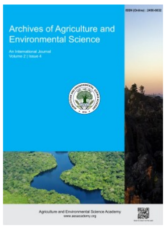
Archives of Agriculture and Environmental Science 9(4): 682-690 (2024)
https://doi.org/10.26832/24566632.2024.090407

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE

CrossMark

Influence of sowing dates and weeding regimes on growth attributes and maize dry fodder yield

Swapan Kumar Paul*, Md. Rejaul Haque, Md. Sojib Kabiraj, Shubroto Kumar Sarkar, Md. Abdur Rahman Sarkar and Md. Harun Rashid

Department of Agronomy, Bangladesh Agricultural University, Mymensingh - 2202, Bangladesh
*Corresponding author's E-mail: skpaul@bau.edu.bd

ARTICLE HISTORY

Received: 23 September 2024
Revised received: 26 November 2024
Accepted: 12 December 2024

Keywords

Growth parameters
Herbage productivity
Maize
Planting times
Weed control

ABSTRACT

Effective agricultural practices are pivotal for ensuring optimal crop yields and sustainable farming. Two critical factors that significantly influence crop productivity are the date of planting and the weeding regime. An experiment was carried out to investigate how the timing of planting and the frequency of weeding impact the growth characteristics and fodder yield of maize. The study involved three planting dates *viz.* 15 November (D_1), 15 December (D_2) and 14 January (D_3) along with five different weeding regimes *viz.* no weeding (W_0), two hand weedings at 15 and 30 days after sowing (DAS) (W_1), pre-emergence herbicide (pendimethalin) + one hand weeding at 30 DAS (W_2), post-emergence herbicide (pyrazosulfuran-ethyl) + one hand weeding at 30 DAS (W_3), and pre-emergence herbicide (pendimethalin) + post-emergence (pyrazosulfuran-ethyl) herbicide (W_4). The growth characteristics and the amount of dry fodder produced were notably affected by the timing of planting, the method of weeding and how these factors interacted. At harvest, the tallest plant (138.48 cm) and total dry matter production plant^{-1} (37.32 g) were recorded in the plants sown on 15 November with the application of pre-emergence herbicide (pendimethalin) + one hand weeding at 30 DAS. The maximum number of leaves plant^{-1} (13.33) and leaf chlorophyll content (116.60) were obtained from15 November with the application of pre-emergence herbicide (pendimethalin) + post-emergence (pyrazosulfuran-ethyl) herbicide and 14 January with the application of pre-emergence herbicide (pendimethalin) + one hand weeding at 30 DAS. The highest dry fodder yield (4.14 t ha^{-1}) was achieved with maize planted on 15 November and treated with pre-emergence herbicide (pendimethalin) + one hand weeding at 30 days after sowing. Based on the study, it can be concluded that planting on November 15 using a pre-emergence + one hand weeding 30 days after sowing may result in the tallest plants, maximum total dry matter production and the maximum dry fodder yield of maize.

Citation of this article: Paul, S. K., Haque, M. R., Kabiraj, M. S., Sarkar, S. K., Sarkar, M. A. R., & Rashid, M. H. (2024). Influence of sowing dates and weeding regimes on growth attributes and maize dry fodder yield. *Archives of Agriculture and Environmental Science*, 9(4), 682-690, https://dx.doi.org/10.26832/24566632.2024.090407

INTRODUCTION

Maize has been used both as fodder and as human food in many countries for many centuries (Kumar, 2014). As farmers focus more on producing food grains for human consumption, there is now a severe shortage of livestock fodder. Fodder is an excellent and highly nutritious feed for livestock whether green or dries (Haque 2003; Hukkeri *et al.*, 1977; Ghosh *et al.*, 2024). The shortage of fodder has been a long-standing issue exacerbated by rapid population growth and remains a major limiting factor in livestock production (Paul *et al.*, 2019; Sarker *et al.*, 2020; Paul *et al.*, 2023). In Bangladesh, about 70.69% of cultivated land is used for agriculture but only 0.03% is dedicated to fodder production (BBS, 2022). The total annual production of dry matter

(DM) is 69,576,000 tons including green grasses and non-conventional crop residues. Despite some progress in fodder production, the country currently faces a net deficit of over 40% in dry matter, 65% in crude protein and 60% in metabolizable energy (Sarker *et al.*, 2021). One of the main factors contributing to the low yield of fodder is the timing of sowing and the management of weeds. The sowing date plays a crucial role in crop growth and development (Haque *et al.*, 2024; Mashregi *et al.*, 2014). To prolong the harvest period, producers often stagger planting dates and use hybrids with varying maturity dates (Williams, 2008). Typically, early sowing extends the maturation process, while late sowing shortens it (Idikut *et al.*, 2005). Both early and late sowing can lead to lower yields due to the potential for unfavorable climatic conditions after planting or during the growing season.

