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Effect of Sowing Dates on Growth, Yield and Juice Quality of Sweet Sorghum Genotypes in Kharif Season (*Sorghum Bicolor (L.) Moench*)

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Research Article

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ABSTRACT

Globally, Sweet sorghums are high energy crops with better growth and yield than fodder sorghum and corn. These are more palatable owing to their sweetness and highly preferred by livestock. Besides, bio-fuel generation these are gaining popularity as fodder crops. In India, sweet sorghums are encouraged for fuel production because of its wider adaptability, from temperate irrigated to dry and high rainfall areas and from warm humid to dry cold environment. Optimum date of sowing is an important parameter, which affect the growth and yield attributes of sweet sorghum among other cultivation practices. To find out optimum date of sowing for kharif season twenty three sweet sorghum genotypes and one hybrid were examined at all India Coordinated Sorghum Improvement Project, MPKV, Rahuri (Maharashtra). From the experiment, it was found that no. of days to attain different phenological stages, plant height, leaf area, PAR, ˚brix, juice yield, computed ethanol, harvest index (%) as well as biological yield was significantly influenced.

The crop sown under late sown condition took high number of days to attain maturity in comparison to the crop sown timely. Reduction in green cane yield, grain yield and biological yield was more in late sowing in comparison to timely sowing in Kharif season probably because of high temperature at the reproductive stage during the crop growing season.

INTRODUCTION

Sweet sorghum is known as the sugarcane of the desert which is similar to grain sorghum, except for its juice-rich sweet stalk. Ripe sweet sorghum consists of about 75% cane, 10% leaves, 10% roots and 5% seeds by weight [1,2] traditionally; these plants are grown mainly for their grain which is used as food as well as a source of starch for different types of beverages. The remaining components of the plant have other uses, for instance as animal fodder. Sweet sorghum requires relatively low nutrient inputs and last for short period of 3-5 months, more interestingly, sweet sorghum requires one-third, or less, of the water required by sugarcane [3]. It is also drought resistant crop due to its capacity to remain dormant during the driest periods, and well adapted to grow in a wide variety of climates including tropical, subtropical, and arid regions [4].

Today, sweet sorghum is making its second debut as a highly versatile feed stock that can be used for food, fodder and fuel. These properties entitle sweet sorghum to be a promising and competitive crop for bioethanol production and industry. Current status of demand and supply of consumption of petroleum around the world has risen from 63 million barrels per day to 93.7 million barrels per day during 1980-2015 as per the United States Energy Information Administration [5]. India's fast growing economy is confronted with the challenge of meeting energy demand. It ranks sixth in the world in terms of energy demand. Its economy is projected to grow at 7%-8% over the next two decades and there will be a substantial increase in demand for fuel for transportation and other energy needs. Furthermore, overpopulation accelerated agricultural practices, leading to enhanced emission of greenhouse gases which leads to climate change. Now it's time to minimize the global energy requirement human needs to use renewable energy recourses like wind, solar energy and bio-based fuels such as ethanol, biodiesel and hydrogen. Wind and solar energy will be primarily of use in generating electricity for households and industry, whereas ethanol, biodiesel and hydrocarbon can be used as a major transportation and industrial fuel. This paper studies and compares various sweet sorghum genotypes for its biological yield, juice quality and quantity at two different sowing dates in kharif 2017.

MATERIALS AND METHODS

Study location

The study was undertaken during the kharif season of 2017 at All India Coordinated Sorghum Improvement Project, M.P.K.V, Rahuri, Maharashtra.

Experimental design

The experiment was carried out in Randomized Block Design with two replications. The gross and net plot size were 3.90 × 3.0 m and 3.60 × 1.80 m, respectively, with spacing 60 × 15 cm and the recommended dose of fertilizer was 100:50:50 NPK kg/ha applied to the soil. The half dose of nitrogen and full dose of phosphorous and potash was given at the time of sowing. The remaining half dose of nitrogen was applied at 35 days after sowing. The three plants in each plot were randomly selected in a net plot area and tagged for recording the growth, yield and other morpho-physiological parameters. The physiological observations, biochemical studies, cane yield and its components were recorded at physiological maturity.

