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CHARACTERIZATION OF PHYSICO-CHEMICAL ATTRIBUTES OF LITCHI FRUIT AND ITS RELATION WITH FRUIT SKIN CRACKING

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ABSTARCT

The study on characterization of physico-chemical attributes of litchi fruit and its relation with fruit skin cracking was conducted to evaluate litchi cultivars for fruit quality attributes such as fruit size, fruit weight, pulp weight, TSS, total sugars, fruit cracking, fruit specific gravity, reducing and non reducing sugars, skin strength and its boron and calcium content. There were no significant difference in plant age group 10 and 20 years except skin strength and skin calcium content but litchi cultivars varied significantly for most of the studied parameters. Cultivar Gola with fruit weight (23.08g), pulp weight (16.58g), TSS (22.13%) and total sugars (21.57%) was significantly superior in quality attributes but also had the maximum fruit cracking (43.50%) than the rest of the cultivars. Cultivar Gola also had the highest reducing sugars (17.98%) and specific gravity (1.092) but the least non reducing sugars (3.59%) amongst the cultivars under study while cultivar Bedana had the least reducing sugar (5.67%) and specific gravity (1.031) but the most non reducing sugars (9.76%). Skin strength (3.26 kg cm^{-2}) and boron content (0.12 mg/100g DW) were highest in cultivar Bedana, while the highest calcium content was in cultivar Surahi (5.00 mg/100g DW).

Key words: Litchi, Cultivars, Fruit Quality, Cracking, Calcium, Boron.

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.), belongs to the family *Sapindaceae*, is an evergreen, subtropical fruit tree, native to South China. It has been grown for as long as 1766 B.C. (Menzel, 2001). China is the leading litchi producing country in the world with an annual production of 950,000 tons but other countries such as South Africa, Israel, Madagascar, Mauritius, USA, Australia India, Pakistan, the Philippines, Thailand, Taiwan, Indonesia, Vietnam and Brazil also have considerable production of litchi (Menzel, 2001; Lemmer, 2002). The litchi fruit is a good source of food, nutrition. The litchi fruit is also rich source of vitamins C (Wall, 2006) and phenolic compounds that have antioxidant activities (Hu *et al*., 2010) but it may decrease after harvest (Taylor, 1993). In Pakistan, litchi is grown on an area of about 572 hectares with a production average of 9250 tons (Shah, 2003). Due to the relatively low total production, about 90% of the litchi fruit is generally marketed in domestic markets for fresh consumption, where it may catch price as high as Rs. 200 per kg. Only a small percentage is processed as juice and drinks while a negligible amount is exported (Rajwana *et al*., 2010).

The extensive production of litchi fruit is limited by high sensitivity to soil and climatic conditions and short postharvest life. The litchi plant requires cool dry winters and warm wet summers for good production (Menzel, 2001) and both low or high temperatures (Menzel and Simpson, 1988), nutrients (Qui *et al*., 1999) and irrigation (Li *et al*., 2001) may result in undesirable yield losses or decreased fruit quality (Waseem, 2002).

The litchi has a short postharvest life due to pericarp desiccation and browning (Kaiser, 1994) and fruit cracking (Singh and Singh, 1995). The skin cracking of litchi fruits exposes the aril to external environments and provides entry to fungal pathogens resulting in rapid decay (Kaiser, 1994). Thus, litchi has relatively short postharvest or storage life (Kaiser, 1994). The problem is further complicated by the fact that only a small number of litchi cultivars are grown for commercial production in Pakistan, with Bedana, Calcutti, Gola, Bombay, Chinese, Lychee Siah and Madrasi being the major litchi cultivar (Rajwana *et al*., 2010). Furthermore, the litchi cultivars posses considerable genetic variations (Huang *et al.,* 2004; Khurshid *et al*., 2004), resulting in marked differences in flushing pattern, flush color, and flowering ability, fruit color, shape and size (Waseem *et al*., 2002; Sivakumar *et al*., 2010) as well as fruit cracking susceptibility (Huang *et al*., 2004). The litchi fruit quality and cracking, beside cultivars (Huang *et al*., 2004), depend on cultural practices such as irrigation (Li *et. al*., 2001) and nutrients application such as Ca, Mg and B (Qui *et al*., 1999; Peng *et al*., 2004). So far, no systematic study has been conducted in Pakistan to evaluate the commonly grown litchi cultivars for fruit quality and sensitivity to fruit cracking, a serious problem in extending litchi cultivation and tapping its potentials for domestic consumption and international trade. Therefore, the present study was initiated to study genetic diversity in various morphological and chemical characteristics of different commercially grown cultivars of litchi in KPK Province of Pakistan and have an insight into the cracking susceptibility of fruit in relation to its physical and chemical attributes.

