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Effect of sowing dates on growth, yield and economics of tomato (*Solanum lycopersicum* L.) hybrids in western undulating zone of Odisha

***B. B. SAHOO, A. NAYAK, B. S. NAYAK, S. K. MOHANTY, N. MANDI, G. PRASAD, S. DAS AND C. M. KHANDA**

Regional Research and Technology Transfer Station, Bhawanipatna, Kalahandi-766001

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ABSTRACT

An experiment was conducted at Regional Research and Technology Transfer Station, Bhawanipatna to determine the effect of sowing dates on growth, yield and economics of tomato hybrids.The experiment was laid out in split-plot design with twelve treatments,comprising two tomato hybrids and six sowing dates and replicated thrice. The tomato hybrid Arka Rakshyak succeeds upon Arka Samrat with maximum numbers of fruits plant^{-1}(25), heavierfruit weight (82.1 g), higher yield of 213.4 q ha^{-1} and 15% higher monetary return.Similarly, the performances of 30th September croop was the best with maximum branches plant^{-1}(12.7), fruits plant^{-1}(30.4) and heaviest fruit weight (97.7g) leading to higher tomato yield of 286. 7q ha^{-1} and earned 85% higher economic return. The growing tendencies of vegetative and reproductive traits in tomato plants were recorded with the decreasing pattern of the monthly average temperature, indicating the positive influence of lower atmospheric temperature on these traits. Considering all the factors it could be concluded that sowing of tomato hybrid Arka Rakshak during 30th September can be recommended for commercial cultivation of tomato in Western Undulating Zone of Odisha.

***Keywords*:** Cost of production, fruit quality, sowing dates, tomato hybrids and yield

Tomato (*Solanum lycopersicum* L.) is a widely grown vegetable, cultivated throughout the year in tropical, subtropical and temperate regions of the world. At present India ranks second in area and production next to China by producing 19.37 million tonnes of tomato from an area of 0.78 million ha. However, in terms of productivity, India (25 t ha^{-1}) stands in tenth position (FAOSTAT, 2020) and remains stable since last lustrum with a negligible rise from 24.2 t ha^{-1}to 25 t ha^{-1} (Anonymous, 2018). During 2017-18, Odisha produced1.31million tonnes of tomato from an area of 0.091 million ha with an average productivity of 14.4 t ha^{-1}(Anonymous, 2018).The state productivity was far less than the national productivity. Bridging the productivity gap from the shrinking cultivable land and unpredictable climatic condition is the key point to be addressed to cater the need of the ever-rising population. On the other hand, the low productivity influences the demand and market price of tomato. Countrywide wholesale price of tomato ranges from Rs. 981.82 q^{-1} (Oct, 2017) to Rs.3982.53 q^{-1} (July, 2017), whereas, in Odisha, the wholesale price of tomato varies from Rs.893.00 q^{-1}during March, 2018 to Rs.5983.00 q^{-1} in July (Anonymous, 2018). Both at national level as well as state level the market price of tomato increases during the month of July to September. Hence, to combat this fluctuation in market price, a continuous supply chain to the local market is essential, which is possible by growing proper hybrid with suitable sowing date for round the year cultivation of tomato.

Tomato is highly sensitive to the abiotic factors like temperature, light and soil moisture. Among these, temperature plays an important role for the seed germination, flower initiation, fruit setting, fruit yield and fruit ripening. Dhaliwal (2014) reported that the optimum temperature for the tomato seed germination is 24°C. High temperature results in flower dropping and reduced fruit setting. Average daily temperature above 30°C or below 10°C affects the fruit setting in tomato. The temperature between 21°C-24°C is suitable for the colour development in tomato. Likewise, relative humidity has a vital role on the pollen viability and fruit setting in tomato. Harel *et. al.* (2014) reported that a moderate reduction in mean daily temperature along with the increased relative humidity from 50% to 70% during the day time, improves the viability of pollen grains in tomato. Apart from these, soil moisture plays a significant role for the growth and yield of tomato. Liu *et. al.* (2019) reported that soil moisture is not a limiting factor during the vegetative growth stage, however, enough water supplies during fruit development and maturity stage is essential for increasing tomato yield. Keeping all these points in mind, the present experiment was formulated to assess the suitable sowing date with suitable hybrid for the commercial cultivation of tomato in western undulating zone of Odisha.

