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RESEARCH PAPER

Variability, correlation and path analysis studies for superior types of sweet orange (*Citrus sinensis* Osbeck)

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Abstract : A survey was undertaken during October-2012 to November-2012 during fruiting of *Ambia Bahar* in Aurangabad and Jalna district of Marathwada region of Maharashtra state and 28 samples were collected from different locations. In present study, the performance of types JAL-11, JAL-13, ABD-1 and ABD-3 showed better values in regards too many characters like number of fruits per tree, length and breadth of fruit, weight of fruit, TSS, total sugar and yield of fruits per tree. Hence, the overall studies indicated that the type JAL-11, JAL-13, ABD-1 and ABD-3 being productive and superior in quality stands for selection and further improvement.

Key Words : Sweet orange, Physico-chemical characters, Correlation, Path analysis

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INTRODUCTION

Sweet orange is a most popular citrus fruit both in tropics and sub-tropics. In Maharashtra state and Marathwada region of the state innumerable seedling of sweet orange are in cultivation. The variation existing in these seedlings has not been exploited for improvement. Attempts to improve sweet orange by selection have been very meagre. Therefore, there are very few released varieties are available for commercial cultivation. Similarly, information about extent of variability, correlation and physico-chemical characters of fruit and yield of different types is needed to plan improvement programme. The present survey and selection work was undertaken with this sole objective.

MATERIAL AND METHODS

The Aurangabad and Jalna district of Marathwada region were selected for survey for superior types of sweet orange. The survey was undertaken during October-2012 to November-2012 during regular fruiting of *Ambia Bahar*. The selected sweet orange locations were visited to collect required information and samples. The promising type from each location was observed carefully for fruiting along with other desirable characters. The yield of selected tree was recorded in terms of number of fruits per tree and weight of fruits in kg. From selected tree of each orchard, 5 fruits of uniform size and maturity were collected randomly from all the sides of the tree. The fruit sample were packed in polythene bag separately for each genotype and brought to laboratory for further study. Physico-chemical analysis of fruit samples were carried out in laboratory, Department of Horticulture, College of Agriculture, Marathwada Krishi Vidyapeeth, Parbhani (M.S.) as per the scientific standard and methods. The data obtained on physico-chemical characters of fruit and other aspects of sweet orange were analyzed statistically for the variability, correlation co-efficient and path co-efficient.

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RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Variability studies :

Selected sweet orange types showed a wide range of variation for physico-chemical characteristics presented in Table 1.

Physical characteristics :

The number of fruits per tree ranged from 208 (ABD-9) to 436 (JAL-14). It may be due to more height and spread. Jadhao (2012) recorded 299 to 410 range for number of fruits per tree which support present findings. The average weight of fruit was 242.27g and it ranged from 137.76g (ABD-13) to 321.26g (JAL-1). It may be due to variation in package of practices. The average yield of fruits per tree was 75.63 kg. The variability in yield of fruits per tree ranged from 38.76 kg (ABD-7) to 106.44 kg (ABD-1). This difference observed due to more number of fruits and variation in weight. Length of fruit ranged from 6.00 cm (ABD-13) to 9.20 cm (JAL-3). Breadth of fruit ranged from 6.00 cm (ABD-7 and ABD-13) to 8.93 cm (JAL-1). Kale (2009) and Jadhao (2012) recorded analogous results to the present finding. Rind thickness of fruit varied from 3.86 mm in JAL-14 to 8.90 mm in ABD-10. It may be due to variability in size of fruit. JAL-8 recorded significantly minimum rind percentage (21.34%), while ABD-10 recorded highest rind percentage (34.35%). It may be due to variability in size of fruit and more rind thickness. In case of juice percentage, ABD-7 (56.16%) recorded highest juice percentage while the lowest juice percentage was recorded in JAL-15 (31.76%). Tilekar (2011) also reported maximum juice content 57.86 per cnet in sweet orange. The average number of seeds per fruit was found 17.15 and JAL-6 (14.33) recorded minimum numbers of seeds per fruit, while JAL-3, JAL-12 and ABD-9 (21.66) recorded highest numbers of seeds per fruit. JAL-1 (11.66) recorded maximum number of segments per fruit while the lowest number of segments per fruit was recorded in ABD-13, JAL-3 and JAL-12 (9.33). The variation in number of segments may be due to size of fruits. Findings of Patil (2004), Kale (2009) and Jadhao (2012) are in agreement with the observations recorded in the present investigation.

