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RESEARCH PAPER

Effects of sowing date and organic mulch on growth, yield, quality and water-use efficiency of spring-sown sweet corn

Amit Bhatnagar • Shraddhanjali Dehury • Pragya Naithani • Gurvinder Singh • Ajay Kumar • Dinesh Kumar Singh

Abstract The major challenges in spring seasons are temperature and moisture stress. Low temperature in early sowing adversely affect germination and initial growth while under late sowing high temperature during reproductive stage reduces yield. Therefore, a field experiment was conducted at G.B. Pant University of Agriculture & Technology, Pantnagar during spring season 2017 to study the effect of different time of sowing and rice straw mulch application on growth dynamics, yield and water use of sweet corn (*Zea mays* L. var. *saccharata*). The experiment consisted of twelve treatments; having four sowing dates (8th, 18th, 28th February and 10th March) in main plots and three mulch application (no mulch, mulch application after 2nd and 3rd irrigation) in sub plots was laid out in split plot design. Crop sown on 8th February being at par with 18th February resulted in significantly more growth, husked cob yield (15.9 t/ha) and total soluble solids (15.59 brix). The increase in yield in 8th February sowing was 23.6 and 14.1 per cent over 28th February and 10th March sowing, respectively. Irrigation water use efficiency remained at par among all sowing dates but water productivity was significantly highest in first sowing date and was significantly lower in last sowing date. Mulch application after 2nd irrigation being at par with after 3rd irrigation resulted into better growth and had significantly more husked cob yield (15.5 t/ha) to a tune of 17.4 and 15.9 per cent respectively, over no mulch. Irrigation water use efficiency and water productivity were more in mulch application than without mulch but total soluble solids remained non-significant.

Keywords: Cob • Growth • Mulch • Sweet corn

Introduction

In the recent years, the popularity of sweet corn (*Zea mays* L. var. *saccharata*) is increasing amongst the farmers due to its short duration and high economic returns. Sweet corn also known as sugar corn has high sugar content. Its cultivation is remunerative for farmers as cobs of sweet corn fetch high price in the market. It is also used in preparation of soup, salad and other recipes. Another advantage of sweet corn is that after picking the cobs, green fodder is used for cattle. Sweet corn is early in maturity because it is harvested at milk stage. Owing to short duration, sweet corn may be easily fitted into different intensive cropping systems. Sweet corn specially during spring season is popular because its green cobs become available during early monsoon period. Time of sowing is one of the major concerns in spring maize cultivation because its harvesting must be completed before sowing of succeeding *kharif* crop. Since temperature plays significant role in growth and development hence sowing time in spring season is crucial factor in deciding productivity (Cao *et al.*, 2024). In case of early sowing in spring season germination is affected due to low temperature while late sown crop face high temperature during its flowering and grain filling stage.

✉ Amit Bhatnagar: bhatnagaramit75@gmail.com

Department of Agronomy, College of Agriculture, GB Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

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Thus sowing time has great influence on yield and quality (Buriro *et al.*, 2015). It is necessary to find out optimum sowing time to harvest good quality cobs. High temperature and elevated rate of evaporation at later growth stages are two major constraints of crop production in spring season. High temperature affects the vegetative and reproductive phase of maize crop and also influences the capacity of grain filling and duration of crop (Lohani *et al.*, 2020). During hot months high soil temperature not only restricts root activities and absorption of moisture and nutrients but also increases rate of evaporation from soil. Moreover, high evapo-transpiration owing to high temperature during spring season demands frequent irrigation. It leads to high cost of cultivation and stress on water resources. It is required to reduce the adverse effect of high soil temperature on crop growth. Application of organic mulch is one option to address these issues. Straw mulch acts as insulator between solar radiations and soil surface and keep soil temperature lower in summer season and thus reduces amount of heat energy required for evaporation. Besides straw mulch behaves like physical barrier against evaporating water vapours from soil (Cai *et al.*, 2015). Mulch on soil surface plays important role in extending availability of soil moisture to roots. Another benefit of mulch is relatively low soil temperature as it act as insulator to heat by direct solar radiation. All these factor together enhance water use efficiency of crop. Many researchers (Sarolia and Bhardwaj, 2012; Lin *et al.*, 2016) have reported that organic mulches are effective in regulating soil temperature, increasing soil moisture content and improving soil physical properties. In north western plains of India, during the start of spring season (February) temperature and evaporation remain low but from March onwards increases rapidly. So in the beginning of season, mulch application would not be effective. Moreover, mulch application at the time of sowing has certain problems like reduced availability of top dressed urea to roots because entire soil surface is covered by mulch. Mulch application at different growth stage of maize shows significant difference at all growth stage of maize (Taye *et al.*, 2015). Therefore, experiment was conducted to find out the effect of time of sowing and different time of mulch application on growth, yield, quality and water use efficiency of sweet corn in spring season.