Weeds reduce photosynthesis efficiency, dry matter production and the distribution of food material to the economic parts of the crop, thus reducing the crop's sink capacity and resulting in poor grain and fodder yield. They also use up valuable conserved moisture and absorb more nutrients from the soil than the crops do (Kabiraj *et al.*, 2020). Yield losses due to weeds in maize range from 28% to 93%, depending on the type of weed flora, intensity and duration of crop weed competition (Sharma & Thakur, 1998). They found that unchecked weed growth in sandy loam soils reduced maize yield by 61.3% compared to a weed free check. Worldwide, yield losses in maize due to weeds are estimated to be around 37% (Oerke & Dehne, 2004). Fodder maize suffers from a serious weed problem as a result of most farmers not using any weed management techniques, which reduces the amount of green and dry fodder produced per unit area. Hand weeding is incredibly expensive, time-consuming, and labor-intensive (Moutussi *et al.*, 2021). An additional problem is the lack of labor during the crucial stage of the crop-weed competition (Islam *et al.*, 2015; Sinha *et al.*, 2018; Sahu *et al.*, 2022). Mostly, farmers rely on hand weeding for weed control in maize, with a few using pre-emergence and post-emergence herbicides. Raghuwanshi *et al.* (2023) indicated that the combination of pre-emergence + pre-emergence herbicide could be an alternative approach to hand weeding and alone herbicides in fodder maize. However, the effectiveness of these herbicides is diminished by various climatic and soil-related factors. Consequently, a combined approach of using both types of herbicides along with hand weeding should be explored. Additionally, there is limited information on production practices that can enhance the dry fodder yield of maize. Given the importance of fodder, the research aimed to determine how planting timing and weed management strategies affect the growth traits and dry fodder yield of maize.

MATERIALS AND METHODS

Research area

The study was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, spanning from November 2016 to May 2017. The research site is situated at 24°75'N latitude and 90°50'E longitude with an altitude of 18 meters. It is characterized by non-calcareous dark grey floodplain soil within the Agro-ecological Zone (AEZ-9) of the Old Brahmaputra Floodplain (UNDP and FAO, 1988). Climatic data, including temperature, relative humidity, precipitation and sunshine hours (Figure 1).

Study design

The experiment involved three different planting dates: 15 November (D_1), 15 December (D_2) and 14 January (D_3) as well as five weed control practices: no weeding (W_0), two hand weedings at 15 and 30 days after sowing (DAS) (W_1), pre-emergence herbicide (pendimethalin) + one hand weeding at 30 DAS (W_2), post-emergence herbicide (pyrazosulfuran-ethyl) + one hand weeding at 30 DAS (W_3), and pre-emergence herbicide (pendimethalin) + post-emergence (pyrazosulfuran-ethyl) herbicide (W_4). The experiment was laid out in randomized complete block design (RCBD) with three replications. Each block was segmented into fifteen unit plots, each measuring 3.15 m by 2 m. Consequently, there were a total of 45 unit plots (15 × 3). A spacing of 0.5 m was maintained between individual unit plots and 1.0 m between the blocks. Firm bunds were constructed around each plot to manage water movement between them.

Crop management

The land was meticulously prepared by undergoing two rounds of tilling with a power tiller followed by laddering. Individual plots were meticulously cleaned of weeds and leveled properly. Various fertilizers were applied according to recommendations, including urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid at rates of 250 kg, 150 kg, 100 kg, 75 kg, 10 kg and 5 kg per hectare. All fertilizers except urea were applied during the final land preparation. Half of the urea was applied during land preparation, and the remaining urea was applied in two equal splits at 30 and 60 days after sowing (DAS). Maize seeds of the variety "Baby Star" were sown according to the specified planting dates in the treatments. Two seeds were placed in each hill within furrows to minimize the risk of germination failure, with seeds sown at a depth of 4-5 cm from the soil surface and spaced at 45 cm × 20 cm intervals. After sowing, seeds were lightly covered with soil. Thinning and gap filling were conducted during the first weeding at 15 DAS. Other intercultural operations such as earthing up, irrigation and pest management were carried out as necessary. To enhance yield and quality, detasseling was performed daily until all tassels were removed from the plants to prevent pollination.

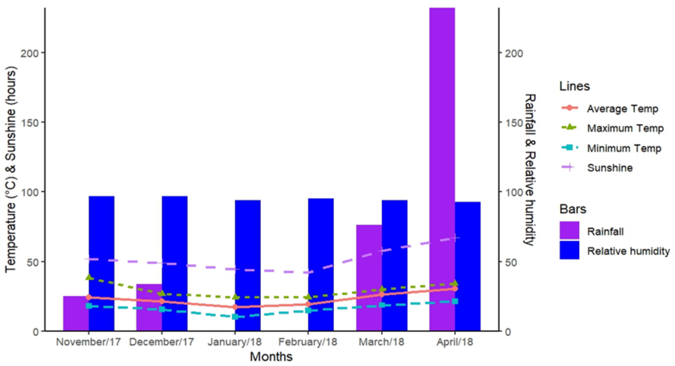


Figure 1. *Distribution of monthly temperature, relative humidity, sunshine hour and rainfall of the experimental site during the crop growth period.*

Data survey

To gather data five randomly selected plants in each plot were marked. Observations were conducted at various stages (30, 45, 60, 75 DAS and at harvest) to evaluate the effects of different treatments on plant growth and fodder yield. Leaf chlorophyll content was measured using a portable SPAD meter (SPAD-502, Minolta Crop, Ramsey, NJ) as an indirect indicator of nitrogen status. Measurements were taken from the marked plants at specific intervals and growth stages. To determine total dry matter, samples were washed and then oven-dried at a constant temperature. The weight of each dried sample was recorded and the total dry matter production per plant was expressed in grams.

Statistical analysis

Analysis of variance (ANOVA) was conducted to determine significant differences in the recorded parameters due to the experimental treatments. Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) was used to assess mean differences. All statistical analyses were carried out using the software Statistix 10.