Chemical characters of fruits :

The highest TSS was obtained from the fruits of JAL-10 (12.03 ^{0}Brix) while the lowest TSS was found in ABD-12 (8.03 ^{0}Brix). The acidity of juice of selected 28 types varied between 0.33 in JAL-15 to 0.47 per cent in ABD-4, ABD-6 and JAL-12 with the mean value 0.39 per cent. The percentage of total sugars was highest in JAL-10 (7.74%) and lowest in ABD-6 (5.42%). The percentage of reducing sugars was highest in ABD-10 (4.70%) and lowest in JAL-11 (3.29%). The percentage of non-reducing sugars was highest in JAL-10 (3.32%) and lowest in ABD-4 (1.82%). Results are similar as observed by Barkule *et. al* (2008).

Correlation studies :

Correlation co-efficient between different pairs of characters is presented in Table 1. Yield of fruits per tree was highly significant and positively correlated with the number of fruits per tree, breadth of fruit and rind percentage. Kakde (1982) reported yield of fruits and number of fruits per tree were highly correlated with each other. The correlation of number of fruits per tree was highly significant and positive with the yield of fruits per tree. The correlation of weight of fruit was highly significant and positive with the length of fruit and breadth of fruit. Similar association was observed by Tilekar (2011) and Khandavi (2012).

Length of fruit was highly significant and positively correlated with the breadth of fruit, weight of fruit and rind thickness. Breadth of fruit was highly significant and positively correlated with the length of fruit, weight of fruit, yield of fruit per tree and rind percentage. Kakde (1982) reported size of fruit and weight of fruit were highly correlated with each other.

Correlation observed between rind thickness and length of fruit and number of seeds was positive and significant. Rind percentage showed significant and positive correlation with the breadth of fruit and yield of fruit per tree. Pingle (2011) reported similar correlations. Number of seeds was significant and positively correlated with the length of fruit and rind thickness.

TSS, total sugar and reducing sugar exhibited highly significant and positively correlated with each other as well as having negative but highly significant correlation with the acidity. Tilekar (2011) reported similar result and correlation about TSS, total sugar, reducing sugar and acidity while, Pingle (2011) reported negative association of acidity with TSS.

Path analysis studies :

Values for direct and indirect effects of different characters on yield are presented in Table 3. Path analysis indicated that number of fruits per tree showed highest positive direct effect on yield of fruits followed by weight of fruit. Length of fruit, rind thickness, number of segments, juice percentage, TSS and acidity also showed positive direct effect on yield of fruits. Remaining other characters showed negative direct effect on yield and this have no significance in selection programme. Similar findings were also reported by Alam *et al.* (1998); Chaudhary *et al.* (2000) and Hossain *et al.* (2000).

Conclusion :

Above results of present investigation showed relationship between various characters of fruit and yield of various sweet orange types under study. The correlation between yield and number of fruits per plant was found to be positively significant. As well as number of fruits per tree

