UNIVERSITI PUTRA MALAYSIA

INFLUENCE OF POTASSIUM, BORON AND ZINC ON GROWTH, YIELD AND FIBER QUALITY OF TWO KENAF (Hibiscus cannabinus L.) VARIETIES

RABAR FATAH SALIH

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By

RABAR FATAH SALIH

Thesis Submitted to School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

To my kind and beloved father, Fatah Salih Smail; and mother, Khadija Qadir Karim. Their prayers have been a major contribution to my success today.

To my brother and sisters, loved them heartily
To the person sacrificing for me and supporting me always (Have Endless Love for Her), my wife, Awat Hammed Smail
Also, to all my friends and to everyone who loves science

Abstract of thesis presented to the Senate of Univeriti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

INFLUENCE OF POTASSIUM, BORON, AND ZINC ON GROWTH, YIELD, AND FIBER QUALITY OF TWO KENAF (*Hibiscus cannabinus* L.) VARIETIES

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February 2016

Chair : Associate Professor Khalina Binti Abdan, PhD
Faculty : Engineering

Kenaf (*Hibiscus cannabinus* L.) consists of two major parts: bast and core, that have greatly different properties in term of anatomy, mechanical, physical and chemical content. Due to these differences, both parts are to be refined separately and the behaviour of the bast fibre is the research of interest.

In this research, different levels of potassium, boron and zinc were used to improve fiber quality, which aim to be utilized in biocomposite and textile industry. This research had been conducted in two field tests. The first field test involved three levels of potassium, three levels of boron and two levels of zinc on two kenaf varieties namely Fuhong FH-952 and kenaf variety 4383. Field test was laid out in randomized complete block design and three replications for each variety. Field test was conducted at Taman Pertanian Universiti, UPM, while second field test utilized optimum fertilizer level for FH-952 variety with various rate of zinc.

In the first part of the project, all levels of potassium, boron, and zinc used showed an improvement on the growth, nitrogen content, fiber yield, morphological, and mechanical properties. Potassium at the rate of 100 kg/ha and 150 kg/ha while boron at the rate of 1.0 kg/ha and 1.5 kg/ha showed good effect on both varieties. Meanwhile, zinc was found effective only on morphological and mechanical properties for both varieties. FH-952 variety gave better performance than 4383 variety in terms of plant growth (plant height and stem diameter) except for leaf number. The maximum height achieved was 232.13 cm and stem diameter was 15.58 mm when 150 kg/ha potassium was added without boron and zinc, which is about 30% of the increment. Nitrogen content showed highly effect on FH-952 variety when the percentage was increased with increasing of potassium rate. The nitrogen content value was recorded at 4.82% with potassium rate of 150 kg/ha without boron and zinc. Similar level of potassium 150 kg/ha showed an improvement in results fresh stem, dry stem, fresh bast, dry bast, fresh core and dry core, it was by 210.4, 58.0, 60.2, 16.6, 150.2 and 41.4 ton/ha, respectively. Fiber length, fiber width and the

cell wall thickness for the FH-952 variety were higher than 4383 variety when potassium was added at the rate of 150 kg/ha without boron and zinc, the value recorded was 2.53 mm, 23.22 µm and 7.73 µm, respectively. The highest value of lumen 9.67 µm and flexibility 47.76 were also recorded by FH-952 variety, when 100 kg/ha of potassium and 1.5 kg/ha boron applied. Variety 4383 has high value of tensile stress at 324.94 MPa and tensile modulus at 54.39 GPa when zinc was added at the rate of 5 kg/ha. However, fiber elongation of FH-952 is better than 4383 variety with 553.3 µm value when potassium, boron, and zinc were added at the rate of 100, 1.5 and 5.0 kg/ha, respectively.

In the second part of the project, the morphological properties of FH-952 variety were also improved when zinc at a lower rate of 1.5 kg/ha was applied, while maintaining potassium and boron at the optimum levels. Fiber length and lumen width were 3.55 mm and 11.28 µm, respectively, when zinc was added at the rate of 1.5 kg/ha, while zinc at the rate of 3 kg/ha showed the best result of flexibility by 49.85.

The overall results indicated that the 4383 variety is more suitable for biocomposite applications and the FH-952 is suggested to be applied in textile processing due to its morphological properties consistency.

Abstrak Tesis abstrak yang dikemukakan kepada Senat Univeriti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGARUH KALIUM, BORON, DAN ZINK TERHADAP TUMBESARAN, HASIL PENGELUARAN DAN KUALITI GENTIAN BAGI DUA JENIS VARIETI KENAF (*Hibiscus cannabinus* L.)

Oleh

RABAR FATAH SALIH

Februari 2016

Pengerusi : Profesor Madya Khalina Binti Abdan,PhD
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Kenaf (*Hibiscus cannabinus* L.) terdiri dari dua bahagian utama, iaitu gentian kulit dan teras, yang keduanya mempunyai sifat anatomi, mekanikal, fizikal dan komposisi kimia yang berbeza. Disebabkan oleh perbezaan ini, kedua-dua bahagian ini diproses secara berasingan dan sifat gentian kulit merupakan kepentingan penyelidikan ini.

