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Weak Neck of *Musa* sp. cv. Rastali: A Review on it's Genetic, Crop Nutrition and Post Harvest

E.T.S. Putra, W. Zakaria, N.A.P. Abdullah and G. Saleh
Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia,
43400 UPM Serdang, Selangor DE, Malaysia

Abstract: Weak neck is the physiological weakening at the pedicel of *Musa* sp. fruit that causes individual fruits to be released prematurely from the hand. The level of resistance to weak neck is different among groups of *Musa* sp. with A and B genomes, diploid, triploid and tetraploid. *Musa* sp. cv. Rastali is AAB genome, but this cultivar is sensitive to weak neck. Sensitivity to weak neck comes from the two A genomes. There is high probability that application of Magnesium (Mg), Boron (B) and Silicon (Si) may solve weak neck on *Musa* sp. cv. Rastali. Magnesium application increases chlorophyll synthesis and photosynthesis rate. Assimilate accumulation on fruit cells triggers cell elongation and cell wall thickening, especially in the neck zone. Boron plays an important role in regulating hormone and enzyme levels in plants. Sufficient boron in plant tissue impedes synthesis and activities of Pectate Lyase (PL) and pectinmethylesterase (PME), thus decreasing cell wall hydrolysis. Plant cells and tissues become stronger with Si application. This is caused by the formation of silica-cuticle double layer on the epidermis. Low temperature along with low relative humidity during storage and ripening decreases the activities of PL and PME. The reduction of PL and PME activities result in a decrease in pectin degradation rate and cell wall hydrolysis, thus reducing the occurrence of weak neck.

Key words: *Musa* sp. cv. Rastali, weak neck, genetic, crop nutrition, post harvest

INTRODUCTION

Banana is the world's fourth most important food crop after rice, wheat and maize. More people in the tropic and sub-tropic region consume this fruit on a daily basis (FAO, 2008). Southeast Asia is the centre origin of bananas. This region comprises of Malaysia, Indonesia, Thailand and the Philippines. These four countries are important banana fruit producers and exporters in the world.

Banana is one of the main fruits exported and it is very popular as compared to other fruit. In particular, Malaysia is one of the world's major exporters of bananas. Since 1990, Malaysia has been gaining recognition for its export of local fruit to overseas market. In 2007, export of bananas reached 33838 tons (FAO, 2008). The cultivation areas for bananas had therefore increased from 23,266 ha in 1985 to 38,678 ha in 1994, 54,138 ha in 2000 and 72,254 ha in 2007 (Department of Agriculture Malaysia, 2008). *Musa* sp. cv. Rastali is one of the common dessert bananas in Malaysia. Total cultivation areas for *Musa* sp. cv. Rastali was 7.14% of the total area for banana in 2007. That was approximately 5,158.94 ha, with the total production of approximately 57321 t. This cultivar has AAB genome (Ploetz *et al*., 2007).

Musa sp. cv. Rastali has a good potential of being exported to overseas markets (Hassan, 2002). However, there are many obstacles faced by the farmers that are interrelated with the development of *Musa* sp. cv. Rastali as a superior commodity, particularly on productivity and post harvest handling. Two of the main obstacles faced by farmers are packing and dispatching the fruits to the market. Long distance transportation cause fruits to be released from its hand. This is called weak neck. Weak neck is the physiological weakening at the pedicel of the fruit that causes individual fruit to be released prematurely from its hand (Saengpook *et al*., 2007). However, weak neck is not prevalent to all *Musa* sp. cultivar. One of the cultivars that is susceptible to weak neck is *Musa* sp. cv. Rastali.

Weak neck decreases the quality of *Musa* sp. cv. Rastali fruit. The fruits thus become unacceptable and the farmer suffers financial losses (Daddzie and Orchard, 1997). Besides that, the development of *Musa* sp. cv. Rastali as a potential export commodity is undermined. These factors caused *Musa* sp. cv. Rastali to be merely used for local consumption.

A holistic approach is needed in order to solve the weak neck problem of *Musa* sp. cv. Rastali. The three aspects that were reviewed were plant genetics, plant

Corresponding Author: Zakaria Wahab, Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor DE, Malaysia

nutrition and post harvest. This study discusses recent information and possible solutions to solving weak neck in *Musa* sp. cv. Rastali.