Table 1 : Physico-chemical characteristics of different sweet orange types

Sr. No.	Samples	Fruits per tree	Weight of fruit (g)	Yield per tree (kg)	Length of fruit (cm)	Breadth of fruit (cm)	Rind thickness (mm)	Rind %	No. of seeds per fruit	No. of segments	Juice%	TSS (°Brix)	Acidity (%)	Total sugar	Reducing sugar	Non-reducing sugar
1.	ABD 1	418	254.66	106.44	8.16	8.20	6.10	27.03	15.66	10.33	47.70	9.70	0.39	7.32	4.44	2.88
2.	ABD 2	268	307.56	82.42	8.83	8.63	6.76	24.01	17.66	10.66	49.56	10.06	0.34	7.22	4.33	2.89
3.	ABD 3	378	246.16	93.04	7.80	7.96	5.60	26.57	16.33	10.66	48.18	8.90	0.44	5.59	3.38	2.20
4.	ABD 4	216	222.70	48.10	7.10	7.63	5.40	22.65	15.00	11.00	51.48	8.20	0.47	5.55	3.73	1.82
5.	ABD 5	248	239.76	59.46	8.13	7.70	4.53	28.55	16.33	9.66	50.86	9.26	0.43	6.15	3.65	2.50
6.	ABD 6	218	301.86	65.80	8.43	8.20	7.16	26.79	18.66	11.00	54.14	8.20	0.47	5.42	3.52	1.90
7.	ABD 7	236	164.26	38.76	6.50	6.00	6.46	30.48	18.33	10.00	56.16	10.26	0.37	7.10	4.23	2.86
8.	ABD 8	338	233.43	78.89	7.13	7.33	6.56	23.52	16.00	10.00	54.78	10.10	0.35	7.43	4.65	2.77
9.	ABD 9	208	314.06	65.32	8.83	8.36	6.23	29.80	19.33	10.00	47.04	8.93	0.46	6.19	4.14	2.05
10.	ABD10	232	288.03	66.82	7.73	7.60	8.90	34.35	17.33	10.66	43.56	10.56	0.35	7.24	4.70	2.54
11.	ABD11	346	210.66	72.88	7.13	7.16	4.33	26.97	16.66	9.66	49.40	10.60	0.36	7.34	4.61	2.73
12.	ABD12	376	190.16	71.50	6.93	6.60	4.40	25.24	15.00	10.33	47.17	8.03	0.44	5.53	3.67	1.86
13.	ABD13	392	137.76	54.00	6.00	6.00	3.90	26.55	16.33	9.33	45.40	10.53	0.34	7.28	4.47	2.81
14.	JAL 1	216	321.26	69.39	8.93	8.93	4.30	30.28	15.00	11.66	49.04	10.00	0.35	7.29	4.33	2.95
15.	JAL 2	316	253.13	79.98	7.46	7.50	4.23	27.45	16.33	11.33	53.09	9.06	0.40	6.45	3.61	2.84
16.	JAL 3	236	313.86	74.07	9.20	8.23	5.10	30.20	19.33	10.33	42.76	9.56	0.43	5.70	3.55	2.14
17.	JAL 4	364	216.76	78.90	7.36	6.83	7.03	30.00	15.66	9.66	42.45	9.63	0.44	6.44	4.37	2.07
18.	JAL 5	386	219.46	84.71	8.20	7.73	5.00	22.45	15.00	10.33	48.33	11.03	0.35	7.42	4.41	2.99
19.	JAL 6	340	223.53	76.00	7.73	6.86	6.23	24.58	14.66	9.66	49.04	9.80	0.41	7.00	4.32	2.68
20.	JAL 7	268	299.83	80.35	7.23	7.20	6.06	22.86	18.33	9.33	40.95	11.40	0.35	7.40	4.43	2.96
21.	JAL 8	318	262.70	83.53	8.06	7.36	4.20	21.84	18.33	10.33	53.08	10.63	0.34	7.48	4.25	3.23
22.	JAL 9	422	174.06	73.45	6.26	6.33	4.56	23.58	19.00	11.00	49.70	9.56	0.42	6.73	3.62	3.11
23.	JAL 10	376	255.36	96.01	8.23	7.46	4.83	22.21	18.33	11.33	48.10	12.03	0.34	7.74	4.42	3.32
24.	JAL 11	412	223.23	91.97	7.13	7.10	6.03	23.27	15.33	10.33	54.73	10.23	0.39	6.13	3.29	2.83
25.	JAL 12	380	253.53	96.34	8.46	7.10	5.10	26.11	19.33	10.66	44.99	8.63	0.47	6.07	3.35	2.70
26.	JAL 13	404	211.96	85.63	7.20	7.20	6.23	22.34	18.33	9.33	43.86	10.80	0.36	7.58	4.47	3.11
27.	JAL 14	436	214.76	93.63	6.40	6.40	3.86	22.94	18.33	10.33	45.51	9.63	0.44	6.48	4.39	2.09
28.	JAL 15	336	241.53	81.15	8.10	7.50	4.73	24.59	19.00	10.00	40.27	11.23	0.33	7.43	4.44	2.98
	Mean	320.96	242.27	75.63	7.64	7.36	5.47	25.93	17.15	10.31	48.28	9.88	0.39	6.71	4.08	2.62
	SE	14.2610	9.2443	2.7529	0.1646	0.1429	0.2341	0.6349	0.3077	0.1239	0.8466	0.1966	0.0094	0.1435	0.0871	0.08612
	SD	74.1025	48.0349	14.3048	0.8556	0.7428	1.2166	3.2991	1.5993	0.6438	4.3992	1.0216	0.0488	0.7458	0.45307	0.4475
	Min.	208	137.76	38.76	6	6	3.86	21.84	14.66	9.33	40.27	8.03	0.33	5.42	3.29	1.82
	Max.	436	321.26	106.44	9.20	8.93	8.90	34.35	19.33	11.66	56.16	12.03	0.47	7.74	4.70	3.32

Table 2: Correlation co-efficients of physico-chemical characteristics of different sweet orange types

Characters	Number of fruits per tree	Weight of fruit (g)	Yield (Kg/ tree)	Length of fruit (cm)	Breadth of fruit (cm)	Rind thickness (mm)	Rind percentage (%)	Number of seeds per fruit	Number of segments	Juice (%)	TSS (^{0}Brix)	Acidity (%)	Total sugar	Reducing sugar	Non-reducing sugar
Number of fruits per tree	1	-.588**	.641**	-.460*	-.500**	-.331	-.509**	-.140	-.175	-.145	.198	-.093	.197	.033	.295
Weight of fruit (g)		1	.220	.841**	.857**	.308	.249	.258	.356	-.148	-.042	.036	-.082	-.043	-.095
Yield (kg/tree)			1	.249	.974**	-.077	.933**	.051	-.504**	-.252	-.246	-.088	-.117	-.001	.975**
Length of fruit (cm)				1	.870**	.997**	.243	.910**	.330	-.435**	-.055	.059	-.083	-.271	-.026
Breadth of fruit (cm)					1	.208	.979**	-.020	-.537**	-.001	-.303	.010	-.162	-.068	.995**
Rind thickness (mm)						1	.358	.939**	-.103	-.484**	-.005	.136	.008	-.221	-.168
Rind percentage (%)							1	.021	-.521**	-.123	-.341	.167	-.198	-.004	.967**
Number of seeds per fruit								1	-.013	-.584**	.149	.437	.041	.056	.122
Number of segments									1	.329	-.056	.161	-.105	-.368	-.541**
Juice percentage (%)										1	-.255	-.596**	-.134	.160	.064
TSS (^{0}Brix)											1	-.870**	.867**	.675**	-.230
Acidity (%)												1	-.892**	.560**	-.792**
Total sugar													1	.833**	-.082
Reducing sugar														1	.381*
Non-reducing sugar															1

