*SKUAST Journal of Research* 25(2): 207-213; (2023)
(*10.5958/2349-297X.2023.00028.4*); NASS rating: 4.17

**Research Paper**

# Physico-chemical and sensory evaluation of fruit quality of introduced exotic apple varieties under high density plantation in Kashmir Valley

Rafiya Mushtaq[1*], Ashaq Pandit[1], M.A. Mir[1], Ab Raouf Malik[1], Ab Waheed Wani[2], M.K. Sharma[1], Nowsheen Nazir[1]

[1]*Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India;* [2]*Lovely Professional University, Punjab*
*e-mail: *rafiazargar.25@gmail.com*

(Received February 03, 2023; accepted May 11, 2023)



ABSTRACT

**This study investigated the performance of various exotic apple varieties grafted on M9T337 rootstock under high density orcharding system. Plant material was imported from a private nursey GRIBA Italy. The study was carried out under temperate conditions of J&K (India) at the experimental field of SKUAST-Kashmir. In the present investigation, the following varieties were studied: Super Chief Sandidge, Gala Red Lum, Fuji Zhen Aztec, and Golden Clone B. The physico-chemical characteristics based on lab investigation of fruits including physical characteristics (fruit weight, fruit length, fruit diameter, L/D ratio, fruit firmness, specific gravity, and no. of seeds) and chemical characteristics (TSS, total titratable acidity, TSS/acid ratio, ascorbic acid, total sugars, and juice content) were followed during the study. Sensory evaluation through a panel of judges was also carried out for various qualitative characteristics (colour, aroma, taste, and flavor). The results showed statistically significant differences among the different varieties. The fruit weight, flesh firmness, and specific gravity were within the range of 157.62-193.99 g, 7.16-8.85 Kg/cm$^2$, and 1.7-1.37 respectively. Similarly, some of the chemical characteristics like TSS, titrable acidity, and total sugars ranged from 11.37-14.12 °Brix, 0.20-0.38 per cent, 9.25-11.37 per cent respectively. The overall results indicate that all the introduced apple varieties are characterized by different quality characteristics and hence can be recommended to further evaluation and cultivation**

**Key words:** Apple, evaluation, high density, Kashmir, quality, sensory

The apple has been grown in Europe and Asia for a very long time and is the most common fruit that grows in temperate climates. Because of the apple's genetic diversity, appropriate varieties have been chosen for diverse environments, and new varieties are still being developed to spread apple culture in both colder and warmer places (Buiteveld *et al.* 2021). In comparison to the wild apples from which they evolved over many years, the commercial cultivars that are now farmed are significantly enhanced. The contemporary apple may have benefited from the evolution of several species. The state of Jammu and Kashmir is blessed with natural agro-climatic conditions, and there is a tremendous amount of potential for horticulture development (Khursheed *et al.* 2020). Over the past few decades, the state's horticultural sector has advanced quickly. However, the productivity and quality of apples are still far below what advanced countries are producing (Wani *et al.* 2021). The reason being the monoculture of varieties, use of seedling origin rootstock and commercial planting system, etc.

The commercial delicious group's production has declined in the past some years as new strains have become more prevalent, changing the apple selection globally (O'Rourke, 2017). The development of new apple plantations is a reliable predictor of the future trend in apple production. In the major apple-producing regions of the world, new apple plantations are being done using improved varieties including Fuji, Gala, Braeburn, Jonagold, Pink Lady, Honeycrisp, etc (Gallardo, 2017). Traditional apple varieties are gradually being phased out over the world, allowing for the emergence of new, high-quality cultivars (O'Rourke, 2003). Because of

their distinctive flavours and improved quality characteristics, more recent apple cultivars are gaining popularity.