WEAK NECK

After harvesting, there are many factors that can decrease the quality of *Musa* sp. cv. Rastali fruits. Generally, the obstacles can be classified in to two groups, i.e., mechanical injury and physiological disorder. Mechanical injury is considered as a type of stress that occurs during the post harvest handling of fruits. Mechanical damage is defined as plastic deformation, peel ruptures and tissue damage caused by external factors (Del Aguila *et al*., 2007). There are three main sources of mechanical injury to banana; these are impact, pressure (compression) and cut (Daddzie and Orchard, 1997). Impact is generally caused by a collision between the fruit with a solid surface and between the fruit during harvest, handling and transportation. Compression injuries are caused by the variable pressure exerted by the adjacent fruit or fruit with a container. Meanwhile, cuts injuries are generally caused by collision between the surface of fruit with a sharp object that caused epidermal ruptures, or because of pressure caused by uneven surfaces, like the edge of the container of fruit (Del Aguila *et al*., 2007).

Physiological disorder occurs on fruit tissue and is not caused by pathogen. Physiological disorder develops as plant response to environmental conditions such as temperature and lack of nutrition (Wills *et al*., 1989). Most of the physiological disorders affect discrete areas of the tissue. Some disorders may affect the skin of the fruit but may leave the underlying flesh intact; others affect only certain areas of the flesh.

The most important physiological disorder affecting *Musa* sp. cv. Rastali is weak neck. Weak neck has been defined by Baldry *et al*. (1981) as the physiological softening and weakening which cause individual fruits in a hand to separate from the crown. Hands of banana with missing fingers can't be sold to consumers and individual fruits that have dropped have no pedicel and can't be marketed (Imsabai *et al*., 2006). For this reasons, weak neck has become a major problem for *Musa* sp. cv. Rastali (Putra *et al*., 2010). Weak neck reduces the quality and selling value of *Musa* sp. cv. Rastali, resulting in financial loss (Daddzie and Orchard, 1997).

There are three possible causes of weak neck: genetics (Semagn *et al*., 2006), nutrition (Williams, 2002) and post harvest handling (Sairam *et al*., 2008). An understanding concerning the relationship among *Musa* sp. cv. Rastali genetics, nutrition and post harvest handling with weak neck is needed in order to solve weak neck on *Musa* sp. cv. Rastali.

GENETICS

Genetics is one of the factors that determine the occurrence of weak neck on *Musa* sp. cv. Rastali. The information concerning the relationship between genetics and weak neck on *Musa* sp. cv. Rastali however is still limited. Information available is still based on the morphological character of *Musa* sp. (Hicks, 1934; Marriott, 1980; New and Mariott, 1983; Semple and Thompson, 1988; Pereira *et al*., 2004).

The level of resistance to weak neck is different among *Musa* sp. with A and B genomes. Generally, the *Musa* sp. with B genome are more resistant to weak neck than those with A genome. The level of resistance to weak neck is also different among *Musa* sp. group of diploids, triploids and tetraploids. The diploid group of *Musa* sp. is more resistant than triploids and tetraploids, while triploids are more resistant than tetraploids. *Musa* sp. within the tetraploid group are the most sensitive to weak neck (Pereira *et al*., 2004).

Hicks (1934) and Semple and Thompson (1988) reported that triploid Cavendish AAA group was the most sensitive to weak neck. Marriott (1980) reported that all of the *Musa* sp. tetraploids were sensitive to weak neck. However, Pereira *et al*. (2004) showed that all of the diploid *Musa* sp. with BB genome were resistant to weak neck. Some triploid *Musa* sp. were also resistant to weak neck. Triploid *Musa* sp. that possessed intermediate resistance to weak neck were Cavendish (AAA) and Grande Naine (AAA). Similar to the findings of Marriott (1980), all of the tetraploid *Musa* spp. experienced weak neck, i.e., Pioneira (AAAB), YB42-21 (AAAB), Buccaneer (AAAA) and Calypso (AAAA) (Pereira *et al*., 2004). Based on previous studies *Musa* sp. that were resistant to weak neck contained the B genome, either in diploids and triploids. Thus, it can be concluded that the carrier of resistance to weak neck is the B genome. *Musa* sp. cv. Rastali is a triploid with an AAB genome, but this cultivar is sensitive to weak neck. Sensitivity to weak neck apparently comes from the two AA genomes present in *Musa* sp. cv. Rastali.

There was a strong relationship between weak neck and fruit morphological characteristic mainly fruit firmness, peel and pulp colour, peel and pulp thickness, pulp to peel ratio and pedicel. A morphological characteristic of the fruit is the interaction between genetics and environmental factors (Pereira *et al*., 2004). Some time, fruit morphological characteristic of crops under limited conditions were better compared with normal conditions.

