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Research Article

FRUITING BEHAVIOR AND FRUIT QUALITY OF LEADING MANGO CULTIVARS GROWN IN SOUTH PUNJAB-PAKISTAN

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Abstract

Mango is an important and exportable fruit crop of Pakistan However, it is being cultivated in Indo-Pakistan region from centuries, yet farmers face decline in mango production due to lack of available knowledge about fruit bearing habits of mango trees. In order to provide this basic information, a three year study plan was carried out on 10 elite varieties of mangoes from 2018-2020 in Punjab Pakistan. Data was statistically analyzed through R statistical programing using ANOVA analysis. The data depicts that cultivar Dusehri, Late Retaul, Sansation and Sufaid Chaunsa took maximum flowering on old shoots while Azeem Chaunsa, Kala Chaunsa, Langra, Sindhri and Anwar Retaul on new shoots. Fruit bearing on old shoots was significantly higher in Dusehri (75.80), while minimum on Azeem Chaunsa (0.0). The fruit bearing on new shoots was significantly higher on Anwar Retaul (99.73), while it was minimum on Dusehri (25.06). Significantly higher fruit weight was observed in Sufaid Chaunsa and total soluble solids were higher in Kala Chaunsa while minimum were observed in Sansation (15.93). Acidity was non-significantly different among the cultivars. Hence, it was concluded that Dusehri, Late Retaul, Sansation and Sufaid Chaunsa took maximum flowering on old shoots while Azeem Chaunsa, Kala Chaunsa, Langra, Sindhri and Anwar Retaul on new shoots. Our studies provide understanding of fruiting behavior which helps in devising mango crop's varietal-specific management system and paves the way for mango's quality and yield enhancement.

Keywords: Mango, fruiting behavior, yield, acidity, total soluble solids.
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1. INTRODUCTION

Mango (Mangifera Indica L.; Anacardiaceae), is a large evergreen tropical fruit plant and is well known as "king of fruits". Pakistan's current mango production stands at 1.72 million tons (MT) from an area of 168.6 thousand hectares, achieving an average yield of 10.2 tons per hectare (GOP, 2022). Mango is mainly cultivated in two vastly different agro-ecological provinces of Pakistan i.e. Punjab and Sindh (Amin et al., 2008, Ziaf et al., 2004). In Punjab, it is mainly grown in Multan, Muzaffargarh, Rahim Yar Khan, Khanewal and Bahawalpur districts while Vehari, D.G. Khan, Rajanpur and Bahawalnagar districts also produce significant mango crop (Balal et al., 2011). Based on the various field studies and surveys conducted by Mango Research Institute, It has been reported that, In Pakistan, more than 30 cultivars are grown commercially, however; 95% area is under 10 cultivars namely Sammar Bahisht Chaunsa (35%), Sindhri (18%), Sufaid Chaunsa (16%), Dusehri (6%), Kala Chaunsa (6%), Anwar Retaul and Late Retaul (6%), Langra, Chanab Gold and Azeem Chaunsa (8%) and rest of the 5% area is under remaining 15 varieties i.e. Fajri, Sansation, Sanglakhi, Lahutya etc. More precisely, the first 5 varieties are

grown on 80% area and about 70% area is under 3 varieties, Sammar Bahisht Chaunsa, Sindhri and Sufaid Chaunsa.

In tropical regions, mango varieties have seeds containing multiple genetically identical embryos (poly-embryonic), while in subtropical areas like Indo-Pak, mangoes are predominantly mono-embryonic. (Mukherjee & Litz, 2009). Mangoes can be grown successfully in diversified climate from sea level to an altitude of 600m; however, it cannot withstand severe cold and frost. Similarly, dry or warm winds also adversely affect the plant performance. Being a tropical fruit, mango crop can be grown under variable climate; however, the suitable minimum and maximum temperature for successful crop production is 4°C during winter and 44°C in summer. The temperature extremes beyond this limit affect the plant health and fruiting. Whereas, the fruiting pattern of mango crops is influenced by factors such as soil type, cultivar, planting distance, planting distance, cultivar, developmental stages, age of the plant, and NPK applications. (Mitra & Mitra, 2001, Reddy et al., 2001, Gawankar et al., 2010).

The time of mango flowering and fruiting does not entirely determine the timing of fruit harvest in South Punjab. However, the temperature variations are the essential climatic factors that determine the fate of growing buds (Davenport, 2000, Davenport, 2003, Davenport, 2007). Therefore, changes in maximum and minimum temperature affect flowering intensity and fruit production in major mango producing districts of Punjab, Pakistan. Likewise, mango cultivars exhibit varying flowering patterns under tropical and subtropical conditions. (Davenport, 2003). To successfully cultivate mangoes, it is essential to comprehend the plant phenology of different mango varieties within a specific ecological setting (Singh & Singh, 1996). These developmental events occur across various mango cultivars in both tropical and subtropical environments. Floral bud induction is associated with environmental conditions and the age of terminal dormant shoots (Davenport, 2007). Mango flowering is significantly impacted by genotypic variations and is a crucial stage in the growth cycle as it directly impacts mango crop yield.

Mango flowering initiates fruit development and dictates the timing of fruit harvest in tropical regions; however, it shows minimal variation from year to year in subtropical regions. Hence, successful flower induction in mango is essential for fruit production. The growth of mango trees is not continuous; instead, it occurs in intermittent bursts of shoots emerging from apical or lateral buds. This process, known as flushing, involves the emergence of new shoots on previously fruited shoots or existing vegetative growth.

The phenological cycle associated with mango involves vegetative growth, root growth, dormancy, flowering/fruit setting and fruit growth and development (Murti & Upreti, 1998). New shoots typically originate as lateral branches from axillary buds near the base of twigs that bore the fruit previous year. Terminal growth typically involves the extension of existing shoots. Manho trees take growth in distinct flushes and in various environmental settings that differ among different varieties. (Jameel et al., 2018).

