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Optimal Planting Date of Watermelon Under Irrigation Conditions at Metema District of Northwestern Ethiopia

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ABSTRACT

Watermelon has been introduced recently as a significant cash crop in the Amhara region. As an emerging crop, the agronomic practices of watermelon have to be studied to maximize productivity. One aspect of this is determining the planting date of watermelon. Hence, field experiments were conducted under irrigation conditions at Metema district in 2021 and 2023. The experimental design used was a randomized complete block design with five sowing dates (December 15, January 1, January 15, February 1, and February 15), each replicated three times. Agronomic data were collected and subjected to analysis of variance, with significant treatment means distinguished using LSD at a 5% significance level. The findings indicated substantial variations ($P < 0.05$) among the sowing dates in terms of fruit length, diameter, average fruit weight, and marketable and total fruit yields per hectare. The highest total fruit yield (30.75 tons per hectare) was recorded from the January 1 sowing date, followed by 27.20 tons per hectare from the December 15 sowing date. Hence, planting watermelon between the second week of December and the first week of January is recommended for the Metema district and similar agro-ecological regions. Moreover, further research is required to determine the optimal nitrogen fertilizer rates and irrigation frequency to reduce the incidence of fruit cracking and enhance crop performance.

1. 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). Watermelon thrives in hot and 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.

Watermelon is adaptable to most of the tropical and subtropical zones of Ethiopia, due to its moderate drought tolerance compared to some other fruits or vegetables, and it has the potential to become a commercial crop. It is a newly introduced cash crop in the country (Damtew, 2021), and the practice of watermelon farming in Ethiopia is still in its nascent stages (Enyew et al., 2020). 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).

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 (Eifediyi and Remison, 2009; Tegen et al., 2021). Among these factors, sowing date 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.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiments were conducted at the Metema District of Northwestern Ethiopia during 2021 and 2023 irrigation conditions. Metema District features a diverse climate and topography that significantly influences its agriculture (Abebe et al., 2024). Geographically, the study area is located between 12°20′0″N and 13°10′0″N latitude and 36°5′0″E and 36°45′0″E longitude, with an elevation ranging from 550 m to 1,600 m above sea level. The specific experimental site is located at an altitude of 681 m above sea level (Figure 1). The average daily Tmax and Tmin 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.