Due to the use of dwarfing and precocious rootstocks during the past 60 years, apple orchard systems have shifted from traditional production systems with huge trees in broad spacing arrangements (70–100 trees/ha) to high-density orchards with smaller closely spaced trees (1000–6000 trees/ha) (Reig *et al*. 2019). The crucial factor in the striking improvements in tree size, spacing, and early production has been dwarfing rootstocks (Robinson, 2011). The most significant dwarfing rootstocks in the world have been those in the Malling series (M.9 and M.26) (Robinson, 2003). Fruit's consumer appeal is influenced by both visual and non-visual qualities, such as firmness (texture), taste, aroma, and flavour, as well as visual qualities including size, uniformity, colour, and freshness (Jaeger *et al.* 2018). Firmness and colour among these qualities seem to be the ones that consumers value the most (Awad and de Jager, 2002; Aaby *et al.* 2002). Unfortunately, it's challenging to evaluate food quality objectively. There is little association between analytical measurements of soluble solids (%SS), titratable acidity (TA), firmness and sensory impressions of sweetness, sourness, and texture (Bourne, 1979). Therefore, in addition to evaluating physico-chemical traits, it is vital to examine the fruit quality of various cultivars based on sensory fruit consumer preference tests.

Change to new varieties with great production potential and strong marketability is essential for the temperate region's apple industry to thrive. Varieties need to be identified which meet our climatic requirements (Mushtaq *et al.* 2019). In addition, in the years to come, we need to shift to the zonalization of apples (i.e, identify a particular variety suited to a particular area based on suitability). All this is possible if we continue to study the new varieties which are acceptable for the larger part of the world consumer and assess their suitability in our valley. Keeping in view, the study was conducted to evaluate exotic apple varieties for various quality attributes based on the physico-chemical characteristics and sensory attributes of these varieties.



## MATERIALS AND METHODS

The varieties under study were introduced from a private nursery GRIBA from Italy and planted in the experimental farm of the SKUAST Kashmir. The exotic varieties were Super Chief Sandidge, Gala Red Lum, Fuji Zhen Aztec, and Golden Clone B grafted on M9T337 rootstockat a spacing of 3x1.5m. The plant material was two year old and had at least five feathers. During the study, all of the trees received the same cultural practices as per the SKUAST-Kashmir package. Five replications and two trees per treatment were used in the randomized complete block design (RCBD) of the experiment. The following parameters were observed during the course of study: fruit weight on monopan balance; fruit length, fruit diameter, and L/D ratio with the help of vernier caliper; fruit firmness with Effegi penetrometer model; specific gravity with the help of water displacement technique; no. of seeds; TSS with hand refractometer. Total titratable acidity, TSS/acid ratio, ascorbic acid, total sugars, and juice content were determined as per the methodology given by A.O.A.C., (1980). A taste panel of experts were selected based on their consistent assessment of samples of experimental apples. The panelists received four coded samples-one from each variety-during each tasting session. Each sample was made up of a longitudinal section of four peeled apples. The panelists were asked to rank the fruits on a scale of 1-4 for consumer acceptability (physical appearance, colour, taste, flavour, texture, firmness, and overall quality) (Williams and Carter, 1977).

| | | |
|---|---|---|
| 1 | = | Poor |
| 2 | = | Fair |
| 3 | = | Good |
| 4 | = | Excellent |