Molecular markers-assisted selection is already helping breeders to improve stress-related traits (Tuberosa and Salvi, 2006; Niknejad *et al*., 2009). The best marker for *Musa* sp. is microsatellites because it is highly polymorphic, show a co-dominant mode of inheritance and easy to interpret (Semagn *et al*., 2006). DNA microsatellites are polymorphic elements which are abundant in nuclear genomes and consist of a succession of a small repeat-unit, usually less than four nucleotides long. Fragments containing microsatellites can be amplified through Polymerase Chain Reaction (PCR) (Creste *et al*., 2003). The use of molecular markers makes possible to find a solution to the weak neck problem of *Musa* sp. cv. Rastali.

CROP NUTRITION

Ferreira *et al*. (2004) said that several characteristics of *Musa* sp. cv. Rastali depends on their genes, for example, their resistance to diseases, height of crop, number of finger/bunch and length of fingers. Even so, those characteristics can be influenced by environmental conditions. One of the environmental conditions mentioned is nutrient supply from the growing media. Nutrient supply for plant depends much on nutritional management. Optimal nutritional management is essential to produce adequate nutrient supply to the plant.

Growth and yield of *Musa* sp. cv. Rastali get the maximum if the mineral nutrient in sufficient quantities. Some ways can be done to meet the needs of the mineral nutrients are fertilizer, inoculation of Plant Growth-Promoting Rhizobacterial (PGPR) and increase the efficiency of nutrient uptake by roots (Mia *et al*., 1998, 2005; Zakaria, 1998; Zakaria *et al*., 1998). Inoculation of PGPR on *Musa* spp. grown under hydroponic conditions, combined with 33% fertilizer-N of the total N requirement, could produce better growth and yields than the *Musa* sp. that get 100% of N-fertilizer. It shows that the application of PGPR can reduce the supply of N-fertilizer, because PGPR play a role as bioenhancer and biofertilizer. Application of PGPR also increases the uptake of Phosphorus (P), Potassium (K), Calcium (Ca) and magnesium (Mg), thus increasing its concentration in tissue (Mia *et al*., 1998, 2005; Zakaria *et al*., 1998). On the other hand, the efficiency of mineral nutrient uptake can be enhanced through root system improvement, which can be achieved through plant breeding programs (Saleh and Gritton, 1994).

The application of several macro and micro elements such as magnesium (Mg) and boron (B) are able to increase the availability of those nutritions for *Musa* sp. cv. Rastali. The availability of Mg and B was reported to increase the productivity of *Musa* sp. cv. Rastali and decrease finger drop (Matoh and Kobayashi, 1998; Mostafa *et al*., 2007). It is related with the important roles of Mg and B in plant physiological activities such as photosynthesis and synthesis of enzyme, hormone and protein (Jones *et al*., 1991; Mostafa *et al*., 2007; Singh *et al*., 2007; Rashid *et al*., 2007). Moreover, B also has the role in strengthening cells and tissues. Boron is also an important inorganic component in the cell wall (Matoh and Kobayashi, 1998).

On the other hand, Silicon (Si) is a beneficial element for monocots. Application of this element had a positive effect on plant growth, yield and plant resistance to pest and plant disease (Basagli *et al*., 2003; Ma *et al*., 2004; Almeida *et al*., 2009; Gorecki and Danielski-Busch, 2009). Silicon has a positive effect in metabolism, i.e., improvement of nutrient imbalance, reduction of mineral toxicities, improvement of mechanical properties of plant tissues and enhancement of resistance to other various abiotic and biotic stress (Iwasaki *et al*., 2002; Kim *et al*., 2002; Henriet *et al*., 2006, 2008). In such cases, the positive effect of Si addition to the plant under optimum conditions is generally not too significant. The positive effect of Si will appear significantly when the plant is subjected to stress (Epstein, 1994; Henriet *et al*., 2006).

Henriet *et al*. (2006) discovered that bananas planted on vertisol are more resistant to fungi. This resistance is related to Si because vertisol has high Si availability. Results from Hinsinger *et al*. (2001) and Rufyikiri *et al*. (2004) also showed that the roots of banana were able to induce Si dissolution so as to increase the availability of Si in the rhizosphere. This information shows that banana plant benefits from Si accumulation, but the mechanism is still unknown.

