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Evidence-Based Wind-Felled Recovery of Plantains

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ABSTRACT

Wind damage and ruin are endemic to the plantain crop all over the world. Apart from pests and diseases that attack plantains, wind effects constitute one of the most devastating and major challenges confronting the plantains and banana farmer. This is especially so with the advent of climate change. Traditionally, wind-felled plantain pseudostems are cut for continued vegetative growth. As a result, any credible recovery method should be a welcome development at loss reduction, sustainable systemic damage control methodology and increased food availability. Rigid support like a fence wall was used to hold uprooted plantain pseudostems at varying inclination angles to the horizontal, in Lagos, Nigeria. Linear horizontal and vertical distances were measured after the side bud plantain shoots occurred to determine the inclination angle. Protractor angular measurements were also taken from the plantain photograph for improved accuracy. The calculated tangent was about 65°, while the protractor measurement was about 60°. Empirical evidence shows that side bud plantain outgrowths were visible for plantain pseudostems inclined approximately 60° to the horizontal, between four and six weeks from the period of inclination. Those plantain pseudostems inclined at about 40° and below withered, while those inclined at 80° to the horizontal showed no side bud outgrowth, but lengthened after about 18 months of dormancy. Also, those plantain pseudostems inclined at about 60° to the horizontal began to fruit after about 18 weeks of inclination. Consequently, plantains recovered by this method fruit much faster than those grown from either suckers or cuttings.

Keywords: bud outgrowth, climate change, dormancy, inclination angle, rigid support

INTRODUCTION

Schoofs *et al*. (1999) and CGIAR (2005) explain that bananas and plantains are staple food for at least 400 million people, such that about 10% (Dankyi *et al.* 2007; Faturoti *et al.* 2007) of the more than 80 million tons produced annually was exported and serves as dessert for many more millions of people. Furthermore, bananas and plantains are the developing world's fourth most important food crop (after rice, milk and wheat), and it is also one of the least researched (Schoofs *et al.* 1999; Biodiversity International 2009) of the major food sources due to the biology of the plantain, itself. Faturoti *et al.* (2007) quoting FAO (2004), report that banana is the world's second most important fruit crop after oil palm, and that its world production stood at about 71 million metric tonnes in 2003 from 130 countries. They also state that plantain was grown in 52 countries in the world, with a total production of about 33 million metric tonnes. In 2002, banana world production hit the more than 70 million metric tonnes mark. That production figure fell slightly between 2002 and 2004 and gradually increased to about 80 million metric tonnes in 2006 (UNCTAD 2009). Considering banana production (without plantains) by "main factors average in the period 2003-2007"; the following statistics were obtained (UNCTAD 2009): India (21%); Brasil (9%); China (9%); Philippines (9%); Ecuador (8%); Indonesia (7%) and rest of the world (37%).

Faturoti *et al.* (2007) corroborate Schoofs *et al.* (1999) and Biodiversity International (2009), at least in Nigeria by enumerating seven gaps of critical concern to plantain and banana production. These include government non-intervention, marketing and production constraints, weak and fragile links among stakeholders, research-farmers divide, project sustainability, and lack of documentation and funding.

Further to the above, and because of the increasing incidence of debilitating pests and banana diseases (Abele 2008), together with increasing world populations, breeders are expending great effort and resources to develop desirable seedless bananas: suitable for growing under a wide range of environmental conditions and also appropriate for many cultural food preferences (Ploetz *et al.* 2007). In 1990, CGIAR decided to extend its support for banana and plantain research beyond the humid and subhumid tropics of Sub-Saharan Africa to include Asia and the Caribbean. Hitherto, the main challenges to CGIAR research include breeding for resistance to Black Sigatoka disease, Fusarium wilt (Panama disease), banana nematodes and banana weevil borer; along with the development of improved production systems (CGIAR 2005). As an answer to the foregoing challenges, two CGIAR centres (Biodiversity International, France and the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria) conduct research on bananas and plantains.