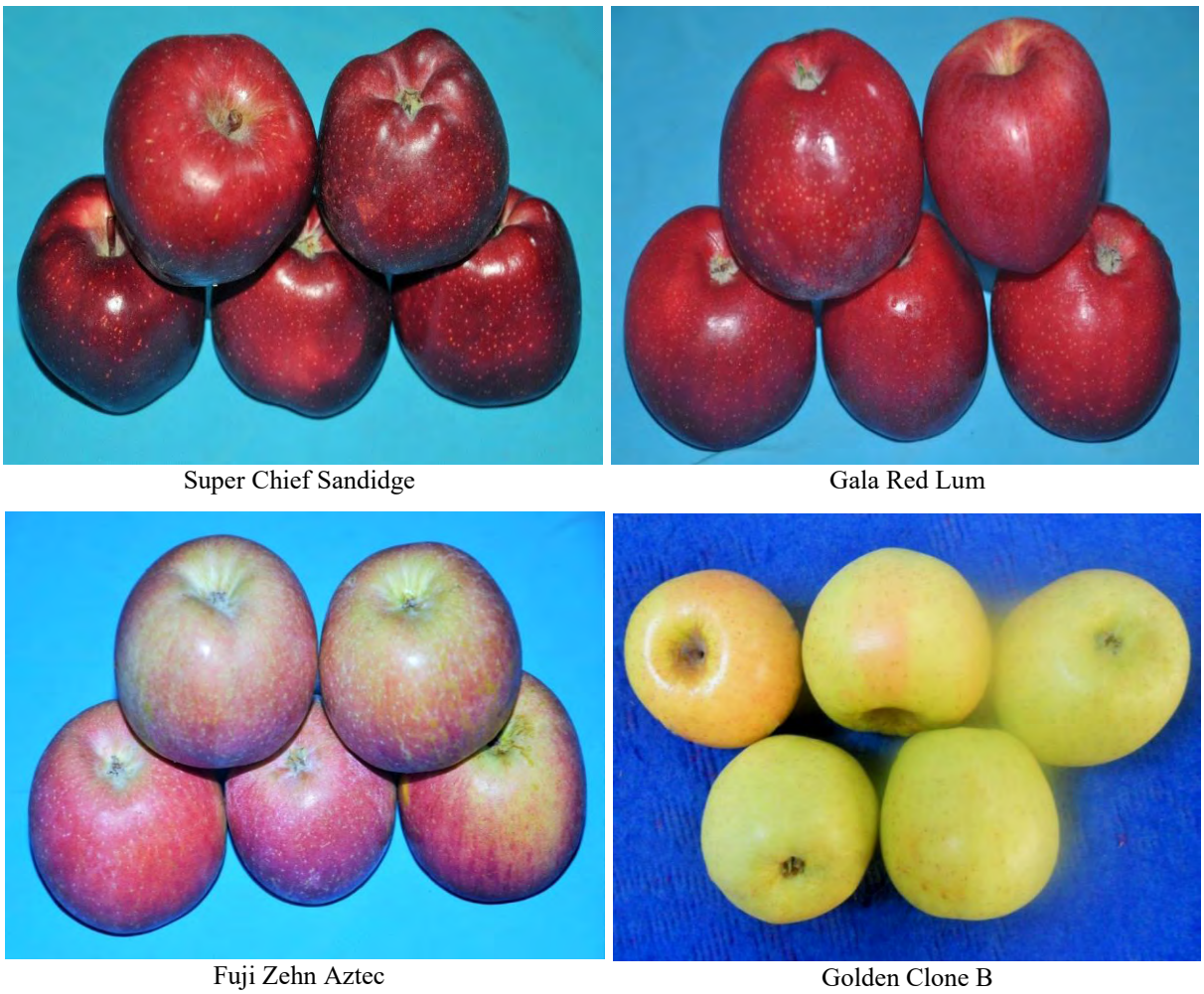
The observations recorded during the investigation were subjected to statistical analysis as per the method of ‘Analysis of Variance’ (Fisher, 1950). The significance and non-significance of treatment effects were judged with the help of the software OP stat (Sheoran et al., 1998). The significant difference in the means was tested against the critical difference at the 5 percent level. Data obtained from the judges for sensory evaluation were subjected to a Chi-square test to test the level of significance.

## RESULTS AND DISCUSSION

The data recorded in the investigation reflected that significant differences were observed in the physical and chemical characteristics of fruits. The maximum fruit weight was observed in the variety Super Chief Sandidge (193.99 g) while the minimum was in Fuji Zhen Aztec (157.62 g). Given that the fruits with seeds and endosperm are the ones where gibberellic acid synthesis takes place (Bareke, 2018), the difference in fruit

