus, the highest total fruit yield (8.49t ha^{-1}) was obtained from the treatment combination of transplanting planting method and seeds primed with 10% MLE, but it was statistically similar to the total yield obtained from the treatment combination of transplanting planting method and seeds primed with 8% MLE. However, the highest marketable fruit yield (7.73 t ha^{-1}) and the lowest unmarketable (0.70t ha^{-1}) yield were recorded from the treatment combination of the transplanting planting method and seeds primed with 8% MLEs. While the lowest total fruit yield (4.67t ha^{-1}) was recorded from the treatment combination of the direct sowing planting method with seeds primed with 6% and 8% MLEs, In general, the transplanting planting method and primed hot pepper seeds showed superior growth performance, fruit weight, fruit length, fruit diameter, marketability, and total fruit yield of hot peppers under the study area compared to others.

5.2. Recommendation

Based on the results of the present work, the growth and productivity of hot pepper can perform well in the study area and other similar agro-ecologies, and farmers can benefit more by practicing the transplanting planting method and priming of seeds with 8% MLEs. However, this result was based on one season and location work. Therefore, it is suggested to repeat the experiment at the study district, different locations, and different seasons by including other priming reagents and different rates of these priming reagents to draw a conclusive recommendation.

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7. APPENDIXES

Appendix Table 1: Mean squares from analysis of variance (ANOVA) for Days to flowering (Days), Number of seeds per pod (No), plant height (cm), Number of branches per plant (No) for planting method and seed priming of Hot pepper at Mersa in 2021/22 cropping season.

Source of variation	DF	Mean of Squares			
		DF (Days)	NSPP (No)	PH (cm)	NBPP (No)
Rep	2	6.19	7.22	4.51	0.32
PM	1	1640.25**	529.77**	233.07**	31.92**
S Pr	5	127.56**	521.17**	135.51**	3.44**
PM*S Pr	5	17.52 ^{ns}	9.95 ^{ns}	25.17*	0.99**
Error	22	11.71	9.87	132.15	0.13

Where; DF = Degrees of Freedom, DF= Days to Flowering, PH=Plant Height, NSPP= Number of seeds per pod, NBPP= Number of branches per plant, NS, * and ** implies non-significant, Significant and highly significance differences at 5% and 1% level of probability, respectively.

Appendix Table 2: Mean squares from analysis of variance (ANOVA) for Number of fruits per plant (No), Fruit diameter (cm), Fruit length(cm)and fruit weight (g) for planting method and seed priming of Hot pepper at Mersa in 2021/22 cropping season.

Source of variation	DF	Mean of Squares			
		NFPP	FD (cm)	FL(cm)	FW(g)
Rep	2	0.18	0.06	0.72	10.40
PM	1	1495.11**	26.87**	68.61**	458.67**
S Pr	5	96.44**	3.10**	9.20**	46.37**
PM*S Pr	5	16.34**	0.37*	1.93**	22.33**
Error	22	1.29	0.13	0.14	2.57

Where; DF = Degrees of Freedom, NFPP= Number of fruits per plant, FD=Fruit Diameter, FL= Fruit length, FW= Fruit Weight, NS, * and ** implies non-significant, Significant and highly significance differences at 5% and 1% level of probability, respectively.

Appendix Table 3: Mean squares from analysis of variance (ANOVA) for Marketable yield (t ha⁻¹), Unmarketable yield (t ha⁻¹), Total fruit yield (t ha⁻¹) and stand count for planting method and seed priming of Hot pepper at Mersa in 2021/22 cropping season.

Source of variation	DF	Mean of Squares			
		MY (t ha ⁻¹)	UMY (t ha ⁻¹)	TFY (t ha ⁻¹)	Stand count
Rep	2	0.89	0.01	0.98	11.66
PM	1	52.56**	0.02 ^{ns}	50.50**	84.03**
S Pr	5	3.48**	0.04*	3.05**	33.33**
PM*S Pr	5	1.09*	0.24**	2.14**	17.76**
Error	22	0.24	0.01	0.23	1.04

Where; DF = Degrees of Freedom, MY= Marketable yield, UMY= Unmarketable yield, TFY= Total fruit yield, NS, * and ** implies non-significant, Significant and highly significance differences at 5% and 1% level of probability, respectively.