Materials and methods

The field experiment was conducted during the spring season, 2017 at the N.E. Borlaug crop research centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand representing the *Tarai* belt of Uttarakhand. It is situated at 29° N latitude, 79.5° E longitude and altitude of 243.83 m above mean sea level

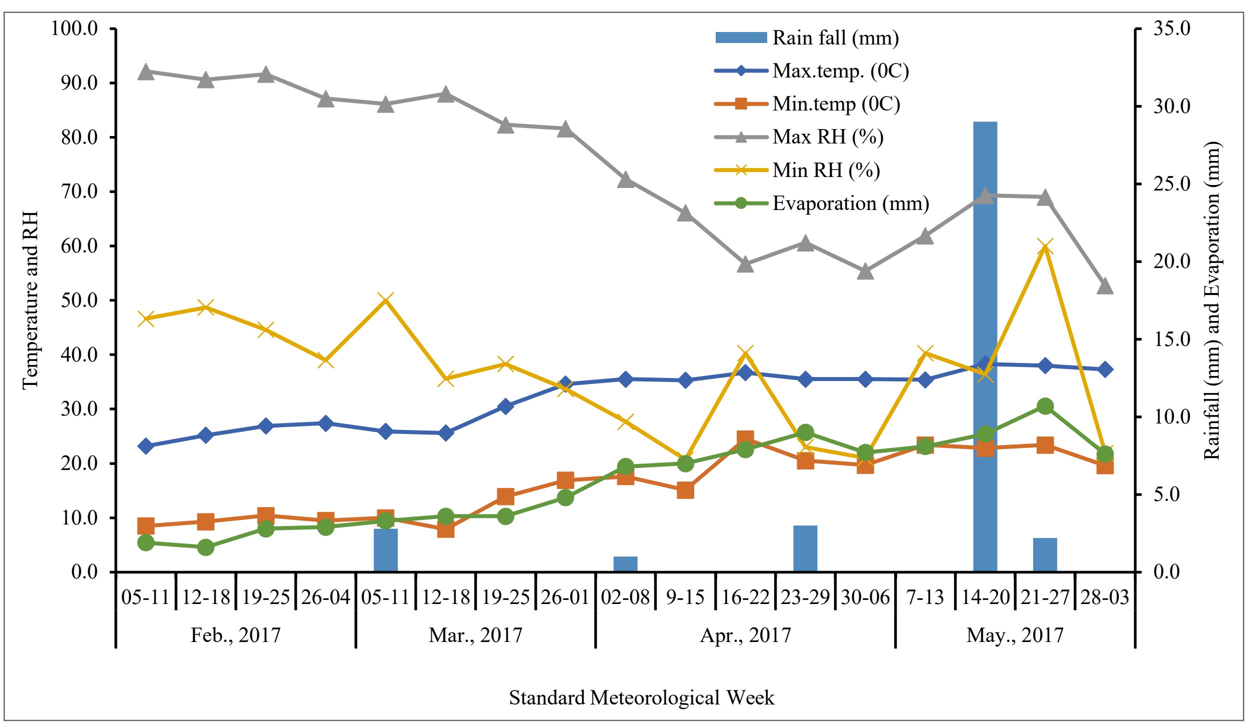

Figure 1. Weather conditions during crop growing period

in the foot hills of Himalaya. The climate of the region is broadly humid sub-tropical with cool winter and hot dry summer. The weekly average of various weather parameters prevailed during the course of investigation are depicted in Figure 1. During the experiment, the maximum temperature ranged from 21.0°C (12th March) to 41°C (16th May) with average 32.9°C whereas the minimum temperature varied from 4.9°C (10th February) to 26.9°C (22nd May) with average 16.8°C. The mean maximum relative humidity was 74 per cent with fluctuation of 45 to 96 per cent. A range of 11.0 to 82.0 per cent was recorded for minimum relative humidity with average 36 per cent. The mean sun shine duration was 8.4 hours which ranged from 0.9 to 11.7 hours per day. During the crop growing period, a total 40.6 mm rainfall was received with in five rainy days. Total evaporation during crop season was 634.2 mm. The texture of soil of experiment field was silty clay loam. The chemical analysis of soil (0-15 cm) indicated that pH was neutral (6.9), organic carbon was in medium range (0.65%), available nitrogen was low (269 kg/ha) and available phosphorus (19.1 kg P/ha) and available potassium (245.3 kg K/ha) were in medium range. The experiment was conducted in split plot design having 4 dates of sowing at 10 days interval (8th February, 18th February, 28th February and 10th March) in main plot and application of rice straw mulch at two different times (after 2nd irrigation and after 3rd irrigation) and no mulch in sub plot with three replications. Rice straw mulch @ 5 t/ha was applied in between two rows of maize after 2nd and 3rd irrigation in the respective treatments. After 2nd irrigation rice straw mulch was applied at 36, 35, 34 and 31days after sowing (DAS) in first, second, third and fourth date of sowing, respectively. Mulch application after 3rd irrigation was executed at 54, 53, 52 and 44 DAS in first, second, third and fourth date of sowing, respectively. The field was prepared by three harrowing followed by levelling with leveler. Sweet corn variety 'Sugar-75' was grown at planting geometry 60 cm × 25 cm. Plot size was 5 m × 4.2 m. One fourth of nitrogen and full dose of phosphorous and potassium were applied as basal through NPK mixture (12:32:16), urea (46% N) and muriate of potash (60% K_2O). Remaining nitrogen in three equal splits was top dressed at 4-5 leaf stage, knee height stage and at initiation of tasseling. One hand hoeing was done before second irrigation to control weeds in each treatment. The number of irrigation were 6, 6, 5 and 5 in first, second, third and fourth date of sowing, respectively. The irrigation depth was 5 cm. To protect the crop from insects chlorantraniliprole @ 0.3 ml/litre water was sprayed the plant height was measured from the ground surface to the tip of the folded leaf, whereas at harvest, it was recorded from ground surface to the ligules of the upper most fully opened leaf. To calculate leaf area per plant all the leaves from three selected plants were removed and categorized in to three groups viz. large, medium and small. Three representative leaves from each category were taken out to measure length and width. Average value of leaf length was multiplied by average value of leaf width to get leaf area of each respective category. Leaf area recorded from each category was multiplied by the total number of leaf of respective category and summed up to get the leaf area of sample. Average leaf area per plant was computed by dividing the value by three. The whole value was multiplied by correction factor of 0.75 (Montgomery, 1911). Leaf area index (LAI) was calculated by dividing leaf area per plant by planting geometry (60 cm × 25 cm). Five plants from sample row (second row from East) were selected