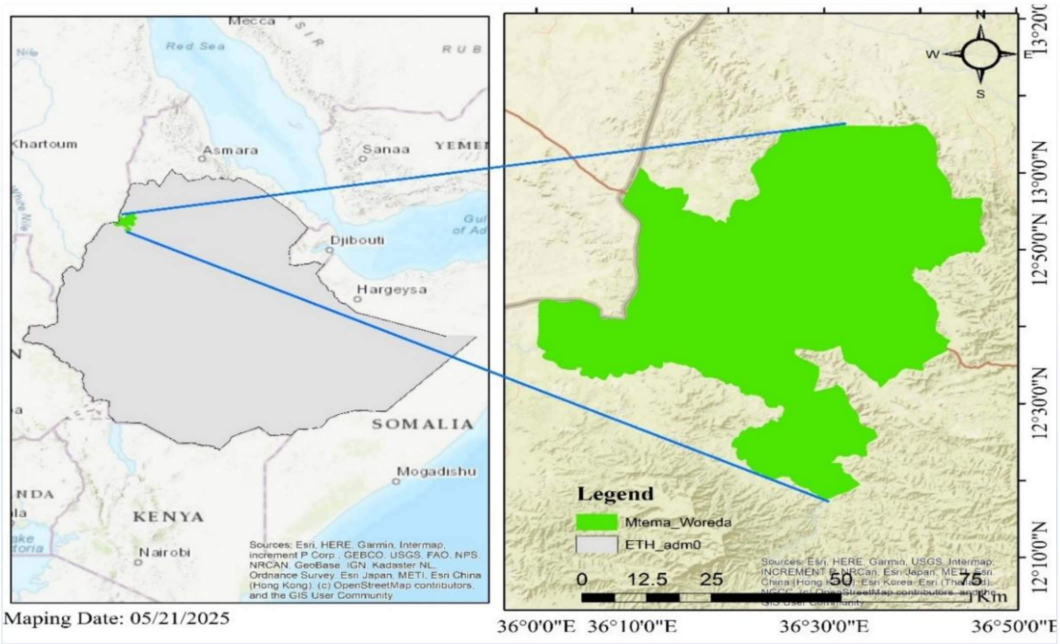

Figure 1: Map of the Study Area

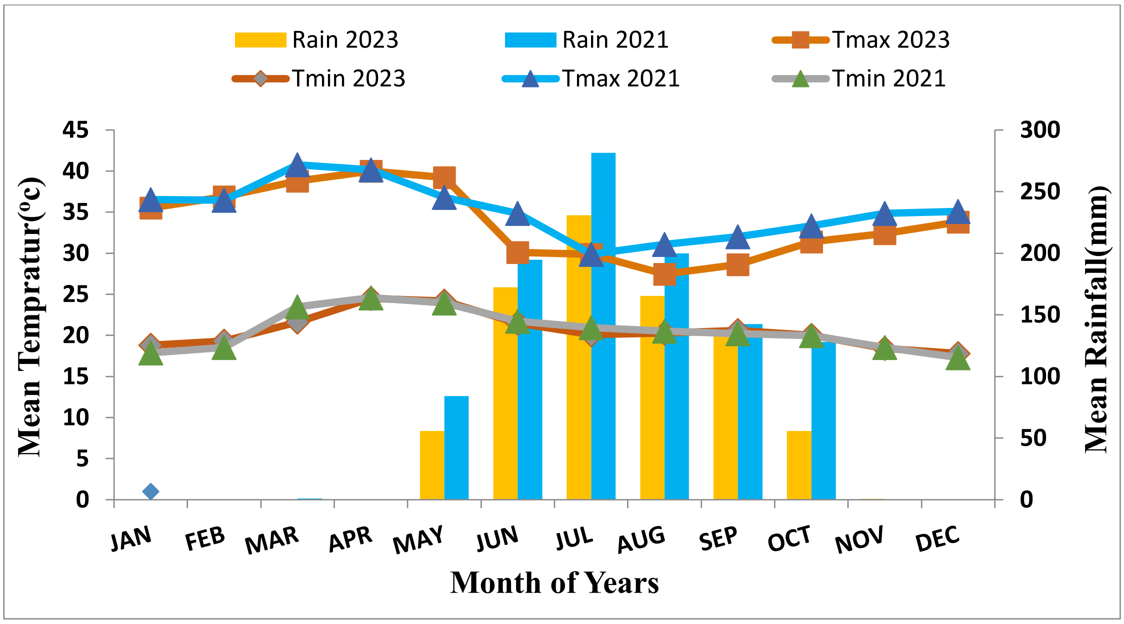

Figure 2: Weather conditions of Metema during 2021 and 2023 G.C. (EMI, 2021 & 2023)

Table 1. Experimental site soil physical and chemical properties

Study Area	Clay (%)	Silt (%)	Sand (%)	pH	TN (%)	Avai. P (meq100g^{-1}soil)	OC (%)	CEC (Cmol^{+} kg^{-1})	BD (g/cm^{3})
Metema	64	20	16	7.3	0.10	9.07	0.46	62.72	1.13

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

2.2. 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 % P_2O_5, 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 ^{0}C (day)
Soil	• Sandy loam • Well-drained and slightly acidic • pH range 6.0 – 6.8

Source:(Damtew, 2021)

2.3. 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 15, January 1, January 15, February 1, and February 15, resulting in a total of five treatments. Each plot measured 7.2 meters in width and 6.3 meters in length (45.36 m^2), 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 two central rows within each plot to assess the impact of the different sowing dates.

2.4. 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. Once the field was adequately prepared, furrows were created with a width of 50 centimeters, maintaining a distance of 180 centimeters between each furrow, and this preparation was completed several days prior to planting. Four seeds were sown in each hole in accordance with the designated planting schedule, and after two weeks, 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 P_2O_5 and N, utilizing Urea (46% N) and NPS (37.7% P_2O_5, 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 first four weeks, subsequently shifting to a frequency of once every seven days until the time of 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.

2.5. 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 (EMI, 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 by the total number of seeds sown per plot.

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

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 reaching physiological maturity, the stage at which the fruit or seed has fully developed and is ready for harvest. Indicators of physiological maturity include 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: Measurements of fruit length and width were obtained from five randomly chosen plants located in the central rows. These dimensions are recorded at physiological maturity within each plot to evaluate fruit development. Fruit length is defined as the distance from the tip to the base of the fruit, while fruit width is determined at the widest point of the fruit.

Average fruit weight (kg) The average weight of fruit was obtained from five randomly chosen fruits located in the central rows. These measurements were taken at physiological maturity within each plot to evaluate fruit weight, with the findings reported in kilograms per plant.

Marketable fruit yield: The yield of marketable fruits was determined by weighing all harvests deemed suitable for sale from each net plot measuring 22.68 m^2, with results expressed in tons per hectare.

Unmarketable fruit yield: The yield of unmarketable fruit was determined by weighing the fruits deemed unsuitable for sale due to various defects such as rot, insect damage, blossom-end rot, cracks, or physiological deformities, from each net plot, and was expressed in tons per hectare.

Total fruit yield: The total fruit yield is defined as the aggregate of both marketable and unmarketable fruit yields, measured in tons per hectare. The weights of these fruits are determined using a precise balance, and the total weights from all harvests are compiled for subsequent 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.

2.6. 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 27.5 to 40.8°C and a minimum of 17.3 to 24.6°C. As illustrated in Figure 2, meteorological data reveal a consistent increase in both maximum and minimum daily temperatures from December to April. During these five months, the highest recorded minimum temperature occurred in April at 24.6°C, while the lowest was noted in December at 17.3°C. Similarly, the peak maximum temperature was also observed in April, reaching 40.8°C, with August recording the lowest maximum temperature of 27.5°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}.