RESULTS AND DISCUSSION

Plant height

The height of the plant varied significantly based on the planting dates, weeding regimes and their interactions. Plant height of maize plant was significantly influenced by planting date. The maximum plant height (123.45 cm) was recorded in the plant that are planted on 14 January (D_3) followed by the plant that are planted 15 December (D_2) and lowest height (121.83) on 15 November (D_1) at harvest stage (Table 1). With weeding treatment, the maximum plant height (131.14 cm) was recorded under two hand weeding at 15 and 30 DAS (W_1) which was statistically identical to W_2(129.82 cm), W_3(125.93 cm) and W_4 (124.22 cm) at harvest while the lowest height (102.04 cm) was calculated with no weeding (W_0) (Table 1). At harvest, the highest plant height (138.48 cm) was recorded in the interaction of 15 November with application of pre-emergence herbicide (pendimethalin) + one hand weeding at 30 DAS ($D_1 \times W_2$) which was statistically similar with $D_1 \times W_3$ (135.64 cm), $D_2 \times W_1$ (133.58 cm) and $D_3 \times W_1$ (133.83 cm). While the lowest one (85.45 cm) was found in the plants sown on 15 November with no weeding ($D_1 \times W_0$) (Table 2). Early or late planting can significantly influence the availability of critical resources such as sunlight, water and nutrients thereby affecting plant height and overall development. When plants are sown at an optimal time they can access these resources more efficiently throughout their growth cycle. Early planting may allow plants to establish before the peak demand for resources while late planting might help avoid certain pests or adverse weather conditions. Nayak *et al.* (2001) found that crops sown on January 16 produced the tallest plants while earlier sowing resulted in shorter plants, likely due to the low temperatures during the crop's vegetative stage. This finding is consistent with Dekhane *et al.* (2017), who noted that all growth parameters were optimal when sowing was done on December 15. Effective weeding is another crucial factor in promoting plant growth. By reducing competition for resources between crops and weeds effective weeding practices ensure that more water, nutrients and sunlight are available to the crops. Similarly, Sharma (2007) reported that two instances of hand weeding led to greater plant height compared to other methods. Arvadia *et al.* (2012) also found that pre-emergence herbicide application significantly increased plant height.

Table 1. Effect of date of planting and weeding regime on plant height at different days after sowing.

Treatment	Plant height (cm)				
	Days after planting (DAS)				
	30	45	60	75	At harvest
Date of planting					
D_1	12.37 b	77.31 a	98.56 b	116.98 a	121.83 b
D_2	14.33 a	63.75 b	105.00 a	118.23 a	122.62 a
D_3	16.00 a	54.40 c	94.30 c	115.50 b	123.45 a
Sig. level	***	***	*	*	*
CV (%)	6.3	1.7	3.8	4.2	1.1
Weeding regime					
W_0	14.17 b	58.83 c	84.44 ab	94.70 b	102.04 b
W_1	14.84 a	68.00 a	96.95 b	124.06 a	131.14 a
W_2	13.84 a	68.97 a	96.33 ab	128.67 a	129.82 a
W_3	14.29 a	68.49 a	105.89 a	118.57 a	125.93 a
W_4	14.06 ab	61.50 b	92.83 ab	118.52 a	124.22 a
Sig. level	*	*	*	***	***
CV (%)	6.39	1.76	3.89	4.29	1.17

In a column, figures with same letter (s) or without do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), * = Significant at 5% level of probability, *** = Significant at 0.1% level of probability. Here, D_1 = 15 November D_2 = 15 December, D_3 = 14 January, W_0 = No weeding, W_1 = Two hand weeding at 15 and 30 DAS, W_2 = Pre-emergence herbicide (Pendimethalin) + hand weeding at 30 DAS, W_3 = Post-emergence herbicide (Pyrazosulfuran-ethyl) + one hand weeding at 30 DAS, W_4 = Pre-emergence herbicide (Pendimethalin) + Post-emergence herbicide (Pyrazosulfuran-ethyl).

Table 2. Interaction effect of date of planting and weeding regime on plant height at different days after sowing.

Interaction (date of planting × weeding regime)	Plant height (cm)				
	Days after sowing (DAS)				
	30	45	60	75	At harvest
D_1×W_0	11.66 d	67.41 bcd	78.14 e	82.2 d	85.45 c
D_1×W_1	11.91 cd	76.75 ab	95.17 abcde	120.67 abc	126.01 ab
D_1×W_2	13.08 bcd	86.75 a	110.67 a	130.61 ab	138.48 a
D_1×W_3	12.68 bcd	86.91 a	107.42 ab	131.86 a	135.64 a
D_1×W_4	12.50 cd	68.75 abc	101.42 abc	119.56 abc	123.56 ab
D_2×W_0	14.33 abcd	64.16 bcd	82.83 de	100.25 cd	110.17 b
D_2×W_1	14.58 abcd	65.33 bcd	87.02 cde	124.33 ab	133.58 a
D_2×W_2	15.08 abcd	59.48 bcde	82.25 de	135.92 a	124.16 ab
D_2×W_3	13.58 bcd	63.36 bcd	85.25 cde	114.33 abc	120.75 ab
D_2×W_4	14.08 bcd	66.41 bcd	91.67 bcde	116.33 abc	124.42 ab
D_3×W_0	16.50 ab	44.91 e	92.33 bcde	101.67 cd	110.50 b
D_3×W_1	18.00 a	61.91 bcde	108.67 ab	127.17 ab	133.83 a
D_3×W_2	13.33 bcd	60.66 bcde	96.08 abcd	119.50 abc	126.83 ab
D_3×W_3	16.58 ab	55.16 cde	89.00 cde	109.50 bc	121.42 ab
D_3×W_4	15.58 abc	49.33 de	85.42 cde	119.67 abc	124.67 ab
Sig. level	*	*	*	*	*
CV (%)	6.39	1.76	3.89	4.29	1.17