and cut just above the ground level with the help of sickle and these cut plants were allowed to sun drying for 48 hours. After sun drying, these plants were dried in the oven at 65±5 °C temperature till constant weight then average weight was expressed in gram per plant. Crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were calculated with the help of formula as reported by Radford (1967). Crop was harvested on 17th May, 20th May, 26th May and 3rd June for first, second, third and fourth date of sowing, respectively. At the time of harvest, the number of plants and number of cobs in each net plot were counted and were expressed on hectare basis. All the cobs were harvested at milk stage from the net plot area and counted. Their weight was taken with husk and it was divided by total number of cobs to determine individual cob weight with husk. The weight of cobs with husk was reported as husked cob yield. Total soluble solids (TSS) in kernels were determined with the help of hand refrectometer at the time of cob picking. Kernels from three cobs were selected from middle of cob to determine TSS. To calculate water use parameters dehusked cob yield was recorded in each plot by weighing the cobs after removing husk from cobs. Irrigation water use efficiency (IWUE) was worked out by using following formula:

$$\text{IWUE (kg/ha-cm)} = \frac{\text{Dehusked cob yield (kg/ha)}}{\text{Total irrigation depth (cm)}}$$

Following formula was used for calculation of water productivity.

$$\text{Water productivity (kg/(ha-cm)} = \frac{\text{Dehusked cob yield (kg/ha)}}{\text{Total water (irrigation+rainfall) applied (cm)}}$$

The data obtained from various observations were statistically analyzed as per procedure of split plot design by using the standard techniques of Analysis of Variance technique with the OPSTAT software created by Sheoran *et al.* (1998). The significant differences were estimated at a 5% probability level to examine the significance of the difference between any two treatment means, when the F test was significant (Gomez and Gomez, 1984).

Results and discussion

Growth and growth indices

The increase in plant height was slower in first 30 days but a rapid increase was observed between 30 and 60 DAS (Table 1). At 30 days after sowing, a trend of increase in plant height was found as sowing was extended from 8th February to 10th March. Crop sown on 10th March recorded significantly highest plant height (45.7 cm). Plant height at 28th February sown crop was also significantly higher than that of 8th and 18th February. Temperature is to be known to influence plant growth. Maize is C4 and temperature loving crop so its growth is greatly affected by temperature. Average daily temperature during first 30 days increased with delay in sowing which was 17.7, 18.1, 20.1 and 22.6°C in first, second, third and fourth sowing dates, respectively. Relatively low temperature during first 30 days in first and second sowing dates resulted in to slower growth of maize and thus caused shorter plants where as higher temperature in late sowing was responsible for taller plants. Plant height was not affected significantly due to different dates of sowing at 60 days after sowing, however, the maximum plant height (109.7 cm) was obtained with 10th March sowing. Crop sown on early dates had less plant height at 30 DAS but between 30 and 60 DAS performed better than late sowing dates and made rapid increase in plant height that rendered non significant difference among different sowing dates. The rate of increase in plant height at 60 DAS compared to 30 DAS under first, second, third and fourth sowing dates was 2.2, 2.2, 1.8 and 1.4 times, respectively. The higher rate of increment in earlier sowing dates and reduced rate in later sowing dates may be ascribed to difference in temperature prevalent during crop growth. The maximum temperature between 30-60 DAS was 31.2, 34.5, 36.2 and 36.9°C in first, second, third and fourth sowing dates, respectively. High temperature during 30-60 DAS in later sowing dates slower down the growth of the plants. At harvest stage, crop sown on 8th February attained significantly higher plant height (135.6 cm) than rest of