3. RESULTS AND DISCUSSION

3.1. 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.

3.2. 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 ($P < 0.05$) influence on both flowering and maturity days. Specifically, the December 15 sowing date yielded notably higher averages for flowering days (53.33) and maturity days (87.00) when compared to the February 15 sowing date. In contrast, the February 15 sowing date exhibited earlier flowering (33.36 days) and fruit maturity (65.33 days), with the February 1 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 2, daily temperatures showed a slight increase from December (33.8°C) to April (40.8°C). This observation in line with 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 15 sowing date achieving the highest emergence percentage (89.70%), while the February 15 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)

Sowing date	Emergence percentage	Days of flowering	Days of maturity
December 15	89.70	53.33	87.00
January 1	81.02	38.67	77.00
January 15	78.46	43.00	72.00
February 1	80.41	37.00	66.00
February 15	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*

3.3. Effect of Sowing Dates on Fruit Yield and Yield-Related Parameters

3.3.1. Fruit length, diameter, and average fruit weight

Analysis of variance revealed that there was a statistically significant ($P< 0.05$) difference among sowing dates on fruit length, diameter, and average weight of watermelon, as illustrated in Table 4. The January 1 sowing date 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 1 sowing date, with the December 15 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 the 2021 and 2023 irrigation seasons

Sowing date	Fruit length (cm)			Fruit diameter (cm)			Average fruit weight (kg)		
	2021	2023	Combined	2021	2023	Combined	2021	2023	Combined
December 15	22.70	20.53	21.62	21.30	16.93	19.12	3.90	5.00	4.45
January 1	23.20	25.27	24.23	21.37	21.47	21.41	4.30	6.63	5.47
January 15	20.29	21.00	20.65	18.69	18.00	18.34	2.72	5.17	3.94
February 1	21.08	18.53	19.81	19.20	14.67	16.93	3.44	5.33	4.39
February 15	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^{*}	2.3^{NS}	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*

3.3.2. Fruit yield of watermelon

Analysis of variance revealed that there was a statistically significant ($P< 0.01$) difference 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 was no statistically significant difference 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).

Fruit yield of watermelon showed an increasing trend when sowing occurred between December and January, but showed a decline for sowing dates from January to February. A significant reduction in total fruit yield was observed, decreasing from 30.75 to 11.15 tons per hectare when comparing the sowing dates of January 1 and February 15 (Table 5). The increased fruit yield at the 1st January sowing date might be due to higher values of yield attributes, like the fruit length, diameter, and average fruit weight, which collectively contributed to the higher fruit yield. Severe yield reductions were observed from the 15th February sowing date. These yield reductions were primarily due to a reduction in both phenological and yield-related parameters of watermelon, which was caused by high-temperature stress negatively affecting reproductive development. February sowing dates led to 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 activity, which in turn affects watermelon fruit yield. A similar finding was reported by Baker (2001), who reported that high-temperature stress adversely affected crop growth and yield. Additionally, S. B. Bellad and Umesh Hiremath (2018) found that high-quality hybrid watermelon seeds can be produced by sowing parental seeds in January, using NPK fertilizer at a rate of 150:135:150 kg per hectare, with a row spacing of 3 meters and plant spacing of 1 meter. Dufault et al. (2006) also reported that Optimal melon yield and quality depend on optimal temperatures for foliage and fruit growth, and pollination.

Table 5. Effects of sowing dates on the fruit yield of watermelon during the 2021 and 2023 irrigation seasons

Sowing date	Fruit yield (ton/ha^{-1})								
	Marketable			Unmarketable			Total		
	2021	2023	Combined	2021	2023	Combined	2021	2023	Combined
December 15	22.43	22.00	22.22	6.68	3.37	5.15	29.00	25.39	27.20
January 1	22.19	29.76	25.97	4.55	3.60	4.08	27.4	34.1	30.75
January 15	17.30	22.9	20.10	2.59	4.50	3.55	19.88	27.43	23.66
February 1	10.35	16.31	13.33	2.33	4.17	3.25	11.34	20.47	15.91
February 15	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*

4. CONCLUSION AND RECOMMENDATION

Adjusting the timing of watermelon sowing date is a critical agronomic practice that significantly influences crop establishment, growth parameters, and final yield. Watermelon, being a warm-season crop, requires specific environmental conditions for optimal performance. The research findings revealed that the timing of sowing significantly affected various growth and yield related parameters of watermelon, including emergence rate, flowering duration, maturation period, fruit length, diameter, average fruit 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 1, which was statistically comparable to the December 15 sowing date. In contrast, the February 15 sowing date resulted in the lowest marketable fruit yield (9.46 tons per hectare) and total fruit yield (11.15 tons per hectare). This study suggests that planting watermelon between December 15 and January 15 is optimal for successful cultivation. This flexibility provides growers with valuable options when planning their production schedule. Therefore, 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. Moreover, further research is required to determine the optimal nitrogen fertilizer rates and irrigation frequency to reduce the incidence of fruit cracking and enhance crop performance.

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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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