Although organic banana production is attractive especially for East and central African producers, because of the stable and high value markets in both the US and EU, while conventional banana markets are stagnating; yet there are a lot of obstacles to entry. Abele (2008) catalogues the following problems, challenges and constraints confronting organic banana producers: lack of experience in intensive organic production; lack of experience in handling and exporting fresh produce; lack of professional management; diseconomies of scale in exporting small quantities (for example, for test exports); poor communication between foreign importers and local exporters; poor negotiation skills and judgment of exporters; lack of familiarity with international markets including knowledge of the organic market place overseas; lack of governmental support for exports; and lack of both physical infrastructure (roads) and political/legal frameworks favourable for sustainable organic production and exports, amongst others.

Perea (1998) explains that banana and plantain breeding

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Research Note

are very complicated and time consuming due to the triploidy, because the genome of 3 groups of 11 chromosomes gives the fruit their sterility.

In addition, Crouch *et al*. (1998) report that the triploidy genome of plantain (*Musa* spp; AAB genome) has been considered intractable to genetic improvement because of the production of putatively homogeneous 2n (=3x) gametes.

Also, the recalcitrance of monocotyledonous plants such as bananas (Hernández *et al*. 1998) to changes and adaptation coupled with the suggestions of Lassoudiere (1997) that climatic conditions (rainfall, light, and wind), soil types, topography and pests are factors to be considered for the choice of cropping system, development operations implementation and crop management sequence. Ortiz (1998) relates the genuine need within a plantain and banana (*Musa* spp.) breeding programme to assess thoroughly the experimental materials used through a sequence of trials to aid identification especially for both homeostatic and genotypic responses. These above factors impact on environmental changes as well as adaptation to specific niches. Proctor and Caygill (1985) explain that banana/plantain possesses certain characteristics, which differentiate them from most other fruits. They are produced on a single shoot that emerges from the pseudostem formed from a closely packed leaf sheath. Norman *et al*. (1996) suggest that the fruit develop parthenocarpically from proximal flowers, which are female. In addition, the fruit in one bunch are of known age and in cultivars under commercial cultivation, receive a similar supply of photosynthate. Norman *et al*. (1996) and Proctor and Caygill (1985) explain that cooking bananas and plantains are classified as *Musa* AAB, having contributions from *Musa balbisiana* genotypes.

As a result, bananas are harvested when allowed to grow to full maturity by cutting the bunch when the fingers have reached a specified girth, or grade, so as to reduce spontaneous ripening. Liew (1996) and other authors have equally suggested that with increasing urbanisation alongside urban poor in many developing countries like Nigeria and Rwanda, homestead garden plantain cultivation where they receive domestic manure has been on the increase. This is so because many people use it for food and has become very expensive as a result of its scarcity. In addition, other low-income urban dwellers plant on roadsides, by water canals and all 'available' unbuilt lands to augment their income, from its sale.

In and around tree crowns and shrubs, wind velocity is reduced and the wind profile changes. Air is slowed down in front of solitary trees, but on either side of the tree, the wind speed increases, behind and below the tree, the air is calm (Larcher 2003). This process leads to uneven rain distribution around individual trees or group of trees like plantains as to affect their water balance. As a result, in calm air, the boundary layer resistance of large leaves like banana or plantain is about three times those of small leaves (Larcher 2003).

A dominant plantain tree uprooted by windstorm creates a complex and a large gap. It opens up a space in the canopy as it falls. Its upturned roots tear up the soil, forms a pit with a heap of mineral soil exposed for both degradation and colonisation (Smith and Smith 2001). Furthermore, the falling plantain pseudostem tears through neighbouring pseudostems, cuts limbs of close canopy, crushes understory suckers and expose the gaps to further wind and insect damage. Additionally, sunlight and soil temperature increase, while both soil moisture and relative humidity decrease. So, wind causes a major disturbance to regeneration because it shapes the canopy of plantain pseudostems exposed to prevailing winds, affects their growth and finally uproots them by wind throw (Robertson 1997; Smith and Smith 2001). As a result, strong winds accompanied by heavy rains, which soften the soil about the plantain pseudostems, are usually very devastating.

