Original Research Article

Influence of planting time and varietyon the growth, development,and yieldof ~~Tomato~~tomato

Abstract: Tomato growth and reproductive properties, particularly fruit yield, are significantly influenced by planting time and variety. In this study, eight open-pollinated tomato cultivars were planted at two different planting periods (December 18th, 2019 and January 18th, 2020) and were used to determine the most effective planting time for tomato~~cultivation~~. Different sowing dates and varieties ~~have~~ had~~a substantial~~significant impacts on tomato yields. The highest number of fruits per plant were recorded in BARI tomato-3 (46.87), followed by BARI tomato-14 (43.22),while the minimum in Marglobe (13.00) in December planting. Khattabegun variety had the highest number of fruits per plant (14.17), followed by BARI tomato-3 (14.02) and BARI tomato-14 (13.97)in January planting. BARI tomato-14 produced the highest yield (38.55 ton~~/~~ha^{-1}), followed by BARI tomato-3 (38.16 ton~~/~~ha^{-1}) in December planting, while the lowest yield was found in Riograndi (9.17 ton~~/~~ha^{-1}). In January planting, the ~~maximum~~ highestyield was found in BARI tomato-15 (12.10 ton~~s~~/ha^{-1}), while the ~~minimum~~ lowestyield was observed in Khattabegun (6.25 ton~~s~~/ha^{-1}). Considering the studied factors ~~features~~ that contribute to increased yields and disease tolerance, ~~the~~ combination of December planting with BARI Tomato-14 ~~is~~ wasmore effective~~lucrative~~.

Key words: Tomato, ~~(*Solanum lycopersicum* L.);~~ pPlanting time,~~;~~Vv~~ariety,~~;~~Yy~~ield,~~;~~Dd~~iseases~~ tolerance,~~;~~Pp~~ests~~ tolerance

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1. Introduction

Tomato (*Solanum lycopersicum* L.) is the World's second most significant and consumed vegetable crop, with a global production of 186,821,216 metric tons and cultivated on 5,051,983 hectares in 2020 (FAOSTAT, 2022). Because of its multiple uses, nutritional advantages, and the rapid changes in global food systems, the tomato is currently the most important marketable vegetable crop in the world (FAOSTAT, 2022; Vats et al., 2020). Annual tomato output has expanded by more than six-fold in the previous fifty years, while global traffic in tomatoes and tomato products has increased by about tenfold. Furthermore, from 1961 to 2018 per capita, tomato consumption increased dramatically from 8 kg to 21.17 kg per day (FAOSTAT, 2020). Tomatoes contribute significantly to human nutrition since they are a good source of vitamins, essential minerals, macronutrients, bioactive compounds, and antioxidants, all of which help to prevent cancer, cardiovascular disease, eye, nerve, and other diseases (Alam et al., 2019; Asiry et al. 2022; Hossain et al., 2019; Huda et al., 2022; Sommer and Vyas, 2012; Tomlinson et al., 2017; Vats et al., 2020; Young and Lowe, 2018).

Tomato quality is affected by climate, growing medium and plant nutrition (Jankauskieno, 2013). Planting periods are highly correlated with local climatic variability. Different sowing dates and types have a significant effect on tomato yield (Rahman et al., 2020). Plant maturity, harvesting time, yield, and crop quality can all be affected by planting time. At the pre-flowering and blooming stages, the high temperature (32^0C) significantly reduced photosynthetic rate, number of fruits,

individual fruit weight, and fruit output per plant. Temperature impacts were more during blooming than pre-flowering (Islam, 2011).

Agronomic practices have long been recognized as critical to crop nutrition (~~Barrett et al., 2007;~~ Souri and Dehnavard, 2018). The nutritional value of tomatoes is controlled by the tomato variety and harvest maturity (Erba et al., 2013). Delayed planting reduces tomato plant heights, fruit set, fruit weights, and yields. Appropriate planting dates boost production while improving vegetable quality (Kleinhenz and Wszelaki, 2003). It is in high demand throughout the year, while most of the tomato production in Bangladesh takes place in winter (Biswas et al., 2017; Islam et al., 2017). The planting time also affects the fruit yield and quality (Tomar et al., 2018).