weight may be caused by varietal characteristics and the presence of seeds in the fertilized fruits. According to Luchi (1987), phenological variations play a significant role in the size of the fruit because fruits from buds with earlier bursts may acquire significant amounts of nutrients and photosynthates. The fruits of Super Chief Sandidge showed a maximum length (65.69 mm) and a minimum length was observed in Fuji Zhen Aztec (56.55 mm). The maximum diameter of fruits was observed in Super Chief Sandidge (74.35 mm) and the minimum in Gala Red Lum (69.87 mm). Weber (2001) asserts that the volume of the tree and the number of fruits produced per tree are directly correlated with fruit size. The apple shape is a crucial aspect of aesthetic appeal, particularly in marketplaces (Budiono *et al.* 2021), where some apple shapes are not acceptable for marketing. The fruits of the Golden Clone B variety had a round form and an L/D ratio of 0.90, whereas the fruits of the variety Fuji Zhen Aztec had a flat shape and an L/D ratio of 0.77. (Fig.1). According to Currie *et al.* (2000), L/D ratio is a particularly popular pattern to describe apple shape. The findings of Janick *et al.* (1996), who claimed that the shape of an apple can range from very flat, oblate, to oblong, was supportive of these findings. The findings of Madial *et al.* (2010), which claimed that Fuji produces more fruits that are flattened on average by 0.89, provided additional support for our research findings. The highest specific gravity was observed in variety Golden Clone B (1.37) and it was lowest in Gala Red Lum (1.02). The specific gravity of fruit is governed by many factors including the mass, volume of fruit, compactness of cells, and intercellular spaces between the cells (Khan *et al.* 2019). The variation can also be the varietal difference, crop load, a vigour of the tree, fruit leaf ratio, and difference in both the number and size of cells.





Super Chief Sandidge | Gala Red Lum

Fuji Zehn Aztec | Golden Clone B

**Fig. 1 : Exotic apple varieties at harvest**

The fruit flesh firmness (Kg/cm$^2$) and the number of seeds per fruit were recorded maximum in Golden Clone B (8.85 Kg/cm$^2$) and Super Chief Sandidge (9.60), respectively. However, the minimum fruit flesh firmness (7.16 Kg/cm$^2$) and the number of seeds (7.56) were observed in Gala Red Lum and Fuji Zhen Aztec, respectively (Table 1). The significant difference between the cultivars in the fruit flesh firmness and number of seeds per fruit may be due to differences in fruit size specific to each variety, number of fruits, number of seeds peculiar

to each cultivar, and stage of maturity of cultivars. These reports align with the results of Sotiropoulos (2013) who observed the fruit firmness in a similar range in the cultivar Fuji Kiku 8. These findings are supported by several workers like Fallahi *et al.* (1994) who observed marked differences in the physical quality parameters of cultivars due to varietal characteristics. The highest juice content (71.54%) and total soluble solids (14.12 ºBrix) were recorded in Gala Red Lum and Super Chief Sandidge, respectively and the lowest juice content (65.23%) and TSS (11.37 ºBrix) both in Golden Clone B. The remarkable difference in the juice content and total soluble solids of fruits may be due to varietal characteristics or it could be due to the size of fruits as well as the number of fruits on a tree. These characteristics are also influenced by climatic and moisture availability during the growing season.

**Table 1: Physical characteristics of exotic apple varieties under high density plantation**

| Variety | Fruit weight (g) | Fruit length (mm) | Fruit diameter (mm) | Length/ diameter ratio | Fruit firmness (Kg/cm$^2$) | Number of seeds/ fruit | Specific gravity |
|---|---|---|---|---|---|---|---|
| Super Chief Sandidge | 193.99 ±9.11 | 65.69 ±0.90 | 74.35 ±0.87 | 0.87 ±0.01 | 7.39 ±0.14 | 9.60 ±0.24 | 1.14 ±0.04 |
| Gala Red Lum | 159.45 ±5.24 | 62.69 ±0.85 | 69.87 ±0.67 | 0.89 ±0.005 | 7.16 ±0.52 | 9.00 ±0.54 | 1.02 ±0.03 |
| Fuji Zhen Aztec | 157.62 ±3.53 | 56.55 ±0.27 | 72.60 ±0.65 | 0.77 ±0.009 | 8.82 ±0.10 | 7.56 ±0.05 | 1.33 ±0.05 |
| Golden Clone B | 159.70 ±4.21 | 64.98 ±1.03 | 71.12 ±0.49 | 0.90 ±0.10 | 8.85 ±0.10 | 9.60 ±0.24 | 1.37 ±0.11 |
| **CD (p≤ 0.05)** | **18.76** | **2.46** | **2.23** | **0.03** | **0.83** | **1.02** | **0.22** |