Mango trees require mature vegetative growth in order to produce fruit each year(Krishnamurthi, 1961, Shu & Sheen, 1987, Whiley et al., 1989). After the leaves of this flush mature, it requires a period of cessation for transformation from vegetative to reproductive growth (Nunez-Elisea & Davenport, 1990, Kulkarni, 2002, Davenport, 2007). However, a significant flowering is also observed on fruited shoots without assuming vegetative growth, but it is highly variable from location to location and variety to variety (Hofman, 1996, Salvador et al., 1997). Hence, these fruited flushes do not require vegetative growth to bear flowers. This divergence is frequent in some cultivars of Pakistan's South-Punjab

region. Unfortunately, neither the efforts were directed to realize this deviatory tendency of some premium cultivars nor the attempts were made to review their management system accordingly to get quality mango production from them, and no significant work has been done to analyze the fruiting behavior of the leading mango cultivars.

Keeping in view this dilemma, the present study was envisaged to document the flowering/fruiting behavior of ten leading mango varieties namely Dusehri, Langra, Anwar Retaul, Sindhri, Samar Bahisht Chaunsa, Kala Chaunsa, Azeem Chaunsa, Late Retaul, Sufaid Chaunsa and Sensation, and their fruiting habits' variation pertaining to different regions and different climatic conditions. This understanding of fruiting behavior helps in devising mango crop's varietal-specific management system, which paves the way for mango's quality and yield enhancement. In return, the country's export potential can grow exponentially.

2. Materials and Methods

The trial was conducted in five major mango producing districts of Punjab i.e. Multan, Rahim Yar Khan, Muzaffar Garh, Khanewal and Vehari. Each location was considered as the replicate. The orchards selected for this experiment possessed all ten mango cultivars namely Dusehri, Langra, Anwar Retaul, Sindhri, Samar Bahisht Chaunsa, Kala Chaunsa, Azeem Chaunsa, Late Retaul, Sufaid Chaunsa and Sensation. Five healthy plants of each variety were selected at each location. The plants were between 20 and 25 years old and were spaced 12 meters (40 feet) apart between rows and individual plants. Investigation were extended over three consecutive seasons: 2018, 2019 and 2020. The flowering panicles produced on new shoots and old fruited shoots were recorded separately. The fruits under experimental plants were harvested for biochemical analysis when physiological maturity was achieved. The behavior of ten elite mango cultivars was documented in five major mango producing districts of the Punjab.

The detail of orchards under study is as follows;

Sr. No.	District	Orchard Name	GPS location
1	Multan	Mango Research Station, Shujabad	N 29º52'; 55.818" E 71º21'12.318"
2	Rahim Yar Khan	Akhtarabad Farm, Khanbela	N 28º94'45.94" E 70º72'09.73"
3	Muzaffar Garh	Al Hamd Mango Farm, Khangarh	N 29º74'01.73" E 71º03'70.68"
4	Khanewal	IRW Farms, Khanewal	N 30º19'56.8" E 71º42'44.0"
5	Vehari	SK Mango Farms	N 29º57'26.23" E 71º58'25.0"

2.1. Flowering Terminals (%)

The flowering terminals were counted in the last week of March by using ring method. A wooden ring of known diameter (approximately 1.5 meter) was used for measuring the fruiting terminals. The ring was placed on all the directions of the plant canopy randomly at variable height at 20 different locations. The flowering terminals on new and old shoots inside the ring were counted separately and finally the figures were expressed in percentage by using the following formula:

$$\text{New/old shoots (\%):} = \frac{\text{Number of } \frac{\text{new}}{\text{old}} \text{ shoots}}{\text{Total number of shoots}} X\ 100$$

2.2. Fruit weight (g)

Fruits were harvested when attained physiological maturity. Twenty fruits were harvested randomly from all around and inside the canopy from each plant. The fruit weight was recorded by weighing the fruits from each replication on a weighing balance (UWE-ESP 5) and the average fruit weight was calculated and expressed in grams.

2.3. Fruit yield (g)

Fruit yield data was recorded in July-August 2018, 2019 and 2020 respectively. All the fruits on the tree were harvested and counted. The fruit yield was recorded by weighing all the fruits on a weighing balance (UWE-ESP 5) and was expressed in kg. Total number of fruits harvested from each replication were counted and the

average fruit weight expressed in g was calculated by using the yield data.

2.4. Total soluble solids (TSS) (ºBRIX) and titratable acidity (TA) (%)

TSS of mango juice from 20 ripe fruits per replication was measured using a digital refractometer (ATAGO, RS-5000) and expressed in OBRIX. For TA estimation, 5 ml of mango juice squeezed from each of the 20 fruits per replication was diluted in a 10-ml flask with distilled water. Phenolphthalein (2-3 drops) were added, and the juice was titrated against 0.1 N NaOH until a pink color appeared. TA of the mango juice, expressed as a percentage (%), was calculated using specific formulas. (Qureshi et al., 2021).

$$\text{TA (\%)} = \frac{0.1\ \text{N NaOH} \times 0.0064}{\text{Volume of juice used}} \times 100$$

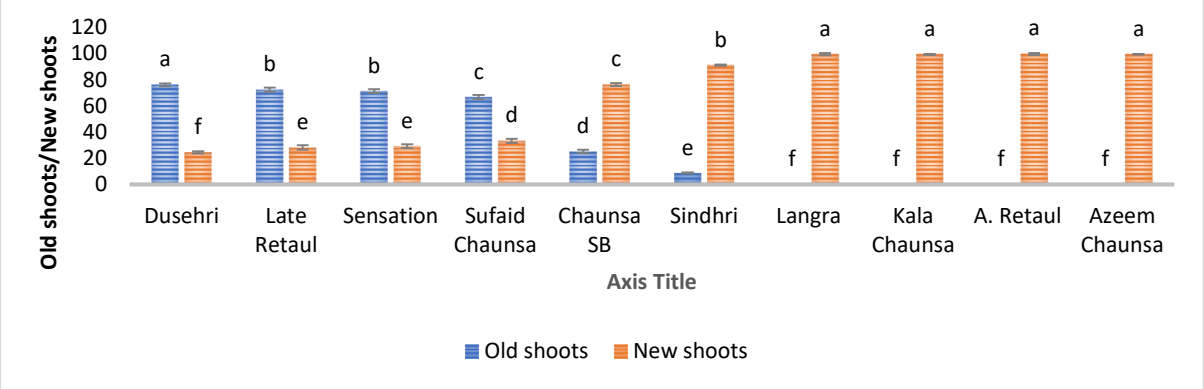

Fig 1: Flowering %age on old shoots and new shoots in different cultivars of mangoes observed during 2018-2020. Here the letters represent the ranking based on Tukey highly significant difference among cultivars (p-value <0.01).

