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Effect of Plant Growth Habit and other Fruit Quality Traits on TSS and Average Fruit Weight in Advanced Breeding Lines of Muskmelon (*Cucumis melo* L.)

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Abstract

Muskmelon (*Cucumis melo* L.) is one of the most diversified (including growth habit trait) species among the members of the Cucurbitaceae family. The fruit is valued for attractive shape, size, flavour, flesh colour and sweetness. For increased acceptability by farmers and consumers, high yielding cultivars with consumer preferred fruit quality traits are desirable. An investigation was carried out to study the influence of plant growth habit and other end user preferred quality traits *viz.,* fruit shape, flesh colour and fruit cavity size on commercially important traits *viz.,* Total Soluble Solids (TSS) and average fruit weight in muskmelon during 2021 rainy season at experimental plots of Namdhari Seeds Pvt. Ltd., Itakudibbanahalli, Karnataka, India. Seventy-two advanced breeding lines (ABLs) were grouped into different classes based on different plant growth habit (3), fruit shape (4), flesh colour (4) and fruit cavity size (3). Trait means of different classes of ABLs were statistically compared for TSS and average fruit weight. Non-significance of means of plant growth habit and fruit cavity size classes for TSS and average fruit weight indicated lack of influence of these traits on TSS and average fruit weight. On the contrary, significant mean differences of four different classes of fruit shape and flesh colour for TSS and average fruit weight suggested prevailing influence of these quality traits on TSS and average fruit weight.

Keywords : Muskmelon, ABLs, Fruit shape, Flesh colour, Fruit cavity size

Muskmelon (*Cucumis melo* L.; 2n = 2x = 24) is one of the most economically important species of the Cucurbitaceae family. It is the most diversified species of the genus *Cucumis* and this variability is reflected at morphological (including growth habit), physiological and biochemical (including TSS) traits (Whitaker and Davis, 1962; Kirkbride, 1993 and Burger *et al*., 2003) and at molecular level (Stepansky *et al*., 1999; Mliki *et al*., 2001; Akashi *et al*., 2002 and Monforte *et al*., 2003). Muskmelon is believed to be originated in East Africa and subsequently diversified into Asia from Mediterranean Sea to Eastern Asia. India is regarded as secondary centre of origin of muskmelon. In India, muskmelon is considered as commercially important cucurbit, widely grown in Uttar Pradesh, Rajasthan, Punjab, Bihar and some parts of Andhra Pradesh, Tamil Nadu and Karnataka mainly for dessert purpose. In a tropical country like India, muskmelon is considered as best thirst quencher during hot summer. Melon fruit is one of the most valued summer fruits because of its high nutritive and medicinal value. It is a good source of vitamin A, vitamin C, carbohydrates and energy (Chakrabarti *et al*. 2001). In addition to this, it has many health promoting benefits. Fruit juice has cooling effect and also acts as a demulcent and diuretic drink. It is also good for eye and skin health, also is a natural remedy for dyspepsia since it is having more of water and fibre content.

There are several types or botanical groups of melon and the recent classification has been proposed by Pitrat *et al.* (2000). Accordingly, the sweet melons belong to the Cantalupensis (Cantaloupe), Reticulatus (Muskmelon), Inodorous (Casaba) and Makuwa groups and the non-sweet, generally long-fruited melons belong to the Chate, Flexuosus and Conomon groups. *Cucumis melo* shows extreme genetic variation for fruit traits such as shape, size, presence of netting, sutures and grooves, flesh colour, sweetness, fruit cavity size, consistency, acidity, aroma and sugar composition. Muskmelon being a dessert fruit, quality parameters like TSS, flesh colour, fruit shape and flesh texture are important ones. However, a common driving point across different market segments of muskmelon is high sugar content and pleasant flavour. Growth habit is a plant architectural trait and muskmelon exhibits different plant growth habits. Variability provides an intriguing subject for investigations into the genetic, biochemical and molecular bases of fruit appearance and quality. Considering high diversity of melon, breeding programs should focus on more than one melon type. A good genotype irrespective of the growth habit must have high yield, market-standard size, small internal cavity and high soluble solids content (Nunes *et al*., 2005).