Table 1. Effect of sowing dates and mulching on plant height, leaf area and dry matter of sweet corn at different growth stages

Treatment	Plant height (cm)			Leaf area (cm^2/plant)			Dry matter accumulation (g/plant)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Sowing date									
8th February	33.6	108.1	135.6	340	3386	3561	2.76	36.8	95.1
18th February	33.4	107.4	134.7	348	3244	3420	2.93	35.3	91.0
28th February	38.3	108.5	128.9	381	3111	3265	3.49	32.2	81.9
10th March	45.7	109.7	123.0	453	2927	3051	4.94	31.4	78.7
SEm±	0.8	1.2	1.1	13	84	68	0.19	0.9	1.4
CD (p = 0.05)	2.8	NS	3.7	44	289	235	0.68	3.0	4.9
Mulch application									
No mulch	37.7	105.4	126.7	380	2904	3049	3.50	31.2	78.2
After 2nd irrigation	37.6	110.5	133.1	375	3364	3498	3.57	35.8	91.3
After 3rd irrigation	38.0	109.4	131.9	388	3233	3425	3.51	34.9	90.4
SEm±	0.6	1.2	1.1	12.	65	43	0.15	0.8	0.9
CD (p = 0.05)	NS	3.5	3.3	NS	195	129	NS	2.3	2.7

the treatments, but it remained at par with that of 18th February. Moreover, plant height in 18th February sowing was also significantly superior to that of 28th February and 10th March. Significantly lowest plant height (123.0 cm) was noted in 10th March. Crop sown on first and second sowing dates continued their higher growth rate after 60 days of sowing and acquired more plant height at harvest. Compared to 60 DAS, the rate of increase in plant height at harvest was 25.4, 25.4, 18.8 and 12 per cent in first, second, third and fourth sowing dates, respectively. Maize plant has determinate growth habit and attained maximum plant height at tasseling stage and no marked increase occurs after this stage. In this study average maximum temperature between 60 DAS to 50% tasseling stage was 36.4, 37.2, 37.6 and 37.9°C and average minimum temperature was 20.4, 21.4, 20.7 and 23.8°C in first, second, third and fourth sowing dates, respectively. Slower rate of increase in plant height under delayed sowing compared to early sowing was due to high temperature (Amajadin *et al.*, 2015). More plant height of maize in early sowing because of favorable temperature was also reported by Burio *et al.* (2015). Among different mulch treatments, plant height was not affected significantly at 30 days after sowing. At both the stages 60 DAS and harvest, mulching after 2nd irrigation resulted into significantly higher plant height (110.5 and 133.1 cm, respectively) than no mulch treatment but it had non significant difference with another mulch treatment. Rice straw mulch was applied after 2nd irrigation and this treatment was executed 36, 35, 34 and 31 DAS in first, second, third and fourth date of sowing, respectively. Since mulch was applied after 30 days of sowing hence, no effect of mulch on plant height was seen at 30 DAS. Another mulch treatment was imposed after 3rd irrigation. This treatment was started 54, 53, 52 and 44 DAS in first, second, third and fourth date of sowing, respectively. At 60 DAS and harvest stage significant effect of mulch on plant height may be attributed to better soil moisture and soil temperature regimes due to covering of soil surface by rice straw during the period of high temperature and high evaporation. Rice straw mulch reduced evaporation from soil and maintained lower soil temperature as compared to unmulched plots (Xiangxiang *et al.*, 2022). The beneficial effect of mulch on plant height due to soil moisture conservation has also been reported by Taye *et al*. (2015).

Leaf area per plant varied significantly due to different treatments at all stages of crop growth (Table 1). It increased rapidly from 30 to 60 DAS but the rate of increase was slow down from 60 DAS to harvest stage. At 30 days after sowing, a trend of increase in leaf area per plant was found as sowing was extended from 8th February to 10th March. Crop sown on 10th March recorded significantly highest leaf area per plant (453 cm^2). Non significant differences were observed among rest of sowing dates with minimum leaf area per plant in first sowing date. At 60 days after sowing, leaf area per plant in 8th February was significantly higher (3386 cm^2) than 10th March sowing, but remained at par with 18th February and 28th February. Crop had significantly lowest leaf area per plant when sown on 10th March. At harvest stage, crops sown on 8th February attained significantly higher leaf area per plant (3561 cm^2) than rest of sowing dates, except 18th February. Moreover, difference between 18th February and 10th March was also significant with minimum value in later date. Leaf area per plant is decided by number of leaves per plant and average leaf size (length and width). The production and development of leaves are greatly influenced by temperature, moisture and nutrients. Different temperature regime under different sowing dates influenced maize growth which brought significant variation in leaf area per plant. Longer and wider leaves owing to better growth in early sowing dates resulted into higher leaf area. Late sown crop faced high temperature at later stage which restricted vegetative growth with the result of reduced leaf area per plant (Williams II, 2008). These results are in confirmation of the findings of Franco *et al.* (2016). Among different mulch treatments, leaf area per plant was not affected significantly at 30 days after sowing. At 60 DAS and harvest stage, mulch applied after 2nd irrigation being at par with another mulch treatment resulted into significantly higher leaf area per plant (3364 and 3498 cm^2, respectively) than without mulch treatment. Reasons cited for difference in plant height due to mulch treatments also hold true for variation in leaf area per plant. The results are in close agreement with Singh *et al.* (2015).