2.5. Statistical analysis

In the experiment, a Randomized Complete Block Design was employed with ten treatments replicated five times, where each plant served as the experimental unit. The data collected was statistically analyzed using analysis of variance over the year Mean comparisons were conducted using the LSD test at a significance level of P≤0.05.

3. Results:

3.1. Fruiting Habit: Flowering on Old Shoots & New Shoots:

Flowering and fruit bearing habit of ten mango cultivars was recorded for three consecutive years 2018-2020. Fruiting on old shoots is characteristics of some varieties while others produce flowers and fruits only on new shoots, hence to analyze the fruiting behavior a two-way ANOVA analysis comparison of fruit bearing habits of varieties was done.

Flowering on old shoots was maximum on Dusehri (76.04%), followed by Late Retaul (72.33%), Sensation (71.26%), Sufaid Chaunsa (66.71%), SB Chaunsa (25.22%) and Sindhri (8.82%) ($p< 0.01$), while flowering on new shoots was higher in A. Retaul (99.64%), Langra (99.48%), Azeem Chaunsa (99.37%), & Kala chaunsa (99.33%) (($P<0.01$). Moderate number of flowers and fruits were observed on new shoots in Sindhri (91.04%), & Chaunsa SB (76.26%), however, minimum flowering & fruiting on new shoots was observed on Sufaid Chaunsa (33.33%), Sensation (29.44%), Late Retaul (28.44%), and Dusehri (24.55%) (Fig 1).

In Punjab, Pakistan the crop is grown in the subtropical climate ranging from very hot during the summer to cold during winter. This climate force the plants for profused flowering every year and the change in climate may affect the crop significantly. Hence we determined, the variation of fruiting behavior among the yeas. ANOVA comparison among years revealed that flowering and fruiting on old shoots was significantly different during years ($p<0.01$). Flowering and fruiting on old and new shoots was maximum in 2018 (32.86%) and 2019 (33.24%), while

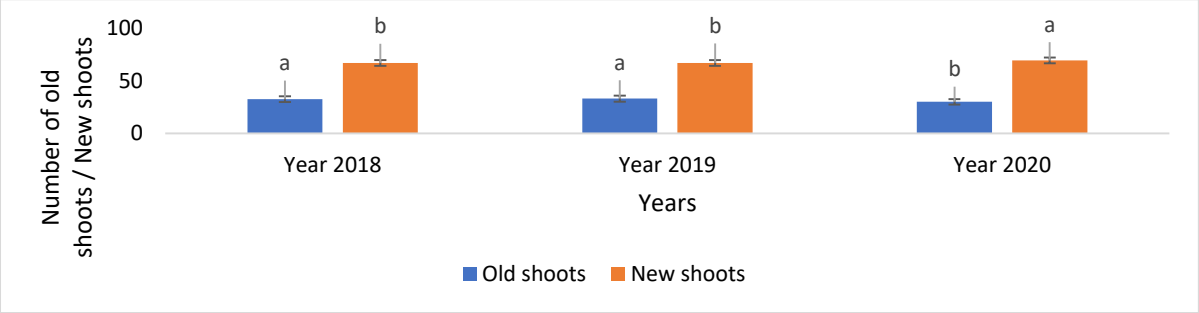

Fig 2: Percentage of old shoots and new shoots observed on mango cultivars during 2018-2020. Here the letter represents the ranking based on Tukey highly significant difference among years. The means were calculated from three-year data obtained from different varieties and locations each year.

minimum flowering & fruiting on old shoots was observed in 2020 (30.17%). The maximum flowering and fruiting on new shoots was observed during 2018, and 2019 while during 2020, lower number of new shoots were observed (Fig 2). The flowering behavior on the old & new shoots was strongly influenced by variety, however minor effect of years was also observed during the study.

The interaction of years and varieties was significantly different ($P < 0.05$). Overall higher flowering on old shoots was observed on Dusehri in 2019 (79.53%) followed by Dusehri in 2018 (75.80%) and Late Retaul in 2019 (73.06%). Minimum flowering and fruiting on old shoots were observed in Azeem Chaunsa, A. Retaul, Kala Chaunsa, Langra and Sindhri (Table 1).

3.2. Fruit weight

Among varieties higher fruit weight was observed in Sufaid Chaunsa (430.533 g) followed by Sindhri (373.11 g), SB Chaunsa (316.42 g), Langra (283.35 g), Kala Chaunsa (281.82 g), Dusehri (246.17 g), Azeem Chaunsa (229.35 g), Sensation (202.02 g), A. Retaul (193.2 g) and Late Retaul (190.62 g) (Fig 3). Two way anova analysis results to determine effect of cultivar ($P<0.01$) and years ($P<0.01$) on fruit weight were significant. The interaction of variety and years was non-significant ($P>0.05$).

Overall, higher fruit weight was observed in all varieties during 2020 (280.72 g), followed by 2018 (274.68 g) and 2019 (268.58 g) (Fig 4).

Over the years 2018-2020, fruit weight was significantly higher in Sufaid Chaunsa (426.8-436.6 g) followed by Sindhri (366-379 g), SB Chaunsa (309.8-322.8 g), Langra (277-289 g), Kala Chaunsa (276-286 g), Dusehri (237-255 g) , Azeem Chaunsa (226-232 g) , Sensation (197-209 g) , A. Retaul (197-202 g) and Late Retaul (187-193 g) (Table 2).

3.3. Total Soluble Solids

Two-way ANOVA analysis was done to determine effect of cultivar and years on total soluble solids. TSS was significantly different among cultivars ($P<0.01$). Among varieties higher total soluble solids were present in Kala Chaunsa (26.06), followed by SB Chaunsa (25.86), Dusehri (25.66), A. Retaul (25.66), Azeem Chaunsa (23.93), Late Retaul (23.46), Sufaid Chaunsa (22.95), Langra (19.6), Sindhri (17.06), Sensation (15.86) (Fig 5)

Among years the higher TSS was observed in fruits collected during 2020 (22.84) followed by 2019 (22.43) and 2018 (22.56) (P-value <0.01) (Fig 6).

Over the years 2018-2020, the comparison of cultivars showed that there was non-significant difference among cultivars regarding total soluble solids (Table 2).