In a column, figures with same letter (s) or without do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), * = Significant at 5% level of probability. Here, D_1= 15 November D_2= 15 December, D_3= 14 January, W_0 =No weeding, W_1= Two hand weeding at 15 and 30 DAS, W_2= Pre-emergence herbicide (Pendimethalin) + hand weeding at 30 DAS, W_3= Post-emergence herbicide (Pyrazosulfuran-ethyl) + one hand weeding at 30 DAS, W_4= Pre-emergence herbicide (Pendimethalin) + Post-emergence herbicide (Pyrazosulfuran-ethyl).

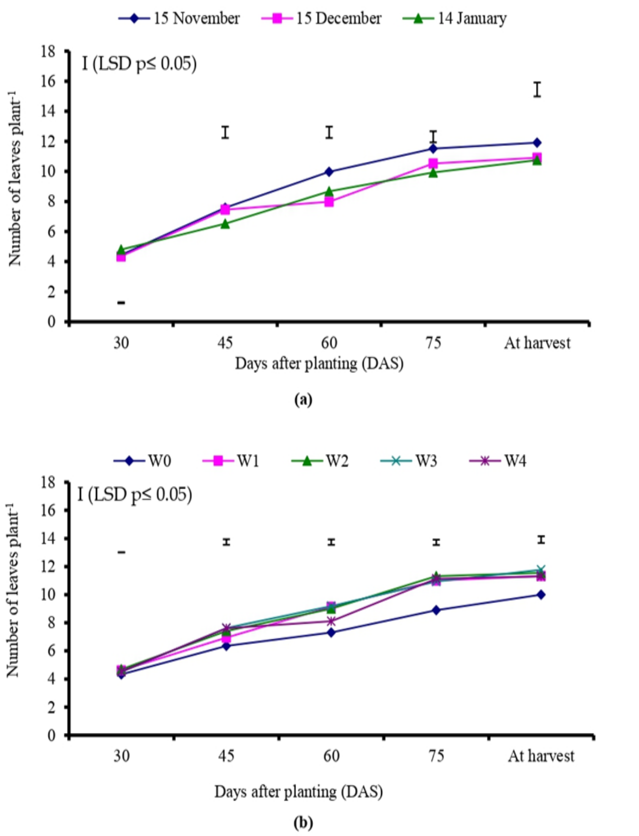


Figure 2. *Effect of date of planting and weeding regime on number of leaves plant^{-1} at different days after sowing.*
Here, D_1= 15 November, D_2= 15 December, D_3= 14 January, W_0 =No weeding, W_1= Two hand weeding at 15 and 30 DAS, W_2= Pre-emergence herbicide (Pendimethalin) + hand weeding at 30 DAS, W_3= Post-emergence herbicide (Pyrazosulfuran-ethyl) + one hand weeding at 30 DAS, W_4= Pre-emergence herbicide (Pendimethalin) + Post-emergence herbicide (Pyrazosulfuran-ethyl).

Number of leaves plant^{-1}

The number of leaves plant^{-1} varied significantly depending on the planting dates, weeding regimes and their interactions. At harvest, the maximum number of leaves plant^{-1} (11.91) was found under the plants of 15 November (D_1) followed by 15 December (D_2) and the lowest one (10.75) was resulted with the plants sown on 14 January (D_3) (Figure 2a). At the harvesting stage, the highest number of leaves (11.78) was found in the plants with application of post-emergence herbicide (pyrazosulfuran-ethyl) followed by one hand weeding at 30 DAS (W_3) which was at par with application of pre-emergence herbicide (pendimethalin) + one hand weeding at 30 DAS (W_2). Conversely, the lowest number of leaves (10.0) was found with no weeding treatment (W_0) (Figure 2b). With interaction, the highest (13.33) and lowest (9.33) number of leaves plant^{-1} was recorded in the plants of 15 November planting with the application of pre-emergence herbicide (pendimethalin) + post-emergence herbicide (pyrazosulfuran-ethyl) (D_1× W_4) and planting on 15 November with no weeding (D_1× W_0) treatment combinations respectively, at harvest (Table 3). The number of leaves per plant is a crucial indicator of vegetative growth and overall plant health. This parameter can significantly influence photosynthetic efficiency, nutrient uptake and the plant's ability to compete for light and other resources. Maga *et al.* (2015) observed that the sowing date significantly impacted both the number of leaves per plant and the grain yield. Various agronomic factors, including planting dates and weeding regimes play a vital role in determining leaf number and consequently, the overall productivity of the crop. Optimal planting dates ensure that plants receive the best possible environmental conditions, such as temperature and light, which are essential for maximizing vegetative growth. Ibrahim *et al.* (2013) found that early sowing of sweet corn results in an increased number of leaves, greater stem diameter and higher nutritive value compared to later planting. Soliman and Gharib (2011) observed that when weeds compete with maize crops, they significantly reduce the number of leaves on maize plants.