MATERIALS AND METHODS

The study on characterization of physico-chemical attributes of litchi fruit and its relation with fruit skin cracking was carried out during the years 2007 and 2008 to evaluate different physical and chemical characteristics of four cultivars of litchi (*Litchi chinensis* Sonn.) i.e. China, Gola, Surahi and Bedana in the agro-climatic conditions of Haripur, Hazara region of KP Province.

The experiment was conducted in RCBD two factorial design with plant age as factor A in main block while different cultivars in subplots. For this purpose two blocks of 10 and 20 year age group with three litchi trees of each cultivar were selected. Data was recorded on physical and chemical characteristics of the litchi fruits from different cultivar.

All the agronomic practices were kept uniform for all the treatments in the experiment.

Fruit weight (g): The fruit weight of 10 fruit in each treatment in each replication was estimated with the help of an electronic balance measuring gram quantity to the third decimal.

Fruit pulp weight (g): The pulp weight was recorded by removing the skin and stone and weight of pulp in 10 randomly taken fruits from each treatment in each replication with the help of an electronic balance measuring gram quantity to the third decimal. Weight of the selected fruits from the tagged branches was recorded in grams.

Fruit skin cracking (%): Fruit cracking %age was recorded by counting the number of total and cracked fruits on the tagged branches and converting the differential into %age.

Specific gravity: The specific gravity was recorded from the selected fruits by measuring their weight (gm) in air and in water and then applying the following formula:

$$Specific\ gravity = \frac{weight\ in\ air}{(weight\ in\ air - weight\ in\ water)}$$

Fruit skin strength (kg cm^{-2}): The firmness of the fruit skin was measured using a penetrometer (FT 011, Italian equipped with 4 mm probe) from the selected tagged fruits and data recorded in kg cm^{-2}. The care was taken to use the smooth and uniform pressure applications throughout the data recording. Each reading consisted of 10 fruits and the data recorded on the two opposite sides of the equatorial area of the fruit.

Total soluble solids (%): The fruit juice was extracted from the mature selected fruits and the TSS measured through hand held refractometer (KROSS HRN-16). The refractometer was first calibrated by using distilled water to have a zero reading. One drop per sample was poured onto the refractometer prism plate. The readings on the prism plate were noted to one decimal place. After each test, the prism plate was cleaned with distilled water and wiped with a soft tissue. The data was averaged and recorded in Brix^{o}.

Total sugars, reducing and non reducing sugars (%): Total and reducing sugars in the litchi fruit juice were determined by the Lane and method as described in A.O.A.C. (1995). For this purpose 10 fruits from treatment in each replication were taken at random. The juice was extracted from the fruit with the help of locally made juice extractor, 25 grams of filtered (whattman-4) juice was transferred to 250 ml volumetric flask. 100 ml of water was added to it and neutralized with 1N NaOH. 2 ml of lead acetate solution was added, solution shaken and let to stand for 10 minutes. The necessary amount of potassium oxalate was added to remove the excess lead and the volume made with water.

Sugars were calculated as:

$$\%\ Reducing\ sugars = \frac{Factor\ x\ dilution\ x\ 100}{titre\ x\ Wt\ or\ volume\ of\ the\ sample}$$

Non reducing sugars = (% total sugars - % reducing sugars) x 0.95Total Sugars = (% reducing sugars + % non reducing sugars)

Care was taken to prepare fresh Fehling A and B solutions each time the sugars determinations were made.

Fruit skin calcium content (mg/100g DW): The selected fruits from the tagged branches were thoroughly washed for ten minutes with tap water and then with distilled water. The fruit skins from the samples were peeled and once again washed with distilled water and allowed to oven dry at 70^{o}C until the achievement of a constant weight. The dried samples were ground to powder and sealed in petri dishes for chemical analysis (Isaac and Kerber, 1971). The calcium content in the fruit skin were determined by the atomic absorption flame spectrophotometer (GBC AA 932). The spectrophotometer was calibrated with a standard solution of 5 µg-ml^{-1} as per recommendations of the manufacturer.