At 30 DAS, gradual increase in dry matter per plant was obtained as sowing was delayed and significantly highest value (4.94 g) was in the last date of sowing (Table 1). The first and second sowing dates did not exhibit significant difference. Dry matter accumulation per plant from 30 to 60 DAS increased rapidly in all the treatments but the rate of increase declined with postponement of sowing. The rate of increase in dry matter accumulation per plant in 60 DAS over 30 DAS was 12.3, 11.0, 8.2 and 5.3 times higher in first, second, third and fourth date of sowing, respectively. Crops sown on 8th February attained significantly higher dry matter per plant (36.8 g) than rest of sowing dates but did not vary statistically with 18th February. Significantly lowest dry matter was noted in 10th March. At harvest stage, increase in dry matter accumulation per plant was 1.58, 1.57, 1.54 and 1.50 times more in first, second, third and fourth date of sowing, respectively compared to that of obtained at 60 DAS. Significantly higher dry matter per plant (95.1 g) was noted in 8th February than rest of the treatments, but it remained at par with 18th February. Moreover, crop sown on 18th February was also significantly superior to that of 10th March. As sowing was delayed from 8th February to 28th February and 10th March the reduction in dry matter accumulation per plant was 13.8 and 20.8 per cent, respectively. Dry matter accumulation is a physiological process governed by photosynthetic rate and photosynthesizing area. Photosynthetic rate is influenced by growth factors primarily temperature. Difference in temperature and in leaf area per plant i.e. photosynthesizing area led to differences in dry matter accumulation. In early sowing dates (i.e. 8th and 18th February) significantly higher leaf area coupled with optimum prevailing temperature led to more dry matter accumulation per plant. The present results are in accordance with the findings of Hai-dong *et al.* (2017). Among mulch treatments, plant dry matter was not affected significantly at 30 DAS, but significant differences were recorded at 60 DAS and harvest stage where mulch application after 2nd irrigation recorded significantly higher dry matter per plant (35.8 and 91.3 g, respectively) than no mulch treatment but was statistically equal with mulching after 3rd irrigation. At harvest stage average increase in dry matter accumulation per plant in mulch treatments over no mulch was 16.2 per cent. Crop grown with mulch had significantly higher leaf area due to better growth thus accumulated more dry matter. Moreover, higher dry matter production per plant under mulched treatments might be attributed to better soil moisture content and temperature which enabled the plant for more photosynthesis (Singh *et al.*, 2016).

An increase in LAI was noted between 30 and 60 DAS but the rate of increase declined between 60 DAS and harvest stage (Table 2). At 30 DAS significantly highest LAI (0.302) was observed in 10th March sowing. Non significant differences were observed among rest of sowing dates with minimum LAI (0.227) in the first sowing date. At 60 days after sowing, crop sown on 8th February had significantly higher LAI (2.258) than 10th March sowing but remained at par with rest of sowing dates. Crop had significantly lowest LAI (1.951) when sown on 10th March. At harvest stage, crops sown on first date attained significantly higher LAI (2.373) than rest of sowing dates except second date. Moreover, difference between 18th February and 10th March was also significant

Table 2. Leaf area index, crop growth rate, relative growth rate and net assimilation rate of sweet corn in spring season as influenced by sowing dates and application of mulch

Treatment	LAI			CGR ($g/m^2/day$)		RGR (mg/g/day)		NAR ($g/m^2/day$)	
	30 DAS	60 DAS	Harvest	30-60 DAS	60 DAS-harvest	30-60 DAS	60 DAS-harvest	30-60 DAS	60 DAS-harvest
Sowing date									
8th February	0.227	2.258	2.373	7.6	10.2	86.8	25.0	8.6	4.4
18th February	0.231	2.163	2.279	7.2	12.0	83.0	30.5	8.4	5.4
28th February	0.254	2.073	2.179	6.4	12.2	74.2	34.6	7.4	5.8
10th March	0.302	1.951	2.036	5.9	12.6	61.6	36.7	6.7	6.3
SEm±	0.009	0.056	0.045	0.2	0.4	2.5	1.1	0.3	0.3
CD (p = 0.05)	0.031	0.198	0.159	0.8	1.4	8.6	3.9	1.0	1.0
Mulch application									
No mulch	0.253	1.936	2.034	6.1	10.5	73.5	31.1	7.5	5.3
After 2nd irrigation	0.249	2.243	2.333	7.1	12.4	77.7	31.9	7.9	5.5
After 3rd irrigation	0.259	2.155	2.283	7.0	12.4	78.0	32.2	7.9	5.6
SEm±	0.008	0.043	0.029	0.2	0.3	1.8	0.9	0.3	0.1
CD (p = 0.05)	NS	0.131	0.086	0.5	0.9	NS	NS	NS	NS