In the present study, the highest ascorbic acid content was observed in Golden Clone B (7.86 mg/100g pulp) and lowest in Super Chief Sandidge (5.82 mg/100g pulp). The TSS/acid ratio is a key characteristic to determine the taste, texture, and feel of fruit segments. It is the sugar/acid ratio that contributes to characteristic flavor. This ratio was found highest in the variety Super Chief Sandidge (70.34) and lowest in Golden Clone B (65.23). The variation among varieties may be due to varietal differences, and differences in the sugar content of varieties. The highest titrable acidity (0.38%) and total sugars (11.37%) were noticed in Golden Clone B and Super Chief Sandidge respectively and the lowest values (acidity 0.20% and total sugars 9.25%) were observed in Super Chief Sandidge and Golden Clone B (Table 2).

**Table 2: Chemical characteristics of exotic apple varieties under high density plantation**

| Variety | TSS (°Brix) | Acidity as malic acid (%) | TSS/acid ratio | Ascorbic acid (mg/100 g pulp) | Total sugar (%) | Juice content (%) |
|---|---|---|---|---|---|---|
| Super Chief Sandidge | 14.12±0.17 | 0.20 ±0.08 (1.09) | 70.34±2.67 | 5.82±0.14 | 11.37±0.19 (3.51) | 70.51±0.05 (8.45) |
| Gala Red Lum | 13.42±0.14 | 0.30 ±0.01 (1.14) | 44.96±1.68 | 5.24±0.09 | 10.3±0.09 (3.36) | 71.54 ±0.11 (8.51) |
| Fuji Zhen Aztec | 12.40±0.23 | 0.32 ±0.14 (1.14) | 39.03±1.65 | 6.78±0.05 | 9.84±0.02 (3.29) | 67.41±0.02 (8.27) |
| Golden Clone B | 11.37±0.19 | 0.38 ±0.06 (1.17) | 29.78±0.48 | 7.86±0.03 | 9.25±0.09 (3.20) | 65.23±0.10 (8.13) |
| **CD (p≤ 0.05)** | **0.58** | **0.03** (0.01) | **5.67** | **0.28** | **0.05** (0.05) | **0.27** |

Values within parentheses are square root transformed values

Apples have a relatively high acid content compared to other fruits (Vangdal, 1985, Huang *et al.* 2018). Consumer acceptability is closely related to acid content which varies with the cultivar and forms an important

standard of maturity (Wills *et al.* 1980). Our results are in consequence with the findings of Blanpied and Blak (1977) and Drkenda *et al.* 2021 who reported that the delicious group of apples has a much lower titrable acidity at maturity than most other apple cultivars. In the present study sensory evaluation (flavour, aroma, taste and colour) and overall acceptability of fruit were recorded through the panel of judges. All the judges observed the variety Super Chief Sandidge and Golden Clone B as good in terms of their flavor and variety Super Chief Sandidge as excellent in its colour, however, the variety Fuji Zehn Aztec was ranked fair in colour by 60 per cent of judges. (Table 3).

**Table 3: Colour and flavour characteristics of exotic apple varieties under high density plantation**

| Variety | Colour | | | | Flavour | | | |
|---|---|---|---|---|---|---|---|---|
| | Poor | Fair | Good | Excellent | Poor | Fair | Good | Excellent |
| Super Chief Sandidge | 0 (0.0) | 0 (0.0) | 0 (0.0) | 15 (100) | 0 (0.0) | 0 (0.0) | 15(100) | 0 (0.0) |
| Gala Red Lum | 0 (0.0) | 0 (0.0) | 12(80) | 3 (20) | 0 (0.0) | 3 (20) | 6 (40) | 6 (40) |
| Fuji Zhen Aztec | 0 (0.0) | 6 (40) | 9 (60) | 0 (0.0) | 0 (0.0) | 3 (40) | 9 (60) | 0 (0.0) |
| Golden Clone B | 0 (0.0) | 3 (20) | 12(80) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 15(100) | 0 (0.0) |
| **Chi square** | 18.90 | | | | 11.46 | | | |
| **p-value** | 0.004 | | | | 0.075 | | | |