We hypothesize that TSS and average fruit weight are not affected by plant growth habit whereas other important fruit quality traits *viz.,* fruit shape, flesh colour and fruit cavity size have influence on TSS and average fruit weight.

Material and Methods

The experimental material consisted of 72 ABLs that have been previously derived from crosses involving genotypes procured from different countries of the world (Fig. 1). Variation exhibited by ABLs with respect to distinct growth habit, fruit shape, flesh colour and fruit cavity size is detailed in Table 1.

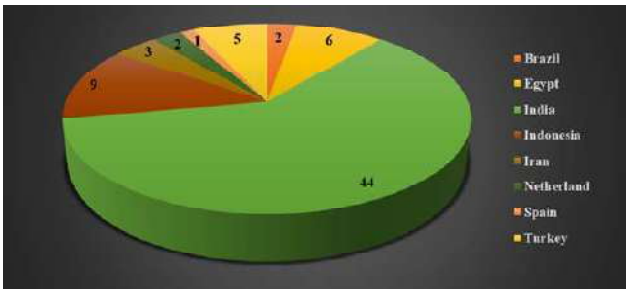

Fig. 1: ABLs classified based on country of collection of parental lines and involved in deriving them

ABLs were evaluated during 2021 rainy season in alpha lattice experimental design with two replications at the experimental plots of Namdhari Seeds, Pvt. Ltd., at Itakudibbanahalli, Tumkur. The experimental site is located at 13.8162° N, 77.3166° E and 787m above mean sea level. Initially, seedlings of 72 ABLs were raised in nursery with all plant protection measures. Fifteen days old seedlings were transplanted to experimental field with a spacing of 1.5m between rows and 0.5m between plants. All recommended package of practices were followed to raise a healthy crop.

Data Recording and Statistical Analysis

Out of twelve plants maintained in each genotype and in each replication, randomly selected six plants were

Table 1

List of morphological traits and their corresponding distinct classes exhibited by 72 ABLs in muskmelon

Trait	Class			
	1	2	3	4
Growth habit	Compact	Bushy	Open	-
Fruit shape	Round	Oval	Elongated globe	Obovate
Flesh colour	Green	Light green	White	Salmon
Fruit cavity size	Small	Medium	Large	-

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tagged, excluding plants at borders. Data were recorded on plant growth habit at vegetative stage (40 DAS). While observations on three qualitative traits *viz.,* fruit shape, flesh colour and fruit cavity size and two quantitative traits *viz.,* TSS (%) and average fruit weight (kg fruit-^{1}) was recorded at fruit maturity stage (110 DAS) (Table 2). Average fruit weight and TSS of ABLs belonging to three growth habit classes, four fruit shape classes, four flesh colour classes and three fruit cavity size classes were computed.

Statistical significance of differences among trait means of average fruit weight and TSS among three growth habit classes *viz.,* (1) Compact, (2) Bushy and (3) Open type, four fruit shape classes (1) Round, (2) Oval, (3) Elongated globe and (4) Obovate, four flesh colour classes (1) Green, (2) Light green, (3) White and (4) Salmon and three fruit cavity size classes, (1) Small, (2) Medium and (3) Large (https://plantauthority.gov.in/crop-dus-guidelines), was examined using F-test (Fisher, 1950). Non significance and otherwise of F tests indicate lack of influence and significant influence of average fruit weight and TSS respectively.