The interaction of years and cultivars was non-significant (p-value >0.05). Higher TSS was observed during 2020 in cultivar Kala Chaunsa (26.53) followed by SB Chaunsa (26.13) in 2020 while minimum

Table 1. Comparison of flowering and fruiting behavior on old shoots and new shoots in ten mango cultivars during 2018-2020.

Variety	Year	Old shoots	New shoots
Dusehri	2018	75.8 ab	25.066 gh
	2019	79.53 a	21.066 h
	2020	72.8 abc	27.533 fgh
Late Retaul	2018	72.93 abc	27.466 fgh
	2019	73.06 abc	27.33 fgh
	2020	71 abc	29.933 fgh
Sensation	2018	72.73 bc	27.66 fgh
	2019	71.86 bc	27.66 fgh
	2020	69.2 bc	31.26 fg
Sufaid Chaunsa	2018	67.46 c	32.26 fg
	2019	68.4 d	32.13 fg
	2020	64.26 d	35.6 f
Chaunsa SB	2018	30.86 e	69.6 e
	2019	27.46 efg	76.8 de
	2020	17.33 ef	82.4 cd
Sindhri	2018	9.03 fg	91.33 abc
	2019	10.66 g	89.53 abc
	2020	6.76 g	92.26 ab
Langra	2018	0.44 g	99.6 a
	2019	0.34 g	99.33 a
	2020	0.18 g	99.53 a
Kala Chaunsa	2018	0.08 g	99.33 a
	2019	0.08 g	99.66 a
	2020	0.08 g	99.00 a
A. Retaul	2018	0.06 g	99.73 a
	2019	0.11 g	99.53 a
	2020	0.057 g	99.66 a
Azeem Chaunsa	2018	0.052 g	99.46 a
	2019	0.052 g	99.66 a
	2020	0.04 g	99.00 a
P-value		<0.05	0.0815
F-value		1.79	1.5118
DF		18	18

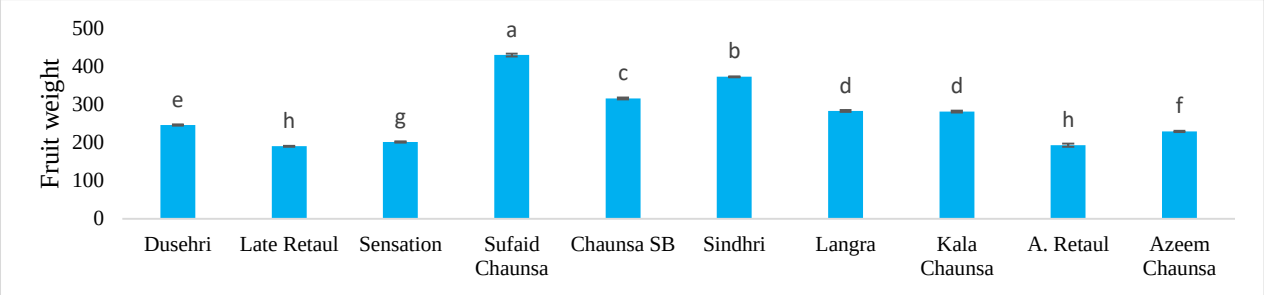

Fig 3: Comparison of fruit weight among different cultivars of mangoes during 2018-2020. Here the letters represent Tukey HSD among means. The means were calculated from three-year data obtained from different locations and years.

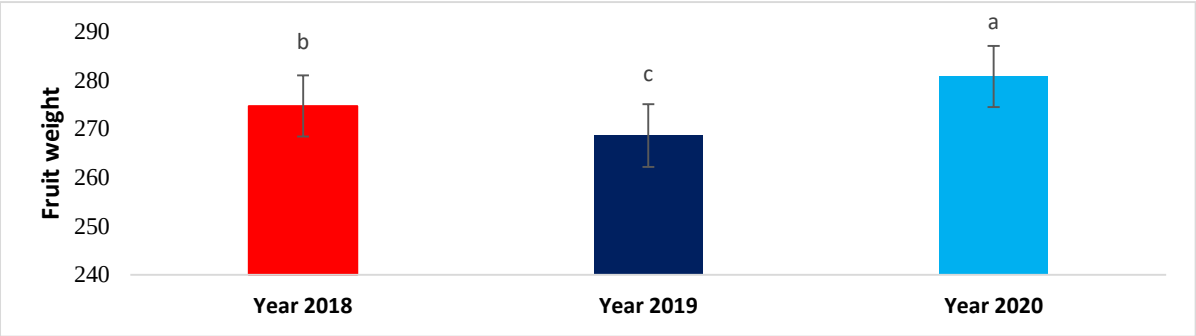

Fig 4: ANOVA analysis comparison of fruit weight among years. Here the letters represent the Tukey HSD difference among mean fruit weight. The means were calculated from mean fruit weight obtained from ten varieties and five locations during 2018-2020

Table 2. Fruit weight, acidity and TSS in ten cultivars of mango during 2018-2020.