Fruit skin boron content (mg/100g DW): The peeled skins of the selected fruits were washed thoroughly first with the tap water and then with distilled water. Ten grams of the sample was taken and dried for 12 hours at 75^{o}C in oven and then ashed for 3 hours at 525^{o}C. Ashes were extracted with 10 ml of 2M HNO_3 and were heated on a hot plate. Filtered contents after dissolution were diluted to a final volume of 50 ml. This solution was used for determination of boron content in the fruit skin by the azomethine-H method using atomic absorption flame spectrophotometer (GBC AA 932) (Harp, 1997). Boric acid standard solution (1000 mg l^{-1}) was used for standardization.

RESULTS AND DISCUSSION

Fruit and pulp weight (g): The fruit weight varied significantly in litchi cultivars with the maximum fruit weight recorded in cultivar Gola (23.08g) followed by China and Surahi with 22.02 and 20.69 g respectively (Table I). The difference in fruit weight of cultivars Surahi and China was, however, non significant. The fruit weight was the lowest (15.20g) in cultivar Bedana. The fruit weight of cultivar Gola which was superior to Surahi and China by 10.03 and 4.59% but was 34.14% higher than cultivar Bedana.

The pulp weight of litchi fruit was comparable to the fruit weight with the maximum in cultivars Gola (16.58 g) followed by cultivars China and Surahi with 16.27 and 15.90 g pulp weight respectively while cultivar Bedana had the lowest pulp weight (11.19 g) among the cultivars under study. The pulp weight of litchi fruit in cultivar Gola which was 34.14% higher than cultivar Bedana but 10.35% and 4.59% higher than cultivars Surahi and China respectively. The fruit and pulp weight in litchi cultivar depend on genetic factors (Khurshid *et al*., 2004), nutrition (Cronje et al., 2009), plant water balance (Baten *et al*., 1994) and fruit orientation (Waseem et al., 2002), thus, it is likely to observe variations in fruit and pulp weight among different cultivars.

Total soluble solids and total sugars (%): The TSS content recorded in cultivars Gola (22.13%) was significantly higher than those of the cultivars China and Surahi (20.39 and 19.49% respectively), while cultivar Bedana had the lowest TSS content (16.27%) (Table I). The TSS of cultivar Gola (22.13%) was higher than cultivars Bedana, Surahi and China (26.48, 11.93 and 7.86% orderly). Considerable variation have been previously reported plant morphology and fruit size (Khurshid *et al*., 2004) as well as biochemical composition such as total soluble solids (Waseem *et al*., 2002, Islam *et al*., 2003).

Total sugars (%): The total sugar contents of different varieties are spread over a wide ranges of 6.74-20.6% (Singh & Singh, 1995) and 55.9-61.4% on dry weight basis (Jiang *et al*., 2006). Sucrose, fructose and glucose are found to be the major sugars in litchi (Jiang *et al*., 2006). The total sugar content of litchi fruit vary between different cultivar types (Wang *et al*., 2006). The data regarding the total sugars revealed the highest total sugars 21.57% in cultivar Gola, followed by 19.67 and 18.50% in cultivars China and Surahi respectively, while cultivar Bedana had the lowest total sugars of 15.43%. The total sugars in cultivar Gola was 28.47, 14.23 and 8.81% higher than cultivars Bedana, Surahi and China accordingly (Table I). The total sugar contents of the fruit depends on genetic factors (Khurshid *et al*., 2004), thus, may vary among different cultivars (Singh & Singh, 1995). It seems like cultivar Gola is a good sugar accumulator than the rest of the cultivars under this study.

Reducing and non reducing sugars (%): The reducing sugar contents of litchi fruits varied significantly among different cultivars with the highest reducing sugars (17.98%), recorded in cultivar Gola followed by 14.28 and 13.73% in cultivars China and Surahi respectively, while cultivar Bedana had the lowest reducing sugars (5.67%). Thus, the reducing sugars of cultivar Gola which was 23.64 and 20.58% higher than cultivars Surahi and China respectively but 68.46% higher than cultivar Bedana. In contrast to the reducing sugars contents of the fruit were significantly higher (9.76%) recorded in cultivar Bedana, while cultivar Gola had the least (3.59%) non reducing sugars (Table I) The litchi cultivars have been shown to have considerable variations have been observed in reducing sugars content of different litchi cultivars (Waseem, 2002) but generally represent more than 70% of the total sugars in the aril (Jiang *et al*., 2006). The relative ratios between these sugars may vary among cultivars (Waseem, 2002) and cultivars Gola may be regarded as monosaccharide prevalent type (Wang *et al*.2006). By similar standards, cultivars Bedana seems to be a disaccharide or polysaccharide accumulator cultivar.