Results and Discussion

In the present investigation, we were able to classify advanced breeding lines into different classes of plant growth habit, fruit shape classes, flesh colour classes and fruit cavity size classes. Thirty-eight of the 72 ABLs exhibited compact type growth habit, 14 of bushy type and 22 showed open type growth habit at their vegetative phase (Fig. 2A). With respect to fruit shape out of 72 lines 39 ABLs were produced round shape fruits, 24 produced oval, five ABLs produced elongated globe shape fruits and four ABLs produced obovate shape fruits (Fig. 2B) Flesh colour exhibited by advanced breeding lines were Green (12), Light green (37), White (7) and Salmon (16), (Bokashi, 1992; Malik, 2014), (Fig. 2C). More than half of the ABLs *i.e.,* 56 lines showed medium fruit cavity size, 14 showed smaller cavity size and very few that is only two lines recorded larger fruit cavity size (Fig. 2D).

The results of ANOVA indicated prevalence of significant variability ($p<0.001$) among advanced breeding lines for TSS and average fruit weight. This result, by and large suggested existence of substantial

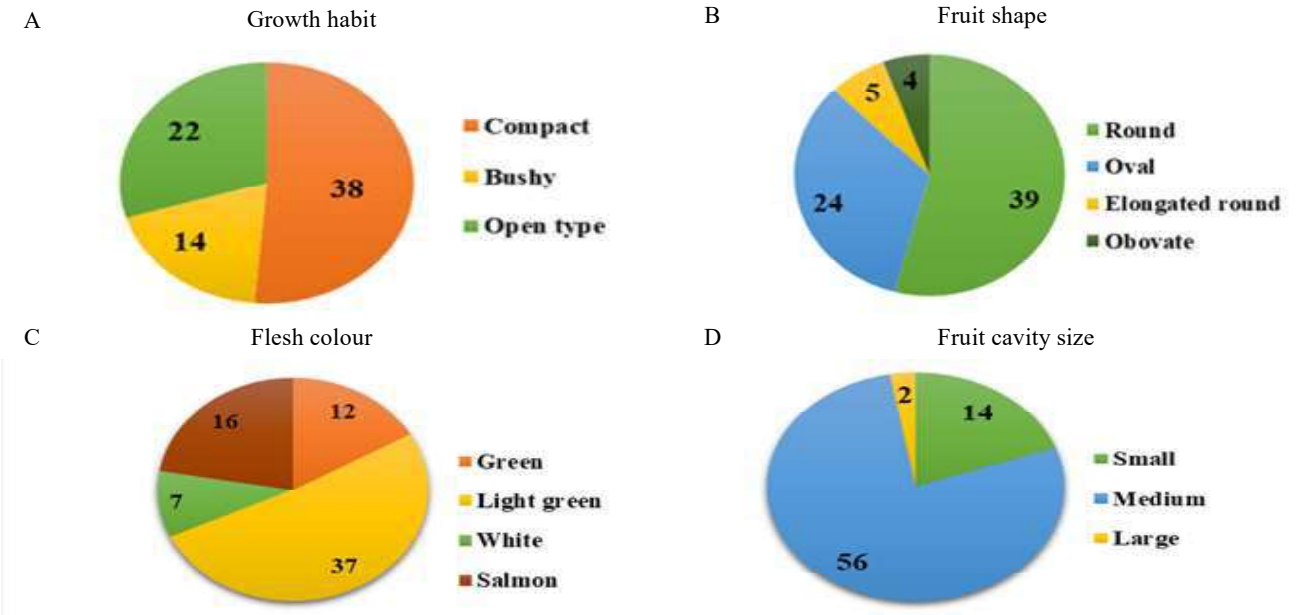

Fig. 2 : Distribution of 72 ABLs grouped under different classes of (A) plant growth habit (B) fruit shape (C) flesh colour (D) fruit cavity size