MATERIALS AND METHODS

The experiment was conducted during the year 2018-19 and 2019-20 at the Regional Research and

Email: bibhutihort@rediffmail.com

Technology Transfer Station, Bhawanipatna, Kalahandi, Odisha situated at 19.55^{0}N latitude and 83.9^{0}E longitude with an altitude of 245m above mean sea level. Soil texture of the experimental site was clay loam with pH-7.36, O.C.-0.71%, E.C.-0.17dSm^{-1}, available Nitrogen-296.6 kg ha^{-1}, available Phosphorus-77.7 kg ha^{-1} and available Potass-223.1 kg ha^{-1}. Annual rainfall of 1922 mm and 1208 mm was received during the year 2018 and 2019, respectively. The mean maximum and minimum temperature were recorded to be 45^{o}C and 11.9^{o}C, respectively.The details of the weather parameters recorded at RRTTS, Bhawanipatna during the experimental years were presented in Table 1.

The field experiment was laid out in a split-plot design with twelve treatments comprising of two tomato hybrids *viz.*Arka Samrat and Arka Rakshyak in main plots and six sowing dates in sub-plots and replicated thrice. Seeds of tomato varieties like Arka Samrat and Arka Rakshyak were purchased from ICAR-Indian Institute of Horticultural Research, Bengaluru and treated with Bavistin @ 5g kg^{-1}of seeds and sown in the well-prepared raised beds under the open field nursery condition for raising seedlings on the scheduled sowing dates *i.e*., 15th July, 30th July, 15th August, 30th August, 15th September and 30th September in both the years. One month old seedlings were treated with Carbendazim 12% + Mancozeb 63% WP solution and planted in the main field maintaining the spacing of 50 x 50 cm in the sizeable plot of 9m^2 with 36 plants plot^{-1}. 125: 60: 125 kg ha^{-1} of N : P_2O_5: K_2O was applied as balanced dose of fertilizer. Half dose of N and K_2O with the full dose of P_2O_5 was applied as basal application and the remaining 50% of N and K_2O was applied in two splits at 15 and 30 days after planting. Appropriate drainage channels were maintained for the July sown and August planted tomato plants to protect the plants from excess water caused by the heavy rainfall, whereas, the tomato crop sown during the month of August and subsequently planted during September required frequent irrigation to obtain a healthy crop yield. Application of pendimethalin 30EC @ 5.0ml l^{-1} before planting along with one hand weeding during the fruiting period was practiced to protect the crop from crop weed competition.

The observation on morpho-physiological characters *viz.* plant height (cm), number of primary branches plant^{-1}, days to 50% flowering, number of fruits plant^{-1}, average fruit weight (g), length and breadth of fruit (cm), number of locules fruit^{-1} and total soluble solids were recorded from five randomly selected plants of each plot. The total number of fruits plant^{-1} was recorded by counting the completely matured fruits from five individual plants at each harvest. Whereas, fruit yield (q ha^{-1}) was estimated from the individual plot yield. The average fruit weight (g) of the tomato fruits was worked out by dividing the total fruit weight plot^{-1} by the number of fruits harvested plot^{-1}. The completely matured fruits' length and breadth were measured by using the digital slide calliper (Mitutoyo South Asia Pvt. Ltd.) from five randomly selected tomatoes of each treatment. The number of locules fruit^{-1} was recorded by counting the inner cavity of the transversely cut ripen fruits. Total Soluble Solid in term of ^{0}Brix was recorded by using a digital pocket refractometer (ATAGO and Co Ltd., Tokyo, Japan), after extracting the fresh tomato juice from the havested tomato fruits. Plant height (cm) was measured using the standard measuring scale and the number of primary branches plant^{-1} was counted from five selected plants after harvesting the crop, the crop yield was not disturbed during the observation. Percentage yield advantage was estimated by comparing the lowest yield recorded due to tomato hybrids as well as sowing dates. The observations recorded on different vegetative growth parameters, yield and yield attributing characters were subjected to statistical analysis and treatment means were compared at 5% level of probability as derived by Gomez and Gomez (1984). The cost of cultivation was calculated considering the major components like land preparation cost, input cost and required manpower cost as presented in Fig. 1. Net return hectare^{-1} was calculated by subtracting the cost of cultivation from gross return. The benefit: cost ratio was estimated by the formula.