Specific Gravity of Fruit: The specific gravity of fruit is related to cell size and intercellular spaces and has been used as maturity and quality index in many fruits and vegetables such as apricots, strawberries, tomato, pea, etc (Wolfe *et al*., 1974; McGlone, 2007). The specific gravity of litchi fruit was the highest (1.092) in cultivars Gola followed by 1.085 in cultivars Surahi with the difference being non significant. The fruits of cultivars China and Bedana had significantly lower specific gravity of 1.05 and 1.03 respectively (Table I). The specific gravity is generally correlated with chemical composition such as starch content, dry matter and total sugars (Zaltzman *et al*., 1987), hence is likely to observe high specific gravity in Gola while the least specific gravity in Bedana.

Fruit Cracking (%): The tendency of fruit skin cracking is a serious postharvest problem of litchi fruit (Li *et al*. 2001). It decreases the visual quality by promoting browning in exposed aril (Huang *et al*., 2004), enhances desiccation and susceptibility to fruit decay by pathogens (Underhill and Critchley, 1992). The data on fruit cracking percentage revealed the highest fruit cracking in cultivars Gola (43.50%), followed by Surahi and China cultivars (31.19 and 23.15% respectively), while the lowest fruit cracking was observed in cultivar Bedana (10.09%) (Table I). The fruit cracking observed in cultivars Gola was higher than Surahi, China and Bedana by 28.30, 46.78 and 76.80% accordingly (Table I), indicating the high susceptibility of cultivar Gola to fruit cracking. Since cultivar Gola had the highest TSS, total and reducing sugars, its aril may exert an increased stress or turgor pressure against the pre-grown pericarp (Joubert, 1986) leading to greater susceptibility to fruit cracking (Wang *et al*., 2006).

Fruit Skin Strength (kg cm^{-2}): The fruit skin strength of litchi cultivars varied significantly with the maximum (3.26 kg cm^{-2}) in cultivar Bedana followed by cultivars Surahi and China with 2.47 and 2.26 kg cm^{-2} respectively, while the minimum skin strength was recorded in cultivars Gola (2.02 kg cm^{-2}). The skin strength was significantly affected by the cultivars x plant age interaction with slight increase cultivar China nad Gola, while a decrease in Gola and Surahi in 20 years ols plants (Fig I). The fruit skin strength of cultivars Bedana was 38.04, 30.67 and 24.23% higher than cultivars Gola, China and Surahi respectively. Since the turgor pressure of the expanding aril against the pre-grown pericarp is believed to cause fruit cracking (Joubert, 1986), the tensile strength of the litchi fruit skin is an important mechanical property to resist the pressure by the aril tissue and, hence, a greater tensile strength is indicative of lower susceptibility to fruits cracking (Huang and Huang 1998).

Calcium Content of Litchi Fruit Skin (mg/ 100 g DW): The calcium content of the fruit skin varied significantly among the cultivars and was the highest (5.00 mg/ 100g DW) in cultivar Surahi followed by cultivar China and Gola with 4.938 and 4.750 mg Ca /100 g dry weight. Litchi cultivar Bedana had the least calcium content of 4.375 mg/100g dry weight (Table II). The skin calcium was non consistent in age group 10 and 20 years and was lower in China and Surahi but higher in Gola and Bedana increase in 20 years old plant (Fig II). Considerable research has been conducted that shows that low calcium content may be responsible for fruits cracking. The calcium is a structural component of the cell walls, and the availability of calcium during early fruit development is important for cracking resistance (Huang *et al.* 2005). Similarly, Qui *et al*. (1999) reported that cultivars which accumulate more calcium, resulting in higher concentrations of structural calcium and galacturonans have greater cracking resistance. The structural calcium levels in litchi pericarp generally decline during 22-52 days after anthesis be due to dilution of structural calcium (Huang et al. 2004). But the least fruit cracking despite the lowest calcium content in fruit skin of cultivar Bedana indicates that Calcium alone may not control the fruit cracking in litchi. This argument is further strengthened by the observation that while the maximum fruit cracking in cultivar Surahi with highest calcium content had about three fold higher fruit cracking than Bedana (Table II).