Values within parenthesis are percentages

The apple skin colour plays an important role in apple fruit trading because customers prefer red-colored apples and thus the cost-effectiveness of red skin apples is greater (Dar et al., 2019). Fruit skin colour is determined by carotenoids, chlorophyll, and anthocyanin (Lancaster, 1992). Our results were supported by the findings of Unuk *et al.* (2012) who reported that the colour development in Fuji apples was considerably slower, with a much larger variation in the stage of development. Variety Super Chief Sandidge stands good in terms of its aroma while the variety Fuji Zhen Aztec showed a fair aroma. In terms of taste, Super Chief Sandidge scored the highest rank (Table 4).

**Table 4: Aroma and taste characteristics of exotic apple varieties under high density plantation**

| Variety | Aroma | | | | Taste | | | |
|---|---|---|---|---|---|---|---|---|
| | Poor | Fair | Good | Excellent | Poor | Fair | Good | Excellent |
| Super Chief Sandidge | 0 (0.0) | 0 (0.0) | 12 (80) | 3 (20) | 0 (0.0) | 0 (0.0) | 6 (40) | 9 (60) |
| Gala Red Lum | 0 (0.0) | 3 (20) | 9 (60) | 3 (20) | 0 (0.0) | 0 (0.0) | 9 (60) | 6 (40) |
| Fuji Zhen Aztec | 0 (0.0) | 9 (60) | 6 (40) | 0 (0.0) | 0 (0.0) | 6 (40) | 6 (40) | 3 (20) |
| Golden Clone B | 0 (0.0) | 6 (40) | 9 (60) | 0 (0.0) | 0 (0.0) | 3 (20) | 6 (40) | 6 (40) |
| **Chi square** | 6.0 | | | | 5.0 | | | |
| **p-value** | 0.42 | | | | 0.54 | | | |

Values within parenthesis are percentages

The variations may be purely the genetic and varietal characteristics. The overall acceptability was observed as highest in Super Chief Sandidge and lowest in Fuji Zhen Aztec (Table 5). The physico-chemical characteristics were seen positively correlated with the sensory evaluation of the studied varieties. Overall, all the varieties exhibited varied and good quality characteristics and hence may be recommended for cultivation and further evaluation in the region to increase high-density farming.

**Table 5: Overall acceptability of exotic apple varieties under high density plantation**

| Variety | Poor | Fair | Good | Excellent |
|---|---|---|---|---|
| Super Chief Sandidge | 0 (0.0) | 0 (0.0) | 3 (20) | 12 (80) |
| Gala Red Lum | 0 (0.0) | 0 (0.0) | 9 (60) | 6 (40) |
| Fuji Zhen Aztec | 0 (0.0) | 3 (20) | 9(60) | 3 (20) |
| Golden Clone B | 0 (0.0) | 0 (0.0) | 12 (80) | 3 (20) |
| **Chi square** | | 10.0 | | |
| **p-value** | | 0.125 | | |

Values within parenthesis are percentage

## CONCLUSION

To establish high density orchards in Kashmir, growers must be aware of the varietal spectrum suitable for the region including the quality and yield attributes. Varieties may perform differently based on agro-climatic conditions of the particular region. Therefore, evaluation of varieties especially for quality characteristics is crucial to fetch good market prices. In our study the four varieties evaluated were found to show diverse characteristics in terms of overall quality characteristics based on the physico-chemical and organoleptic evaluation for overall quality. Among the varieties studied Super Chief Sandidge performed first in terms of overall quality. Fuji Zehn Aztec variety showed poor colour than expected or observed in other regions. Gala Red Lum showed good performance in terms of colour, taste and overall acceptability. The varieties can therefore be recommended for further evaluation and ultimate adoption by growers of Kashmir to uplift the adoption of modern high density farming in the region.