$$\text{Benefit:cost ratio} = \frac{\text{Gross return (Rs.ha}^{-1})}{\text{Cost of cultivation (Rs.ha}^{-1})}$$

RESULTS AND DISCUSSION

Plant height (cm)

Plant height varied among the tomato hybrids as well as the sowing dates of the experiment (Table 2). Considering the pooled value there was no significant variation recorded among the hybrids, but Arka Samrat recorded maximum plant height of 103.3cm as compared to Arka Rakshyak (99 cm). Among the sowing dates, the plant height of tomato hybrids significantly varied from 82.0 cm to 94.7 cm and 100.9 cm to 122.9 cm during the individual years of investigation. However, the pooled data showed that maximum plant height was recorded when sown on 15th September (106.5cm) followed by 30th September (102.5cm). Enhanced plant height on sowing during the September and transplanted in October might be ascribable to the favourable atmospheric temperature due to having monthly mean minimum temperature of 19.5^{o}C and 22.6^{o}C; and monthly mean maximum temperature of 31.2^{o}C and 30.8^{o}C in the month of October, 2018 and 2019, respectively. Present finding was supported by

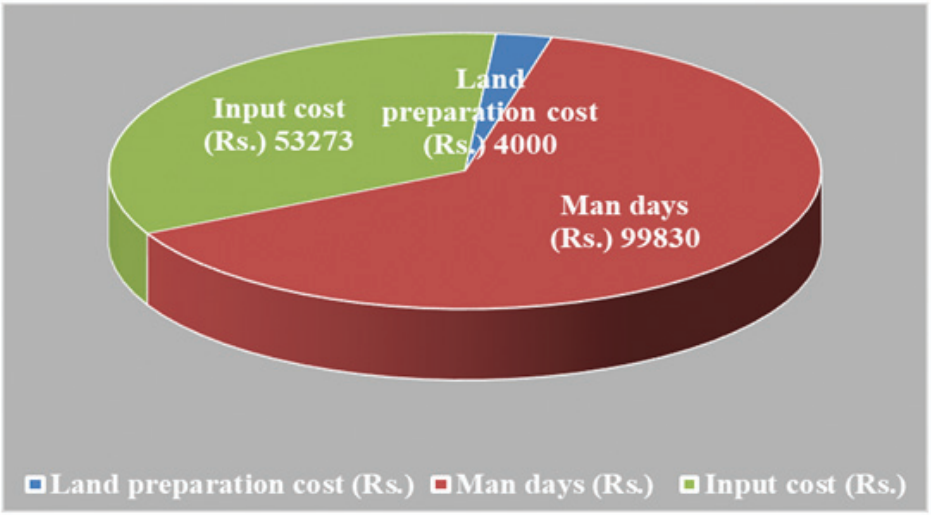

Fig. 1: Cost of cultivation of tomato (1 ha area)