Table I: The influence of plant age on fruit and pulp weight, TSS, total sugars, reducing and nonreducing sugars %age of litchi cultivars.

Plants Age	Fruit Quality Characteristics of Litchi Cultivars					
	Fruit Weight (g)	Pulp Weight (g)	TSS (%)	Total Sugars (%)	Reducing Sugars (%)	Non Reducing Sugars (%)
10 years	20.05	14.94	19.57	18.78	12.91	5.87
20 years	20.44	15.03	19.56	18.80	12.92	5..86
Significance	NS	NS	NS	NS	NS	NS
Cultivars China	22.02 b	16.27 b	20.39	19.67 b	14.28	5.39
Gola	23.08 a	16.58 a	22.13	21.57 a	17.98	3.59
Surahi	20.69 c	15.90 c	19.49	18.50 c	13.73	4.73
Bedana	15.20 d	11.19 d	16.27	15.43 d	5.67	9.76
LSD	0.561	0.139	0.067	0.432	0.034	0.026

Interaction between age and cultivar = Non significant.

Boron content of litchi fruit skin (mg/ 100 g DW): The data on boron content of litchi fruit skin indicated that cultivar Bedana had the highest boron content of the fruit skin (0.120 mg/100 g DW), followed by cultivars China and Gola with 0.112 and 0.109 mg/100 g DW, with the difference being non significant. Cultivar Surahi with 0.101 mg/100g DW had the lowest boron content among the cultivars under the study (Table II). Boron is an important micronutrient involved in the metabolism of nitrogen, phosphorus and absorption of salts, cell wall development, cell division, and the movement of sugars and its deficiency results in fruit discoloration and cracking (Dale and Krystyna, 1998). Application of Boron in litchi fruit increased the TSS and total sugars, and decreased the fruit cracking (Kumar *et al*., 2001; Ruby *et al*., 2001). The highest boron content of fruit skin and the least fruit cracking in cultivar Bedana indicates that boron may help in decreasing cracking susceptibility either by promoting calcium metabolism in cell wall as suggested by (Yamaguchi *et al*., 1986) or directly involving in cell wall structure through formation of borate esters with hydroxyl groups of cell wall carbohydrates and/or glycoproteins (Loomis and Durst 1992; Matoh *et al*., 1992; Blevins and Lukaszewski, 1998).

Table II. The specific gravity of fruit and skin strength, calcium and boron content and fruit cracking percentage of litchi cultivars.

Plants Age	Fruit and Fruit Skin Characteristics				
	Specific Gravity of Fruit	Skin Strength (kg cm-2)	Fruit Skin B Content (mg/100g DW)	Fruit Skin Ca Content (mg/100g DW)	Cracked Fruit (%)
10 years	1.61	2.52	0.11	4.719	27.14
20 years	1.069	2.49	0.11	4.813	25.97
Significance	NS	NS	NS	NS	NS
Cultivars China	1.052 c	2.26 c	0.112 b	4.938 b	23.15
Gola	1.092 a	2.02 d	0.109 b	4.750 c	43.50
Surahi	1.085 b	2.47 b	0.101 c	5.000 a	31.19
Bedana	1.031 d	3.26 a	0.120 a	4.375 d	10.09
LSD	0.007	0.019	0.002	0.015	0.029
Age x Cultivar	NS	*	NS	*	NS

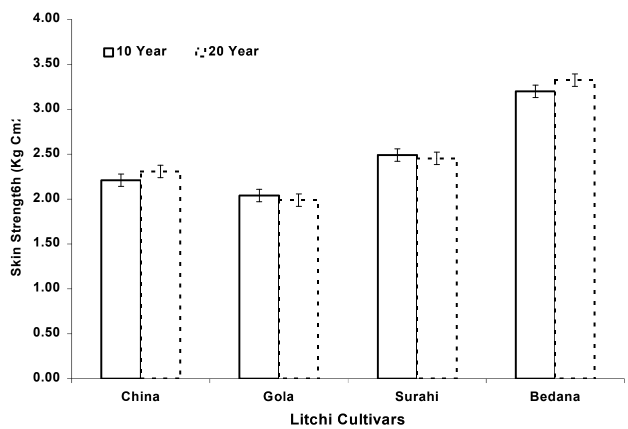

Fig I. Fruit skin strength (kg cm^{-2}) in two age groups of litchi cultivars.