Dalam kajian ini, tahap kalium, boron dan zink yang berbeza diguna untuk meningkatkan kualiti gentian kulit, yang bertujuan untuk kegunaan dalam industri biokomposit dan tekstil. Kajian ini telah dijalankan dalam dua ujian lapangan. Ujian lapangan pertama melibatkan tiga tahap kalium, tiga tahap boron dan dua tahap zink ke atas dua kenaf varieti iaitu Fuhong FH-952 dan varieti 4383. Ujian lapangan telah ditetapkan dalam reka bentuk rawak blok lengkap dan tiga ulangan bagi setiap varieti. Ujian lapangan telah dijalankan di Taman Pertanian Universiti, UPM, sementara, ujian lapangan kedua menggunakan kepekatan baja yang optimum untuk varieti FH-952 dengan kadar zink ynag berbeza

Dalam fasa pertama projek itu, semua tahap kalium, boron, dan zink yang digunakan telah menunjukkan peningkatan terhadap tumbesaran, kandungan nitrogen, hasil pengeluaran serat, sifat-sifat morfologi, dan mekanikal. Kalium pada kadar 100 kg/ha dan 150 kg/ha sementara boron pada kadar 1.0 kg/ha dan 1.5 kg/ha menunjukkan kesan yang ketara pada kedua-dua varieti. Sementara itu, zink didapati memberi kesan hanya pada sifat morfologi dan mekanikal pada kedua-dua varieti. Varieti FH-952 memberikan prestasi yang lebih baik daripada varieti 4383 dari segi tumbesaran (ketinggian dan diameter) kecuali bilangan daun. Ketinggian maksimum yang dicapai adalah 232.13 cm dan diameter batang ialah 15.58 mm apabila 150 kg/ha kalium ditambah tanpa boron dan zink iaitu kira-kira 30% peningkatan. Kandungan nitrogen telah menunjukkan kesan ketara kepada varieti FH-952 apabila peratusan itu meningkat dengan peningkatan kadar kalium. Nilai kandungan nitrogen dicatatkan pada 4.82% dengan kadar kalium 150 kg/ha tanpa boron dan zink. Tahap kalium

yang sama 150 kg/ha menunjukkan peningkatan pada hasil batang segar, batang kering, kulit segar, kulit kering, teras segar dan teras kering, iaitu pada 210.4, 58.0, 60.2, 16.6, 150.2 dan 41.4 tan/ha, masing-masing. Panjang gentian kulit, diameter kulit gentian dan ketebalan dinding sel untuk varieti FH-952 adalah lebih tinggi daripada varieti 4383 apabila kalium ditambah pada kadar 150 kg/ha tanpa boron dan zink, nilai yang dicatatkan adalah 2.53 mm, 23.22 µm dan 7.73 µm, masing-masing. Nilai tertinggi lumen 9.67 µm dan fleksibiliti 47.76 juga direkodkan oleh FH-952 variati, apabila 100 kg/ha kalium dan 1.5 kg/ha boron digunakan. Variati 4383 mempunyai nilai tinggi tegasan tegangan pada 324.94 MPa dan modulus tegangan pada 54.39 GPa apabila zink ditambah pada kadar 5 kg/ha. Walau bagaimanapun, pemanjangan gentian FH-952 adalah lebih baik daripada variati 4383 dengan nilai 553.3 µm apabila kalium, boron, dan zink ditambah pada kadar masing-masing 100, 1.5 dan 5.0 kg/ha.

Dalam fasa kedua ujian lapangan, ciri-ciri morfologi variati FH-952 juga telah bertambah baik apabila zink pada kadar yang lebih rendah iaitu 1.5 kg/ha diaplikasikan, disamping mengekalkan kalium dan boron pada tahap optimum. Panjang gentian dan lebar lumen adalah 3.55 mm and 11.28 µm, masing-masing, apabila zink telah ditambah pada kadar 1.5 kg/ha, sementara zink pada kadar 3 kg/ha menunjukkan yang hasil terbaik fleksibiliti pada 49.85.

Secara keseluruhannya, keputusan ini menunjukkan bahawa variati 4383 adalah lebih sesuai untuk aplikasi biokomposit dengan sifat mekanikal yang bersesuaian dengan keupayaan gentian untuk aplikasi produk tersebut dan variati FH-952 dicadangkan untuk digunakan dalam pemprosesan tekstil kerana sifat morfologi yang lebih konsisten pada struktur dalaman gentian.

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I certify that a Thesis Examination Committee has met on 23 February 2016 to conduct the final examination of Rabar Fatah Salih on his thesis entitled "Influence of Potassium, Boron and Zinc on Growth, Yield and Fiber Quality of Two Kenaf (*Hibiscus cannabinus* L.) Varieties" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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ANOVA	Analysis of Variance
a.s.l.	Above sea level
β	Beta
B	Boron
B1B2B3	Boron (0, 1.0 and 1.5)
B/ha	Boron per hectare
°C	Degree celsius
C	Carbon
C3	Three carbon compound
Ca	Calcium
cm	Centimeter
CO_2	Carbon dioxide
Cu	Copper
CWT	Cell wall thickness
Cv	Cultivars
DAP	Day after planting
DBN	Distance between nodes
DBY	Dry bast yield
DCY	Dry core yield
DF	Degree of freedom
DP	Degree of the cellulose polymerization
DSY	Dry stem yield
EC	Electrical conductivity
EFB	Oil palm empty fruit bunch
FAO	Food and Agriculture Organization
FBY	Fresh bast yield
FCY	Fresh core yield
Fe	Iron
FH-952	Fuhong-952 kenaf variety
FSY	Fresh stem yield
FD	Fiber diameter
FW	Fiber width
FL	Fiber length
F.V	F Value
FX	Flexibility
g	Gram