Parameters studied

The physiological processes *viz.*, rate of photosynthetic and Photo-synthetically Active Radiation (PAR) was measured with help of IRGA instrument. The green cane yield was recorded after stripping the leaves, sheath and panicle in kg/net plot.

The observation ˚Brix was recorded at physiological maturity by hand refractometer. The juice from stripped stalk was extracted at physiological maturity by using three roller crusher. The juice from the cane at physiological maturity analyzed for computed ethanol (lit/ha) with the help of formula given by Smith et al. [6].

$$\text{Computed ethanol yield (lit/net plot)} = \frac{5.324 \times \text{Juice yield(lit/net plot)} \times \text{Total sugar (\%)}}{1000}$$

RESULT AND DISCUSSION

Effect of different sowing dates on plant height (cm)

Growth is an effect of metabolic activities of the plant, when anabolic processes are more than catabolic processes, there is synthesis and accumulation of various organic substances which result in growth. Plant height is an important part of a coordinated suite of life-history traits including seed mass, time tore production, longevity and the number of seeds a plant can produce per year [7]. Though plant height is basically a genetically controlled character, it is being influenced by environmental conditions and sowing timing. From the results, the maximum plant height was recorded in timely kharif compared to late kharif sowing date, because in timely kharif sowing date the rain was uniformly distributed, with a total rainfall of 497.80 mm and also favorable climatic conditions prevailing during the crop growth period whereas, late sowing resulted in poor and prolonged germination, stunted growth and reduction in yield. These findings derive support from Kulkarni et al., Sutoro et al. and Mutkule [8-10].

Effect of different sowing dates on leaf area (dm^2)

Leaf area plays an important role in photosynthesis and easily gets influenced by interaction between environmental and genetic constitution of plant. Rapid leaf area development occurred during 60 to 90 DAS and declined thereafter due to senescence. Similar finding was reported by Repe [11]. In last phase leaf area per plant decreased which was attributed to shading and senescence. From the perusal it could be seen that, the highest mean leaf area was observed in the month of June sowing date at 90 DAS growth stage followed by July sowing date, mainly due to favorable climatic conditions prevailing during the crop growth period. The higher number of leaves and highest leaf area that leads to higher source of food material which transferred towards the sink gives more grain yield. Similar results were obtained by Baviskar [12].

Effect of different sowing dates on stem girth (cm)

Secondary growth is characterized by an increase in girth of the plant, which caused by cell division in the lateral meristem. Stem girth is an associated trait of component biomass in sweet sorghum. Linear increase in stem girth was recorded in all the genotypes in periodical phases. The data revealed that the stem girth increased progressively and rapidly up to 90 DAS and thereafter the increase was marginal. From the two sowing dates it could be seen that, the highest mean stem girth is observed in the month of June sowing date, which was followed by July sowing date. The higher stem girth was mainly due to higher biomass and favorable climatic conditions, prevailing during the crop growth period. Similar findings were shown by Mutkule [10].

Effect of different sowing dates on days to physiological maturity

Sweet sorghum is considered to be at physiological maturity when the translocation of photosynthates is stopped to panicle. It refers the development stage after which no further increase in dry matter production. The accurate determination of physiological maturity is important for timely harvest of crop to avoid further losses due to unfavorable environmental conditions. From the results, the minimum mean number of days required for physiological maturity was recorded in the month of June sowing date followed by July sowing date. The environmental effect revealed that the genotypes RSSV-355 and CSV-19SS recorded the significantly lowest mean number of days required for physiological maturity (119) compared to late sowing date. The present findings were also in accordance with the findings of Ismail et al. and Kumar et al. [13,14].