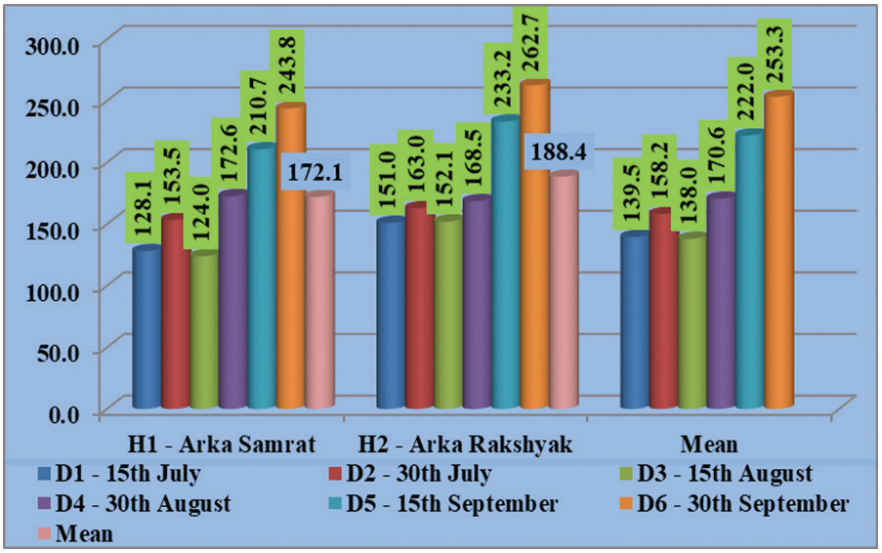

Fig. 2: Effect of sowing dates on yield of tomato hybrids (pooled data of two years)

the earlier finding of Dhaliwal (2014) who reported that day temperature of 25-30°C and night temperature of 15-20°C encouraged the vegetative development in tomato plants.

Number of primary branches plant^{-1}

There was no significant influence observed for number of primary branches plant^{-1} by the tomato hybrids. However, maximum branches plant^{-1} (12.1) was observed in the tomato hybrid Arka Rakshyak (Table 2). Tomato hybrid Arka Rakshyak was able to record maximum primary branches plant^{-1}due its comparatively short plant height than the tomato hybrid Arka Samrat. Cardoso *et.al.* (2018) reported that the management of plant density resulted in balanced vegetative and reproductive development in tomato plants as it facilitates the optimum amount of solar radiation reaching the interior of the plant canopy and increase the rate of photosynthesis. Number of branches plant^{-1} significantly varied among different sowing dates during both the years. It ranged from 9.9 to 13 branch plant^{-1} among the six sowing dates. Maximum 13 branch plant^{-1} was observed for 15th September followed by 30th September (12.7 branch plant^{-1}) and 15th August (11.1 branch plant^{-1}) sowing date and this might be due to having low atmospheric temperature during active vegetative growth period. It was reported that the vegetative growths of young tomato plants are

Table 1: Weather parameter at RRTTS, Bhawanipatna, Odisha during 2018-19 and 2019-20

	Monthly mean temperature (°C)				Monthly mean humidity (%)				Rainfall (mm)		Number of Rainy Days	
	Min.	Max.	Min.	Max.	Max.	Min.	Max.	Min.				
Month/Year	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
July	25.2	30.9	24.8	31.7	84.9	81.3	85.1	84.0	647.4	363.5	17.0	18.0
August	24.5	29.9	24.5	30.6	90.0	88.9	88.6	84.4	855.4	408.0	17.0	15.0
September	23.9	31.7	24.4	31.4	82.2	79.2	85.7	79.9	180.7	171.6	10.0	10.0
October	19.5	31.2	22.6	30.8	77.2	69.8	86.1	73.4	73.0	69.3	2.0	6.0
November	15.8	31.1	16.9	29.4	75.8	62.9	81.8	66.2	0.0	7.0	0.0	1.0
December	13.3	26.2	14.2	27.7	85.4	64.9	81.3	63.5	82.0	0.0	2.0	0.0
January	11.1	27.8	14.3	27.9	79.6	56.2	83.2	65.9	2.6	9.2	1.0	1.0
February	15.8	32.3	15.5	28.9	68.3	46.1	76.0	54.8	27.0	48.2	2.0	4.0
March	21.3	36.1	21.2	34.7	68.1	39.9	68.8	44.6	25.7	170.2	1.0	3.0
April	24.9	40.2	23.0	37.8	52.4	36.4	58.9	40.6	10.4	30.8	1.0	2.0
May	26.9	41.3	26.4	39.9	56.7	44.0	54.8	38.9	12.6	16.0	2.0	1.0
June	27.1	37.6	25.3	35.1	71.8	55.8	72.0	64.9	110.2	253.8	6.0	9.0

Table 2: Effect of sowing dates on plant height, number of branches and days to 50% flowering of tomato hybrids (Two-year pooled data).