with minimum value in later date. LAI depends on leaf area per plant and planting geometry. The geometry was same in all treatment but differences in leaf area per plant caused variations in LAI. Non significant differences were recorded for LAI among different mulch treatments at 30 days after sowing. Crop grown with mulch application after 2nd irrigation being at par with another mulch treatment exhibited significantly higher LAI at 60 DAS (2.243) and at harvest (2.333) than that of grown without mulch. Higher values of leaf area per plant in both mulch treatments caused more LAI. Singh *et al.* (2016) also reported that straw mulch in spring maize increased leaf area index.

During 30-60 DAS, statistically more CGR was noted in crop sown on 8th February (7.6 $g/m^2/day$) followed by 18th February with non significant difference between both (Table 2). Sowing after 18th February resulted in to continuous significant reduction in CGR where minimum value (5.9 $g/m^2/day$) was observed in 10th March sowing. CGR during 60 DAS- harvest stage was higher than during 30-60 DAS but the trend of CGR was reversed where significantly higher CGR (12.6 $g/m^2/day$) was obtained in last date of sowing (10th March) and significantly lowest CGR (10.2 $g/m^2/day$) was recorded in 8th February. However, CGR of crop sown on 28th February was statistically at par with that of 18th February. Crop growth rate is decided by dry matter accumulation per day per unit area. The differences in CGR among different dates of sowing were simply due to variations in dry matter accumulation per plant under different treatments. Early sown crop had more dry matter accumulation at 30 and 60 DAS, therefore exhibited higher CGR between 30-60 DAS where time interval between two stages was 30 days for all the treatments. Though at 60 DAS and harvest stage, dry matter production was higher in early sowing dates but had less CGR between 60 DAS-harvest. It was due to the fact that crop sown early took more number of days to harvest than that of crop sown late. The crop duration in first, second, third and fourth sowing date was 98, 91, 87 and 85 days, respectively thus, the time interval between 60 DAS and harvest was 38, 31, 27 and 25 days, respectively. Since CGR depends on dry matter production between two time intervals of crop growth hence longer time interval between 60 DAS and harvest in early date of sowing resulted into lower value despite more dry matter accumulation. During 30-60 DAS and 60 DAS-harvest, mulch application after 2nd and 3rd irrigation being at par each other obtained significantly more CGR (7.1 and 12.4 $g/m^2/day$, respectively) than without mulch. The differences in CGR among mulch treatment were because of variations in dry matter accumulation per plant. Both mulch treatments recorded more dry matter accumulation therefore, exhibited higher CGR (Oroka and Frank, 2016).

The perusal of data revealed that RGR was significantly affected due to sowing dates (Table 2). RGR decreased with delay in sowing where crop sown on 8th February attained significantly higher RGR (86.8 mg/g/day) as compared to that of sown on 28th February and 10th March sowing however, it remained at par with 18th February sowing. Significantly lowest RGR (61.6 mg/g/day) was obtained in last sowing. During 60 DAS- harvest stage, RGR decreased in comparison to between 30-60 DAS. The delay in sowing led to increase in RGR where significantly highest (36.7 mg/g/day) and lowest (25.0 mg/g/day) values were obtained in crop sown on last and first dates, respectively. Relative growth rate depends on ratio of newly formed photosynthates and existing accumulated photosynthates in unit time. The variations in RGR among different sowing dates were because of differences in dry matter and time interval between two crop growth stages under consideration. During 30-60 DAS, the time interval was same (30 days) for all the treatments so more dry matter accumulation in early sowing resulted into higher RGR. At 60 DAS- harvest, the value of RGR increased with delay in sowing despite reduced dry matter production because of the reason that crop maturity period declined with each successive sowing dates. Time interval between 60 DAS to harvest was minimum (85 days) for last sowing date which caused higher RGR. At 30-60 DAS and 60 DAS-harvest stages crop grown with and without mulch exhibited statistically same value of RGR. However, numerically more RGR was recorded in mulch treatment. Mulching increased dry matter production per plant but could not show superiority for relative increase in dry matter. It was due to the fact that crops grown with and without much had significantly different amount of growth (dry matter production) but their rate of growth with existing accumulated dry matter did not vary enough to make it significant. Therefore, significant differences were recorded for CGR but not for RGR. Similar results of mulch on crop growth rate and relative growth rate in maize were also observed by Oroka and Frank (2016).