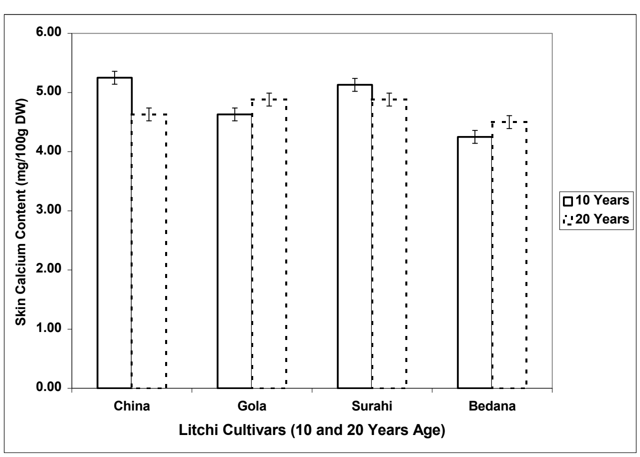

Fig II. Fruit skin calcium content (mg/100g DW) in two age groups of litchi cultivars

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REFERERNCES

AOAC, (1995). Official methods of Analysis, 16th (ed). Association of Official Analytical Chemist, Washington, DC.

Blevins D. G. and K. M. Lukaszewski (1998). Boron in plant structure and function Annu. Rev. Plant Physiol. Plant Mol. Biol. 49:481–500

Cronje, R. B., D. Sivakumar, P. G. Mostert and L. Korsten (2009). Effect of different preharvest treatment regimes on fruit quality of Litchi cultivar 'Maritius' Journal of Plant Nutrition. 32:19-29.

Dale G. B. and M. L. Krystyna (1998). Boron in plant structure and function, Annu. Rev. Plant Physiol. Plant Mol. Biol. 49:481-500.

Harp, D. L. (1997). Modifications to the azomethine-H method for determining boron in water. Analytica Chimica Acta, 346: 373-379

Hu, Z. Q., X. M. Huang, H. B. Chen, and H. C. Wang (2010). Antioxidant capacity and phenolic compounds in litchi (*Litchi chinensis* sonn.) pericarp. Acta Hort. 863:567-574.

Huang, X. M. and H. B. Huang (1998). Using wet strength tester to measure the mechanical strength of plant cell walls. Plant Physiology Communications, 34: 207-209.

Huang, X. M., W. Q. Yuan, C. Wang, J. G. Li, H. B. Huang, L. Shi and Y. Jinhua (2004). Linking cracking resistance and fruit desiccation rate to pericarp structure in litchi (*Litchi chinensis* Sonn.). J Hort. Sci. Biotech. 79:897-905.

Isaac, R. A. and J. D. Kerber (1971) Atomic absorption and flam photometery: Techniques and uses in soil, plant and water analysis. pp: 18-38. In Instrumental methods for analysis of soils and plants tissue. (ed) Walsh, L.M. Soil Sci. Soc. Am. Madison, WI.

Islam, M. S., M. Ibrahim, M. A. Rahman, M. A. Uddin and S. K. Biswas (2003). Pakistan Journal of Biological Sciences 6: 70-72.

Jiang, Y. M., Y. Wang, L. Song, H. Liu, A. Lichter, O. Kerdchoechuen and D. C. Joyce, J. Shi (2006). Postharvest characteristics and handling of litchi fruit - An overview. Aust. J. Exp. Agric. 46:1541-1556.

Joubert, A. J. (1986). Litchi. In Hand Book of Fruit Set and Development; Monselise, S.P. Ed.; CRC Press: Boca Raton, FL, pp. 233-246.

Kaiser, C. (1994). Litchi (*Litchi chinensis* Sonn.) pericarp color retention: Year book- South African litchi grower's association. 6:32-35.

Khurshid, S., I. Ahmad and M. A. Anjum (2004). Genetic diversity in different morphological characteristics of litchi (*Litchi chinensis* Sonn.), Int. J. Agri. Biol., 6:1062-1065.