	Plant height (cm)			Number of primary branches plant^{-1}			Days to 50% flowering		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Main Plot									
H_1 - Arka Samrat	88.9	117.7	103.3	7.4	13.7	10.6	33.8	28.9	31.4
H_2 - Arka Rakshyak	86.8	111.2	99.0	8.0	16.2	12.1	37.5	29.0	33.3
SEm±	0.5	1.0	0.3	0.3	0.7	0.2	2.1	1.5	0.6
LSD (0.05)	3.3	6.2	NS	NS	4.2	NS	NS	NS	NS
Sub Plot									
D_1 - 15th July	88.5	109.7	99.1	8.2	13.3	10.7	35.0	30.3	32.7
D_2 - 30th July	94.7	100.9	97.8	7.0	12.7	9.9	37.3	26.3	31.8
D_3 - 15th August	86.3	113.8	100.0	7.6	14.6	11.1	27.7	28.8	28.3
D_4 - 30th August	84.3	117.9	101.1	7.3	14.2	10.8	39.2	27.0	33.1
D_5 - 15th September	91.4	121.6	106.5	9.5	16.4	13.0	40.0	31.2	35.6
D_6 - 30th September	82.0	122.9	102.5	6.8	18.5	12.7	34.7	30.2	32.4
SEm±	0.6	0.7	0.8	0.1	0.3	0.3	0.7	0.5	0.7
LSD (0.05)	1.7	2.0	NS	0.4	0.9	NS	2.0	1.4	NS

Table 3: Effect of sowing dates on flowering, fruiting and fruit size of tomato hybrids (Two-year pooled data)

	Number of fruits plant^{-1}			Length of fruits (cm)			Breadth of fruits (cm)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
Main Plot									
H_1 - Arka Samrat	13.9	34.7	24.3	5.2	5.2	5.2	5.2	5.4	5.3
H_2 - Arka Rakshyak	15.2	34.7	25.0	5.5	5.9	5.7	4.6	4.8	4.7
SEm±	0.4	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0
LSD (0.05)	2.3	NS	NS	NS	0.7	NS	0.1	0.9	0.1
Sub Plot									
D_1 - 15th July	12.1	29.0	20.6	5.4	5.7	5.6	5.1	5.0	5.0
D_2 - 30th July	12.9	30.9	21.9	5.6	5.7	5.6	5.1	5.0	5.0
D_3 - 15th August	12.2	35.5	23.9	5.4	5.6	5.5	4.8	5.1	5.0
D_4 - 30th August	13.1	30.4	21.7	5.2	6.0	5.6	5.0	5.6	5.3
D_5 - 15th September	17.7	41.1	29.4	5.4	5.2	5.3	5.1	5.0	4.9
D_6 - 30th September	19.3	41.4	30.4	5.2	5.1	5.2	4.8	4.9	4.8
SEm±	0.3	0.3	0.4	0.0	0.0	0.0	0.1	0.1	0.1
LSD (0.05)	0.8	0.9	1.0	0.1	0.1	NS	NS	0.2	NS

Table 4: Effect of sowing dates on fruit quality and yield of tomato hybrids (Two-year pooled data)