g/cm^3	Gram per cubic centimeter
g/plant	Gram per plant
GPa	Gigapascal
H_2SO_4	Sulfuric acid
HT	Plant height
IAA	Indole acetic acid
ICP-AES	Inductively coupled plasma–atomic emission spectroscopy
IJSG	International Jute Study Group
INTROP	Institute of Tropical Forestry and Forest Production
IPC TM-650	Institute for Interconnecting and Packaging Electronic Circuits or (Association Connecting Electronics Industries) Test Methods Manual
K	Potassium
K1K2K3	Potassium (0, 100 and 150)
K/ha	Potassium per hectare
kg/ha	Kilogram per hectare
K_2O	Potassium oxide
kN	Kilonewton
LAI	Leaf area index
LW	Lumen width
LN	Leaf number
m	Meter
mm	Millimeter
mm/min	Millimeter per minute
µm	Micrometer
MARDI	Malaysian Agricultural Research and Development Institute
mg/kg	Milligram per kilogram
Mg	Magnesium
Mn	Manganese
ml	Milliliter
M.S	Mean square
MPa	Megapascal
m^2	Square meter
N	North
46% N	Nitrogen
ND	Not detected
n.d.	No date
ns	Not significant
OPF	Oil palm fiber

OPFR	Oil Palm Fronds Rachis
P	Phosphorus
ppm	Parts per million
pH	Potential of Hydrogen
plants/ha	Plants per hectare
R	Replication
RCBD	Randomized Complete Block Design
RNA	Ribonucleic acid
S	South
SS	Sum of square
SAS	Statistical Analysis System
SE	Standard error
seeds/kg	Seeds per kilogram
SFL	Single fiber length
SNK	Student-Newman-Keuls
T	Treatment
TPU	Taman Pertanian Universiti
t/ha	Ton per hectare
V	Variety
Z	Zinc
Z1Z2	Zinc (0 and 5.0)
Z1Z2Z3Z4Z5	Zinc (0, 1.5, 3.0, 4.5 and 6.0)
%	Percent

CHAPTER 1

INTRODUCTION

1.1 Background

Natural plant fibers except cotton fiber are not perfect fibers for yarn and textiles including kenaf, jute, flax, ramie, and others. Textile grading also of the natural fibers in textiles and yarn have the following characteristics: fiber length, fineness, elongation, flexibility, diameter, luster, and its color. It is different based on economical request. Fiber's length, fineness, strength and stiffness determine the commercial value of the natural fibers (Lips and Dam, 2013). Natural fibers can be used in engineering applications due to the morphological properties. Consequently, a gap exists to determine the relationship between the morphological characteristics and the mechanical properties based on the textile process which the gap needed to focus on and resolve.

Nevertheless, valuable engineering products made from natural resources such as kenaf plants are widely used (Akil *et al.,* 2011) because they are renewable and environmentally friendly. The fiber reinforced polymer composite sector, largely use kenaf fibers as a fiber in the field of engineering (Mahjoub *et al.,* 2014).

Therefore, it is necessary to develop kenaf fiber if it is suitable for the requirements of most engineering applications. Furthermore, the development of kenaf fiber properties is required for excellent marketing of the products made from kenaf fibers.

It is unfortunate so far that for textile processing, the bast kenaf quality is not adequate to make clothes. Eventually, some researchers blended the bast fiber of kenaf with other natural fibers especially cotton to solve this problem. Thus, the problems of kenaf bast fiber are repeated during fabric processing. Several previous studies showed the fact about the problems of the kenaf bast fiber (Ramaswamy *et al.,* 1994; Zhang, 2003; Ismail *et al.,* 2011).

Kenaf fiber is blended with cotton, several textile products can be produced using the conventional textile machinery (Ramaswamy *et al.,* 1994). Estimation of price and suitability of fiber are determined by the mechanical properties and the fineness of the fiber for the purpose of quality yarn manufacturing. Welford (1996) found that a fiber which could offer high tenacity and a small and an even diameter would be welcomed to the textile field.

Moreover, Rowell and Stout (1998) stated that the kenaf and jute fibers are strong but exhibits brittle break and have only a slight extension at break. Three varieties of kenaf are treated to determine the quality properties in using textile. A small and even diameter is necessary for producing good quality yarn (Samad *et al.,* 2002). Furthermore, if kenaf bast fiber is coarse, brittle, and too short, it is difficult to use it for textile processes (Zhang, 2003). However, Ismail *et al.* (2011) reported that the elongation at the break of the kenaf bast fiber is too short because the kenaf fibers are stiff. Harwood *et al.* (2008) reported that flax has also faced the same problem for yarn products. They further stated that flax is so stiff such that the blending and spinning of yarn products into fine yarns is difficult.

Kenaf (*Hibiscus cannabinus* L.) which grows in a warm season is an herbaceous plant and a fellow of the Malvaceae family. It was introduced in Malaysia in early 1990s. It was also known as a potential alternative fiber material for wood composite, pulp, and paper under the 7th Malaysian Plan 1996-2000 during late 1990s (Khalil *et al.,* 2010).

