**Optimal Planting Date of Watermelon** (*Citrullus lanatus*) **Under Irrigation Condition** **at Metema District, Northwestern Ethiopia**

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**ABSTRACT**

Watermelon has been introduced recently as a significant cash crop in the Amhara region. Accordingly, agronomic practices have to be studied to maximize productivity. One aspect of this is determination of planting date for watermelon. Hence, identifying the optimal planting time remains essential to enhancing crop production and achieving better yields. To address this, field experiments were conducted under irrigation conditions at Metema district in 2021 and 2023. The experiment used a Randomized Complete Block Design with five sowing dates (December 15th, January 1st, January 15th, February 1st, and February 15th), replicated three times. Agronomic data were systematically collected and analyzed through analysis of variance, with significant treatment means differentiated using LSD at a 5% significance threshold. The findings indicated significant variations (P < 0.05) among the sowing dates concerning fruit length, diameter, average fruit weight, and both marketable and total fruit yield per hectare. The highest total fruit yield recorded was 30.75-ton ha-1 from the January 1st sowing date, followed by 27.20-ton ha-1 from the December 15th sowing date. Based on these results, it is recommended that farmers in the study area and similar agro-ecological zones consider planting watermelon between the second week of December and the first week of January.

***Key words:*** *Citrullus lanatus, Metema, fruit yield, sowing date and Watermelon.*

# **INTRODUCTION**

Watermelon (*Citrullus lanatus*) is an important annual fruit-bearing vegetable that is classified within the Cucurbitaceae family. This crop is cultivated globally, with a particular prevalence in semi-arid regions (Fatondji et al., 2008). It is adaptable to most of the tropical and subtropical zone of Ethiopia, due to its low water requirement and has the potential to be a commercial crop. Watermelon is a newly introduced cash crop in the country (Damtew, 2021). This fruit is important for fresh consumption and agro-processing, such as juice making, nectars and fruit cocktails (Tegen *et al*., 2024). Watermelon is composed of approximately 6% sugar and 92% water by weight, and it serves as a source of potassium, vitamins A and C, amino acids (Reetu and Tomar, 2017), and other essential antioxidants such as lycopene, which is crucial for human metabolism by functioning as an oxygen radical scavenger (Damtew, 2021).

Watermelon thrives in hot, arid environments characterized by average daily temperatures ranging from 22 to 30°C. The ideal soil temperature for optimal root development lies between 20 and 35°C. This crop is highly sensitive to frost (FAO, 2024). Watermelons grow best on sandy loam soils, with good drainage and a slightly acidic pH. Furthermore, germination rates are notably hindered when soil temperatures drop below 21°C (Damtew, 2021).

As reported by FAO (2024), the leading global producers of watermelon include China, Turkey, Iran, Brazil, the United States, Egypt, and Russia. The worldwide production of watermelon amounts to 77.5 million tons, cultivated across 3.1 million hectares. In Africa, Algeria stands out as the foremost producer of watermelon, followed by Egypt and Morocco, while the practice of watermelon farming in Ethiopia is still in its nascent stages (Enyew et al., 2020).

The agronomic practices associated with watermelon cultivation in Ethiopia remain inadequately defined, and research examining the influence of these practices on growth and yield is scarce. It is essential to optimize critical production factors such as sowing date, plant density, and cultivar selection to ensure successful watermelon farming (Tegen et al., 2021). Among these factors, the timing of sowing is particularly significant, as it greatly affects both the growth and yield of watermelon crops (Nestor et al., 2018). This significance is largely due to the variability in weather conditions experienced during the growing season. When crops are planted at less than ideal times, they may encounter extreme temperatures and moisture levels, which can negatively impact their physiological functions and overall productivity. In contrast, planting at the optimal time can create conducive conditions for enhanced photosynthate accumulation and improved fruit yield (Dube et al., 2020). Although various studies have investigated watermelon production across different regions, there is a notable lack of research regarding planting timing in the Metema District. Consequently, we undertook field experiments aimed at identifying the optimal planting date for watermelon in this area, taking into account the effects of varying sowing dates on growth and fruit yield.

# **MATERIALS AND METHODS**

## Description of the Study Area

The experiments were conducted at the Metema District under the Gondar Agriculture Research Center during 2021 and 2023 irrigation conditions. Metema District, located in the North Gondar Zone of the Amhara Region in northwestern Ethiopia, features a diverse climate and topography that significantly influences its agriculture and ecology (Abebe et al., 2024). Geographically, the study area is located between 12°20′N and 13°10′N latitude and 36°05′E and 36°45′E longitude, at an altitude of 681 meters above sea level (Figure 1). The average daily maximum and minimum temperatures are 35°C and 23°C, respectively, with an annual rainfall of 1250 mm (Figure 2). The soils at the experimental site are vertisols with a clay texture, and the pH is neutral. The soil profiles exhibit low levels of available phosphorus and total nitrogen, with a bulk density of 1.13 g/cm³ (Table 1). The predominant crops cultivated during the main season are sesame, sorghum, and cotton, while onion and tomato are primarily grown under irrigation.