Incidentally, plantain pseudostems growing in gaps, or along plantain garden edges, roadsides, and power lines suffer more from blow down, than those plantain pseudostems in the dense interior (Robertson 1997; Smith and Smith 2001). Dieback makes plantains prone to wind throws from less severe windstorms and it is a function of seasonal climatic fluctuations. These fluctuations include changes in wind regimes, rainfall patterns, evapotranspiration, which negatively impact plantation stability, plantain growth and also its regeneration (Robertson 1997). For plantain pseudostems growing on shallow or poorly drained soils with the roots spreading along, if these roots are not well anchored, are especially vulnerable to uprooting (Robertson 1997; Smith and Smith 2001).

Windbreaks are often planted in subtropical banana areas, especially near the sea to reduce prevailing wind damage (Robinson 1996; Holderness *et al*. 2000). Stover and Simmonds (1987) explain that only at the coastal areas of South Africa that, bananas might be affected by strong winds. But in Southeast Asia, Molina and Valmayor (2003) explain that the most serious climatic problem confronting commercial producers of banana in Asia and the Pacific are tropical storms and typhoons. Bananas are sensitive to strong winds, especially for tall cultivars bearing a heavy bunch of fruit. Windstorms cause blow downs (Robertson 1997) and typhoons can result in the complete destruction of banana plantations. The investigation of windbreak shading on the phenology, physiology and yield on banana, by Eckstein *et al*. (1997), reveal a reduction of monthly leaf emergence rate, an extended life cycle and a reduced bunch mass.

The *limba*-banana intercropping combination has been successfully practiced for a long time in Zaire (D. R. Congo). *Musa sapientum* of the Gros-Michel variety has been popular, and annual banana yields have been approximately 3 t/ha. Competition for plant nutrients at root level is minimal because of the creeping nature of the banana roots and the banana's life span, estimated at about 10 years (wsare.usu.edu 2003). Similarly, the *Luta* windbreak agroforestry project of the Commonwealth of the Northern Mariana Islands (CMNI) was established to protect fragile plants from damage. The objectives of this initiative are to establish a dense, multi-row windbreak/shelterbelt that will protect fragile crops from prevailing and seasonal wind damage and at the same time, provide a marketable crop (Taimanao 2003).

The evidence-based wind-felled plantains recovery protocol investigates the most probable inclination angle for side bud outgrowths in toppled (Asemota 2004; Sikora and Pocasangre 2004), wind-felled and wind-damaged plantain (*Musa* spp.) pseudo-stems that were supported on props and other rigid supports like a fence wall. It must, however, be clarified that this current study is actually the full account paper to the Asemota (2004) "Abstract-like" *Musa* News report. While a "News" item evokes some curiosity for the moment, it quickly fades into obscurity, and certain death. A news item is momentary, transitory and does not have the character for attracting further continuous and persistent investigation. Therefore, this study is an attempt to prevent that landmark plantain behaviour documented in Asemota (2004) as published in the June 2004 Issue of *InfoMusa* from death, obscurity and oblivion. It is also, to stimulate debate, discussion and research in consonance with new ways for studying plantains and bananas; in the light of current realities.

Previous studies, for instance Robinson (1996), Proctor and Caygill (1985) and Norman *et al*. (1996) explain that such toppled, up-rooted and damaged plantain pseudo-stems were cut for continued vegetative growth. It was observed in this study that the angle of tilt was critical for producing side bud outgrowths in wind-felled plantain pseudo-stems.

In the light of the foregoing, therefore, the current study was undertaken to test whether supporting wind-felled plantain pseudostems at appropriate inclination angles result in plantain corm switching. This procedure should ultimately lead to plantain pseudostems side shoot outgrowth. It is hypothesised that, by using rigid supports and focusing on the proper inclination angle that a previously wind-damaged plantain pseudostem will be recovered. Indeed, plantain pseudostems recovered by this method fruit much faster than those grown from either cuttings of previous cultivars or suckers.