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In the eastern side of Bangladesh, including the Chittagong Hill Tracts areas, farmers have been cultivating tomato between October to March without knowing the best time for planting tomatoes. Due to a lack of knowledge of planting time, the tomato growers had not got maximum production though they used ~~modern~~ improvedvarieties. Therefore, the experiment was conducted to investigate the impact of planting times and varieties on tomato performance in the eastern regions of Bangladesh.

2. Materials and methods

The experiment was conducted during Robi season of 2019-2020at the RARS research field, Hathazari, Chittagong, Bangladesh. During the experimental period, the data of different environmental factors i.e., maximum and minimum rainfall, maximum and minimum temperature, and relative humidity (RH) was obtained from weather station of RARS research field, Hathazari (Table 1).A total of eight tomato varieties, including four BARI varieties (BARI tomato 2, BARI tomato 3, BARI tomato 14, and BARI tomato 15) and four commercial varieties (Marglobe,Roma VF, Riograndi, and

Khattabegun), were used in this study. December 18th, 2019 and January 18th, 2020 were the dates for the first and second plantings,respectively of 30-days old seedlings in the main field, respectively. Planting period and varietal effect were used as variables in the experiment with a split-plot design. Plot dimensions were 4m × 3m with a plant spacing of 70cm× 45cm. Urea, TSP, MoP, and Gypsum were applied at 500kg, 200kg, 200kg, and 100kgha^{-1} per hectare of land, respectively, in addition to the 10 ton ha^{-1}s of cow manure. Half of the cow dungmanure, all TSP, and all MoP were applied to the land during final land preparation. The remaining cow manure was utilized to prepare the pit. The total amount of urea was applied in three equal instalments at 21, 35, and 45 days. Intercultural operations were carried out when needed. Days to 50% flowering, plant heights at first harvest, individual fruit weights, lengths and girthbreadth, and fruits per plant were recorded. The CROP STAT application was used to analyse the collected data. Before analysis, disease and insect infestation data were square-root ([x + 0.5]) normalized and the original values were given in parenthesis.

3. Results

There were significant differences among the variables in Table 2, Table 3, and Table 4. Some crucial parameters showed significant differences in tomato varieties ($p \leq 0.05$). Plant height at first harvest was found to be significantly affected by the relation between planting times and varieties.Local tomato variety Khattabegun was proven to have the highest plant height (118.40 cm and 108.84 cm) at both planting times, whereas BARI tomato-14 was shown to have the second-highest plant height (111.47 cm and 91.07 cm). The commercial variety Roma VF had the was found to have the lowest plant height of at both planting times (46.15cm and 41.01cm during the firsts

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and second planting times, respectively). Days of 50% flowering were significantlyaffectedby both planting times and varieties. Roma VF took the maximum number of days (50.67 and 41.49) to reach 50% flowering, whereas BARI tomato 2 required the minimum number of days (50.67 and 41.49) to reach 50% flowering (Table 2).

The number of fruit clusters per plant showed was a significant affected by tomato variety and planting timeeffect. Riograndi had the highest number of fruit clusters per plant (12.15), followed by BARI tomato 14, BARI tomato 15, and BARI tomato 3 (10.67, 10.47, and 10.27, respectively) in December planting. During the initial planting, Khattabegunes had the lowest number of fruit clusters per plant (6.24) (Table 2).

There was a significant correlation between planting time and the number of fruits per plant. In the initial planting, BARI tomato-3 had the highest number of fruits per plant (46.87), followed by BARI tomato-14 (43.22), while Marglobe had the fewest lowestnumber of fruits per plant (13.00). During the second planting time, BARI tomato-3 and BARI tomato-14 were second and third with 14.02 and 13.97 fruits per plant, respectively.