Kenaf is a fast growing plant which can be harvested in only 4 to 5 months (Paridah and Khalina, 2009). Therefore, it is suitable to plant it twice a year. Kenaf, one of the significant plants of the world, is cultivated for the production of gunny bag, sackcloth, rope, and twine (Dempsey, 1975; Webber *et al.,* 2002a). Moreau *et al.* (1995) and Ramaswamy *et al.* (1995) stated that the coarse fabrics are produced due to blend jute and pineapple fibers. However, kenaf is better than jute if treated properly, because it is lustrous, higher in tensile strength, and stronger in resistance to rot. These characteristics have made kenaf to be a valuable natural fiber source available for industrial and clothes uses.

Currently, there are many kenaf applications. Potentially, it can be changed into paper, building material, sound absorbent, particleboard, and fiberboard. It is also used as a filler in polymer composite (Zampaloni *et al.,* 2007; Liu *et al.,* 2007; Paridah *et al.,* 2009; Juliana *et al.,* 2012).

However, after wood and bamboo, kenaf is considered as a traditional third-world crop. It originated from Africa, and it has been introduced for industrial uses as a new resource (Khalil and Suraya, 2011). In addition, it is commercially planted in more than 20 countries around the world. Kenaf was introduced in Asia in about 1990.

Currently, India, China, and Thailand are among the principal kenaf fiber manufacturers in the global bast fiber market (FAO, 2012). Kenaf, an important bast fiber, is largely cultivated for its fibers. Moreover, the kenaf stems are also used in biocomposites and insulation mat, and in textile applications (Alexopoulou *et al.,* 2013).

1.2 Problem Statement

Kenaf fiber is one of the most important plant fibers in Malaysia. As known, kenaf fibers are very beneficial to a broad range of composite and textile uses. These impacts make it feasible for kenaf fibers to be studied, so as to improve the quality of the crop.

Generally, this kind of natural fiber has a problem with quality, and may relate with an agronomy. These problems appear during the textile process and yarn products. Since the fiber bundles are coarse and stiff (hard), they eventually create problems for kenaf processing. Furthermore, the shortness of the single fibers of the bast kenaf causes many problems for textile industries. Moreover, the physical properties of the fiber have a strong relationship with the mechanical properties. For instance, when the fiber has high modulus, the fibers have less elongation and low flexibility. For yarn products, a fiber which has good length and small diameter is accepted. Reddy and Yang (2005) stated that a fiber has low modulus fiber which is flexible, soft, and durable.

Kenaf fiber is used in a broad range of manufacturing. Therefore, its quality is very important to improve. This project aims to find the alternative way to improve the bast fiber of kenaf for the processing of the textile by using agronomy approach. Also, it tries to prevent these adverse properties in the production of higher quality yarns for fabric.

1.3 Justification

It is believed that kenaf bast fibres produce fibre with excellent morphological and mechanical properties, while the fertilizers potassium, boron, and zinc adding at different concentrations. On the other hand, it is expected that the manipulation of potassium, boron and zinc will increase the length between nodes of fiber, and improve flexibility. It is also expected that the coarseness and brittleness become lower.

On the other hand, in this work, it is hypothesized that the combination of potassium, boron, and zinc would increase plant height, stem diameter, nitrogen content, and fiber yield. Also, it would improve the morphological and mechanical properties of the kenaf varieties. Potassium, boron, and zinc are considerably important for most plant and it encourage researcher to supplement these fertilizers. To the best of the researcher's knowledge, no study has been conducted to investigate the impact of the combination of potassium, boron, and zinc on kenaf. Information on the relationship between these fertilizers and kenaf varieties are limited.

1.4 Scope and Limitations

This study focuses on two new kenaf varieties; FH-952 and 4383. It was limited to an investigation of improving quality and quantity for both varieties. Two field experiments were conducted at Taman Pertanian Universiti (TPU), Universiti Putra Malaysia, Serdang, Selangor which was to improve growth parameters: plant height, stem diameter, and leaf number, and also to increase and improve fiber yield, morphological, and mechanical properties of kenaf fibers by increasing nitrogen content in the cell wall of the fibers through adding of potassium, boron, and zinc at different concentrations.

1.5 Objectives

The goal of the project is to improve kenaf bast fiber quality for textile processing industry purposes. The specific objectives are:

1) To determine the effect of potassium, boron, and zinc on the growth of kenaf plants,
2) To determine the effect of potassium, boron, and zinc on the mechanical properties of bast fiber for two kenaf varieties, and
3) To investigate quality and morphological properties of two kenaf varieties.

REFERENCES

Abdul-Hamid, H., Yusoff, M. H., Ab-Shukor, N. A., Zainal, B., & Musa, M. H. (2009). Effects of different fertilizer application level on growth and physiology of *Hibiscus cannabinus* L.(Kenaf) planted on BRIS soil. *Journal of Agricultural Science*, *1*(1), 121.

Abid, M. U. H. A. M. M. A. D., Ahmad, N., Ali, A. S. G. H. A. R., Chaudhry, M. A., & Hussain, J. A. M. I. L. (2007). Influence of soil–applied boron on yield, fiber quality and leaf boron contents of cotton (*Gossypium hirsutum* L.). *J. Agric. Sci. Soc*, *3*(1), 7-10.

Abu Bakar, A., & Hassan, A. (2009). Oil palm empty fruit bunch fibre-filled poly (*vinyl chloride*) composites. In: Research on Natural Fibre Reinforced Polymer Composite. Universiti Putra Malaysia Press, Serdang, Selangor, pp. 14-35. ISBN 978-967-344-002-3

Adair, W. S., & Snell, W. J. (1988). Organization and in vitro assembly of the Chlamydomonas reinhardtii cell wall. *Self-assembling architecture*, 25-41.