MATERIALS AND METHODS

The materials used were wind-felled and partly broken growing plantain pseudo-stems (*Musa* spp; AAB genome) from suckers of previous cultivation that were subjected to the normal operating weather conditions on a homestead garden at *Ipaja*, a Lagos suburb in Nigeria. The sample size chosen for this study was 1 in 20; such that the statistical power probability is 0.05. A significance criterion is a statement of how unlikely a result must be if the null hypothesis is true, to be considered significant. For a criterion of 0.05, the probability of obtaining the observed effect when the null hypothesis is true must be less than 0.05 (Moore and McCabe 1993; Montgomery *et al*. 1998). Additionally, the Frequentist approach to inference was chosen in this study mainly because the Bayesian approach allows probabilities to have an interpretation as representing the scientist's belief that given values of the parameters are true (Moore and McCabe 1993; Montgomery *et al*. 1998).

Props and fence wall (as support) were other materials used for the experiment. The first plantain specimen was up-rooted by wind after rainfall in mid-May 1997. The above plantain pseudostem was stood by props to stand in the near up-right position. Because of the slimy nature of the plantain pseudostem, it shifted on the props to rest on fence wall by gravity. Hitherto, such plantain is cut for vegetative growth (Proctor and Caygill 1985; Robinson 1993; Norman *et al*. 1996; Robinson 1996). Similarly, in early May 1998 wind and rainfall left up-rooted, partly broken and mangled plantain pseudostems. In addition, another plantain pseudostem was supported using props about 45° to the horizontal. A third plantain pseudo-stem that was up-rooted from its base was supported with props as usual but lying almost vertically and accompanied by a spatial orientation of about 80° to the horizontal. Other damaged plantain pseudo-stems were left unattended, with some of their leaves touching the ground.

Additionally, on 1st October, 2001 wind action made two plantain pseudostems to lie at about 40 and 60°, respectively, on the fence wall, as before, for continued growth (if any).

Lineal measures, tangent angle calculations and protractor measurements of tilted plantain pseudo-stems were also used on the photographs taken, to determine the angle for which side bud is most probable.

Hitherto, windbreaks, intercropping, shading and other methods like nets and bricks have been used to reduce plantain and banana wind damage. However, rigid supports like prop was only used to prevent the bunch from falling to the ground and not used for wind-felled plantain pseudostem recovery purposes.

RESULTS AND DISCUSSION

Some plants need to be supported, staked or guyed because they can easily be blown over by the wind or because they get top-heavy with blossoms or fruit. Staking plants while they are growing is much easier because the branches are a little more flexible and less likely to break than when they are fully grown (copper-tree 2006). A plant support device may include a base that connects to a supporting post. The base may comprise a plate including a series of receptacles that connect to the supporting post and position the post in a generally vertical orientation (Stevenson 2006). The base may include spacers capable of creating aeration gap and slots that limit the rotation of the base when positioned within a container.

Lianas are woody climbing plants that begin their life cycles as seedlings rooted in the ground, but eventually rely on other plants for physical support in order to reach the top of the forest canopy (Vleut and Perez-Salicrup 2005). These lianas have a strong impact on forest dynamics because of their changes in stem density, biomass, and species richness as they affect the self-supporting plants during tropical forest succession (Letcher and Chazdon 2009). Lianas have been shown to negatively affect plants they climb upon by competing with them for common resources such as light, water and other nutrients, and most importantly by causing them physical damage (Vleut and Perez-Salicrup 2005). The above is in contradistinction with propping of plantains with dead logs or other non-growing supports (**Fig. 1**). Furthermore, lianas show a variety of adaptations for attaching themselves to, and climbing over their host like stem twining: the use of tendrils, thorns, and spines, and adhesive adventitious roots (Vleut and Perez-Salicrup 2005; Letcher and Chazdon 2009). As a result, liana seedlings negatively affect their supporting tree seedlings, and could impair tree regeneration.

Fig. 1 Tsambunu plantain bunch propping in Rwanda. Photo: Nsabimana A.