Table 3. Interaction effect of date of planting and weeding regime on number of leaves plant^{-1} at different days after sowing.

Interaction (date of planting × weeding regime)	Number of leaves plant^{-1}				
	Days after sowing (DAS)				
	30	45	60	75	At harvest
$D_1 \times W_0$	4.08 ab	5.41 f	8.58 cde	9.14 fg	9.33 d
$D_1 \times W_1$	4.34 ab	6.58 cdef	9.58 abcd	10.67 cdef	11.08abcd
$D_1 \times W_2$	4.33 ab	8.25 abcd	11.00 a	12.53 ab	12.75 ab
$D_1 \times W_3$	4.66 ab	9.08 a	10.75 ab	12.33 abc	13.08 ab
$D_1 \times W_4$	4.83 ab	8.58 ab	10.0 abc	12.89 a	13.33 a
$D_2 \times W_0$	3.91 b	6.83 bcdef	5.83 g	9.50 efg	10.25 cd
$D_2 \times W_1$	4.58 ab	7.33 abcde	7.33 efg	10.66 cdef	11.41 abcd
$D_2 \times W_2$	4.91 ab	7.41 abcde	7.83 def	11.33 abcde	11.75 abc
$D_2 \times W_3$	4.25 ab	7.41 abcde	7.91 de	10.75bcdef	11.41 abcd
$D_2 \times W_4$	4.09 ab	8.33 abc	6.00 fg	10.41 def	9.75 cd
$D_3 \times W_0$	5.00 a	6.83 bcdef	7.50 efg	8.06 g	10.41 cd
$D_3 \times W_1$	4.91 ab	6.91 bcdef	10.50 ab	11.66 abcd	11.50 abcd
$D_3 \times W_2$	4.83 ab	6.58 cdef	8.16 cde	10.08 def	10.16 cd
$D_3 \times W_3$	4.58 ab	6.41 def	8.91 bcde	9.75 efg	10.83 bcd
$D_3 \times W_4$	4.66 ab	5.91 ef	8.33 cde	10.08 def	10.83 bcd
Sig. level	*	*	*	*	*
CV (%)	1.99	1.77	1.19	1.32	2.39

In a column, figures with same letter (s) or without do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), * = Significant at 5% level of probability. Here, D_1 = 15 November D_2 = 15 December, D_3 = 14 January, W_0 = No weeding, W_1 = Two hand weeding at 15 and 30 DAS, W_2 = Pre-emergence herbicide (Pendimethalin) + hand weeding at 30 DAS, W_3 = Post-emergence herbicide (Pyrazosulfuran-ethyl) + one hand weeding at 30 DAS, W_4 = Pre-emergence herbicide (Pendimethalin) + Post-emergence herbicide (Pyrazosulfuran-ethyl).

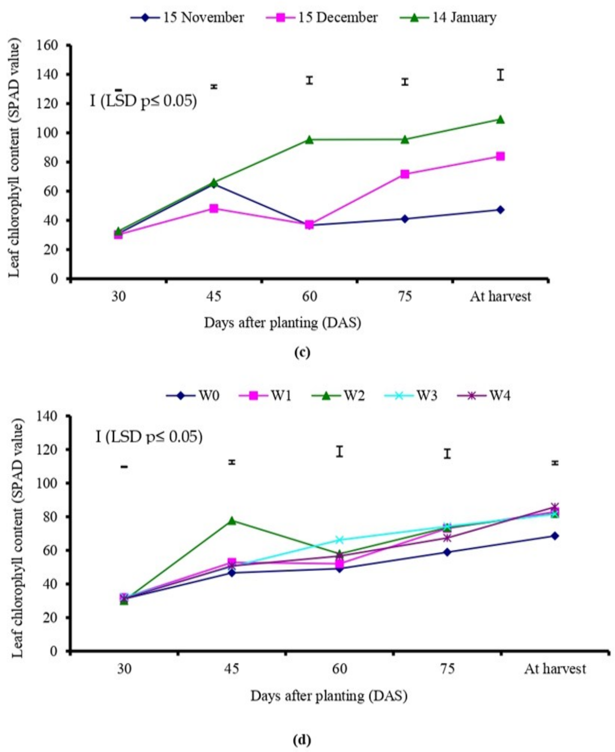


Figure 3. *Effect of date of planting and weeding regime on leaf chlorophyll content at different days after sowing.*
Here, D_1 = 15 November, D_2 = 15 December, D_3 = 14 January, W_0 = No weeding, W_1 = Two hand weeding at 15 and 30 DAS, W_2 = Pre-emergence herbicide (Pendimethalin) + hand weeding at 30 DAS, W_3 = Post-emergence herbicide (Pyrazosulfuran-ethyl) + one hand weeding at 30 DAS, W_4 = Pre-emergence herbicide (Pendimethalin) + Post-emergence herbicide (Pyrazosulfuran-ethyl).