Adamson, W. C., Long, F. L., & Bagby, M. O. (1979). Effect of nitrogen fertilization on yield, composition, and quality of kenaf. *Agronomy Journal*,*71*(1), 11-14.

Agbaje, G. O., Saka, J. O., Adegbite, A. A., & Adeyeye, O. O. (2008). Influence of agronomic practices on yield and profitability in kenaf (*Hibiscus cannabinus* L.) fibre cultivation. *African Journal of Biotechnology*, *7*(5).

Aji, I. S., Sapuan, S. M., Zainudin, E. S., & Abdan, K. (2009). Kenaf fibres as reinforcement for polymeric composites: a review. *International Journal of Mechanical and Materials Engineering*, *4*(3), 239-248.

Akar, D. (2007). Potential boron pollution in surface water, crop, and soil in the Lower Buyuk Menderes Basin. *Environmental Engineering Science*,*24*(9), 1273-1279.

Akgul, M., & Tozluoglu, A. (2009). Some chemical and morphological properties of juvenile woods from beech (*Fagus orientalis* L.) and pine (*Pinus nigra* A.) plantations. *Trends in Applied Sciences Research*, *4*(2), 116-125.

Akil, H., Omar, M. F., Mazuki, A. A. M., Safiee, S. Z. A. M., Ishak, Z. A. M., & Bakar, A. A. (2011). Kenaf fiber reinforced composites: A review.*Materials & Design*, *32*(8), 4107-4121.

Akubueze, E. U., Ezeanyanaso, C. S., Orekoya, E. O., Akinboade, D. A., Oni, F., Muniru, S. O., & Igwe, C. C. (2014). Kenaf fiber (*Hibiscus cannabinus* L.): a viable alternative to jute fiber (*Corchorus genus*) for agro-sack production in Nigeria. *World J Agric Sci*, *10*(6), 308-331.

Alam, AKMM., Khandker, S., Gani, M.N., Khandker, S. & Ahmed, S.A. (2000). Uptake addition and balance of nutrients under integrated fertilizer management in jute based cropping patterns. *B. J. Sci. and Tech. 2*(2): 147 - 153. In: Effects of n, p, k and s application on yield and quality of white jute (*Corchorus capsularis* l.) var. bjc - 2197.

Al-Bahadly, E. A. O. (2013). *The mechanical properties of natural fiber composites* (Doctoral dissertation, Faculty of Engineering, Swinburne University of Technology for the degree of Doctor of Philosophy at Swinburne University of Technology).

Alexopoulou, E., Christou, M., Mardikis, M., & Chatziathanassiou, A. (2000). Growth and yields of kenaf varieties in central Greece. *Industrial Crops and products*, *11*(2), 163-172.

Alexopoulou, E., Papatheohari, Y., & Kipriotis, E. (2007). Response of kenaf (*Hibiscus cannabinus* L.) growth and yield to nitrogen fertilization. *JOURNAL OF FOOD AGRICULTURE AND ENVIRONMENT*, *5*(2), 228.

Alexopoulou, E., Papatheohari, Y., Christou, M., & Monti, A. (2013). Origin, Description, Importance, and Cultivation Area of Kenaf. In *Kenaf: A Multi-Purpose Crop for Several Industrial Applications* (pp. 1-15). Springer London.

Alloway, B. J. (2004). *Zinc in soils and crop nutrition*. Brussels, Belgium: International Zinc Association.

Amel, B. A., Paridah, M. T., Sudin, R., Anwar, U. M. K., & Hussein, A. S. (2013). Effect of fiber extraction methods on some properties of kenaf bast fiber. *Industrial Crops and Products*, *46*, 117-123.

Anderson, K. (2007). Selecting the right fiber for the right product. *Writer/reporter for* [TC]², 1-2. www.techexchange.com

André, A. (2006). *Fibres for strengthening of timber structures*. Luleå tekniska universitet/Civil and Environmental Engineering/Structural Engineering.

Andreini, C., Banci, L., Bertini, I., & Rosato, A. (2006). Counting the zinc-proteins encoded in the human genome. *Journal of proteome research*, *5*(1), 196-201.

Anon, (2012). Did you know? *Malaysia Airlines Going Places, September*. In: Salit, Tropical Natural Fibres and Their Properties.

Ashori, A., Harun, J., Raverty, W. D., & Yusoff, M. N. M. (2006). Chemical and morphological characteristics of Malaysian cultivated kenaf (*Hibiscus cannabinus*) fiber. *Polymer-Plastics Technology and Engineering*, *45*(1), 131-134.

Aravind, P., & Prasad, M. N. V. (2003). Zinc alleviates cadmium-induced oxidative stress in Ceratophyllum demersum L.: a free floating freshwater macrophyte. *Plant Physiology and Biochemistry*, *41*(4), 391-397.

Aravind, P., & Prasad, M. N. V. (2004). Zinc protects chloroplasts and associated photochemical functions in cadmium exposed *Ceratophyllum demersum* L., a freshwater macrophyte. *Plant Science*, *166*(5), 1321-1327.

Arbaoui, S., Evlard, A., Mhamdi, M. E. W., Campanella, B., Paul, R., & Bettaieb, T. (2013). Potential of kenaf (*Hibiscus cannabinus* L.) and corn (*Zea mays* L.) for phytoremediation of dredging sludge contaminated by trace metals. *Biodegradation*, *24*(4), 563-567.