	Average fruit weight (g)			Number of locules fruit^{-1}			TSS (^{0} Brix)			Yield (q ha^{-1})			Yield advantage (%)
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	
Main Plot													
H_1 - Arka Samrat	65.8	86.0	75.9	4.3	4.6	4.4	4.7	5.5	5.1	172.1	221.7	196.9	0
H_2 - Arka Rakshyak	74.0	90.1	82.1	2.9	4.1	3.5	4.1	5.6	4.9	188.4	238.4	213.4	8.4
SEm±	0.4	0.9	0.7	0.1	0.2	0.1	0.6	0.2	0.1	4.6	4.7	1.5	
LSD (0.05)	2.6	5.5	NS	0.5	NS	NS	NS	NS	NS	27.7	28.5	5.3	
Sub Plot													
D_1 - 15th July	63.9	68.5	66.2	3.5	4.1	3.8	4.5	4.0	4.2	139.5	124.1	131.8	0
D_2 - 30th July	69.0	79.5	74.3	3.9	4.3	4.1	4.6	4.6	4.6	158.2	181.9	170.1	29.0
D_3 - 15th August	56.1	81.7	68.9	3.5	4.2	3.9	4.2	5.0	4.6	138.0	223.7	180.9	37.2
D_4 - 30th August	72.0	88.7	80.7	3.8	4.4	4.1	4.2	6.3	5.3	170.6	263.2	216.9	64.6
D_5 - 15th September	77.0	95.3	86.2	3.4	4.5	4.0	4.7	6.7	5.7	222.0	267.3	244.6	85.6
D_6 - 30th September	80.7	114.6	97.7	3.5	4.6	4.0	4.5	6.8	5.6	253.3	320.2	286.7	117.5
SEm±	0.8	0.7	1.0	0.1	0.1	0.1	0.1	0.2	0.2	2.0	2.8	3.0	
LSD (0.05)	2.5	2.1	2.7	NS	NS	NS	NS	0.5	NS	6.0	8.2	8.5	

Table 5: Effect of sowing dates on gross return, net return and B:C ratio of tomato hybrids (Two-years pooled data).

	Cost of cultivation (₹ ha^{-1})	Gross return (₹)	Net return (₹)	B:C ratio
Main Plot				
H_1 - Arka Samrat	157103	295350	138247	1.9
H_2 - Arka Rakshyak	157103	320100	162997	2.0
Sub Plot				
D_1 - 15th July	157103	197700	40597	1.3
D_2 - 30th July	157103	255150	98047	1.6
D_3 - 15th August	157103	271350	114247	1.7
D_4 - 30th August	157103	325350	168247	2.1
D_5 - 15th September	157103	366900	209797	2.3
D_6 - 30th September	157103	430050	272947	2.7

considered as their relative growth rate. At high atmospheric temperature, the relative growth rate is initially high but finally decreases rapidly with time (Octogen decrease), whereas in case of lower temperature, the relative growth rate is initially low but the declination is also slower than the declination with higher temperature.

Days to 50% flowering

Early flowering occurs in tomato hybrid Arka Samrat (31.4 DAT) as compared with Arka Rakshyak (33.3 DAT). Days to 50% flowering in tomato plants varied significantly among the sowing dates for individual year of the experiment (Table 2). But the mean number of days from transplanting to 50% flowering varied from 28.3 days to 35.6 days, which were insignificant for tomato hybrids. The earliest flowering occurs on the 15th August sowing date (28.3 DAT) and late flowering occured on the 15th September sowing date (35.6 DAT). The earliest flowering on 15th August sowing date might be due to the congenial environmental condition during the month of October *i.e.,* high temperature and relative humidity. Though during the month of October, the temperature and relative humidity were high, the average monthly rainfall was 73 mm and 69.3 mm during the corresponding years of the experiment. Probably the rainfall which was far lower than the rainfall that occurred during the previous months is favorable for the early flowering in tomato plants.

Generally, earliness in tomato is environmental responsive and thereby, estimate of 50% flowering with response to different sowing time could be helpful to determine the exact duration of planting to flowering.

Number of fruits plant^{-1}

The tomato hybrids had no significant effect on the number of fruits plant^{-1}; maximum 25 fruits plant^{-1} was recorded by the tomato hybrid Arka Raksayak (Table 3). The number of fruits plant^{-1} significantly varied from 20.6 to 30.4 among the sowing dates. Maximum 30.4 numbers of fruits plant^{-1}were recorded in 30th September sowing date followed by the 15th September sowing date (*i.e*., 29.4 fruits plant^{-1}). Fruiting in tomato hybrids followed a systematic increasing order for the number of fruits plant^{-1} among the sowing dates.