Tomato yields Yield per plot showedvaried significant differences in with both planting times and varieties. In December planting, BARI tomato-14 had the highest yield per plot(…. ton ha^{-1}) (48.26 kg), followed by BARI tomato-3 (…. ton ha-146.33kg),whilelowest yield per plots was recorded in Riograndi (…. ton ha-110.77 kg). For second planting, BARI tomato-15 produced the highest yields per plot (…. ton ha-114.30 kg), while Khattabegunhad the production was the lowest yield (…. ton ha-17.5kg) (Table 2).

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Individual fruit weights wereas significantly affected by planting times and varieties. Individual fruit weights of 168.54gm and 97.29gm were recorded for Marglobe, while 70.49gm and 63.53gm were recorded for Khattabegunes in December and January, respectively (Table 3). For fruit length, there was a strong time-variety relation but planting time had no significant effect. The maximum fruit length was recorded in Marglobe 6.30 cm in December and 5.87 cmin January, whereas the minimum fruit length was observed in Khattabegun(3.94 cm and 3.91 cm), respectively (Table 3). For fruit breadthgirth, there was a substantial time-variety interaction, but there was no significant effect of planting time. BARI tomato-2 had the highest fruit breadth girthof 6.17 cm during December planting, whereas the lowest fruit breadth girthwas 2.46 cm in Khattabegunes. When the BARI tomato-14 was planted in January, the maximum fruit breadth girthwas 5.86 cm and the minimum was 2.88 cm.

Total yields of tomato varied significantly with planting time and variety. The relation between time and variety was significant for total yield. Total yield of 38.55 tonsper hectareha^{-1} was recorded in December planting for BARI tomato-14, followed by BARI tomato-3 with 38.16 tons per hectareha^{-1}. The lowest yield was in Riograndi (9.17 ton/ha^{-1}) in December planting. In January planting, the highest total yield was recorded in BARI tomato-15 (12.10 tons/ha^{-1}), while the lowest total yield was observed inKhattabegun(6.25 ton ha^{-1}s per hectare) (Table 3).

Levels of infections due to bacterial wilt disease did not significantly vary with planting time and tomatoThere was no statistically significant interaction between time and variety for bacterial wilt disease. Level of bBacterial wilt disease infection was infected by 6.9% and 5.48% in Riograndi variety plots, whereas the Khattabegun variety wasplotsinfected by 1.34% and 1.12% in December and January planting,

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respectively (Table 4).Early-blight infestations were significantly influenced by both the planting time and tomato varietytime variety correlation. During December planting, Roma VF had the highest infestation rate of (2.41%). , while BARI tomato-3, BARI tomato-15, Marglobe, and the local variety had no significant differences. There was no infestation in BARI tomato-3, BARI tomato-15, andKhattabegun, whileRiograndi had 4.13% infection by early blightplots were infested during January planting of Riograndi (Table 4).There were no significant differences in number of fruits infected by fruit borer (p≥0.05). The number of infected fruits per plot were highest in BARI tomato 2 (2.15%), followed by BARI tomato 3 (2.23%) in December and January planting, respectively. In both cases, there was no infestation observed in the Khattabegun variety. There was no significant differences in In case of virus infestation, the interaction was found non significant between planting time and variety. The highest virus infested plant was found in Marglobe (3.27%) and the lowest in BARI tomato 14 and BARI tomato 15 (1.12%) at December planting but in January planting, the maximum infestation was recorded in Khattabegun (2.90%) while no viral infestation was observed in BARI tomato 3 and BARI tomato 14 (Table 4).