Arbaoui, S., Campanella, B., Rezgui, S., Paul, R., & Bettaieb, T. (2014). Bioaccumulation and photosynthetic activity response of kenaf (*Hibicus cannabinus* L.) to cadmium and zinc. *Greener Journal of Agricultural Sciences, 4* (3), pp. 091-100.

Aref, F. (2010). Influence of zinc and boron interaction on residual available iron and manganese in the soil after corn harvest. *Am. Euras. J. Agric. Environ. Sci*, *8*(6), 767-772.

Ates, S., Ni, Y., Akgul, M., & Tozluoglu, A. (2008). Characterization and evaluation of Paulownia elongota as a raw material for paper production.*African journal of biotechnology*, *7*(22).

Azizi Mossello, A., Ainun, Z. M. A., & Rushdan, I. (2009). Chemical, morphological, and technological properties of Malaysian cultivated kenaf (*Hibiscus cannabinus* L.) fibers. *Kenaf Biocomposites, Derivatives & Economics, Bandar Baru Seri Petaling, Kuala Lumpur: Pustaka Prinsip Sdn. Bhd.*

Bada, B. S., & Raji, K. A. (2010). Phytoremediation potential of kenaf (*Hibiscus cannabinus* L.) grown in different soil textures and cadmium concentrations. *African Journal of Environmental Science and Technology*,*4*(5).

Bada, B. S., Arowolo, T. A., & Ozoike, P. N. (2014). Assessment of heavy metal content of soil and kenaf (*Hibiscus cannabinus* L.) In a nutrient degraded soil amended with dairy sludge. *Journal of Applied Phytotechnology in Environmental Sanitation*, *3*(4).

Baley, C. (2002). Analysis of the flax fibres tensile behaviour and analysis of the tensile stiffness increase. *Composites Part A: Applied Science and Manufacturing*, *33*(7), 939-948.

Bañuelos, G. S., Bryla, D. R., & Cook, C. G. (2002). Vegetative production of kenaf and canola under irrigation in central California. *Industrial crops and products*, *15*(3), 237-245.

Banuelos, G. S., Cardon, G., Mackey, B., Ben-Asher, J., Wu, L., Beuselinck, P., ... & Zambrzuski, S. (1993). Boron and selenium removal in boron-laden soils by four sprinkler irrigated plant species. *Journal of Environmental Quality*, *22*(4), 786-792.

Bednarz, C. W., Shurley, W. D., Anthony, W. S., & Nichols, R. L. (2005). Yield, quality, and profitability of cotton produced at varying plant densities.*Agronomy Journal*, *97*(1), 235-240.

Beckermann, G. (2007). Performance of hemp-fibre reinforced polypropylene composite materials. *Research Commons at the University of Waikato*, *2*(5), 18.

Bell, R. W., & Dell, B. (2008). *Micronutrients for sustainable food, feed, fibre and bioenergy production*. International Fertilizer Industry Association (IFA).

Bel-Berger, P., Von Hoven, T., Ramaswamy, G. N., Kimmel, L., & Boylston, E. (1999). Textile technology. *J Cotton Sci*, *3*, 60-70.

Bert, N. (2002). Kenaf fibres. In *Presentation of the 5th Annual Conference of the American Kenaf Society, Memphis TN Nov* (pp. 7-9).

Bilba, K., Arsene, M. A., & Ouensanga, A. (2007). Study of banana and coconut fibers: Botanical composition, thermal degradation and textural observations. *Bioresource technology*, *98*(1), 58-68.

Blackburn, R. S. (Ed.). (2005). *Biodegradable and sustainable fibers*. The Textile Institute. CRC press.

Bledzki, A. K., & Gassan, J. (1996). Einfluß von haftvermittlern auf das feuchteverhalten naturfaserverstärkter kunststoffe. *Die Angewandte Makromolekulare Chemie*, *236*(1), 129-138.

Blevins, D. G., & Lukaszewski, K. M. (1998). Boron in plant structure and function. *Annual review of plant biology*, *49*(1), 481-500.

Brennan, R. F. (2005). *Zinc application and its availability to plants* (Doctoral dissertation, Murdoch University).

Brown, P. H., & Shelp, B. J. (1997). Boron mobility in plants. *Plant and soil*,*193*(1-2), 85-101.

Brown, P. H., & Hu, H. (1998). Boron mobility and consequent management in different crops. *Better Crops*, *82*(2), 28-31.

Burns, R. G., DeForest, J. L., Marxsen, J., Sinsabaugh, R. L., Stromberger, M. E., Wallenstein, M. D., ... & Zoppini, A. (2013). Soil enzymes in a changing environment: current knowledge and future directions. *Soil Biology and Biochemistry*, *58*, 216-234.

Bolaños, L., Lukaszewski, K., Bonilla, I., & Blevins, D. (2004). Why boron?.*Plant Physiology and Biochemistry*, *42*(11), 907-912.

Bowman, D. T. (2007). Variety selection in 2007 cotton Information. *North Carolina State Uni. Coop. Ext. Publ. AG-417. North Carolina Stat Uni., Releigh*, 27-38.

Cabangbang, R. P., & Zabate, P. Z. (1978). Field performance and fiber properties of foreign and local varieties of ramie (*Boehmeria nivea*). *Philippine Journal of Crop Science, 3*(2), 76-77.