Variety	Year	Fruit weight	TSS	Acidity	Yield
Dusehri	2018	245.000 gh	25.666 bcd	0.1726 a	223.800 efghij
	2019	237.866 gh	25.733 ab	0.1686 a	246.4000 cdefghi
	2020	255.667 fg	25.466 ab	0.1786 a	241.4000 defghij
Late Retaul	2018	190.866 jk	23.466 de	0.1840 a	237.400 defghij
	2019	187.400 jk	22.999 e	0.1840 a	240.400 defghij
	2020	193.600 jk	23.933 cde	0.1802 a	220.200 efghijk
Sensation	2018	199.733 jk	15.933 gh	0.1933 a	148.333 lm
	2019	197.200 jk	15.933 gh	0.1853 a	135.600 m
	2020	209.133 ij	15.733 h	0.1913 a	152.000 klm
Sufaid Chaunsa	2018	429.200 a	22.933 e	0.1913 a	278.866 bcdef
	2019	426.800 a	22.866 e	0.1786 a	289.400 bcde
	2020	435.600 a	23.066 de	0.1786 a	317.200 b
Chaunsa SB	2018	316.600 c	25.733 ab	0.1886 a	235.733 defghij
	2019	309.800 cd	25.733 sb	0.1826 a	300.400 bcd
	2020	322.866 c	26.133 a	0.1846 a	295.266 bcd
Sindhri	2018	373.33 b	17.26 g	0.1827 a	295.266 bcd
	2019	366.466 b	16.866 gh	0.1807 a	327.40 b
	2020	379.533 b	17.0665 gh	0.1867 a	269.600 bcdefg
Langra	2018	283.400 e	19.533 f	0.1745 a	223.800 efghij
	2019	277.000 ef	19.333 f	0.1686 a	217.00 fghijk
	2020	289.600 e	19.933 f	0.1806 a	230.600 defghij
Kala Chaunsa	2018	281.933 e	25.933 a	0.1779 a	316.066 bc
	2019	276.933 ef	25.733 ab	0.1799 a	208.600 ghijkl
	2020	286.600 e	26.533 a	0.1759 a	209.733 fghijkl
A. Retaul	2018	197.33 jk	25.333 sbc	0.1813 a	205.800 ghijkl
	2019	180.066 k	25.733 ab	0.1733 a	191.400 ijklm
	2020	202.200 jk	25.933 a	0.1832 a	176.800 ijklm
Azeem Chaunsa	2018	229.400 hi	23.866 de	0.1866 a	418.60 a
	2019	226.33 jk	23.466 de	0.1826 a	267.00 bcdefgh
	2020	232.333 jk	24.466 bcd	0.1826 a	197.600 hijklm
P-value		0.9645	0.6538	>0.05	40.898
F-value		0.484	0.8390	0.3544	12.032
DF		18	18	18	18

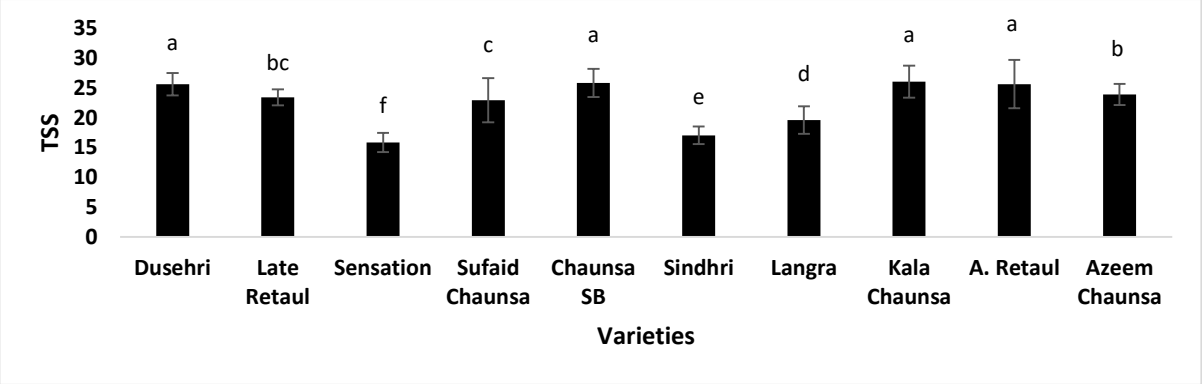

Fig.05: The comparison of total soluble solids among different varieties obtained from the different locations of southern Punjab Pakistan. Here the comparison is made on the basis of TSS values obtained from all varieties in different years from different locations. The letters represent Tukey honestly significant difference among means.

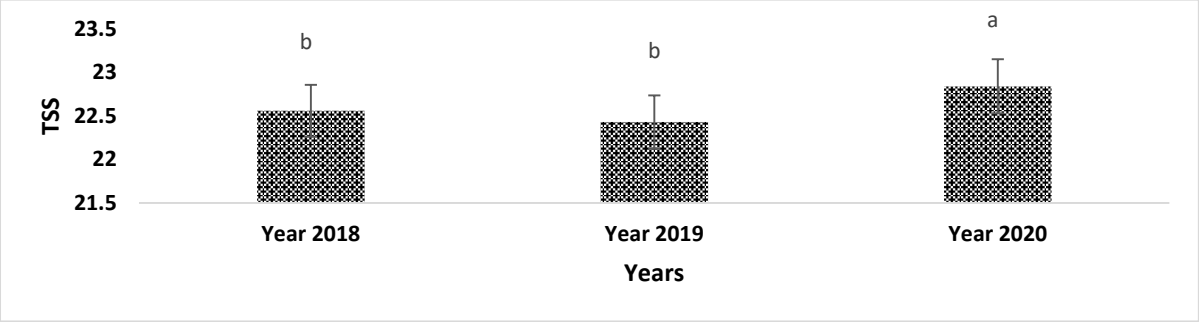

Fig 6: The comparison of TSS among fruits collected from different locations and varieties in southern Punjab Pakistan. Here error bar represents standard error around mean. TSS was significantly different in between years (P-value <0.01).

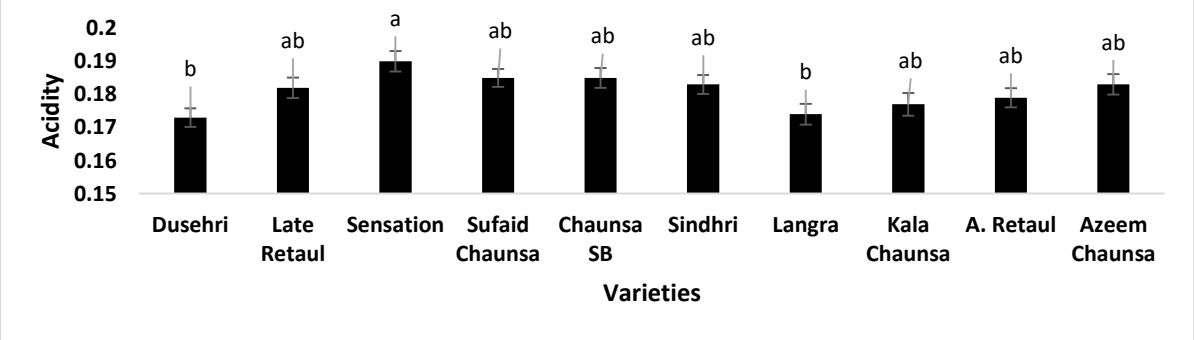

Fig 07: Comparison of acidity among fruits collected from different varieties during 2018-2020. Here the means were calculated from the acidity values of fruits collected from different locations during 2018-2020. The letters represent ranking based upon Tukey HSD among mean acidity values for each variety. Error bars represent standard error around mean.