Leaf chlorophyll content (SPAD value)

The timing of planting, weeding and their combined effects significantly influenced leaf chlorophyll content. The maximum chlorophyll content (109.27) was found in the plants that are planted on 14 January (D_3) while the minimum result (47.30) was obtained from 15 November (D_1) at harvest (Figure 3c). The maximum (85.85) and minimum (68.6) chlorophyll content was found in the plants with application of pre-emergence herbicide (pendimethalin) + post-emergence herbicide (pyrazosulfuran-ethyl) (W_4) and no weeding (W_0) treatments respectively and the rest of the three treatments are statistically identical (Figure 3d). At harvest, the chlorophyll content was maximum (116.60) in the plants of 14 January planting with the application of pre-emergence herbicides (pendimethalin) + one hand weeding at 30 DAS ($D_3 \times W_2$) which was at par with the plants of 14 January planting with the application of post-emergence herbicides (pyrazosulfuran-ethyl) + one hand weeding at 30 DAS ($D_3 \times W_3$) and the minimum chlorophyll content (37.65) was found in the plants of 15 November sowing with no weeding ($D_1 \times W_0$) (Table 4). Optimizing both planting and weeding schedules is essential for maximizing chlorophyll content in leaves, thereby enhancing the photosynthetic capacity and overall health of the crop. Chlorophyll is vital for photosynthesis directly impacting plant growth and productivity. The timing of planting determines the environmental conditions such as light and temperature that plants are exposed to during critical growth stages. For instance, planting dates that align with optimal sunlight availability and moderate temperatures support higher chlorophyll synthesis whereas suboptimal conditions can lead to reduced chlorophyll content. Planting later than other sowing date's results in more intense sunlight after February, while planting on November 15 receives less sunlight in January. This difference leads to lower chlorophyll content 45 days after sowing.

Table 4. Interaction effect of date of planting and weeding regime on leaf chlorophyll content at different days after sowing.

Interaction (date of planting × weeding regime)	Leaf Chlorophyll Content (SPAD value)				
	Days after sowing (DAS)				
	30	45	60	75	At harvest
$D_1 \times W_0$	28.33 ab	31.56 e	24.13 c	23.99 g	37.65 e
$D_1 \times W_1$	30.45 ab	39.40 de	34.19 c	47.11 ef	49.43 de
$D_1 \times W_2$	30.45 ab	39.69 de	41.64 c	47.97 ef	51.39 de
$D_1 \times W_3$	32.32 a	38.38 de	42.96 c	44.81 ef	49.82 de
$D_1 \times W_4$	33.333 a	38.51 de	40.23 c	41.01 fg	48.21 de
$D_2 \times W_0$	31.576 ab	46.01 cd	35.84 c	60.59 de	63.39 cde
$D_2 \times W_1$	32.51 a	57.13 abc	36.36 c	83.40 abc	95.35 abc
$D_2 \times W_2$	26.46 b	49.16 bcd	38.68 c	75.92 cd	77.51 bcd
$D_2 \times W_3$	32.22 a	41.86 de	36.20 c	78.82 bcd	80.27 bcd
$D_2 \times W_4$	28.59 ab	46.46 cd	38.74 c	60.00 def	103.01 ab
$D_3 \times W_0$	33.42 a	62.33 ab	87.23 b	91.99 abc	104.75 ab
$D_3 \times W_1$	32.75 a	61.93 ab	85.46 b	88.55 abc	104.01 ab
$D_3 \times W_2$	33.39 a	67.97 a	93.31 b	96.82 ab	116.60 a
$D_3 \times W_3$	31.71 ab	70.73 a	119.52 a	99.03 a	114.68 a
$D_3 \times W_4$	32.01 a	67.35 a	90.94 b	101.28 a	106.30 ab
Sig. level	*	*	*	*	*
CV (%)	1.43	1.82	3.66	1.67	4.07

In a column, figures with same letter (s) or without do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), * = Significant at 5% level of probability. Here, D_1 = 15 November D_2 = 15 December, D_3 = 14 January, W_0 = No weeding, W_1 = Two hand weeding at 15 and 30 DAS, W_2 = Pre-emergence herbicide (Pendimethalin) + hand weeding at 30 DAS, W_3 = Post-emergence herbicide (Pyrazosulfuran-ethyl) + one hand weeding at 30 DAS, W_4 = Pre-emergence herbicide (Pendimethalin) + Post-emergence herbicide (Pyrazosulfuran-ethyl).

Table 5. Interaction effect of date of planting and weeding regime on total dry matter production plant^{-1}.

Interaction (date of planting × weeding regime)	Total dry matter plant^{-1} (g)				
	Days after sowing (DAS)				
	30	45	60	75	At harvest
$D_1 \times W_0$	0.16 fg	0.46 f	7.25 c	14.41 gh	16.45 g
$D_1 \times W_1$	0.27 bcd	0.67 f	49.18 a	24.82 bc	29.89 d
$D_1 \times W_2$	0.33 a	0.82 f	16.40 abc	29.61 a	37.32 a
$D_1 \times W_3$	0.24 cde	0.82 f	15.26 abc	26.94 ab	33.88 bc
$D_1 \times W_4$	0.22 def	0.84 f	12.71 abc	27.76 a	35.44 ab
$D_2 \times W_0$	0.20 efg	0.60 f	6.56 c	14.76 gh	17.45 fg
$D_2 \times W_1$	0.15 g	1.53 de	44.87 ab	22.80 cd	30.0 d
$D_2 \times W_2$	0.20 efg	3.02 b	12.00 abc	17.06 fg	26.66 e
$D_2 \times W_3$	0.20 efg	2.00 d	11.72 bc	28.59 a	31.82 cd
$D_2 \times W_4$	0.15 g	2.15 cd	11.91 bc	29.05 a	36.85 ab
$D_3 \times W_0$	0.26 bcd	0.99 ef	5.751 c	13.40 h	20.32 f
$D_3 \times W_1$	0.22 def	3.36 b	13.46 abc	19.00 ef	31.20 cd
$D_3 \times W_2$	0.31 abc	4.02 a	15.92 abc	21.37 de	34.02 bc
$D_3 \times W_3$	0.24 de	2.79 bc	10.60 bc	23.65 cd	36.18 ab
$D_3 \times W_4$	0.31 ab	4.02 a	15.43 abc	23.06 cd	35.55 ab
Sig. level	***	***	*	***	***
CV (%)	1.73	2.84	4.14	1.18	3.99