Figure 1: Map of Study Area

**Figure 1:** Metema weather conditions of average 2021 and 2023

**Table 1**: Experimental site soil physical and chemical properties

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Study Area | Clay (%) | Silt (%) | Sand (%) | pH | TN (%) | Avai. P (meq100g-1soil) | OC (%) | CEC (Cmol+ kg-1) | BD (g/cm3) |
| Metema | 64 | 20 | 16 | 7.3 | 0.06 | 2.04 | 0.46 | 62.72 | 1.13 |

***Note****: \*OC= Organic carbon, TN= Total Nitrogen, P=Available Phosphorus, BD= Bulk Density*

* 1. **Experimental Materials**

One commonly grown watermelon variety (Crimson Sweet) was used as planting material. The variety was selected based on its adaptation (Table 2) and better performance in the study area. Crimson Sweet is an open-pollinated variety that represents a long-veining type. The variety can develop fruits within 80 days of planting. It has light green fruit with dark stripes, high sugar content, and excellent shipping quality. Seeds used for planting have the same storage life, typically no more than one year after production. Store watermelon seeds in a cool, dark, and dry place and always put seeds in an airtight container to keep out moisture and humidity. When stored under these conditions, watermelon seeds can remain viable for 5 years (Nerson, 2002). Urea (46% N) and NPS (37.7 % P2O5, 18.7% N and 6% S) were used as fertilizer sources.

**Table 2:** Optimal Ecological Requirements for Watermelon Production

|  |  |
| --- | --- |
| Altitude | 0 – 1,500 meters above sea level |
| Growing Temperature | 22 – 28 0C (day) |
| Soil | * Sandy loam
* Well-drained and slightly acidic
* pH range 6.0 – 6.8
 |

Source:( Damtew, 2021)

## **Experimental design and** treatments

The experiments were conducted using a randomized complete block design with three replications. The experimental treatments included five sowing dates: December 15th, January 1st, January 15th, February 1st, and February 15th, resulting in a total of five treatments. Each plot measured 7.2 meters in width and 6.3 meters in length (45.36 m²), organized into four rows, accommodating a total of 28 watermelon plants per plot. The arrangement of the plants allowed for inter-row and intra-row spacings of 1.8 meters and 0.9 meters, respectively, to facilitate optimal growth and management practices. Treatments were allocated randomly to each plot, with a spacing of 1.5 meters maintained between plots and replications to mitigate cross-contamination and promote suitable growth conditions. Comprehensive data on growth and yield parameters were gathered from all rows within each plot to thoroughly assess the impact of the different sowing dates.

## **Experimental Procedures**

The experimental field was established by tilling the soil to a depth of 25–30 cm with a tractor, followed by comprehensive land preparation to eliminate stones and achieve a level surface. Manual furrows were constructed to ensure effective irrigation, and these were prepared several days prior to planting. Four seeds were sown in each hole in accordance with the designated planting schedule, and after a two-week period, thinning was conducted to retain a single plant per hole. Immediately following planting, irrigation was implemented to uniformly achieve field capacity in soil moisture across all treatments throughout the growing season. Fertilization was administered at a rate of 46 kg ha⁻¹ for both P₂O₅ and N, utilizing Urea (46% N) and NPS (37.7% P₂O₅, 18.7% N, and 6% S). The entire quantity of NPS and half of the Urea was applied at the time of planting, while the remaining 50% of Urea was applied at the onset of flowering. Furrow irrigation was conducted every five days during the initial four weeks, transitioning to seven-day intervals until harvest. Weeding was performed regularly to maintain weed-free plots. Pest management included the application of Dimitotic 40% insecticide at a rate of 1 liter per hectare to control Cucumber beetles when 10% or more of the seedlings showed signs of infestation. Manual weeding involved the physical extraction or cutting of weeds close to the soil surface. The crop was harvested upon reaching physiological maturity.

## Data Collection

***Weather data:*** Daily meteorological observation data, including maximum and minimum temperature and rainfall (mm) were collected from the Ethiopian Meteorology Institute (EMI) Metema weather station (Ethiopian Meteorology Institute, 2021&2023).