Application of nutrition can also be used in for disease control. Controlling of plant disease by managing the nutrition application pattern gave a better yield than using pesticides. Fawe *et al*. (2001) reported that Si given to plants cultivated through hydroponics had a positive effect in controlling several diseases. As an example, application of Si on melon, cucumber and strawberry that were planted through hydroponics increased plant resistance to powdery mildew disease (Fawe *et al*., 2001).

Datnoff *et al*. (2001) said that the application of Si can decrease the main disease aggression level on paddy, i.e., blast, brown spot, sheath blight, leaf scald and grain discoloration. These diseases were caused by fungi aggression. Controlling diseases that are caused by fungi with Si application gave better yield than fungicide application. This condition will decrease the intensity of fungicide application and help achieve agriculture sustainability.

Weak neck is caused by physicochemical changes during fruit growth and maturation. During fruit maturation, content of glucose, fructose, sucrose and total sugar increase but the starch decreases (Osman *et al*., 2000). This condition causes the rigidity of cells in peels of *Musa* sp. cv. Rastali fruit to decrease rapidly, which eventually leads to weak neck.

Ultrastructural study on six cultivars of *Musa* sp., i.e., Rastali, Awak, Tanduk, Abu, Berangan and Lemak Manis showed that cells of *Musa* sp. cv. Rastali collapsed completely after ripening and cells of *Musa* sp. cv. Awak became thinner making these two cultivars prone to weak neck. The cells of the other four cultivars became elongated and the cell wall became thicker after ripening, thus not showing weak neck symptom. Cultivars with elongated cells at the neck zone and thick cell walls after ripening are more resistant to weak neck. Cell elongation and the thickening of cell wall after ripening can be modified by nutrient application of Mg, B and Si during planting (Putra *et al*., 2010).

Marschner (1986) and Williams (2002) reported that some elements are important in structural integrity, i.e., P, Ca, Mg, B and Si. Deficiency in these elements decreases structural integrity of cells and this condition is a possible cause of weak neck. Adequate Mg, B and Si in plant tissues can increase the strength of cells, tissues and organs by increasing lignin in tissues (Salerno *et al*., 2004). Lignin is a polymer of phenolics, especially phenylpropanoids and is primarily a strengthening agent in the wall. It also defends against fungal/pathogen attack (Salerno *et al*., 2004). Besides lignin, other organic materials in cells that are important to cell strength are suberin, wax and cutin which are associated with wall waterproofing (Richard, 2008). Depositions of Mg, B and Si in the plant tissue increase the thickness of cell wall and size of vascular bundle (Williams, 2002). Thicker cell walls and bigger vascular bundle increases the strength of the organ.

Magnesium is a component of chlorophyll hence, magnesium application on *Musa* sp. cv. Rastali may increase chlorophyll synthesis. An increase in leaf chlorophyll content result to an increase in the photosynthesis rates and also Net Assimilation Rate (NAR). When assimilate concentration on plant tissue increases part of it is be translocated to fruit cells. Assimilate accumulation on fruit cells induces cell elongation and the thickening of the cell wall, especially at the neck zone (Smithson *et al*., 2004).

There is a high probability that application of B may resolve weak neck on *Musa* sp. cv. Rastali. Boron plays an important role in regulating hormone and enzyme levels in plants (Rashid *et al*., 2007). For example, sufficient B concentration in plant tissue will impede synthesis and activities of Pectate Lyase (PL) and pectinmethylesterase (PME), where PL and PME are enzymes that stimulate pectin degradation and cell wall hydrolysis. Reduction of PL and PME decreases pectin degradation rate and cell wall hydrolysis and finally reduce weak neck on *Musa* sp. cv. Rastali.

Silicon is another beneficial element for monocots including *Musa* sp. Accumulation of Si during stressed condition will impede destruction of plant cells and tissues. Plant cells and tissues become stronger when the formation of silica-cuticle is doubled on the layer of epidermis (Fawe *et al*., 2001; Datnoff *et al*., 2001).

Apart from the role of Mg, B and Si individually, application of Mg, B and Si concurrently appears to be interrelated in plant. Balanced nutrition is essential for optimum crop growth and maximum quantity and quality of yield. Studies concerning nutrition management for resolving weak neck on *Musa* sp. cv. Rastali have never been reported, therefore, this aspect is necessary for further investigation.