In a column, figures with same letter (s) or without do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT), * = Significant at 5% level of probability, *** = Significant at 0.1% level of probability. Here, D_1 = 15 November, D_2 = 15 December, D_3 = 14 January, W_0 = No weeding, W_1 = Two hand weeding at 15 and 30 DAS, W_2 = Pre-emergence herbicide (Pendimethalin) + hand weeding at 30 DAS, W_3 = Post-emergence herbicide (Pyrazosulfuran-ethyl) + one hand weeding at 30 DAS, W_4 = Pre-emergence herbicide (Pendimethalin) + Post-emergence herbicide (Pyrazosulfuran-ethyl).

Total dry matter plant^{-1}

The total dry matter production per plant in maize was significantly affected by the planting date, weeding practices, and their interaction effects. The maximum TDM (31.46 g) was found in the plants of 14 January (D_3) which was statistically identical to 15 November (D_1) while the lowest (28.57 g) TDM was recorded with 15 December at the time of harvest (Figure 4e). At harvest, the highest (35.96 g) and lowest (18.08 g) TDM was found in the plants with the application of pre-emergence herbicide (pendimethalin) + post-emergence herbicide (pyrazosulfuran-ethyl) (W_4) and no weeding (W_0) respectively (Figure 4f). The maximum (37.32 g) and minimum (16.45 g) TDM was found in the plants of 15 November with the application of pre-emergence herbicide (pendimethalin) + one hand weeding at 30 DAS ($D_1 \times W_2$) and planting on 15 November with no weeding ($D_1 \times W_0$) respectively, at harvest stage (Table 5). These findings emphasize the complex interplay between planting date, weeding practices and their combined effects on TDM production in maize. Optimal agronomic decisions such as selecting appropriate planting times and implementing effective weed control measures are crucial for maximizing yield potential and ensuring sustainable agricultural practices. The timing of planting can affect the environmental conditions to which the crop is exposed thereby impacting its growth cycle and productivity. Shirkhani *et al.* (2012) found that the earliest planting date resulted in the highest fresh yield and dry yield compared to the other two planting dates. Similarly, effective weeding practices are essential for minimizing competition for resources thereby promoting healthier plant development.

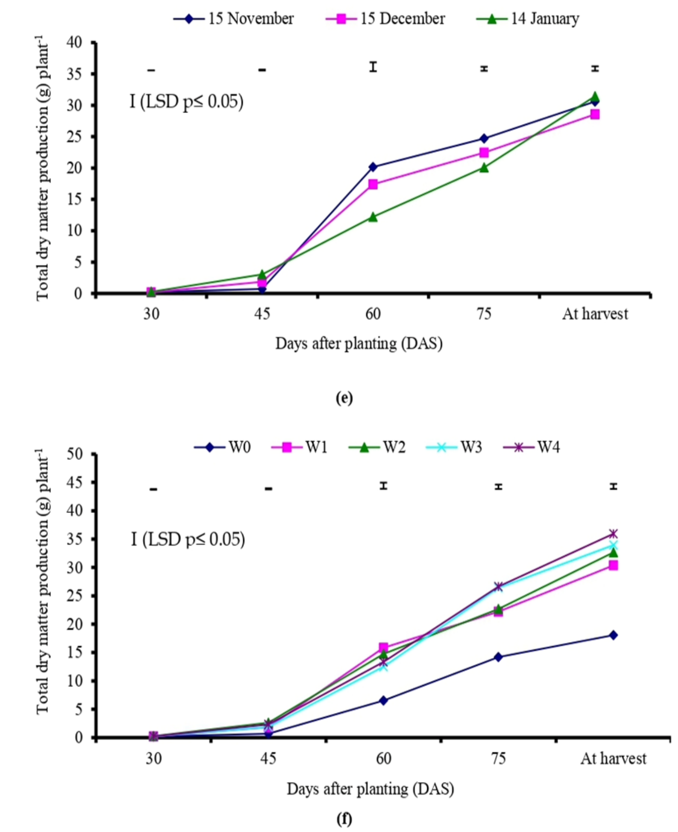


Figure 4. *Effect of date of planting and weeding regime on leaf chlorophyll content at different days after sowing.*
Here, D_1= 15 November, D_2= 15 December, D_3= 14 January, W_0 =No weeding, W_1= Two hand weeding at 15 and 30 DAS, W_2= Pre-emergence herbicide (Pendimethalin) + hand weeding at 30 DAS, W_3= Post-emergence herbicide (Pyrazosulfuran-ethyl) + one hand weeding at 30 DAS, W_4= Pre-emergence herbicide (Pendimethalin) + Post-emergence herbicide (Pyrazosulfuran-ethyl).