Plant stakes, plant ties, plant cages, trellises and arbors, bean poles and houses (Copper-tree 2006), decorative plant supports, link stakes, Y-stakes, grow through rings, border restraints, indoor plant support, shrub support, loop stakes, obelisks (Harrodhorticultural.com) are some of the generally used methods for supporting various plants. Chrysanthemum plants with a few blooms are generally supported by a steel or bamboo stake for each branch. Metal hoops can also be used where paper or plastic covered wire ties are used to fasten plants to stakes (Editors of Reader's Digest 2009). Metal hoops are also a good way to support bent and crooked plant and peonies. Also, tomato supports are set in place before plants get too large. Smaller varieties can be supported with small cages, but larger indeterminate varieties need large cages or tall stakes. These cages are secured with stakes so that they do not topple over (Nardozzi and Perry 2008). Also, blossom end rot shows up as dark, sunken spots on blossom end of tomatoes, peppers and squash. The rotting is caused by calcium imbalance in the plant, because the plant is unable to take up enough to

Fig. 2 July 1997 Wind-felled plantain pseudo-stem.

Fig. 3 May 1998 Plantain lying at 80°, and dormant for about 18 months.

Fig. 4 October 2001 Plantains lying at 40° and 60°, respectively, to the horizontal.

supply the rapidly developing fruit. If there are strawberries, it is to remove any berries that show signs of dark coloration or rot disease, and mulch under plants with straw to reduce contact with the ground where the disease spores reside (Nardozzi and Perry 2008).

In the study of herbaceous monocot plant form and function along a tropical rain forest light gradient, Swenson (2008) observed several potential adaptive reversals to tropical dicot trait strategies. One of those reversals is that shade-tolerant (ST) species were more likely to experience damage due to falling debris when compared to light-demanding (LD) species. As a result, for understorey herbaceous plants there would be no reason to have denser tissue to prevent them against physical damage as even the densest non-woody tissue would be destroyed by falling branches.

Generally, mechanical constraints determine the size and shape of self-supporting plants. Therefore, upright stems may become unstable mechanically if too slender and they could buckle. Naturally, the plant structure should be able to withstand both gravitational and wind loads which induce bending moments (Spatz and Bruechert 2000). The limit of a plant's structure is reached if at any point the bending moment is larger than the critical bending moment, and failure results. Depending upon the root-soil interaction, effective sail area (flexibility of branches), drag coefficient, and wind profile, which may be different for a solitary tree than for a tree within a dense stand, could lead to plant lodging. Flexibility combined with the viscoelastic behaviour of the plant, are the solution to dynamic wind loads effects (Robertson 1997; Spatz and Bruechert 2000; Smith and Smith 2001). Additionally, it is a challenge for a biologist to be able to trace the "principle of constant safety factors" to adaptive growth in response to photo-mechanical stimuli. This is especially so because neither the photo-mechanical receptor nor the signal transduction process, has as yet been elucidated. The following sub-section discusses wind-felled plantains recovery results with particular reference to this study.

The 1997 plantain specimen (**Fig. 2**) was observed to bud instinctively about 91.4 cm along the length of the inclined plantain pseudo-stem. Also, the budded plantain leaf sheath appeared in the direction of the rising sun, may be, because of photosynthesis or phototropism or to both. The calculated tangent angle to the horizontal was about 65° while the protractor measurement from its photograph was close to 60° to the horizontal. Although the actual period of switching for the plantain pseudo-stem could not be ascertained, the visible leave sheaths were detected about six (6) weeks later in early July 1997. But, by 12 weeks, the original plantain pseudo-stem withered, and fruiting occurred 18 weeks (October 1997) later, with 10 fingers.

Similarly, in May 1998, plantain pseudo-stems were felled and others broken at different heights above the ground. The plantain specimen supported about 45° to the horizontal budded in the direction of the rising sun (Dennyson 1989) about 83.8 cm above the ground (damaged about 91.4 cm above the ground). Probably because of constant and continuous rainfall, the bud appeared about 12 days, later. Unfortunately, and immediately following after this side bud growth appearance, the rains ceased and unnoticed vigorous termite activity damaged all its system roots. As a result, the plantation pseudo-stem withered and fell under gravity by its own weight.