## REFERENCES

A.O.A.C. 1980. Methods of Analysis; 14th ed. Association of Official Agriculture Chemists. Washington, D.C; USA 957.

Aaby, K., Haffner, K, Skrede, G. 2002. Aroma quality of Gravenstein apples influenced by regular and controlled atmosphere storage. *Lebensmittel-Wissenschaft und –Technologie,* **35**: 254- 259.

Awad, M.A. and deJager, A. 2002. Influences of air and controlled atmosphere storage on the concentration of potentially healthful phenolics in apples and other fruits. - *Postharvest Biology and Technology,* **27**:53-58.

Bareke, T.J. 2018. Biology of seed development and germination physiology. *Advances in Plants & Agriculture Research,* **8**: pp.336-46.

Blanpied, G.D. and Blak, V.A. 1977. A comparison of pressure tests, acid levels and sensory evaluation of over ripeness in apples. *Hort Science,* **12**:73-74.

Bourne, M.C. 1979. Rupture tests vs. small-strain tests in predicting consumer response to texture. *Food Technology,* **10**: 67-70.

Budiono, S., Purba, J.T., Adirinekso, G.P. and Rajagukguk, W., 2021. Market Growth Strategy through Consumers' Satisfaction, Product Quality and Brand Image: Evidence from Jakarta Indonesia.

Buiteveld, J., Koehorst-van Putten, H.J., Kodde, L., Laros, I., Tumino, G., Howard, N.P., van de Weg, E. and Smulders, M.J., 2021. Advanced genebank management of genetic resources of European wild apple, Malus sylvestris, using genome-wide SNP array data. *Tree Genetics & Genomes*, **17**, pp.1-15.

Currie, A.J., Ganeshanandan, S., Noiton, D.A., Garrick, D., Shelbourne, C.J.A. and Oraguzie, N. 2000. Quantitative evaluation of apple (Malus × domestica Borkh.) fruit shape by principal component analysis of Fourier descriptors. *Euphytica,* **111**: 219- 227.

Dar, J.A., Wani, A.A., Ahmed, M., Nazir, R., Zargar, S.M. and Javaid, K., 2019. Peel colour in apple (Malus× domestica Borkh.): An economic quality parameter in fruit market. *Scientia Horticulturae*, **244**, pp.50-60.

Drkenda, P., Ćulah, A., Spaho, N., Akagić, A. and Hudina, M., 2021. How Do Consumers Perceive Sensory Attributes of Apple? *Foods*, **10**: p.2667.

Fallahi, E., Brenda, R.S., Fellman, K.J., Longstroth, M.A., Colt, M.W. and Ketchie, D.O. 1994. Tree growth and productivity and postharvest fruit quality in various strains of 'Delicious' apple. *Journal of the American Society for Horticultural Science,* **199**: 389-395.

Fisher, M. 1950. Colour atlas of fruit cultivar, pp. 320.

Gallardo, R.K. 2017. The economics of apple production Hildegard Garming, Thünen Institute of Farm Economics, Germany. In *Achieving sustainable cultivation of apples* pp. 509-534. Burleigh Dodds Science Publishing.

Huang, Z., Hu, H., Shen, F., Wu, B., Wang, X., Zhang, B., Wang, W., Liu, L., Liu, J., Chen, C. and Zhang, R., 2018. Relatively high acidity is an important breeding objective for fresh juice-specific apple cultivars. *Scientia Horticulturae*, **233**, pp.29-37.

Jaeger, S.R., Machín, L., Aschemann-Witzel, J., Antúnez, L., Harker, F.R. and Ares, G., 2018. Buy, eat or discard? A case study with apples to explore fruit quality perception and food waste. *Food Quality and Preference*, **69**, pp.10-20.

Janick, J., Cummins, J., Brown, S. and Hemmat, M. 1996. APPLES ***In****:* Fruit Breeding Vol I: Tree and Tropical Fruits, pp 1-77 (Eds. J., Janick and J.N., Moore), Wiley, New York.