During 30-60 DAS, a trend of reduction in NAR was observed with delay in sowing where higher value (8.6

g/m^2/day) was recorded on 8th February which was at par with 18th February but was significantly superior to rest of sowing dates (Table 2). Sowing on 10th March resulted into significantly lower NAR (6.7 g/m^2/day). NAR values decreased during 60 DAS- harvest stage. NAR showed an increase with postponement of sowing. Significantly highest NAR (6.3 g/m^2/day) was obtained in crop sown on 10th March. The second highest NAR value was obtained in crop sown on 28th February which was significantly higher than 8th February but it remained statistically at par with 18th February sowing. NAR is decided by leaf area and dry matter production per unit leaf area in unit time. Not only leaf area but also rates of increase in leaf area are important in determining NAR. Both the growth parameters leaf area and dry matter production at different time interval were more in early sowing. During 30-60 DAS time interval was 30 days for all treatment but due to more leaf area and dry matter, NAR was higher in early sowing. But during 60 DAS-harvest the time interval for different sowing date was different (98, 91, 87 and 85 days, respectively in first, second, third and fourth sowing dates) and was the lowest for the last sowing dates. Therefore, NAR in later sowing dates was more due to reduced duration between 60 DAS and harvest. During 30-60 DAS and 60 DAS- harvest, different mulch treatments failed to produce significant differences in NAR value of sweet corn with numerically higher value in mulch treatments. Though leaf area and dry matter was more in mulch treatment but their rate of increase between two successive stages could not crossed the level of significance in comparision to unmulch condition. This resulted into non significant difference in NAR. These results corroborate the findings of Meena *et al*. (2021).

Yield attributes and yield

The data indicated that both sowing dates and mulch application did not influence plant population in unit area significantly (Table 3). However, numerically the maximum number of plants (6.47/m^2) was recorded in second date of sowing followed by first date. Whereas among mulch treatments, mulch applied after 3rd irrigation recorded the maximum plant population (6.43/m^2). Plant population depends on number of seeds sown in unit area and mortality percentage. In present study the crop geometry (60 cm × 25 cm) in each treatment was same hence plant population remained non significant.

Under different sowing dates, number of cobs ranged from 0.94 to 0.97/plant but differences were not enough to be significant (Table 3). Mulch treatments also failed to produce significant difference in number of cobs/plant with maximum value (0.97 cobs/plant) in treatment having mulch which was applied after 2nd irrigation. Since number of cobs per unit area depends on plant population hence, non significant variation in plant population was responsible for at par difference in number of cobs in sowing dates and mulch treatments. These results are in line of Shrestha

Table 3. Yield attributes, yield and total soluble solids (TSS) of sweet corn in spring season as affected by sowing dates and application of mulch

Treatment	Plant population /m^2	No. of cobs/ plant	One cob weight with husk (g)	Husked cob yield(t/ha)	Total soluble solids (brix)
Sowing date					
8th February	6.34	0.96	261	15.9	15.59
18th February	6.47	0.94	254	15.4	15.40
28th February	6.21	0.97	231	13.9	14.51
10th March	6.37	0.95	212	12.8	13.62
SEm±	0.07	0.02	6	0.24	0.21
CD (p = 0.05)	NS	NS	21	0.84	0.75
Mulch application					
No mulch	6.37	0.95	212	12.8	14.71
After 2nd irrigation	6.24	0.97	257	15.5	14.83
After 3rd irrigation	6.43	0.95	250	15.2	14.80
SEm±	0.11	0.02	10	0.54	0.19
CD (p = 0.05)	NS	NS	32	1.62	NS

et al. (2016) who also reported non significant differences in number of cobs due to different sowing dates.

Crop sown on February 8th attained significantly higher single cob weight with husk (261 g) as compared to that of 28th February and 10th March sowing (Table 3) but remained at par with 18th February. Significantly higher single cob weight in early sowing may be reasoned to better growth of plants. Better translocation of photosynthates from source to sink in early sowing treatment due to favorable weather conditions (relatively low temperature at reproductive stage) might have contributed towards heavier weight of cobs (Shrestha *et al.*, 2018). These finding are well supported by Rajablarijani *et al.* (2014) who observed that low temperature during anthesis is favorable for higher yield. Among different mulch treatment, significantly higher cob weight was observed with mulch application after 2nd irrigation (257 g) as compared to without mulch treatment but did not vary statistically with treatment in which mulch was applied after 3rd irrigation. Proper development of cobs in mulch treatments resulted in to higher individual cob weight. The positive effect of rice straw mulch on cob weight of spring maize was also reported by Singh *et al.* (2016).