The third sample that was supported at close to the vertical (about 80° to the horizontal) was dormant from May 1998 up to mid-November 1999 (18 months before the plantain was observed to be growing in length. The length during the period of dormancy was about 167.6 cm but grew about another 15 cm to begin to flower on 3rd December 1999 (**Fig. 3**). Probably, because of the girth circumference that was about 38 cm, only 3 banana-like fingers were produced with two fingers joined together at the middle. The above observations corroborate the work of Eckstein *et al.* (1997) that windbreak effects on the phenology, physiology and yield on banana and plantain, result from a reduction of monthly leaf emergence rate, an extended life cycle and a reduced bunch mass.

In addition, the plantain (**Fig. 4**) inclined at 40° withered while that at 60° to the horizontal budded 25.4 cm along its length on 3rd November 2001 from 1st October 2001 (Asemota 2004).

However, the fourth group that were left unattended, all withered and died, probably because they were unable to make their food through the process of photosynthesis.

Incidentally, Cobley and Steele (1976) and Norman *et al*. (1996) agree that when plantain pseudostems grown from suckers are about 5.5-10 months old and have produced 30-50 leaves, the apical growing points of the corm becomes reproductive and instead of leaves, it produces an inflorescence which grows up inside the pseudostem on a long unbranched axis. The foregoing fact, therefore, shows that wind-felled plantains pseudostems recovered by the method demonstrated in this study fruit much faster than those grown from either suckers or cuttings.

For rapidly growing organs like primary roots and shoots, and in some rhizomes (plantain and banana), which are stems that grow horizontally beneath the soil surface, the precise control of the direction of growth is, indeed, a gravity-sensing guidance system. In plantain guidance systems, there must be at least three components: (1) a sensory mechanism to detect whether or not the plantain pseudostem is on course, (2) a reaction mechanism which, on receipt of the appropriate signals from the sensory mechanism that the plantain pseudostem is off-course, can initiate growth changes in the plantain pseudostem to ensure that it is brought back on course; and (3) a plantain communication mechanism to conduct the signals from the sensory plantain mechanism to the plantain reaction mechanism (Wilkins 1989).

As a result, the course upon which the plantain pseudostem grows in the near upright position will have been set during the processes of evolution and adaptation to be the most advantageous for the successful survival of the plantain or banana pseudostem.

Furthermore, there exists in many non-growing mature plantain shoots, and in non-growing mature parts of growing plantain shoots, a capacity for plantain reorientation (Fuchs 1980) so that the plantain pseudostem side bud outgrowth shoot can regain its preferred orientation with respect to gravity, should it have been disturbed by wind or other abiotic factors (Wilkins 1989).

However, such plantain side bud outgrowth recovery mechanism is also found in the leaf sheath bases (nodes) of the shoots of grasses and cereals (Wilkins 1989). This plantain pseudostem recovery mechanism is of importance because it provides the wind-felled plantain shoots, with the capacity to regain a vertical orientation, if the plantain shoot has been knocked over by wind, and supported at the appropriate inclination angle.

CONCLUSION

In the light of the foregoing results and discussion, it is inferred that wind damaged plantain pseudo-stems might be salvaged and recovered when supported approximately 60° to the horizontal. This was so because the rhizome and the side bud out growth seem to respond most to sunlight and phototropism at about 60° inclination angle. This phototropic response must be based on the distribution of light intensity set up within the corm by purely optical mechanisms. The plantain corm switching to produce side bud outgrowths may have arisen through possible learning and adaptation processes to the environment. Evidence from this study shows that side bud plantain outgrowths were visible for plantain pseudostems inclined approximately 60° to the horizontal, between four and six weeks from period of inclination. Those plantain pseudostems inclined at about 40° and below withered, while those inclined at 80° to the horizontal show no side bud outgrowth, but lengthened after about eighteen (18) months of dormancy.