TABLE 2

Description of fruit traits of muskmelon lines used in the study

Trait	Description	Method of Observation	References
Growth Habit	Growth habit is a plant architectural trait in muskmelon exhibiting different kinds.	Recorded growth habitat at vegetative phase (40 DAS) on visual basis	-
Fruit shape	Fruit shape is one of the most important physical properties and consumer preference parameter. Consumers prefer fruits of equal weight and uniform shape. Classification of ABLs based on fruit shape is vital in meeting quality standards and increasing market value. It is also helpful in planning packaging, transportation and marketing operations and also may provide an optimum packaging configuration	Shape of the fruit in longitudinal section was observed visually	Bokashi, 1992; Kandasamy, 2004; Shivapriya and Sudhakar, 2014
Flesh colour	The development of flesh colour is an ethylene dependent trait. Flesh colour is an important trait from the consumer point of view. Expression of colour in the fruit flesh is conditioned by its carotenoid type and concentration which in turn is influenced by genetic and environmental factors.	Flesh colour of the fruit was observed visually at Fruit maturity stage (110 DAS)	Bokashi, 1992; Malik, 2014
Fruit cavity size	Small seed cavity is a desirable character in muskmelon as it decides fruit flesh quantity.	Cavity size was measured using a centimetre scale after making a transverse cut across the melon fruit.	Ahmed, 2009
Total soluble solids (TSS)	TSS content is a reliable indicator of quality. TSS can be measured quickly by squeezing juice from the melon fruit flesh on a refractometer. Breeders routinely use this method to screen large quantities of fruits for sweetness. Expected TSS of melon fruit flesh is at least 9% to be considered as acceptable. Large genetic variability observed among melon germplasm for TSS and sugar concentration is accounted mainly for differences in the levels of sucrose.	Flesh of five fruits in each ABL was crushed separately and a drop of juice was placed on Hand Refractometer (0-32%) and the reading was noted and expressed in percentage.	Hubbard *et al.*, 1989; Stepansky *et al.*, 1999b; Burger, 2000; Rodriguez, 2002
Average fruit weight (kg)	Average fruit weight is of economic importance as it is directly proportional to fruit yield vine^{-1}	Weight of randomly chosen 3 individual fruits harvested at maturity from each ABL was recorded. Mean fruit weight was calculated and expressed in kilograms fruit^{-1}.	Ibrahim, 2014

TABLE 3

Analysis of Variance among advanced breeding lines for TSS (%) and average fruit weight (kg) *

Source of variation	Degrees of freedom	TSS (%)	P value	Average fruit weight (kg)	P value
Replication	1	1.0000		0.22158	
Genotype	71	20.0266 ***	2×10^{-16}	0.76928 ***	2×10^{-16}
Block	16	2.1011		0.05893	
Residuals	55	1.2070		0.06356	

Significant @ P=0.05, ** Significant @ P=0.01, *** Significant @ P=0.001

variability among ABLs for commercially important traits such as TSS and average fruit weight in muskmelon (Table 3). These results are in agreement with those of Prasad (2004) and Sushmitha *et al*. (2017).

TSS and average fruit weight among ABLs were comparable among plants bearing different plant growth habit classes (compact, bushy and open type) which supports our hypothesis (Table 4). Similarly, there were no significant differences among ABLs bearing different fruit cavity sizes (Small, Medium and Large) for TSS and average fruit weight which is contrary to the hypothesis we made (Table 5) as indicated by 'F' test. These results suggest lack of either desirable / undesirable effects in favour of any plant growth habit and fruit cavity size concerning TSS and average fruit weight.

On the contrary ABLs differing for four different fruit shape classes (Round, Oval, Elongated globe and Obovate) exhibited significant influence on TSS and average fruit weight (Table 6) and the results are in agreement with those of Potekar, 2014. TSS was higher in case of round shape fruits. While, elongated round shaped fruits expressed higher average fruit weight (Table 6). Similarly, there were significant differences among ABLs with different fruit flesh colour for TSS and average fruit weight. Plants having salmon flesh colour showed higher TSS and that of white flesh registered low TSS (Table 7), (Fageria and Luthra, 2005).