TSS was observed in Sensation (15.73-15.93) during 2018-2020 (Table 2).

3.4. Acidity

A two-way ANOVA analysis was performed to assess how cultivar and years impact acidity levels in mango cultivars. Overall, among varieties, Sensation was highly acidic (0.19%), followed by Chaunsa SB (0.18%), Azeem Chaunsa (0.18%), Sindhri (0.18%), Late Retaul (0.18%), Sufaid Chaunsa (0.179%), A. Retaul (0.179%), Kala Chaunsa (0.177%), Langra (0.174%), and Dusehri (0.173%) (Fig 7) (P<0.01).

Among years, non-significant difference was observed in acidity among fruits

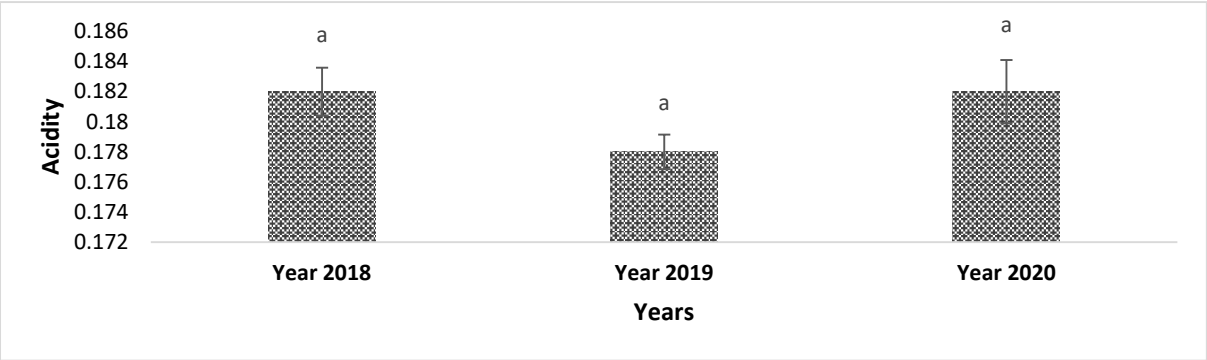

Fig. 08: Comparison of acidity among fruits collected during 2018-2020. Here the means were calculated from acidity values of fruits collected from different varieties and locations. The letters represent the ranks based upon Tukey HSD among means. Error bars represents standard error around mean values.

collected during 2018-2020 (0.178%-0.182%) (Fig 08) (P>0.05).

The interaction of varieties and years was non-significant (P-value > 0.05). Sensation had higher acidity (0.191-0.193) followed by SB Chaunsa (0.1866), while comparatively lower acidity was observed in Dusehri and Langra (0.1688).

3.5. Yield (Kg)/Plant

Among varieties, highly significant difference was observed regarding yield (Fig 09) (P<0.01). Over the years, Sindhri variety had higher yield (297.422), followed by Sufaid Chaunsa (295.15), Azeem Chaunsa (294.40), Kala Chaunsa (244.8), Dusehri (237.2), SB Chaunsa (236.17), Late Retaul (232.66), Langra (223.8), A. Retaul (191.33), and Sensation (145.31) (Fig. 09).

Among years, yield was at par in 2019 (258.36) and 2018 (242.36) while in 2020 comparatively lower yield was observed (218.75) (Fig 10) (P-value <0.01).

Year-wise yield obtained from different varieties was also compared through two-way interaction ANOVA analysis (P<0.01). Overall, Azeem Chaunsa during 2018 had maximum fruit yield followed by Sindhri during 2018, Sufaid Chaunsa during 2020, Kala Chaunsa during 2018, while lower fruit yield was obtained from Sindhri during 2019 (135.6) (Table 2).

Alternate bearing is common in Kala Chaunsa, Chaunsa SB and Azeem Chaunsa. During 2018, Azeem Chaunsa, and Kala Chaunsa had bumper crop while Chaunsa SB had comparatively lower yield,

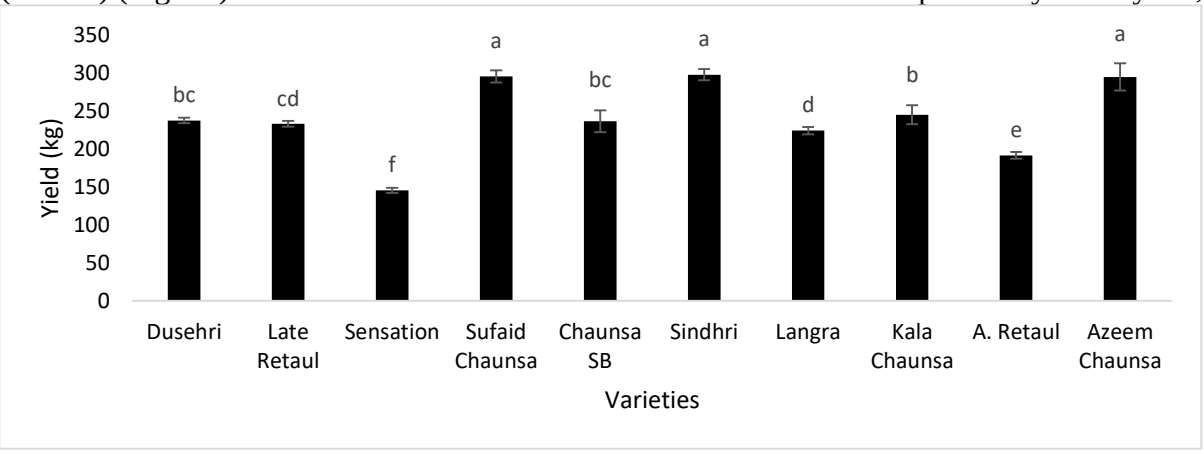

Fig 09: Comparison of yield among varieties from different orchards during 2018-2020. Here the means were calculated based from data obtained from different orchards and locations of southern Punjab during 2018-2020. The letters represent the significant difference among mean yield based upon Tukey HSD at 5% level of significance. Here error bars represent SEM.