4. Discussion

The pPlanting time and variety had significantly impact on the growth, as well as yield and yield components of tomatoes. Planting times influenced plant heights (cm), fruit yields (g), total yields (ton/ha), diseases, and pest infestations (Afreen et al., 2017). Tomato growths and yields were influenced by environmental conditions (Light, temperature, CO2, humidity, soil moisture),fertilizer, farming system, and plant genetic materials as reported by influenced crop performance in the field (Souri and Sooraki (, 2019; Weston, 1988; Ciardi et al., 1998;Vavrina, 1998; Damato and Trotta, 2000; Paul

~~and Metzger, 2005~~). According to Jong et al. (2009) environmental factors affect the commencement of fruit setting and growth. Gent (1992) found that delayed planting of heat-tolerant early tomato varieties delayed fruit maturity by two weeks. With enough time for growing, the highest plant heights were~~as~~ observed after first transplanting that was done on 18th December ~~18~~. The impact of transplanting time on environmental temperature is mostly shown in ~~height of the plant~~plant ~~(~~heights (Islam et al., 2017). Srivastava and Srivastava (2007) found that seedling transplanting time affects tomato plant heights. Tomato plant heights decreased after late planting owing to environmental conditions. The environment controls the fruit yield per plant (Islam et al., 2017). On the other hand, Drost and Price (1991) found that early transplanting increased~~s~~ fruit yield of tomato planted on 18thDecember ~~18~~ which gave the most exquisite fruits,maybe it's because of the long growing season and the ideal day-night temperature for fruit development. Tomato p~~P~~lant ~~cultivat~~ed on 18thJanuary had ~~18produced~~ the lowest number of fruits and yields per plant. In this case, the highest yield was achieved by planting tomato~~es~~ in December, which is corroborated by earlier studies (Ahammad et al.,~~2009~~2013; Rogers and Wszelaki, 2012~~; Sharma and Tiwari, 1996~~). Late planting that was done on 18thJanuary ~~18~~had the lowest yields. Late planting had significant effect on tomato growth, yields, and yield components. Islam et al. (2017) observed early planting increased tomato production. The 18th of December transplant improved all yield-related characters compared to the 18thJanuary transplants. Sanjoy (1999) reported a decline in fruit yield and other yield-related traits in recent plantings.

During blossom and ripening stages of late-cultured plants, they were affected by harsh conditions such as high temperatures and humidity. A study by Preedy and Watson

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(2008) demonstrated that tomatoes thrive in high altitudes with little humidity and high light intensity. Fruit set percentage and fruit weight per plant declined when the daily mean temperature was 29°C, compared to 25 °C (Harel, 2014). The decline in production is mainly due to the decrease in pollen viability and poor pollen development (Sato et al., 2006). According to the findings, planting in December led to ~~results in~~ more blossoms and fruit compared to ~~than planting in~~ January planting. This result is consistent with the previous studies.

Planting time manipulation affects the diversity and abundance of different insect pests;therefore, it is considered as one of the crucial factors for reducing the infestation by insect pests to get optimum yield in tomato (Afreen et al., 2017).In the present study it was observedthat ~~the~~ infestation caused by Bacterial wilt, Early blight, fruit borer, and virus were more observed on tomato planted on 18th ~~in~~ December than those planted on ~~18 planting than~~18th January, more especially on ~~18 plantingin~~ BARI tomato-2, BARI tomato-14, and BARI tomato-15. Highest ~~The higher~~ infestations~~was observed~~ causedby b~~B~~acterial wilt, e~~E~~arly blight, and fruit borerwere observed in tomatoplanted on 18th ~~in~~ January ~~18planting~~ compared to those planted on 18th December. ~~18 planting v~~Virus ~~in BARI tomato-3 and Roma VF except virus infection; virus~~ infection was higher in BARI tomato-3 planted on 18th December ~~18~~compared to those planted on 18th ~~ing than~~ January~~18 planting in BARI tomato-3~~, while Roma VF was not infected by virus. Marglobe variety planted on 18th December was more susceptible to ~~highly infested by~~ e~~E~~arly blight, fruit borer, and virus compred when ~~in December 18 planting~~ compared ~~to on~~18th January~~18 planting~~, while,bacterial wilt infestation was opposite trend. The infestation by early blight, fruit borer, and virus was high late planting compared to early planting in Variety Riogrande