Implications in Breeding Muskmelon

Muskmelon being a dessert fruit, quality parameters like flesh colour, fruit shape and total soluble solids are important. It is possible to develop new muskmelon cultivars with desired combination of both farmer and end user preferred traits. We believe that round fruits with salmon colour flesh are likely to be preferred by consumers, as round and salmon

TABLE 4

Relationship of plant growth habit with TSS (%) and average fruit weight (kg) among advanced breeding lines of muskmelon

Growth habit	Mean		Source of variation	Degrees of freedom	Mean sum of squares		P value
	TSS (%)	Average fruit weight (kg)			Total soluble solids (TSS) (%)	Average fruit weight (kg)	
Compact			Between Groups	2	8.8482	0.4121	TSS (%) 0.4191
Bushy	10.98	1.35					
Open	9.71	1.52					
type	10.93	1.58	Within Groups	69	10.0470	0.3931	Average fruit weight (kg) 0.3560

TABLE 5

Relationship of fruit cavity size with TSS (%) and average fruit weight (Kg) among advanced breeding lines of muskmelon

Fruit cavity size	Mean		Source of variation	Degrees of freedom	Mean sum of squares		P value
	TSS (%)	Average fruit weight (kg)			Total soluble solids (TSS) (%)	Average fruit weight (kg)	
Small	9.03	1.61	Between Groups	2	30.7311	0.2170	TSS (%) 0.0830
Medium	11.12	1.43					
Large	11.25	1.3	Within Groups	69	9.5866	0.3894	Average fruit weight (kg) 0.5753

TABLE 6

Relationship of fruit shape with TSS (%) and average fruit weight (kg) among advanced breeding lines of muskmelon

Fruit shape	Mean		Source of variation	Degrees of freedom	Mean sum of squares		P value
	TSS (%)	Average fruit weight (kg)			Total soluble solids (TSS) (%)	Average fruit weight (kg)	
Round	11.72	1.41	Between Groups	3	33.5115 **	1.2009 *	TSS (%) 0.01
Oval	9.12	1.55					
Elongated globe	10.9	1.62	Within Groups	68	8.9766	0.3927	Average fruit weight (kg) 0.04
Obovte	10.37	1.24					

* Significant @ P=0.05, ** Significant @ P=0.01

TABLE 7

Relationship of flesh colour with TSS (%) and average fruit weight (Kg) among advanced breeding lines of muskmelon

Flesh colour	Mean		Source of variation	Degrees of freedom	Mean sum of squares		P value
	TSS (%)	Average fruit weight (kg)			Total soluble solids (TSS) (%)	Average fruit weight (kg)	
Green	9.79	1.55	Between Groups	3	80.9436 **	1.4231 *	TSS (%) 2.7×10^{-6}
Light green	9.76	1.64					
White	9.57	1.34	Within Groups	68	6.8840	0.3388	Average fruit weight (kg) 0.008
Salmon	14.15	1.04					