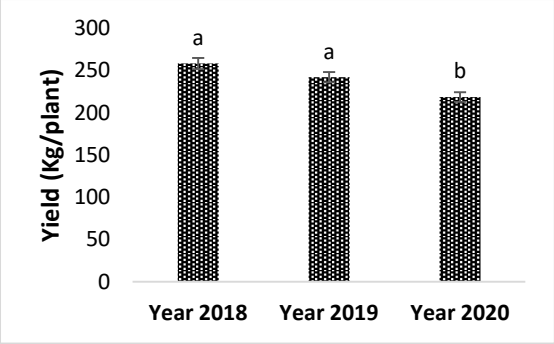

Fig 10: Comparison of yield during different years. Here the means were calculated from average yield values obtained from different orchards at multiple locations in south Punjab, during different years as well. The letters represent the ranks based upon Tukey HSD among means.

however, during 2019, higher yield was observed in Chaunsa SB, while Kala Chaunsa and Azeem Chaunsa had comparatively lower yield. In 2020, Kala Chaunsa, Azeem Chaunsa and Chaunsa SB had moderate to lower yield (Fig 11).

The comparison of percent share of each variety showed that production of mangoes was extremely affected by variety fruiting behavior on old shoots and new shoots. The comparison of yield showed that mango cultivar Kala Chaunsa had 99.66% flowering and fruiting on new shoots as compared to 0.08 percent flowering on old shoots. Similarly, mango cvs. A. Retaul (99.73 percent flowering on new shoots),

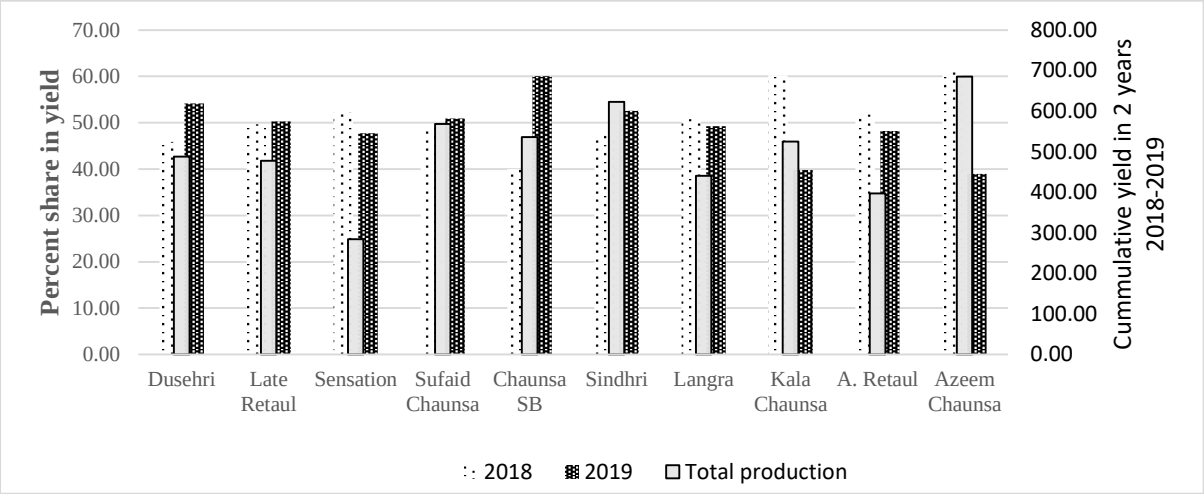

Fig 11. Percent share of each variety in alternate bearing during 2018-2019.

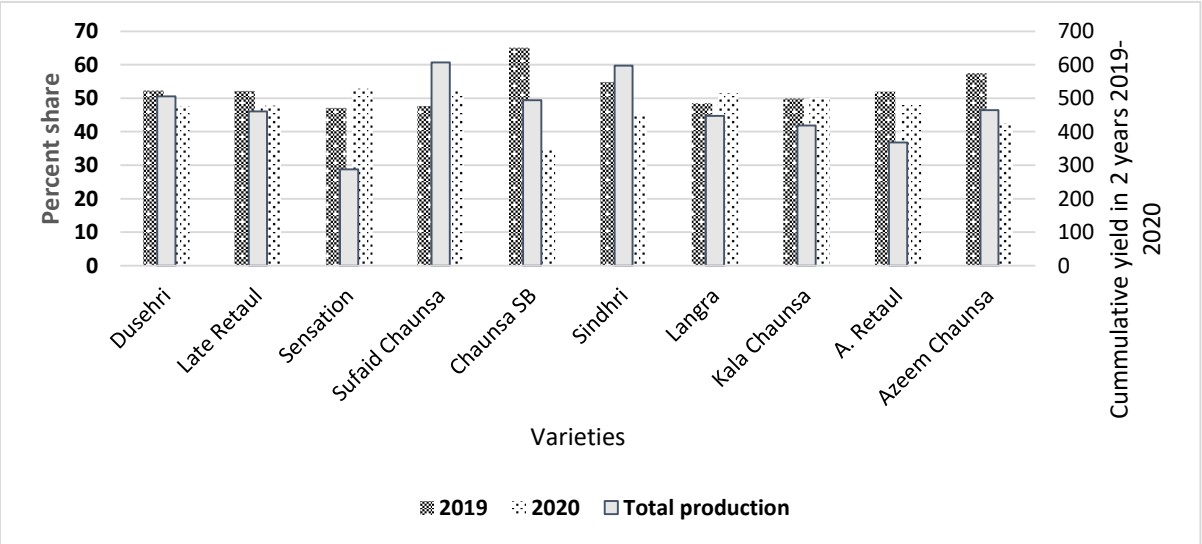

Fig. 12: Percent share of each variety in cumulative yield during 2019-2020.

Langra (99.6 % fruiting on new shoots) and Azeem Chaunsa (99.66 percent flowering on new shoots) exhibited the similar trend. These cultivars may be named as new-shoot varieties. In addition, the percentage of flowering on new mature shoots moderately high in Sindhri (92.2 %) and SB Chaunsa (82.4%), so categorizing both the cultivars under moderately new-shoot bearer varieties. However, mango cultivars Dusehri, Late Retaul, Sensation and Sufaid Chaunsa exhibited heavy bearing on old fruited shoots, with maximum fruiting percentage of 79.53%, 73.06 %, 72.7%, and 68.4% on old fruited shoots respectively. Therefore, they are termed as old fruited cultivars. Although these mango cultivars performed differently during 2018 to 2020, in terms of bearing fruits on new and old shoots, the data was statistically insignificant (Fig 11).