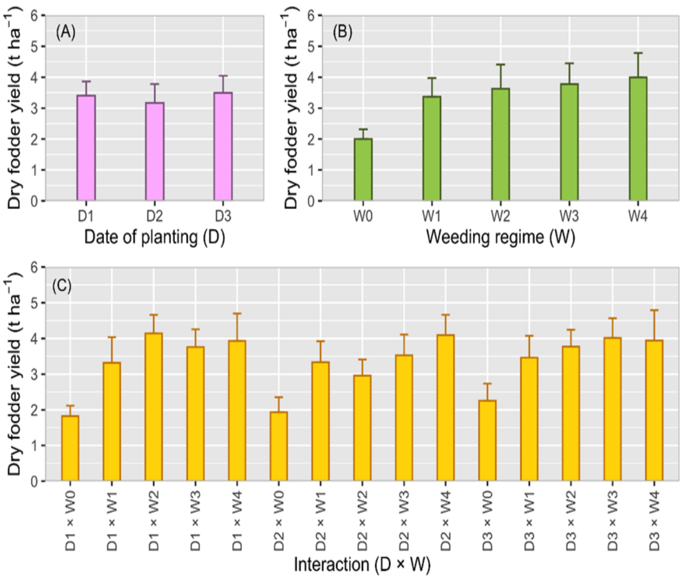


Figure 5. *Effect of date of planting and weeding regime on dry fodder yield at harvest.*
Here, D_1= 15 November D_2= 15 December, D_3= 14 January, W_0 =No weeding, W_1= Two hand weeding at 15 days after sowing (DAS) and 30 DAS, W_2= Pre-emergence herbicide (Pendimethalin) followed by one hand weeding at 30 DAS, W_3 = Post-emergence herbicide (Pyrazosulfuran-ethyl) + one hand weeding at 30 DAS, W_4= Pre-emergence herbicide (Pendimethalin) + Post-emergence herbicide (Pyrazosulfuran-ethyl).

Dry fodder yield (t ha^{-1})

The planting date, weeding regime and their combined effects significantly influenced the dry fodder yield at harvest (Figure 5). The highest dry fodder production (3.49 t ha^{-1}) was achieved with maize planted on 14 January (D_3) which was statistically similar to the yield from planting on 15 November (D_1). In contrast, the lowest yield (3.17 t ha^{-1}) was observed with planting on 15 December (D_2). At harvest, plots treated with a pre-emergence herbicide (pendimethalin) + post-emergence herbicide (pyrazosulfuran-ethyl) (W_4) produced the highest dry fodder yield (3.99 t ha^{-1}), whereas the lowest yield (2.00 t ha^{-1}) was found in plots with no weeding treatment (W_0). The interaction between planting date and weeding showed that the highest yield (4.14 t ha^{-1}) was achieved with maize planted on 15 November and treated with pre-emergence herbicide (pendimethalin) + one hand weeding at 30 days after sowing ($D_1 \times W_2$). This yield was similar to those from the $D_2 \times W_4$ (4.09 t ha^{-1}) and $D_3 \times W_3$ (4.01 t ha^{-1}) treatments. The lowest yield (1.82 t ha^{-1}) was recorded for maize planted on 15 November with no weeding ($D_1 \times W_0$). The increase in dry matter yield from plots maintained weed free throughout the growing season was attributed to the absence of weed crop competition. Without the presence of weeds, crops have unfettered access to essential resources such as light, water and nutrients. This results in more robust growth and higher yields of dry matter. These findings are consistent with the research by James *et al.* (2000), which demonstrated that plots with uncontrolled weeds for a certain period experienced a significant reduction in maize dry matter yields. The weeds compete with crops for critical resources, thereby hindering their growth and reducing overall yield. Similar results were recorded by Lee Sang Moo *et al.* (2007), who also observed that effective date of planting leads to substantial improvements in crop performance.

Conclusion

Various growth traits and dry fodder yield were significantly influenced by different planting dates and weeding practices. At harvest, the tallest plants (138.48 cm), highest total dry matter plant^{-1} (37.32 g) and maximum dry fodder yield (4.14 t ha^{-1}) were observed in plants sown on November 15 with the use of a pre-emergence herbicide (pendimethalin) + hand weeding 30 days after sowing. The study concludes that sowing on November 15 and applying a pre-emergence herbicide (pendimethalin) + hand weeding 30 days after sowing can produce the tallest plants, maximum total dry matter and highest dry fodder yield.

DECLARATIONS

Authors contribution

Conceptualization, methodology: S.K.P. and M.A.R.S.; Software, validation: S.K.P. and M.H.R.; Investigation: S.K.P. and S.K.S.; Data curation: M.R.H.; Writing - original draft preparation: M.S.K. and S.K.S.; Writing-review and editing: S.K.P. and M.H.R.; Supervision: S.K.P. and M.A.R.S.; All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare no conflict of interest.

Ethics approval: This study did not involve any animal or human participant and thus ethical approval was not applicable.

Consent for publication: All co-authors gave their consent to publish this paper in AAES.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

Supplementary data: Not available.

ACKNOWLEDGEMENTS

Swapan Kumar Paul gratefully acknowledge the financial support provided by the Ministry of Science and Technology, Government of the People's Republic of Bangladesh which enabled us to conduct the research (Project No: 39.00.0000.09.06.79.2017/2-10 BS).

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