Effect of different sowing dates on rate of photosynthesis

Sorghum is a C_4 plant and efficiently converts solar energy into chemical energy. High level of photosynthesis and accumulation of photosynthates during grain filling stage determines the yield. The main factor affecting rates of photosynthesis are light intensity carbon dioxide concentration and temperature. The low light intensity and temperature fluctuations in kharif season, weather transitory or constant cause physiological, biochemical and molecular changes that adversely affect sweet sorghum growth and productivity by reducing photosynthesis. The lowest mean photosynthetic rate (27.50 to 36.00 µmol CO_2 m^{-2} s^{-1}) was recorded at June sowing date, followed by (29.00 to 38.50 µmol CO_2 m^{-2} s^{-1}) July sowing date, because of weather and climate variation at physiological maturity. This might due to low photoperiod 11.1-12.1 hr and sunshine 4.5-9.6 hrs in GS_3 of late kharif sowing date. These findings also match with Mutkule and Borkar [10,15].

Effect of different sowing dates on Photosynthetically Active Radiation (PAR)

The productivity of plant communities is governed in part by their ability to absorb and utilize Photosynthetically Active Radiation (PAR) in sweet sorghum. Dhopate, et al. [16] reported that solar radiation is one of the primary factor influencing the transpiration, photosynthesis and growth of a plant. They also reported that cloudy conditions influences the input of solar radiation and reduces the radiation intensity by about 40%-50% than normal.

So, from the overall results the lowest mean Photosynthetically Active Radiation (PAR) (997.81) was recorded at June sowing when compared to July sowing date (1072.80).

Effect of different sowing dates on ˚brix

The data on ˚brix were recorded at physiological maturity of the crop growth. The specific trend of changes in ˚brix was reported in the all sweet sorghum genotypes because of environmental conditions and seasonal impact on genotypes. From the results, the mean ˚brix was recorded highest in the month of June sowing date (18%) when compared to late sown date (17%). ˚Brix values are known to be highly dependent on temperature, environment, and agronomic practices, and thus are highly variable among different locations and planting years. Cole et al. [17] reported a 21% difference in ˚brix values between two consecutive years, presumably due to environmental differences. Similar result was reported by Mutkule, higher value of ˚brix in the kharif season as compared to rabi season [10].

Effect of different sowing dates on juice yield (lit/ha)

The juice yield, fresh biomass and ˚brix are important characters for good recovery of ethanol from sweet sorghum juice. As the sweet sorghum juice is extracted from the stalk, higher the green stalk yield would give higher amount of juice. Results revealed significant differences due to different season sowing dates which effects on juice yield. The juice yield (lit/ha) was influenced by climatic condition. Significantly the higher juice yield was recorded at physiological maturity and their after it declined towards maturity stage. This might be due to rapid conversion sugar of sugar after milky stage to maturity. From the overall experiment results, the mean of Juice yield (lit/ha) was recorded highest in the month of June sowing date (6778 lit/ha) due to higher biomass and favorable climatic conditions prevailing during the crop growth period (i.e. max temp. 32.1˚C, min temp. 22.8˚C was prevailed during 60 DAS) followed by July sowing date. These findings also match with Ratnavathi et al. [18].

Effect of different sowing dates on computed ethanol (lit/ha)

The sweet sorghum has potential materials for production of ethanol. The juice mostly contains sucrose, glucose and fructose sugars and such type of high sugar crop can be used to produce fuel and alcohol. The computed ethanol per cent was varied with sweet sorghum varieties. Rutto et al. [19] reported ethanol yield ranged from 745 to 1331 lit/ha from different sweet sorghum varieties. Rono et al. [20] reported 230-423 lit/ha absolute ethanol yield in different sweet sorghum genotypes. From the results, the computed ethanol (lit/ha) was recorded highest in the month of June sowing date (423 lit/ha), the hybrid RSSH-50 recorded the highest computed ethanol (799 lit/ha) in month of June sowing date followed by July sowing date. Thus, it was inferred that high yield of computed ethanol in these genotypes was mainly attributed due to higher cane yield; juice yield and total sugar. Similar results were reported by Dalvi et al. [21].