The comparison of fruiting behavior and yield during 2019-2020, showed that Dusehri, Late Retul, Sensation, Sufaid Chaunsa and Sindhri showed 47-52 % fruiting yield per year (Fig 12), while Azeem Chaunsa, and Chaunsa SB produced 57 and 63 percent yield respectively in 2019. On the basis of fruiting behavior, we assume that Kala Chaunsa, Azeem Chaunsa and Chaunsa SB are the varieties which exhibit alternate bearing, while some varieties for example Dusehri, Late Retaul, Sensation, Sufaid Chaunsa, and Anwar Retaul can be categorized as the regular bearer because they showed around 50% production in each year (Fig 12).

4. Discussion

Mango bears flower and fruit on new mature growth. The fruited shoot gets new growth, which rests during the dormancy period and reaches maturity before bearing flowering and fruiting on the same shoot (Murti & Upreti, 2000). This phenomenon of fruiting on new mature growth is well documented and preferred to obtain mango crop. The same fruiting pattern on new mature shoots is also reported in Pakistan's commercial mango varieties(Nafees et al., 2010). However, some important mango cultivars, especially late maturing mango cultivars bear flowering and fruiting on old shoots, which cannot take vegetative growth after fruit harvest due to low temperature and initiation of dormancy period in the region. The current study provides insight into different mango cultivars' flowering and fruiting habits on new mature and old shoots. The maximum number of flowers and fruits on old shoots were observed in mango cv. Dusehri followed by Late Retaul, Sensation, Sufaid Chaunsa, Sammar Bahisht Chaunsa and Sindhri (Fig 1). Conversely, the mango varieties Anwar Retaul, Langra, Azeem Chaunsa and Kala Chaunsa flowered profusely on new mature shoots (Fig 1).

Before this study, the only advised method to get a mango tree to flower and fruit was to acquire new growth from the mango trees after harvesting. Nonetheless, the study showcases that the fruiting on old shoots is imperative to get regular fruiting from late-maturing mango varieties, which are either reluctant to acquire new growth or produce weak growth due to lowering the temperature during the months of September-October in the country.

The study bifurcates the mango cultivar into three groups on the basis of fruit weight. First, Large size group that encapsulates Sufaid Chaunsa and Sindhri, with average fruit weight of 435.6 g/fruit and 379.5 g/fruit respectively. Conversely, mango cultivars SB Chaunsa (322 g/fruit), Langra (289.6 g/fruit), and Kala Chaunsa (286.6 g/fruit) though not as heavy as Sufaid Chaunsa and Sindhri, still possess a respectable fruit weight, averaging at 322 g/fruit, 289.6 g/fruit and 286.6 gram per fruit respectively. This group of mango cultivars is categorized as Medium Size fruit. In a similar manner, the minimum average fruit weight was observed in Late Retaul (187 g), A. Retaul (197 g), Sensation (197 g), Azeem Chaunsa (226 g), and Dusehri (237 g). Therefore, this group of fruit is named as the small size mangoes. However, the selection of a cultivar ultimately depends on the grower's

preference, market demands, and specific usage requirements (Iqbal et al., 2012)

TSS and acidity of all the varieties under the trial showed significant variations suitable for the morphological characterization of these cultivars. However, these variations are not affected by the bearing habits of these varieties, whether they bear on old shoots or new mature shoots. Among the varieties under study, the highest total soluble solids (TSS) were present in Kala Chaunsa, followed by Chaunsa SB, Dusehri, Anwar Retaul, Azeem Chaunsa, Late Retaul, Sufaid Chaunsa, Langra, Sindhri, and Sensation (Fig 6). In addition, the highest acidity percentage was found in mango cv Sensation, followed by Chaunsa SB, Anwar retaul, Kala Chaunsa, Langra and Dusehri. Although all the cultivars exhibited varied fruit weight, TSS and Acidity, their relationship with the fruiting on new mature shoots or old shoots can never be established. Therefore, it is construed from these results that fruit weight, TSS, and acidity are the specific features of a variety and are not associated with fruiting new mature shoots or old shoots (Akhtar et al., 2009).

The yield comparison amongst the varieties was highly significant. Over the years, the maximum yield was observed in Sindhri, followed by Sufaid Chaunsa, Azeem Chaunsa, Kala Chaunsa, Dusehri, Chaunsa SB, Late Retaul, Langra and Anwar Retaul. In comparison, the minimum yield was recorded in Sensation in 2019. Moreover, the study finds no relationship between fruiting on old and new mature shoots with yield (Naz et al., 2014). However, it did reveal its connection with regular or alternate bearing habits of different mango cultivars.

Alternate bearing is a phenomenon wherein fruit plants, including mango, produce a bumper crop in one year, called on-year, and low in the subsequent year, off-year (Kumar et al., 2021). This irregular bearing phenomenon is considered normal in mango as it is presumed to produce 60% crop during one year and 40% during the off year (Chandler, 1950). However, the current study revealed that the late-maturing cultivars that bear fruit on old shoots are regular bearers, such as Late Retail and Sufaid Chaunsa. On the contrary, the other late maturing varieties, Azeem Chaunsa, Kala Chaunsa and Chaunsa SB, solely dependent on new mature shoots for fruiting, are strong irregular bearers.

The varieties that bear flower and fruit on old shoots are regular bearers such as Dusehri, Late Retail, Sensation and, more importantly, Sufaid Chaunsa, a substantial exportable variety of Pakistan. Ironically, the varieties that bear fruit on new mature shoots tended to alternate bearing, such as Chaunsa SB, Azeem Chaunsa, Kala Chaunsa and Langra. This study opens new vistas for studying and overcoming the alternate bearing habits of irregular-bearing mango cultivars.

5. Conclusion

Based on the results we conclude that flowering behavior of mango cultivars differ significantly. Dusehri, Late Retaul, Sansation and Sufaid Chaunsa took maximum flowering on old shoots while Azeem Chaunsa, Kala Chaunsa, Langra, Sindhri and A. Retaul on new shoots. This novel work will help in devising mango crop's varietal-specific management system, which paves the way for mango's quality and yield enhancement. In return, the country's export potential can grow exponentially. The study may be fruitful in demarcating the harvesting season of mango crop and may also be helpful in targeting several breeding objectives.

6. Conflicts of Interest:

The authors declare no conflict of interest.

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