Kumar, A., C. Singh, M. Ral and R. Ranjan (2001). Effect of irrigation, calcium and boron on fruit cracking in litchi cv "Shahi". Orissa J. Hort. 29:55-57.

Lemmer, D. (2002). Report on the Chinese litchi industry. S.A. Litchi Growers' Assoc. Yearbook. 13:1-4.

Li, J. G., H. B. Huang, F. F. Gao, X. M. Huang and H. C. Wang (2001). An overview of litchi fruit cracking. Acta Hort. 558:205-208.

Loomis W. D., R. W. Durst (1992). Chemistry and biology of boron. Bio-Factors 3:229–39.

McGlone, V. A., J. C. Christopher and B. J. Robert (2007). Comparing density and VNIR methods for predicting quality parameters of yellow fleshed kiwifruit (*Actinidia chinensis*). Postharvest Biology and Technology. 46:1-9.

Menzel, C. M. (2001). The physiology of growth and cropping in lychee. South African Litchi Growers' Association Yearbook. 12:9-14.

Menzel, C. M. and D. R. Simpson (1988). Effect of temperature on growth and flowering in litchi (*Litchi chinensis* Sonn.) cultivars. J. Hort. Sc. 63:349-360

Peng, J., X. Tang and H. Feng (2004). Effects of brassinolide on the physiological properties of litchi pericarp (*Litchi chinensis* cv. Nuomoci). Sci. Hort. 101:407-416.

Qui, Y., J. Cheng, L. Qu, B. Wang and P. Yuam (1999). Relationship between fruit cracking and endogenous hormones in 'nuomoci' litchi variety. J. Fruit Sc. 16:276-279.

Rajwana, I. A., A. U. Malik, A. S. Khan and R. Anwar (2010). Lychee industry in Pakistan: Potential and Prospects. Acta Hort. 863:67-72.

Ruby, R., V. S. Brahmachari and R. Rani. (2001). Effect of foliar application of calcium, zinc and boron on cracking and physicochemical composition of litchi. Orissa J. Hort. 29:50-54.

Shah, S. S. H. (2003). Fruit orchard survey in district Haripur. Project for Horticulture Promotion (East), Abbottabad, NWFP, Pakistan. pp. 14-15.

Singh, P. and I. S. Singh (1995). Physico-chemical changes during fruit development in litchi (*Litchi chinensis* Sonn.). Mysore J. Agric. Sci. 29:252-255.

Sivakumar; D., L. Terryb and L. Korsten (2010). An overview on litchi fruit quality and alternative postharvest treatments to replace sulfur dioxide fumigation, Food Reviews Int. 26:162-188.

Taylor, J. E. (1993). Exotics. In: G.B. Seymour, J.E. Taylor and G.A. Tucker (Editors), Biochemistry of Fruit Ripening. Chapman and Hall, London. Pp. 53-82.

Underhill, S. J. R. and C. Critchley (1992). The physiology and anatomy of lychee (*Litchi chinensis* Sonn.) pericarp during fruit development. J. Hort. Sci. 67:437-444.

Wall, M. M. (2006). Ascorbic acid and mineral composition of longan (*Dimocarpus longan*). Lychee (*Litchi chinensis*) and rambutan (*Nephelium lappaceum*) cultivars grown in Hawaii. J. Food Compos. Anal. 19:655-663.

Wang, H. C., H. B. Huang, X. M. Huang and Z. Q. Hu (2006). Sugar and acid compositions in the arils of *Litchi chinensis* Sonn.: cultivar differences and evidence for the absence of succinic acid. J. Hort. Sci. Biotech. 81:57-62.

Waseem, K., A. Ghafoor and S. U. Rahman (2002). Effect of Fruit Orientation on the Quality of Litchi (Litchi chinenesis Sonn) under the Agro-Climatic Conditions of Dera Ismail Khan–Pakistan, International Journal of Agriculture & Biology, 4: 503–505.

Yamaguchi, T., T. Hara and Y. Sonoda (1986). Distribution of calcium and boron in the pectin fraction of tomato leaf cell wall. Plant Cell Physiol. 27:729-732.

Zaltzman, A., B. P. Verma and Z. Schmilovitch (1987). Potential of quality sorting of fruits and vegetables using fluidized bed medium. Trans. ASAE. 30: 823-831.