Effect of different sowing dates on fresh biomass (t/ha)

Sweet sorghum possesses genetic diversity for high biomass production. Biomass yield and biomass conversion efficiency are critical factors for ethanol productivity. Sweet sorghum, by virtue of its C_4 photosynthetic system and rapid dry matter accumulation is an excellent bio-energy crop. From the overall results, the fresh biomass yield (t/ha) was recorded highest in the month of June sowing date (76.28 t/ha) and the hybrid RSSH-50 recorded the highest fresh biomass yield (107.41 t/ha), mainly due to higher plant height (444.33 cm at harvest), leaf area (71.54 dm^2 at 90DAS), photosynthetic rate (36.00 at P.M) and stalk girth (8.31 at P.M) in the month of June sowing when compared to July sowing date. Similar reports on wide variation for this trait were made by Dalvi et al., Chavan et al. and Nirmal et al. [21-23].

Effect of different sowing dates on green cane yield (t/ha)

In case of sweet sorghum, the major component traits for biomass are plant height, cane weight, stalk girth and leaf area, for ethanol production. From the results, the grand mean of green cane yield (t/ha) was recorded highest in the month of June sowing date (43.42 t/ha) followed by July (39.06 t/ha) because of uniformly distributed rain in timely kharif 2017, with a total rainfall of 497.80 mm and also favorable climatic conditions prevailing during the crop growth period (i.e. max temp. 32.1˚C and min temp. 22.8˚C was prevailed during 60 DAS) Almodares et al., reported that earlier sowings of sweet sorghum generally have higher yields of stalk and sugar [24].

Effect of different sowing dates on harvest index (%)

The harvest index represents the proportion of plant biomass allocated into grains; it describes the plant capacity to allocate biomass (assimilates) into the formed reproductive parts of the plant. From the overall results the highest grand mean of harvest index (20.34%) was recorded in the month of June sowing date and the hybrid RSSH-50 recorded the highest harvest index (23.92%). Under late sown conditions major reduction in grain weight per spike was primarily due to reduction in the grain weight under terminal stresses. Significant reduction was observed in grain filling duration resulting in reduced grain size and total grain yield. The findings showed that grain yield has positive association with number of grains/earhead, harvest index and leaf dry matter Similar report was presented by Pawar and Patil et al. (Tables 1-4) [25-30].

Table 1. Index represents the Plant height (cm) at harvest.

Sr.No.	Genotypes	Plant height (cm) at harvest		Mean leaf area (dm^2) at 90 DAS		Stem girth (cm) at harvest	
		T. kharif	L. kharif	T. kharif	L. kharif	T. kharif	L. kharif
1	RSSV 350	343.07	330.09	60.04	51.88	8.13	7.24
2	RSSV 494	367.63	359.19	62.43	56.77	8.16	7.37
3	RSSV 493	353.97	341.11	57.85	52.18	8.3	7.51
4	RSSV 313	330.9	319.84	61.37	55.7	8.15	7.36
5	RSSV 495	269.3	256.84	49.14	43.48	7.11	6.32
6	RSSV 355	338.65	327.83	59.68	54.01	8.13	7.34
7	RSSV 503	312.58	303.61	57.21	51.54	8.01	7.22
8	RSSV 386	344.85	333.99	53.64	47.97	8.33	7.54
9	RSSV 540	329.3	317.91	61.51	55.84	8.35	7.56
10	RSSV 542	292.17	280.56	57.99	52.33	8.1	7.31
11	RSSV 466	325.87	315.14	56.59	50.93	8.08	7.29
12	RSSV 454	345.23	335.24	61.18	55.51	8.2	7.41
13	RSSV 499	311.47	299.76	57.04	51.37	8.03	7.24
14	RSSV 453	272.2	261.26	51.53	45.86	8.1	7.31
15	RSSV 545	352.9	336.26	58.68	53.01	8.03	7.24
16	SPV 2057	415.37	404.14	65.06	59.4	8.36	7.57
17	RSSV 260	361.62	350.53	54.62	48.96	8.13	7.34
18	RSSV 269	366.68	356.41	56.1	50.44	8.01	7.22
19	RSSV 512	406.12	395.21	64.4	58.73	8.26	7.47
20	RSSV 430	355.23	343.58	55.73	50.07	7.98	7.19
21	SSV 84 (C)	306.48	295.84	58.59	52.92	7.5	6.71
22	CSV 19SS (C)	364.28	353.14	63.03	57.36	8.31	7.52
23	RSSH 50 (C)	444.33	434.91	71.54	65.88	8.56	7.77
24	AKSSV 22SS (C)	339.1	328.69	60.49	54.83	8.06	7.27
	Grand Mean	343.72	332.54	58.98	53.21	8.1	7.31
	S.E. ±	11.54	11.1	2.3	2.18	0.14	0.15
	CD at 5%	34.6	33.28	6.89	6.54	0.42	0.45