POST HARVEST

Information on post harvest of *Musa* sp. cv. Rastali aids in determining the occurrence or absence of weak neck. Several treatments are often applied to *Musa* sp. cv. Rastali which had been harvested in order to reduce the risk of weak neck. Several post harvesting techniques which were applied for reducing weak neck are usually applied during ripening and post harvest. Compared to the other aspects, i.e., genetic and plant nutrition, modification of environmental condition during post harvesting and ripening for eliminating of weak neck is the best to be done.

Several studies have shown that weak neck occurred because of the relative humidity and the extreme temperature in storage and during ripening (Semple and Thompson, 1988). High relative humidity increases the activity of Pectate Lyase (PL) and pectinmethylesterase (PME). High PL and PME activity increases pectin hydrolysis. The concentration of water soluble pectin in the peel and pedicel is usually high and this can decrease fruit firmness. The peel of *Musa* sp. fruit also become soft and easy to breaks. This condition is also observed on the pedicel. The pedicel becomes weak thus weakening the neck region or abcission layer (Imsabai *et al*., 2006; Saengpook *et al*., 2007).

Another factor is ethylene where weak neck decreases if the concentration of ethylene in the storage and ripening process increased. High ethylene concentration accelerates ripening and water loss. This condition was likely the cause of weak neck (Paull, 1996), which is similar to the mechanism during leaf abscission (Sexton and Roberts, 1982).

According to Seymour (1993), softness of *Musa* sp. cv. Rastali fruit peel is the same as in the other tissues. This is because depolymerization of pectin in the primary cell wall and middle lamella. Besides that, the softening of peel on *Musa* sp. cv. Rastali fruit also involved cell wall hydrolysis.

Weak neck on *Musa* sp. cv. Rastali is not related to the activities of endopolygalactoronase (endo-PG) and exo-PG, but it relates with the activities of PL and PME. The fact shows that weak neck is not caused by abscission but it is more likely caused by the breaking of the peel at the junction of the fruit and the hand. Previous research from Putra *et al.* (2010) showed that weak neck in *Musa* sp. cv. Rastali was caused by disintegration, collapse and thinning out of cells along the neck region. Imsabai *et al.* (2006) had determined that weak neck was not caused by fruit weight, peel thickness and water content of the peel at the pedicel area.

Based on the above explanation, more experiments on post harvesting should be done to reduce of the activities of PL and PME. Result showed that the low relative humidity and temperature during storage and ripening of *Musa* sp. cv. Rastali were able to decrease the activities of PL and PME. The reduction of PL and PME decreases pectin degradation rate and cell wall hydrolysis. Slow pectin degradation and cell wall hydrolysis reduces weak neck (Saengpook *et al.*, 2007). Ethylene application during ripening will speed up fruit ripening and water loss. *Musa* sp. cv. Rastali which has ripened quickly and underwent drastic reduction in water content would not experience to weak neck (Paull, 1996).

CONCLUSIONS

The most important problems related to the physiology of *Musa* spp. are weak neck, breakage of peel and destruction caused by cold temperature. Among those, weak neck is the main problem of *Musa* sp. as a commodity. Weak neck is the physiological weakening at the pedicel of *Musa* sp. fruit that causes individual fruits to be released from its hand prematurely.

The level resistance to weak neck is different among groups of *Musa* spp. with A and B genomes, diploid, triploid and tetraploid. *Musa* sp. group for B genome is more resistant to weak neck than A genome. The diploids group of *Musa* sp. is more resistant than triploids and tetraploids, while triploids are more resistant than tetraploids. *Musa* sp. cv. Rastali is AAB genome, but this cultivar is sensitive to weak neck. Sensitivity to weak neck is thought to come from the two A genomes.

There is high probability that application of Mg, B and Si can resolve weak neck on *Musa* sp. cv. Rastali. Magnesium application increases chlorophyll synthesis and photosynthesis rate. Assimilate accumulation on fruit cells induces cell elongation and the thickening of cell wall, especially in the neck zone. Boron plays an important role in regulating hormone and enzyme levels in plants. Sufficient amounts of B in plant tissue impede the synthesis and activity of PL and PME. Plant tissue and cells become stronger with Si application. This causes the formation of silica-cuticle double layer on the epidermis.

Low temperature along with relative humidity in storage as well as the process of ripening can reduce the weak neck problem because these conditions are able to decrease the activities of PL and PME. The reduction of PL and PME result to a decline in pectin degradation rate and cell wall hydrolysis. Slow pectin degradation and cell wall hydrolysis can reduce weak neck on *Musa* sp. cv. Rastali.

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