Khan, M.A., Singh, K., Patel, K.K. and Siddiqui, M., 2019. Some Physical Properties of Wood Apple (Feronia Limonia L.). Recent Adv Food Sci Nutr Res 2019: 79-86. *Recent Advancement in Food Science and Nutrition Research* pp.79-86.

Khursheed, V. and Taufique, M., 2020. Spatial analysis of horticulture efficiency and fruit production concentration in Kashmir Valley. *GeoJournal*, **85**, pp.1635-1643.

Lancaster, J.E. and Dougall D.K. 1992. Regulation of skin color in apples, *Critical Reviews in Plant Sciences,* **10**: 487-502 (*DOI: 10.1080/07352689209382324*).

Luchi, T. 1987. Influencia e localizacao de gemasfloriferassobrefenologia e crescimento de ramos e frutosemmacieiras. EMBRAPA. *Boletim de Pesquisa* **13**: 12p.

Madial, R.H., Herter, F.G., Leite, G.B. and Petri, J.L. 2010. Influence of flower structure in the flower production and fruit set in some apple cultivars. *Acta Horticulturea,* **872**: 309-311.

O'Rourke D. 2003. World production, trade, consumption and economic outlook for apples. *In:* Ferree D.C. and Warrington I.J. (Eds.) Apples: botany, production, and uses. CABI publishing, CAB international, UK. pp: 15-28.

O'Rourke, D., 2017. Consumer trends in apple sales. In *Achieving sustainable cultivation of apples* (pp. 535-546). Burleigh Dodds Science Publishing.

Reig, G., Lordan, J., Sazo, M.M., Hoying, S., Fargione, M., Reginato, G., Donahue, D.J., Francescatto, P., Fazio, G. and Robinson, T., 2019. Long-term performance of 'Gala', Fuji'and 'Honeycrisp'apple trees grafted on Geneva® rootstocks and trained to four production systems under New York State climatic conditions. *Scientia Horticulturae*, **244**: pp.277-293.

Robinson, T., 2011. Advances in apple culture worldwide. *Revista Brasileira de Fruticultura*, **33**, pp.37-47.

Robinson, T.L. 2003. Apple orchard planting system. ***In***: *Apples* (Eds. D.C., Ferrec and I.J., Warrington), Cabi Publ., Wallingford, UK. pp: 345-407.

Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C. and Pannu, R.S. 1998. Statistical Software Package for Agricultural Research Workers. Recent Advances in information theory, Statistics & Computer Applications by D.S. Hooda & R.C. Hasija Department of Mathematics Statistics, CCS HAU, Hisar 139-143.

Sotiropoulos, T. 2013. Assessment of quality attributes of the apple cultivar 'Fuji Kiku 8' grown in Northern Greece. *Acta Horticulturea* **981**: 671-674.

Unuk, T., Tijskens, L.M., Germsek, B., Zadravec, P., Vogrin, A., Hribar, J., Simcic, M. and Tojnko, S. 2012. Effect of location in the canopy on the colour development of three apple cultivars during growth. *Journal of the Science of Food and Agriculture,* **92** : 2450-2458.

Vangdal, E. 1985.Quality criteria for fruit for fresh consumption. *Acta Agriculturae Scandinavica* **35**: 41-47.

Wani, S.A., Kumar, S., Naqash, F., Shaheen, F.A., Wani, F.J. and Rehman, H.U., 2021. Potential of apple cultivation in doubling farmer's income through technological and market interventions: an empirical study in Jammu & Kashmir. *Indian Journal of Agricultural Economics*, **76**, pp.278-291.

Weber, M.S. 2001. Optimizing the tree density in apple orchards on dwarfing rootstocks. *Acta Horticulturea* **557**: 229-234.

Williams, A.A. and Carter, C.S., 1977. A language and procedure for the sensory assessment of Cox's Orange Pippin apples. *Journal of the Science of Food and Agriculture*, **28**, pp.1090-1104.

Wills, R.B., Bambridge, P.A. and Scott, K.J. 1980. The use of flesh firmness and other objective tests to determine consumer acceptability of Delicious apples. *Australian Journal of Experimental Agriculture,* **20**: 252-256.