Table 2. Index represents the days required for physiological maturity.

Sr. No.	Genotypes	Days required for physiological maturity		Rate of Photosynthesis		Photosynthetically active radiation	
		T. kharif	L. kharif	T. kharif	L. kharif	T. kharif	L. kharif
1	RSSV 350	122	123	33	35.5	967	1040
2	RSSV 494	124	126	35	37	1190	1265
3	RSSV 493	125	127	34	36	1080	1155
4	RSSV 313	128	130	33.5	35	914	989.5
5	RSSV 495	123	125	27.5	29	823.5	898.5
6	RSSV 355	119	121	33	35	926.5	1001.5
7	RSSV 503	123	125	32	34.5	870	945
8	RSSV 386	127	129	33	35	997	1072
9	RSSV 540	125	127	32.5	34.5	897.5	972.5
10	RSSV 542	121	123	28	30.5	830	905
11	RSSV 466	126	128	32.5	34	882.5	957.5
12	RSSV 454	130	131	33	35.5	1007.5	1082.5
13	RSSV 499	128	130	31	33.5	850	925
14	RSSV 453	124	126	29	31	835	910
15	RSSV 545	127	129	33	35	1052.5	1127.5
16	SPV 2057	129	130	36	37	1202.5	1277.5
17	RSSV 260	138	140	32.5	35.5	1100	1175
18	RSSV 269	129	131	34	36	1135	1210
19	RSSV 512	124	126	34	36.5	1196	1271
20	RSSV 430	129	131	33	35.5	1086	1161
21	SSV 84 (C)	121	123	31	33.5	838	913
22	CSV 19SS (C)	119	121	34.5	36	1117	1192
23	RSSH 50 (C)	135	137	36	38.5	1212.5	1287.5
24	AKSSV 22SS (C)	122	125	33	35	937.5	1012.5
	Grand Mean	126	128	32.68	34.77	997.81	1072.8
	S.E. ±	1.03	2.16	1	1.12	19.5	13.5
	CD at 5%	3.1	6.45	2.99	3.36	56.92	39.3

Table 3. Index represents the sugar content of an aqueous solution (˚Brix).

Sr. No.	Genotypes	˚Brix		Juice yield (lit/ha)		Computed ethanol (lit/ha)	
		T. kharif	L. kharif	T. kharif	L. kharif	T. kharif	L. kharif
1	RSSV 350	18	17	5162	4660	344	307
2	RSSV 494	17	17	7958	7477	481	447
3	RSSV 493	18	18	6821	6339	426	391
4	RSSV 313	19	18	7104	6608	441	405
5	RSSV 495	16	16	4563	4088	246	217
6	RSSV 355	19	18	6301	5813	389	355
7	RSSV 503	18	18	5255	4780	349	314
8	RSSV 386	18	17	6034	5545	357	324
9	RSSV 540	17	17	4655	4209	302	270
10	RSSV 542	18	17	4805	4322	320	285
11	RSSV 466	18	17	6654	6166	415	380
12	RSSV 454	18	18	7986	7497	493	457
13	RSSV 499	19	18	6847	6345	457	419
14	RSSV 453	18	18	6808	6334	417	383
15	RSSV 545	18	17	7807	7306	461	426
16	SPV 2057	18	18	6201	5691	408	370
17	RSSV 260	18	18	7067	6572	429	394
18	RSSV 269	19	18	7382	6888	442	408
19	RSSV 512	17	17	8192	7733	489	456
20	RSSV 430	18	18	5980	5541	402	368
21	SSV 84 (C)	18	18	6121	5626	387	352
22	CSV 19SS (C)	17	16	8359	7885	513	478
23	RSSH 50 (C)	17	17	12505	11152	799	705
24	AKSSV 22SS (C)	19	18	6103	5635	373	340
	Grand Mean	18	17	6778	6258	423	386
	S.E. ±	0.24	0.3	147	135	11	10
	CD at 5%	0.72	0.89	439	399	31.00	29.00