De Koning (1994) and Hazra and Som (2015) reported that the optimal temperature for pollination and fruit setting in tomato is around 18^{o}C - 21^{o}C. Emami (2014) reported that average temperature below 10^{o}C and above 30^{o}C hampers fruit setting in tomato. Probably the temperature during flower initiation in the month of December favours in fruit setting of tomato which was sown in the last week of September and subsequently transplanted during the last week of October. According to Harel *et al*. (2014) relative humidity between the ranges of 50% to 70% is generally considered to be optimal for pollination in tomato in comparison to humidity of 30% to 40%. Whereas, increasing humidity above 90% may hamper the pollination in tomato. In present investigation during the month of December, the percentage of relative humidity varied from 64.9% to 85.4%, and 63.5% to 81.3% during both the years of investigation,which favoured pollination and fruit setting of tomato.

Length of fruits (cm)

Fruit length in the tomato plants was neither influenced due to the tomato variety nor due to the different sowing dates. Among the tomato hybrids, comparatively lengthy tomato fruits (5.7cm) were observed in tomato hybrid Arka Rakshyak than in the tomato hybrid Arka Samrat (5.2cm), whereas among the sowing dates highest lengthy fruit of 5.6 cm was recorded on 15th July, 30th July and 30th August as compared with the other sowing dates (Table 3).

Breadth of fruits (cm)

The fruit breadth of tomatoes significantly varied among the tomato hybrids, whereas, the fruit breadth was not significantly influenced by the sowing dates. The highest fruit breadth (5.3 cm) was recorded in tomato hybrid Arka Samrat as compared with the tomato hybrid Arka Rakshyak (4.7 cm). Among the sowing dates 30th August recorded the highest fruit breadth of 5.3 cm than the rest of the sowing dates (Table 3).

Average weight of fruits (g)

Tomato hybrids had no significant effect on the average fruit weight. However, it was significantly affected by sowing dates. Heavier fruit weight was recorded in Arka Rakshyak (82.1g) in comparison toArka Samrat (75.9 g) as in Table 4. Among the sowing dates, maximum fruit weight (97.7 g) was observed on the 30th September sowing date. An increasing order was observed in fruit weight of tomato fruits starting from 15th July to 30th August, with a deviation in the fruit weight on the 15th August sowing date. It has been observed that the fruit weight of late sown tomato plants was much better than the early sown tomato plants, which confirmed the finding of Cremaschi *et al.* (2010).

Number of locules fruit^{-1}

Number of locules in tomato fruits is important for the assessment of qualitative as well as quantitative development of tomatoes. Salunkhe *et al.* (1974) reported that the quality of tomato fruits depends upon the proportion of outer and inner wall tissue because of the highest contents of dry matter, insoluble solids and reducing sugars remains in inner wall than the pericarp.Tomato fruit with less numbers of locule is highly desirable in processing industries. Among the tested hybrids, tomato hybrid Arka Samrat recorded maximum 4.4 locules fruit^{-1}as compared with Arka Rakshyak (3.5); whereas, among the sowing dates, number of locules fruit^{-1} varied from 3.8 to 4.1 (Table 4). Tomato fruits produced from 30th July and 30th August sowing dates recorded maximum number of locules fruit^{-1}(4.1) followed by the 15th September and 30th September sowing dates (4.0). Irrespective of variety or sowing dates there were no significant variation for locule number which indicate the uniformity of fruits.

TSS (^{0} Brix)

Total soluble solid (TSS) in tomato is one of the primary quality traits essential for the processing purpose. Emami (2014) described 50 to 65% of TSS contents are sugar, glucose and fructose. Others are lipids, citric and malic acids present in low concentrations of TSS. The amount and proportion of these sugar, glucose and fructose influence the organoleptic quality of tomato fruits. Higher TSS, optimum acidity and higher ascorbic acid content are the desirable components considered by the processing industries.