Also, those plantain pseudostems inclined at about 60° to the horizontal began to fruit after about eighteen (18) weeks of inclination. Consequently, plantains pseudostems recovered by this method fruit much faster than those grown from either suckers or cuttings, probably because these "non-growing" props are not in competition for sunlight, water and other nutrients with the guyed plantains.

REFERENCES

Abele S (2008) Organic bananas from Africa? *IITA Research for Development (R4D) Review,* Edition 1, Frontiers, 1-8 Available online: http://r4review.org/2008/09/organic-bananas-from-africa/

Asemota GNO (2004) Propping up toppled plantain plants. *INFOMUSA* **13 (1)**, 39

CGIAR (2005) Research and impact: Areas of Research: Banana. Available online: http://www.cgiar.org/impact/research/banana.html

Cobley LS, Steele WM (1976) *An Introduction to the Botany of Tropical Crops* (2nd Edn), Longman, London, 371 pp

Copper Tree Health Consulting (2006) *Kids Valley Garden- A Gardening Resource for Kids.* Available online: http://www.copper-tree.ca/garden/support.html

Crouch HK, Crouch JH, Jarret RC, Cregan PB, Ortiz R (1998) Segregation at microsatellite loci in haploid and diploid gametes of *Musa*. *MUSARAMA* **12 (1)**, 7

Dankyi AA, Dzomeku BM, Anno-Nyako FO, Adu-Appiah A, Gyamera-Antwi (2007) Plantain Production Practices in the Ashanti, Brong-Ahafo and Eastern regions of Ghana. *Asian Journal of Agricultural research* **1 (1)**, 1-9

Dennison DS (1989) Phototropism. In: Wilkins MB (Ed) *Advanced Plant Physiology*, English Language Book Society/Longman, Avon, United Kingdom, pp 149-161

Eckstein K, Robinson JC, Fraser C (1997) Physiological responses of banana (*Musa* AAA, Cavendish sub-group) in the subtropics. VII. Effects of windbreak shading on phenology, physiology and yield. *Journal of Horticultural Science* **72 (3)**, 389-396

Editors of Reader's Digest (2009) *How to support Chrysanthemum Plants in Your Organic Garden.* Available online: http://home.howstuffworks.com/how-to-support-chrysanthemum-plants-in-your-organic-garden

Faturoti BO, Madukwe MC, Tenkouano A, Agwu AE (2007) A review of policy acts and initiatives in plantain and banana innovation system in Nigeria. *African Journal of Biotechnology* **6 (20)**, 2297-2302

Fuchs JJ (1980) Discrete Adaptive Control: A sufficient condition for stability and applications. *IEEE Transactions on Automatic Control* **AC-25 (5)**, 940-949

Hernández JB, Remy P, Sagi L, Swennen R, Galan-Sauco V (1997) Chemotactic movement to wound exudates and attachments of *Agrobacterium tumefaciens* to single cells and tissues from banana plants. *MUSARAMA* **12 (1)**, 11

Holderness M, Frison E, Sharrock S, Kairo M (2000) Organic banana 2000: towards an organic banana in the Caribbean, *INIBAP*, Montpellier, 206 pp

Larcher W (2003) *Physiological Plant Ecology* (4th Edn), Springer, Berlin, pp 61, 263

Lassoudiere A (1997) The natural conditions of banana plantations in the dollar and ACP zones. *MUSARAMA* **11 (1)**, 11

Letcher SG, Chazdon RL (2009) Lianas and self-supporting plants during tropical forest succession. *Forest Ecology and Management* **257 (10)**, 2150-2156

Liew KW (1996) Field diseases in commercial banana production. *MUSARAMA* **12 (1)**, 2

Molina AB, Valmayor RV (2003) Banana production systems in Southeast Asia. Available online: http://www.inibap.org/publications/proceedings/foosecu.pdf

Montgomery DC, Runger GC, Hubele NF (1998) *Engineering Statistics* (1st Edn), John Wiley, New York, 149 pp