***Soil data:*** The initial soil of the experimental field was collected from depths of 0-20 cm. These soil samples were analyzed for soil textural class, CEC, pH in water, EC in water, total N, phosphorus (meq/100g soil) and total organic carbon using standard analytical methods.

***Emergence percentage:*****Emergence %** refers to the proportion of seeds that **successfully emerge** from the soil and grow into seedlings under field or natural conditions. The emergence % was calculated by dividing the actual number of emerged seeds to the total number of seeds sown per plot.

 Emergence (%) = $\frac{Number of seeds emerged}{Number of seeds sowing}$ x 100

***Days to flowering:*** The number of days from sowing to the first appearance of flowers, recorded once at least 50% of the plants have started flowering. For each plot, this stage is recorded as the number of days from planting to flowering.

***Days to physiological maturity:*** This refers to the number of days taken from sowing to 90% of the plants reached physiological maturity, the stage at which the fruit or seed has fully developed and ready for harvest. Indicators of physiological maturity includes a change in skin and flesh colors, drying or browning of the tendrils near the stem and a hollow sound when the fruit is tapped (Park & Cho, 2013; Hodges, 2003).

***Fruit length and width:*** These dimensions are measured at physiological maturity in each plot to assess fruit development. Fruit length is measured from the tip of the fruit to the base and Fruit width is also measured at the widest point of the fruit.

***Marketable fruit yield:*** This was recorded by weighing all harvests of marketable fruits (suitable for sale) from each net plot and was calculated in tons per hectare.

***Unmarketable fruit yield:*** This was recorded by weighing fruits that are not suitable for sale due to defects like rot, insect damage, blossom-end rot, cracks, or physiological deformities, from each net plot and expressed in tons per hectare.

***Total fruit yield:*** Sum of marketable and unmarketable fruit yields, expressed in tons per hectare. The weights of marketable and unmarketable fruits are recorded using a sensitive balance. The cumulative weights from all harvests are summed for data analysis.

*Data analysis*

Data for vegetative growth and yield of watermelon were analyzed using R Software (R 4.3.1). Significant differences among treatment means were determined using a least significant difference (LSD) test, with a significance level set at P<0.05 (De Mendiburu & Simon, 2015). The LSD test allowed for the comparison of means to identify statistically significant differences between the effects of different sowing dates.

# **RESULTS AND DISCUSSION**

## Weather and Soil Conditions of The Experimental Site

**Field experiments were carried out under irrigated conditions during the growing seasons of 2021 and 2023. The daily temperature fluctuations ranged from a maximum of 25.9 to 40°C and a minimum of 18.4 to 24.5°C. As illustrated in Figure 2, meteorological data reveal a consistent increase in both maximum and minimum daily temperatures from December through April. During these five months, the highest recorded minimum temperature occurred in April at 24.5°C, while the lowest was noted in December at 17.8°C. Similarly, the peak maximum temperature was also observed in April, reaching 40°C, with December recording the lowest maximum temperature of 33.8°C. According to the soil analysis presented in Table 1, the pH level was neutral at 7.3. The contents of total nitrogen (0.061%), available phosphorus (2.04 meq/100g), and organic carbon (0.46%) were found to be relatively low, indicating a need for fertilizer remediation. The cation exchange capacity was notably high at 63.72 cmol+ kg⁻¹ (Tadesse et al., 1991). Furthermore, the particle-size distribution analysis indicated a significant clay content of 64%. Soil profile samples demonstrated an increasing trend in bulk density from the upper to the lower layers, with an overall bulk density measured at 1.13 g cm⁻³.**

##  Effects of Sowing Dates on Phenological Parameters of Watermelon

The ANOVA results show that the sowing date significantly affected **the phenological parameters of watermelon. There were no significant interactions between sowing dates and years, indicating that the performance of each sowing date was similar across different years.**