In the present experiment, total soluble solid of the tomato fruits varied from 4.9 to 5.1 ^{o} brix among the tomato hybrids (Table 4) and this observation was in corroboration with the findings of Purkayastha and Mahanta (2011). Statistically TSS of tomato fruits observed throughout this experiment was neither influenced by the tomato hybrids nor by their sowing dates. Maximum 5.1 ^{o} brix of total soluble solid was recorded by the hybrid Arka Samrat as compared with Arka Rakshyak (4.9 ^{o} brix), while among the sowing dates total soluble solids varied from 4.2 ^{o} brix to 5.7 ^{o} brix. Maximum 5.7 ^{o} brix of total soluble solid was recorded by the tomatoes produced from the 15th August sowing date.

Fruit yield (q ha^{-1})

Significant variations for the yield of tomato fruits were observed among the tomato hybrids and sowing dates presented in Fig. 2. Maximum 213.4 q ha^{-1} of tomatoes were produced by the tomato hybrid Arka Rakshyak, which was 8.4 percent higher than the tomato hybrid Arka Samrat (196.9 q ha^{-1}). Tomato hybrid Arka Rakshyak produced maximum fruit yield with higher fruit weight (Table 4).

Among the sowing dates, the yield of tomato hybrids increased from the 15th July sowing date to 30th August sowing date. Maximum 286.7 q ha^{-1} of tomato were produced in the 30th September sowing date followed by 15th September (244.6 q ha^{-1}) which was 117.5 and 85.6 percent higher yield than the tomatoes produced on the 15th July sowing date, respectively.

Moreover, an increasing order in the plant height (100.9 cm to 122.9 cm), number of branches plant^{-1} (12.7 to 18.5 branches plant^{-1}), average fruit weight (79.5g to 114.6g), total soluble solid (4.6 to 6.8 ^{o}brix) and fruit yield (181.9 q ha^{-1} to 320.2 q ha^{-1}) of tomato were recorded along with the decreasing pattern of the minimum (24.4°C to 14.2°C) and maximum (31.4°C to 27.7°C) monthly mean temperature during second year of investigation. It clearly indicated the positive impact of lower temperature on the systematic growth and development of vegetative as well as reproductive phases of tomato plants; these observations were in accordance with the earlier findings of Rajasekar *et. al.* (2013). Shamshiri *et al.* (2018) reported that tomato plant is very sensitive to high air temperatures during the reproductive stage and results very few percentages of fruit set with a significant loss of fruit yield; this might be the possible reason in reduced estimates for most of the characters under study for the early sown crop.

Economics

The economics of the experiment presented in Table 5 revealed a wide variation in gross return as well as net return obtained by the sale price of the tomatoes. Tomato hybrid Arka Rakshyak earned comparatively higher net return of Rs.162997 ha^{-1} than Arka Samrat (Rs.138247 ha^{-1}). On the other hand, the net return earned by the tomatoes produced on different sowing dates varied from Rs. 40597 ha^{-1} to Rs. 272947 ha^{-1}. 30th September sowing date earned maximum net return of Rs. 272947 followed by the 15th September (Rs. 209797), both of these sowing dates earned comparatively higher net return than rest of the sowing dates.Tomato hybrid Arka Rakshak recorded highest B:C ratio of 2.0 as against 1.9 in Arka Samrat. Among the date of sowing 30th September recorded maximum B:C ratio of 2.7 followed by 15th September with B:C ratio of 2.3. Commercially, early production of tomato is important for its fast availability, more demand with higher market prices. However, early planting dates with unfavourable climatic conditions were unable to enhance production and quality of tomato fruit as compared with the late planting dates.

Arka Rakshak produced maximum (213.4q ha^{-1}) fruit yield as compared toArka Samrat (196.9 q ha^{-1}). Among the sowing dates, 30th September sowing recorded highest tomato yield of 286.7 q ha^{-1}. Thus, sowing of tomato hybrid Arka Rakshak during 30th September can be recommended for commercial cultivation of tomato in western undulating zone of Odisha.

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