Moore DS, McCabe GP (1993) *Introduction to the Practice of Statistics* (2nd Edn), W. H. Freeman and Co., New York, pp 477-485

Nardozzi C, Perry L (2008) Supporting Plants and Other June gardening Tips. Available online: http://perrysperennials.info/articles/jun08tips.html

Norman MJT, Pearson CJ, Searle GE (1996) *Tropical Food Crops in their Environment* (2nd Edn), Cambridge University Press, Cambridge, UK, pp 319-335

Ortiz R (1998) AMMI and stability analyses of bunch mass in multilocational testing of *Musa* germplasm in Sub-Saharan Africa. *MUSARAMA* **12 (1)**, 6

Perea DM (1998) Potential for banana and plantain through biotechnology. *MUSARAMA* **12 (1)**, 5 (in Spanish)

Perez L (1997) Prueba exploratoria sobre el compotamiento agronomico de la resiembra "caballo" "macollo". [Investigation of the agricultural behaviour of "caballo" or "macollo" plantings]. *MUSARAMA* **12 (1)**, 23 (in Spanish)

Ploetz RC, Kepler AK, Daniells J, Nelson SC (2007) *Banana and Plantain-an overview with emphasis on Pacific island cultivars.* Traditionaltree.org, pp 1-27. Available online: www.traditionaltree.org

Proctor FJ, Caygill JC (1985) Ethylene in commercial post-harvest handling of tropical fruit. In: Roberts JA, Tucker GA (Eds) *Ethylene and Plant Development*, Butterworths, London, pp 317-322

Robertson A (2001) Forestry. In: Thompson RD, Perry A (Eds) *Applied Climatology: Principles and Practice* (1st Edn), Routledge, London, pp 229, 332

Robinson JC (1996) *Bananas and Plantains*, CAB International, Wallingford, 248 pp

Robinson JC (1993) *Handbook of Banana Growing in South Africa*, Institute for Tropical and Subtropical Crops, Nelspruit, South Africa, 168 pp

Schoofs HB, Panis P, Strosse HS, Mayo-Mosqueda A, Lopez Torres J, Roux N, Dolzel J, Sweenen R (1999) Bottlenecks in the generation and maintenance of morphogenic banana cell suspensions and plant regeneration via somatic embryogenesis therefrom. *INFOMUSA* **8 (2)**, 3-7

Sikora RA, Pocasangre LE (2004) New technologies to increase root health and crop production. *INFOMUSA* **13 (2)**, 25-29

Smith RL, Smith TM (2001) *Ecology and Field Biology* (6th Edn), Benjamin Cummings-Addison Wesley Longman, New York, pp 465-468

Spatz HC, Bruechert F (2000) Basic biomechanics of self-supporting plants: wind loads and gravitational loads on a Norway spruce tree. 1998 Conference on "Wind and other Abiotic Risks to Forests" No. 2 Joensuu, Finland. **35 (1-3)**, 33-44. Available online: http://cat.inist.fr/?aModele=afficheN&cpsidt=1469813

Stover RH, Simmonds NW (1987) *Bananas* (3rd Edn) Longmans, London, pp 468

Swenson NG (2009) Herbaceous monocot plant form and function along a tropical rain-forest light-gradient: a reversal of dicot strategy. *Journal of Tropical Ecology* **25**, 103-106

Taimanao E (2003) Luta windbreak/agroforestry project. Available online: http://www.fao/docrep/x5651e/x5651eCa.htm

UNCTAD (2009) *Banana.* Available online: http://www.unctad.org/infocomm/anglais/banana/sitemap.htm

Vleut I, Perez-Salicrup DR (2005) Lianas and their supporting plants in the understorey at Los Tuxtlas, Mexico. *Journal of Tropical Ecology* **21**, 577-580

wsare.unu.edu (2003) Limba-Banana Intercropping. Available online: http://wsare.unu.edu/projects/2003/FW01-091A.pdf

Wilkins MB (1989) Gravitropism. In: Wilkins MB (Ed) *Advanced Plant Physiology*, English Language Books Society/Longman, Avon, UK, pp 163-182