* and ** indicate significance of values at P=0.05 and P=0.01, respectively

Table 3: Direct and indirect effect of different characteristics on yield of fruits

Characters	Number of fruits per tree	Weight of fruit (g)	Length of fruit (cm)	Breadth of fruit (cm)	Rind thickness (mm)	Rind percentage (%)	Number of seeds per fruit	Number of segments	Juice (%)	TSS (^{0} Brix)	Acidity (%)	Total sugar	Reducing sugar	Non-reducing sugar
Number of fruits per tree	1.1589	-0.5174	-0.0534	0.0382	-0.0163	0.0206	0.0047	-0.0008	-0.0090	0.0118	-0.0075	0.7347	-0.0748	-0.6486
Weight of fruit (g)	-0.6811	0.8804	0.0977	-0.0654	0.0152	-0.0101	-0.0088	0.0016	-0.0092	-0.0025	0.0029	-0.3074	0.0974	0.2091
Length of fruit (cm	-0.5327	0.7402	0.1162	-0.0664	0.0082	-0.0098	-0.0058	0.0015	-0.0076	-0.0032	0.0043	-0.3094	0.2569	0.0563
Breadth of fruit (cm)	-0.5800	0.7542	0.1011	-0.0764	0.0102	-0.0082	0.0006	0.0019	-0.0000	-0.0068	0.0008	-0.3379	0.1525	0.1841
Rind thickness (mm)	-0.3830	0.2707	0.0193	-0.0158	0.0495	-0.0145	-0.0010	-0.0004	-0.0010	-0.0002	0.0016	0.0300	-0.4015	0.3693
Rind percentage (%)	-0.5895	0.2192	0.0282	-0.0154	0.0177	-0.0406	-0.0007	0.0002	-0.0077	-0.0140	0.0135	-07357	0.0087	0.7155
Number of seeds per fruit	-0.1619	0.2271	0.0196	0.0014	0.0014	-0.0008	-0.0342	-0.0000	-0.0167	0.0089	0.0029	0.1532	0.1192	-0.2688
Number of segments	-0.2032	0.3137	0.0383	-0.0322	-0.0051	-0.0022	0.0004	0.0046	0.0206	-0.0164	0.0130	-0.8678	0.8249	0.0348
Juice percentage (%)	-0.1677	-0.1301	-0.0141	0.0000	-0.0008	0.0050	0.0091	0.0015	0.0626	-0.0152	0.0048	-0.4994	0.6316	-0.1394
TSS (^{0}Brix)	0.2299	-0.0368	-0.0063	0.0087	-0.0002	0.0095	-0.0051	-0.0012	-0.0159	0.0599	-0.0705	3.2462	-1.5128	-1.6888
Acidity (%)	-0.1075	0.0315	0.0061	-0.0007	0.0009	-0.0067	-0.0012	0.0007	0.0037	-0.0521	0.0810	-3.3295	1.5453	1.7402
Total sugar	0.2280	-0.0724	-0.0096	0.0069	0.0003	0.0080	-0.0014	-0.0010	-0.0083	0.0520	-0.0722	-3.733	-1.8663	-0.8359
Reducing sugar	0.0387	-0.0382	-0.0133	0.0052	0.0088	0.0001	0.0018	-0.0017	-0.0176	0.0404	-0.0558	3.1083	-2.2418	-0.8359
Non-reducing sugar	0.3422	-0.0838	-0.0029	0.0064	-0.0083	0.0132	-0.0041	-0.0000	0.0039	0.0460	-0.0642	3.095	-0.8532	-2.1965

Residual factor 0.0335, Bold values denote direct effect

showed highest positive direct effect on yield of fruits. The study of variability also indicated that effective improvement can be made for number of fruits per tree and yield per tree by selection from existing population. Thus, these two statistical parameters proved very useful in exercising the selection of promising sweet orange types in the present investigation. So, the overall studies indicated that the type JAL-11, JAL-14, ABD-1 and ABD-3 being productive and superior in quality stands for selection and further improvement.

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