Cakmak, I., Hengeler, C., & Marschner, H. (1994). Partitioning of shoot and root dry matter and carbohydrates in bean plants suffering from phosphorus, potassium and magnesium deficiency. *Journal of Experimental Botany, 45*(9), 1245-1250.

Cakmak, I. (2000). Tansley Review No. 111. Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. *New Phytologist*, 185-205.

Cakmak, I. (2008). Enrichment of cereal grains with zinc: agronomic or genetic biofortification?. *Plant and Soil, 302*(1-2), 1-17.

Cañigueral, N., Vilaseca, F., Méndez, J. A., López, J. P., Barberà, L., Puig, J., ... & Mutjé, P. (2009). Behavior of biocomposite materials from flax strands and starch-based biopolymer. *Chemical Engineering Science, 64*(11), 2651-2658.

Cabangbang, R. P., & Zabate, P. Z. (1978). Field performance and fiber properties of foreign and local varieties of ramie (*Boehmeria nivea*). *Philippine Journal of Crop Science, 3*(2), 76-77.

Catroga, A., Fernando, A., & Oliveira, J. S. (2005, October). Effects on growth, productivity and biomass quality of kenaf of soils contaminated with heavy metals. In *Biomass for energy, industry and climate protection-Proceedings of the 14th European biomass conference and exhibition, ETA-Florence, WIP-Munich* (pp. 149-152).

Catroga, A. M. D. (2009). *Contributo para o estudo das potencialidades do Kenaf* (*Hibiscus cannabinus* L.) *na fitorremediação de solos contaminados com metais pesados* (Doctoral dissertation, FCT-UNL).

Chaney, R. L. (1993a). Zinc phytotoxicity. In *Zinc in soils and plants* (pp. 135-150). Springer Netherlands.

Chaney, (1993b). Risks associated with use of sewage sludge in Agriculture. In *Proc. 15th Federal Convention.vol.1. Australian water and wastewater Association, Queensland, Australia; 1993. In: Role of Zinc in Plant Nutrition- A Review*, pp. 374-391.

Chhabra, K. L., Bishoni, L. K., Bhattoo, M. S. (2004). Effect of macro and micronutrients on the productivity of cotton genotypes. Int. Symp. "Strat. Sust. Cot. prod.- A G. Vis." 2 Crop Prod. 23 25. In: Effect of sulphur and micronutrients (iron and zinc) on yield and quality of cotton in a vertisol.

Cheng, Z. (2001). Kenaf research, products and applications in Japan. *Plant Fibers Prod*, 23(3), 16-24.

Chew, W. Y., Abdul Malek, M. A., & Ramli, K. (1982). Nitrogen and potassium fertilization of Congo Jute (*Urena lobata*) and kenaf (*Hibiscus cannabinus*) on Malaysian peat. *MARDI Res Bull, 10*(3), 317-322.

Clement, J. D., Constable, G. A., Stiller, W. N., & Liu, S. M. (2012). Negative associations still exist between yield and fibre quality in cotton breeding programs in Australia and USA. *Field Crops Research, 128*, 1-7.

Coates, W. (1996). Kenaf performance in northwestern Argentina. *Industrial Crops and Products, 5*(3), 223-228.

Cosentino, S.L., & Copani, V. (2003). Agroindustria, 2, 2/2: 137-145. In: Effects of Nitrogen, Phosphorus and Potassium Levels on Kenaf (*Hibiscus cannabinus* L.) Growth and Photosynthesis under Nutrient Solution

DahmardehGhalehno, M., & Nazerian, M. (2013). The investigation on chemical and anatomical properties of Roselle (*Hibiscus sabdariffa*) stem. *Cellulose*, 40, 44-73.

Dang, H. K., Li, R. Q., Sun, Y. H., Zhang, X. W., & Li, Y. M. (2010). Absorption, accumulation and distribution of zinc in highly-yielding winter wheat. *Agricultural sciences in China*, 9(7), 965-973.

Day, P. R. (1965). Particle fractionation and particle-size analysis. *Methods of Soil Analysis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling*, (methodsofsoilana), 545-567

Dempsey, J. M. (1975). Fiber crops. *Univ. Presses of Florida*.

Dhindsa, R. S., Beasley, C. A., & Ting, I. P. (1975). Osmoregulation in cotton fiber accumulation of potassium and malate during growth. *Plant Physiology, 56*(3), 394-398.

Disante, K. B., Fuentes, D., & Cortina, J. (2011). Response to drought of Zn-stressed Quercus suber L. seedlings. *Environmental and experimental botany, 70*(2), 96-103.

Dong, H., Tang, W., Li, Z., & Zhang, D. (2004). On potassium deficiency in cotton–disorder, cause and tissue diagnosis. *Agriculturae Conspectus Scientificus (ACS), 69*(2-3), 77-85.

Donohue, T. M., & Osna, N. A. (2003). Intracellular proteolytic systems in alcohol-induced tissue injury. Alcohol Research and Health, 27, 317-324.

Domingo, L. E., & Kyuma, K. (1983). Trace elements in tropical Asian paddy soils: I. Total trace element status. *Soil science and plant nutrition, 29*(4), 439-452.

El-Defan, T. A. A., El-Kholi, H. M. A., Rifaat, M. G. M., & Allah, A. E. A. (1999). Effect of soil and foliar application of potassium on yield and mineral content of wheat grains grown in sandy soils. *Egyptian J. Agric. Research, 77*(2), 513-522.