* + 1. **Days to flowering and maturity**

**The findings regarding the impact of sowing date on the flowering and maturity periods of watermelon are presented in Table 3. Statistical analysis revealed that the sowing date had a significant influence on both flowering and maturity days (P < 0.05). Specifically, the December 15th sowing date yielded notably higher averages for flowering days (53.33) and maturity days (87.00) when compared to the February 15th sowing date. In contrast, the February 15th sowing date exhibited earlier flowering (33.36 days) and fruit maturity (65.33 days), with the February 1st sowing date following closely behind (Table 3). The observed differences in flowering and maturity durations associated with the planting dates may be attributed to variations in temperature at each sowing period. As illustrated in Figure 1, daily temperatures showed a slight increase from December (33.8°C) to February (38.8°C). This observation corroborates the findings of Tegen et al. (2021), which indicated that earlier phenological events occurred at Ribb, followed by Woramit. Notably, the year 2019 experienced earlier flowering and maturity compared to 2018, attributed to relatively warmer conditions, with Ribb recording higher temperatures than Woramit. These results are also consistent with the research conducted by S. B. Bellad and Umesh Hiremath (2018), which indicated that watermelon thrived and produced higher yields during cooler months. Furthermore, the sowing date significantly influenced the emergence percentage (P < 0.05), with the December 15th sowing date achieving the highest emergence percentage (89.70%), while the February 15th sowing date recorded the lowest (70.39%) (Table 3). This observation aligns with Damtew (2021), who noted that watermelon seeds exhibited optimal emergence and growth at temperatures ranging from 25°C to 30°C.**

**Table 3:** Effects of sowing date on the emergence %, flowering, and maturity days of watermelon (combined data of 2021 and 2023)

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Emergence percentage | Days of flowering | Days of maturity |
| December 15th | 89.70 | 53.33 | 87.00 |
| January 1st | 81.02 | 38.67 | 77.00 |
| January15th | 78.46 | 43.00 | 72.00 |
| February1st | 80.41 | 37.00 | 66.00 |
| February 15th | 70.39 | 33.67 | 65.33 |
| Mean | 79.99 | 41.13 | 73.47 |
| LSD (0.05) | 12.02\* | 1.61\*\* | 0.97\*\* |
| CV (%) | 12.55 | 2.10 | 0.70 |

***Note:*** *\*, \*\* F test significant at P= 0.05, and 0.01 levels, respectively. LSD = least significant difference at 5%, and CV (%) = coefficient of variation*

## Effect of Sowing Dates on Fruit Yield and Yield-Related Parameters

### Fruit length, diameter and average fruit weight

**Fruit length, diameter, and average weight exhibited significant variations (P < 0.05) in response to the sowing date, as illustrated in Table 4. The second earliest sowing date, January 1st, led to a notable increase in fruit weight, length, and diameter across both growing seasons. The highest recorded average fruit weight (5.47 kg), length (24.23 cm), and diameter (21.41 cm) were associated with the January 1st sowing date, with the December 15th sowing date following closely behind. This phenomenon can be explained by the extended duration of favorable growth conditions afforded by earlier sowing, which enables plants to mature into robust and healthy specimens, thereby resulting in enhanced average fruit weight and diameter. This observation aligns with the findings of El-Shabrawy and Hatem (2008), who reported that earlier sowing dates significantly improved various fruit characteristics, including weight, length, and diameter.**

**Table 4:** Effects of sowing dates on the yield related parameters of watermelon during 2021 and 2023 irrigation season

|  |  |  |  |
| --- | --- | --- | --- |
| Treatment | Fruit length (cm) | Fruit diameter (cm) | Average fruit weight (kg) |
| 2021 | 2023 | Combine | 2021 | 2023 | Combine | 2021 | 2023 | Combine |
| December 15th | 22.70 | 20.53 | 21.62 | 21.30 | 16.93 | 19.12 | 3.90 | 5.00 | 4.45 |
| January 1st | 23.20 | 25.27 | 24.23 | 21.37 | 21.47 | 21.41 | 4.30 | 6.63 | 5.47 |
| January15th | 20.29 | 21.00 | 20.65 | 18.69 | 18.00 | 18.34 | 2.72 | 5.17 | 3.94 |
| February1st | 21.08 | 18.53 | 19.81 | 19.20 | 14.67 | 16.93 | 3.44 | 5.33 | 4.39 |
| February 15th | 21.37 | 19.67 | 20.52 | 18.47 | 16.67 | 17.57 | 3.86 | 4.50 | 4.18 |
| Mean | 21.73 | 21.78 | 21.36 | 19.80 | 17.68 | 18.68 | 3.64 | 5.30 | 4.49 |
| LSD (0.05) | 2.37\* | 4.79\*\* | 2.54 \* | 2.3NS | 4.13\*\* | 2.57\* | 1.84\* | 0.83\*\* | 0.83\* |
| CV (%) | 5.87 | 12.45 | 9.94 | 8.68 | 12.83 | 11.51 | 21.58 | 8.61 | 15.43 |

***Note:*** *\*, \*\* F test significant at P= 0.05, and 0.01 levels, respectively. NS= non-significant, LSD = least significant difference at 5%, and CV (%) = coefficient of variation*