* Significant @ P=0.05, ** Significant @ P=0.01, *** Significant @ P=0.001

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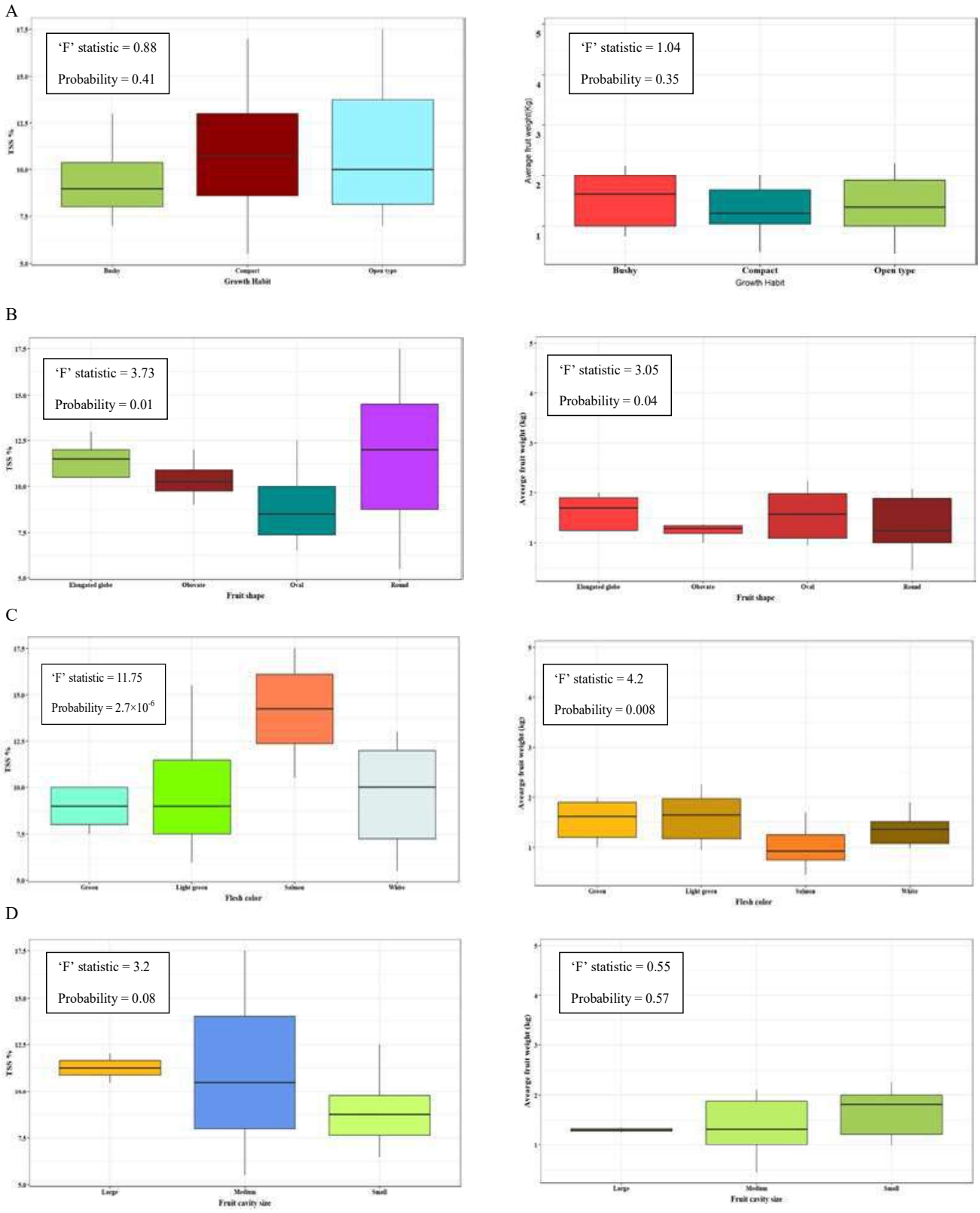

Fig. 3 : Box-Whisker plots depicting the effect of (A) growth habit (B) fruit shape (C) flesh colour (D) fruit cavity size on TSS and average fruit weight in 72 Advanced Breeding Lines (ABLs) of muskmelon

colour fleshed fruits have higher TSS and have market standard size. Understanding the variability for commercially important traits among ABLs with different fruit shape and fruit flesh colour classes is expected to enable and enhance the pace and efficiency of developing high yielding muskmelon cultivars with desired combinations of quality traits.

Our study suggested that fruit quality traits such as fruit shape and fruit flesh colour are consumer preferred traits have significant effect on TSS and average fruit weight. On the contrary, plant growth habit and fruit cavity size has no influence on TSS and average fruit weight in muskmelon. As of Indian market is concerned, melon fruit with round shape and salmon flesh colour is more preferrable in comparison to other flesh colour and fruit shape (Commercial melon breeder, Namdhari seeds, Pvt. Ltd., Bidadi, Bangalore). Hence from the study lines with preferred traits can be utilized in breeding program to affect the crosses to develop particular hybrids for Indian market. In middle east and European countries green fleshed fruits are of consumer preference (Karchi *et al*., 2000) and long melons are preferred in India and Pakisthan as their tender fruits are eaten raw. Hence, according to the needs breeder's objectives specificity we can utilize them in developing cultivars with desired combination of fruit traits.

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