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but bacterial wilt infestation was high in early planting than late planting.Moreover,Khattabegun variety showed high infestation by bacterial wilt when planted on 18th ~~in~~ December ~~18planting compa~~compared when planted on 18th ~~red to~~ January ~~18 planting~~ and virus infestation showed opposite trend. The same tomato variety did not show susceptibility to ~~but no infestation was observed by~~ early blight and fruit borer ~~in this variety~~. However, most of the varieties were more susceptible to ~~highly infected by~~ Bacterial wilt, early blight, fruit borer, and virus when planted on 18th ~~in~~ December ~~18planting~~ compared to 18th January ~~18 planting~~. A study ~~was~~ conducted by Afreen et al. (2017), indicated that ~~they observed that~~ planting ~~of~~ tomato on ~~in~~ 10th December was ~~is~~ effective in controlling ~~for~~ insect pest~~s~~'infestation and increasing fruit yields~~reduction with better yield~~.Waluniba and Ao (2014) also indicated that tomato planted on 4th Decemberwere highly infested by a~~A~~phids and whiteflies, w~~y showed higher infestation in December 4 planting w~~hile those planted on 19th ~~l~~December were more prone to leaf miner and tomato fruit borer attacks~~showed higher infestation in December 19 planting in Tomato (Waluniba and Ao, 2014)~~.

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5. Conclusion

The growth and yield of tomato was significantly affected by ~~different~~ planting dates and varieties. Planting t~~T~~omato ~~planting~~ on 18th December ~~18~~using ~~with~~BARI tomato-14 andr ~~followed by~~ BARI tomato-3 varieties leads to ~~is suitable for~~ optimum fruit yields with less disease and pest infestations. However, Khattabegunes (local variety) show~~ed~~ high tolerance ~~t capacity against~~to bacterial wilt, early blight, and virus which may be used as breeding materials for biotic stress tolerance in tomato ~~variety.~~

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Table 1. Monthly weather data of tomato growing period.

Month	Rainfall	Max. tem.	Min. tem.	Max. RH (%)	Min RH (%
November, 2020	3	28.9	18.5	80	30
December, 2020	23	27.06	14.53	96.33	57.66
January, 2021	26	26.82	14.94	95.4	50
February, 2021	11	29.13	16.36	94.66	30.33
March, 2021	6	32.62	20.67	94.75	41.75
April, 2021	87	33.77	24.07	93.25	45.75

Table 2. Effect of planting time and variety on tomato production and yield components.

Varieties	Plant heights at 1st harvest		Days to 50% flowering		No. of fruit clusters per plant		No. of fruits/plant		Fruit yield/plo (kg)	
	1st Time (Dec)	2nd time (Jan)	1st time (Dec)	2nd time (Jan)	1st time (Dec)	2nd time (Jan)	1st time (Dec)	2nd time (Jan)	1st time (Dec)	2 ti (J
BARI tomato 2	64.67	52.03	34.33	25.00	9.84	3.12	33.53	12.28	39.75	10
BARI tomato 3	70.37	48.27	37.00	25.33	10.27	2.68	46.87	14.02	46.33	11
BARI tomato 14	111.47	91.07	38.67	26.33	10.47	2.68	43.22	13.97	48.26	8
BARI tomato 15	74.27	63.80	34.33	27.00	10.67	2.67	36.23	11.46	41.11	14
Marglobe	73.77	56.90	43.33	37.80	7.00	4.27	13.00	7.26	15.16	11
Roma VF	46.15	41.01	50.67	41.94	7.40	5.93	19.00	10.44	16.40	10
Riograndi	51.84	42.90	35.00	34.39	12.15	6.00	30.33	10.77	10.77	9
Khattabegun	118.40	108.84	48.33	43.69	6.24	6.30	27.33	14.17	13.28	7
LSD ($p \leq 0.05$)	V=3.86		V=2.98		V=0.76		V=2.73		V=2.65	
	SD=5.10		SD=3.95		SD=0.95		SD=1.47		SD=3.98	
	V x SD=5.46		V x SD=4.21		V x SD=1.07		V x SD=3.86		V x SD=3.	