### Fruit yield of watermelon

Analysis of variance revealed that there was statistically significant difference (P < 0.01) among sowing dates on marketable, unmarketable, and total fruit yields of watermelon. The highest marketable fruit yield (25.97 tons ha-1), unmarketable fruit yield (4.08 tons ha-1), and total fruit yield (30.75 tons ha-1) were obtained from the 1st January sowing date. However, there were not statistically different from the 15th December sowing date, which produced 22.22 tons ha-1 of marketable fruit, 5.15 tons ha-1 of unmarketable fruit, and 27.02 tons ha-1 of total fruit yields. The lowest yields of marketable fruit yield (9.46 tons ha-1), unmarketable fruit yield (1.86 tons ha-1), and total fruit yield (11.15 tons ha-1) were recorded from the 15th February sowing date (Table 5). The planting dates had a significant effect on fruit yield. Severe yield reductions were observed from the last two planting dates. These yield reductions were primarily due to a reduction in both the number of fruits and the weight of individual fruits, which was caused by high-temperature stress negatively affecting reproductive development. February Late sowing dates led poor growth performance and lower fruit yields because of fluctuating weather conditions, such as increasing daytime temperatures. Higher daily temperatures later in the growing season can negatively impact pollinator/insects’ activity, which in turn affects watermelon fruit yield. Similar finding was reported by Baker (2001)who reported that high-temperature stress adversely affected crop growth and yield. Additionally, Eifediyi and Remison (2009) found that early planting at the beginning of the wet season is beneficial for crops like cucumber for maximum yield.

 **Table 5:** Effects of sowing dates on the fruit yield of watermelon during 2021 and 2023 irrigation season

|  |  |
| --- | --- |
| Treatments | Fruit yield (ton/ha-1) |
| Marketable  | Unmarketable  | Total  |
| 2021 | 2023 | Combine | 2021 | 2023 | Combine | 2021 | 2023 | Combine |
| December 15th | 22.43 | 22.00 | 22.22 | 6.68 | 3.37 | 5.15 | 29.00 | 25.39 | 27.20 |
| January 1st | 22.19 | 29.76 | 25.97 | 4.55 | 3.60 | 4.08 | 27.4 | 34.1 | 30.75 |
| January15th | 17.30 | 22.9 | 20.10 | 2.59 | 4.50 | 3.55 | 19.88 | 27.43 | 23.66 |
| February1st | 10.35 | 16.31 | 13.33 | 2.33 | 4.17 | 3.25 | 11.34 | 20.47 | 15.91 |
| February 15th | 11.91 | 7.02 | 9.46 | 2.28 | 1.43 | 1.86 | 13.86 | 8.45 | 11.15 |
| Mean | 16.84 | 19.6 | 18.22 | 3.66 | 3.24 | 3.58 | 20.30 | 23.17 | 21.73 |
| LSD (0.05) | 5.87\*\* | 6.34\*\* | 4.75\*\* | 1.55\*\* | 1.31\*\* | 1.57\*\* | 5.84\*\* | 4.33\*\* | 5.28\*\* |
| CV (%) | 18.52 | 17.17 | 21.76 | 22.50 | 22.15 | 36.70 | 15.27 | 9.93 | 20.31 |

***Note:*** *\*, \*\* F test significant at P= 0.05, and 0.01 levels, respectively. LSD = least significant difference at 5%, and CV = coefficient of variation*

# **CONCLUSION AND RECOMMENDATION**

Adjusting the timing of sowing is a crucial management approach aimed at enhancing crop growth and productivity by aligning with the most advantageous seasonal conditions, such as temperature, sunlight, and precipitation at the planting location. This research assessed five different planting dates in the Metema district of Northwestern Ethiopia to determine the optimal times for maximizing watermelon yield. The findings revealed that the timing of sowing significantly affected various growth and yield parameters of watermelon, including emergence rate, flowering duration, maturation period, fruit length, diameter, average weight per fruit, and overall fruit yield. Notably, the highest marketable fruit yield (25.97 tons per hectare) and total fruit yield (30.75 tons per hectare) were achieved with the sowing date of January 1st, which was statistically comparable to the December 15th sowing date. This suggests that both dates are suitable for watermelon cultivation. Conversely, the February 15th sowing date resulted in the lowest marketable fruit yield (9.46 tons per hectare) and total fruit yield (11.15 tons per hectare). Consequently, it is recommended that in the Metema district and similar agro-ecological regions, watermelon should be planted between the second week of December and the first week of January to maximize production and productivity.

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**Availability of data and materials**

All relevant data generated from the study and reported in the manuscript are included in this article. Further data sets are available from the principal investigator upon request.

**Conflict interest**

The authors declare no conflict of interest.

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