A progressive reduction in husked cob yield was recorded as sowing was delayed (Table 3). Significantly higher husked cob yield was obtained in February 8th sowing (15.9 t/ha) as compared to 28th February and 10th March sowing but was at par with February 18th sowing. The comparative increase in yield in 8th February sowing was 23.6 and 14.1 per cent over 28th February and 10th March sowing, respectively. Significantly more cob yield in the first and second dates of sowing was due to higher values of cob weight. Reduction in husked cob yield with delay in sowing may be attributed to low cob weight (Hai-dong *et al.,* 2017). These results are in line with those of Shrestha *et al.* (2018) who noticed that yield of sweet corn in spring season was higher in early sowing due to more values of yield attributes. Temperature during anthesis is very important which affect yield (Patel *et al.*, 2024). Crop sown on first, second, third and fourth date of sowing faced average daily temperature 28.8, 29.2, 30.1 and 30.7°C, respectively during 50% tasseling to harvest stage. High temperature during reproductive stage in late sown crops was responsible for lower cob yield. The findings of Shrestha *et al.* (2016) also revealed that high temperature during reproductive phase adversely affect pollen viability, receptivity of silk, cell division in endosperm, duration in grain filling, kernel development and enzyme activities. The significant difference was also recorded in mulch treatments. Crop grown with mulch application after 2nd irrigation produced significantly higher husked cob yield (15.5 t/ha) than that of without mulch but was statistically same to that of grown with mulch application after 3rd irrigation. Difference between no mulch and mulching after 3rd irrigation was also significant. An improvement in husked cob yield to a tune of 17.4 and 15.9 per cent was recorded in mulch application after 2nd and 3rd irrigation, respectively over no mulch treatment. The higher husked cob yield in mulch treatment may be attributed to reduced evaporation loss of applied water. Moreover, mulch maintained favorable soil temperature. It might influenced yield attributes positively and thus yield (Akter *et al.*, 2022). Higher yield of maize due to mulching was also reported by Xing *et al.* (2024).

Quality

The results revealed that total soluble solids (TSS) progressively decreased with delay in sowing of crop (Table 3). The crop sown on 8th February being at par with 18th February exhibited significantly higher TSS (15.59% brix) than other sowing dates. Moreover, sweet corn sown on 18th February also recorded significantly higher TSS as compared to 28th February and 10th March sowing. Sowing on the last date had significantly minimum TSS (13.62% brix). As sowing was delayed the TSS was declined. This was probably the effect of high temperature at the time of harvesting of late sown crops which might resulted into low sugar content (Kettler *et al.*, 2022). The reduction in sucrose content in sweet corn at high temperature was also mentioned by Brecht (2016). Different mulch treatments were failed to bring significant improvement in TSS of sweet corn crop.

Water use efficiency

Non significant differences in irrigation water use efficiency (IWUE) were observed due to different sowing dates however, numerically the maximum value (398 kg/ha-cm) was observed in 28th February and the lowest was in 10th March (Table 4). The variation in IWUE were due to difference in dehusked cob yield and number of irrigations given to each date of sowing. Number of

Table 4. Influence of sowing dates and application of mulch on irrigation water use efficiency (IWUE) and water productivity of sweet corn in spring season

Treatment	Depth of irrigation (cm)	Rainfall (mm)	Total water applied in crop (cm)	IWUE (kg/ha-cm)	Water productivity (kg/ha-cm)
Sowing date					
8th February	30	7.6	30.7	381	371
18th February	30	36.6	33.6	371	330
28th February	25	36.6	28.6	398	348
10th March	25	36.6	28.6	366	319
SEm±	-	-	-	7	6
CD (p = 0.05)	-	-	-	NS	21
Mulch application					
No mulch	26.3	29.4	29.2	334	302
After 2nd irrigation	26.3	29.4	29.2	405	366
After 3rd irrigation	26.3	29.4	29.2	397	359
SEm±	-	-	-	13	12
CD (p = 0.05)	-	-	-	40	36

irrigations in first, second, third and fourth sowing dates were 6, 6, 5 and 5, respectively. Crop sown on 28th February had the lower cob yield as well as irrigations as compared to earlier sowing but high IWUE may be ascribed to more proportionate increase in cob yield per unit amount of irrigation water applied. An increase in water use efficiency with delay in sowing was also reported by Feyzbakhsh *et al.* (2015). Mulch application after 2nd irrigation being at par with after 3rd irrigation recorded significantly higher IWUE (450 kg/ha-cm) as compared to no mulch treatment. Due to mulch application IWUE increased by 20.0 per cent over no use of mulch. Higher IWUE in mulch treatments over no mulch was because of higher cob yield. The present results are in accordance with the findings of Xing *et al.* (2024) who observed high water use efficiency of maize due to application of organic mulch.

Significantly highest water productivity (371 kg/ha-cm) was recorded in first date of sowing followed by third date of sowing (Table 4). Significantly lower value was noted in last sowing which was at par with second date of sowing. The differences in water productivity among different treatments were due to variation in cob yield, number of irrigations and amount of rainfall received during crop season. Mulch applied after 2nd irrigation recorded significantly higher water productivity (366 kg/ha-cm) than no mulch treatment however, it was statistically at par with mulch applied after 3rd irrigation. An increase in water productivity to a tune of 20.0 per cent was noted due to mulch application. Higher water productivity in mulch treatments was due to more dehusked cob yield. These findings are in the lines of Shah *et al.* (2023).

Conclusion

It can be concluded that sowing of sweet corn in spring season during first fortnight of February is favorable for better growth, higher cob yield and superior quality. Application of rice straw mulch @ 5 t/ha after 2nd irrigation or 3rd irrigation is helpful for increasing production and water use efficiency.

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