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Table 3. Effect of planting time and variety on tomato production and yield components.

Varieties	Individual fruit wt. (gm)		Fruit length (cm)		Fruit ~~breadth~~ girth (cm)		Total yield (/ha^{-1})	
	1st time (Dec)	2nd time (Jan)	1st time (Dec)	2nd time (Jan)	1st time (Dec)	2nd time (Jan)	1st time (Dec)	2nd time
BARI tomato 2	120.85	67.87	5.81	4.72	6.17	4.44	31.01	8.
BARI tomato 3	92.80	63.87	5.60	4.23	5.18	4.47	38.16	9.
BARI tomato14	94.65	63.00	6.10	5.26	4.99	5.86	38.55	8.
BARI tomato 15	85.53	67.83	5.82	4.06	5.10	4.64	33.42	12
Marglobe	168.54	97.29	6.30	5.87	5.59	4.74	16.24	9.
Roma VF	84.96	66.37	5.97	5.48	5.01	4.64	13.94	9.
Riograndi	80.25	77.48	5.67	5.44	4.49	5.40	9.97	7.
Khattabegun	70.49	63.53	3.94	3.91	2.46	2.88	10.23	6.
LSD (p ≤ 0.05)	V=8.61 SD=3.71 V x SD=12.17		V=0.55 SD=NS V x SD=0.78		V=0.48 SD=NS V x SD=0.67		V=2.81 SD=3.07 V x SD=3.	

Table 4. Diseases and insect infestation as influenced planting time and varieties.

Varieties	Bacterial wilt/~~plot~~ (%)		Early blight (%)		Fruit borer (%)		Virus (%)	
	1st time (Dec)	2nd time (Jan)	1st time (Dec)	2nd time (Jan)	1st time (Dec)	2nd time (Jan)	1st time (Dec)	2nd tim (Jan)
BARI tomato 2	4.20 (19.8)	1.76 (3.3)	1.53 (2.2)	1.12 (1.1)	2.15 (5.3)	1.39 (1.7)	2.71 (7.3)	1.12 (1.1)
BARI tomato 3	1.6 (4.2)	1.68 (4.3)	0.71 (0.0)	0.71 (0.0)	1.86 (3.0)	2.23 (4.8)	1.75 (3.2)	0.71 (0.0)
BARI tomato14	2.51 (7.5)	2.00 (4.3)	1.35 (2.2)	1.35 (2.2)	1.94 (4.0)	1.86 (3.7)	1.12 (1.1)	0.71 (0.0)

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BARI tomato 15	3.71	2.00	0.71	0.71	1.39	1.18	1.12	1.53
	(13.5)	(4.3)	(0.0)	(0.0)	(1.7)	(1.3)	(1.1)	(2.2)
Marglobe	5.44	4.80	0.71	2.30	1.48	1.10	3.27	2.64
	(31.1)	(23.9)	(0.0)	(6.3)	(2.0)	(1.0)	(10.4)	(8.3)
Roma VF	4.83	5.47	2.41	3.61	1.25	1.48	1.34	1.67
	(22.9)	(31.2)	(5.4)	(12.5)	(1.7)	(2.0)	(6.3)	(6.3)
Riograndi	6.9	5.48	1.53	4.13	1.71	1.93	1.97	2.89
	(47.8)	(31.3)	(2.6)	(16.7)	(3.0)	(3.3)	(6.3)	(15.5)
Khattabegun	1.34	1.12	0.71	0.71	0.71	0.71	1.51	2.90
	(2.1)	(1.08)	(0.0)	(0.0)	(0.0)	(0.0)	(3.1)	(10.4)
LSD ($p \leq 0.05$)	V=1.62		V=0.68		V=NS		V=1.3	
	SD=0.85		SD=NS		SD=NS		SD=N	
	V x SD=NS		V x SD=0.96		V x SD=NS		V x SD=NS	

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