Table 4. Index represents the fresh biomass (t/ha).

Sr. No.	Genotypes	Fresh biomass (t/ha)		Green cane yield (t/ha)		Harvest index (%)	
		T. kharif	L. kharif	T. kharif	L. kharif	T kharif	L kharif
1	RSSV 350	63.64	56.9	37.94	33.44	18.18	16.26
2	RSSV 494	81.59	75.24	45.71	41.46	21.95	19.6
3	RSSV 493	83.78	77.43	42.49	38.31	19.44	16.99
4	RSSV 313	75.5	68.74	43.11	38.61	20.51	18.66
5	RSSV 495	58.42	51.67	31.81	27.18	16	13.55
6	RSSV 355	69.19	62.83	37.22	32.92	18.99	16.22
7	RSSV 503	73.56	66.71	35.61	31.24	21.68	19.5
8	RSSV 386	73.42	67.07	40.09	35.65	21.4	19.49
9	RSSV 540	87.17	80.92	45.31	41.26	17.26	15.15
10	RSSV 542	63.67	57.3	31.86	27.49	20.76	18.53
11	RSSV 466	79.5	72.85	35.38	31.13	16.83	14.41
12	RSSV 454	72.91	66.25	38.64	34.27	19.88	17.76
13	RSSV 499	54.51	47.67	27.83	23.27	17.8	15.55
14	RSSV 453	70.75	64.19	36.92	32.68	20.14	17.34
15	RSSV 545	81.47	75.2	42.39	38.09	23.03	20.9
16	SPV 2057	59.93	52.97	33.79	29.16	20.29	18.44
17	RSSV 260	88.9	82.14	71.12	66.55	22.19	20.1
18	RSSV 269	87.71	81.06	61.35	57.04	21.78	19.79
19	RSSV 512	87.34	81.07	53.07	48.89	20.9	18.45
20	RSSV 430	78.06	71.4	48.7	44.07	22.07	20.29
21	SSV 84 (C)	68.54	61.88	37.08	32.71	21.8	19.81
22	CSV 19SS (C)	86.49	80.14	54.51	50.33	20.43	18.03
23	RSSH 50 (C)	107.41	101.05	72.62	68.25	23.92	22.11
24	AKSSV 22SS (C)	77.17	70.61	37.61	33.37	20.85	18.87
	Grand Mean	76.28	69.72	43.42	39.06	20.34	18.16
	S.E. ±	8.12	8.35	4.66	3.41	1.17	1.15
	CD at 5%	23.69	24.38	13.61	9.86	3.41	3.37

CONCLUSION

Sowing date has significant influence on growth as well as yield characteristic of sweet sorghum. Late kharif sowing date yield recorded higher reduce ratio compared to timely sown crop date. More reduction was because of the less precipitation, fluctuate temperature, humidity and sunshine hr during the crop growth period. As per the findings of the present investigation the genotypes *viz.*, RSSV-260, RSSV-269, RSSV-512 and CSV-19SS were found superior for green cane yield which could be exploited commercially for high biomass production in terms of green cane yield in timely kharif season. Simultaneously these genotypes could be utilized in further breeding programme. The hybrid RSSH-50 and the genotypes RSSV-260, RSSV-540, RSSV-493 were found to be efficient for producing high biomass, coupled with high better juice quality parameters. Further, future research can be directed towards production of high energy sorghum as hopeful attempts to overcome from energy crisis to some extent.

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