Epstein, E., & Bloom, A. J. (2005). Inorganic components of plants. Mineral nutrition of plants: principles and perspectives, 2nd edn. *Sinauer Associates, Inc., Massachusetts*, 44-45.

Fagbemigun, T. K., Fagbemi, O. D., Otitoju, O., Mgbachiuzor, E., & Igwe, C. C. (2014). Pulp and paper-making potential of corn husk. *International Journal of AgriScience*, 4(4), 209-213.

Faircloth, J. C. (2007). Cotton variety trials. *Virginia cotton production guide. Virginia Polytechnic Inst. and State Univ. Coop. Ext. Publ*, 424-300.

Fakhradeen, A.Q.S., & Rabar, F. S. (2011). Response of growth, and yield for six genotypes of cotton (*Gossypium hirsutum* L.) to potassium fertilization. *Journal of Kirkuk University for Agricultural Sciences, 2*(1), 84-93.

Fakhradeen, A.Q.S., & Rabar, F. S. (2010). Response of fibers properties of some cotton (*Gossypium hirsutum* L.) genotypes to potash fertilization. *Journal of Tikrit University for Agricultural Sciences, 11*(3), 110-119.

FAO. (2012). *FAO Production year book 3. New York: FAO*. In: Foroughi, M. (2012). Performance of kenaf (*Hibiscus cannabinus* L.) genotypes and their variability based on DNA micrositellite makers (Doctoral dissertation, Universiti Putra Malaysia).

FAT, O., Ghazali, A., & Rosli, W. W. (2014). Diversified Biometric, Chemical and Morphological Composition of Elaeis Guineesis Frond Vascular Bundles for Pulp and Paper Configuration.

Fidelis, M. E. A., Pereira, T. V. C., Gomes, O. D. F. M., de Andrade Silva, F., & Toledo Filho, R. D. (2013). The effect of fiber morphology on the tensile strength of natural fibers. *Journal of Materials Research and Technology*, 2(2), 149-157.

Fleming, G. A. (1980). Essential micronutrients. I. Boron and molybdenum. *Applied soil trace elements. edited by Brian E. Davies.*

Gamstedt, E. K., & Almgren, K. M. (2007) Natural fiber composites –with special emphasis on effects of the interface between cellulosic fibers and polymers. *Proceedings of the 28th Ris* International Symposium on Materials Science*. In: The Mechanical Properties of Natural Fiber Composites, a Thesis of PhD, p. 18.

Gemici, Ü., & Tarcan, G. (2002). Distribution of boron in thermal waters of western Anatolia, Turkey, and examples of their environmental impacts. *Environmental Geology, 43*(1-2), 87-98.

Gething, P. A. (1993). Improving returns from nitrogen fertilizer. The potassium-nitrogen partnership. *Research Topics-International Potash Institute*, (13 2nd revision).

Ghazali, M. J., Azhari, C. H., Abdullah, S., & Omar, M. Z. (2008). Characterization of natural fibres (sugarcane bagasse) in cement Composites. In *Proceedings of the World Congress on Engineering* (Vol. 2, pp. 2-4).

Graham, R. D., Welch, R. M., Grunes, D. L., Cary, E. E., & Norvell, W. A. (1987). Effect of zinc deficiency on the accumulation of boron and other mineral nutrients in barley. *Soil Science Society of America Journal, 51*(3), 652-657.

Goodman, A. M., Ennos, A. R., & Booth, I. (2002). A mechanical study of retting in glyphosate treated flax stems (*Linum usitatissimum*). *Industrial crops and products, 15*(2), 169-177.

Gormus, O. (2002). Effects of rate and time of potassium application on cotton yield and quality in Turkey. *Journal of agronomy and crop science, 188*(6), 382-388.

Gupta, U. C., Kening, W. U., & Liang, S. (2008). Micronutrients in soils, crops, and livestock. *Earth Science Frontiers, 15*(5), 110-125.

Gupta, U. C. (1993). *Boron and its role in crop production*. CRC press.

Gyul'akhmedov, A. N., & Mamedov, O. K. (1984). Boron content in soils of central Burma. *Izv. Akad. Nauk. Az. SSR, Ser. Biol. Nauk, 1*, 49-51.

Hafeez, B., Khanif, Y. M., & Saleem, M. (2013). Role of zinc in plant nutrition-a review. *American Journal of Experimental Agriculture, 3*(2), 374-391.

Han, J. S., Mianowski, T., & Lin, Y. Y. (1999). Validity of plant fiber length measurement—a review of fiber length measurement based on kenaf as a model. *Kenaf Properties, Processing and Products*, 149-167.

Hänsch, R., & Mendel, R. R. (2009). Physiological functions of mineral micronutrients (Cu, Zn, Mn, Fe, Ni, Mo, B, Cl). *Current opinion in plant biology, 12*(3), 259-266.

Hardy David, H., Ray Tucker, M., Catherine, E., Stokes and Steve Troxler. (2003). Crop fertilization based on North Carolina soil tests. N.C. *Department of Agriculture and Consumer Services Agronomic Division. Circular No. 1 updated February* 2014.

Harun, J., Paridah Md, T., & Khalina, A. (2009, February). Kenaf-Its establishment and journey towards energizing the wood-based and biocomposite industry in Malaysia. In *International Conference on Prospect of Jute and Kenaf as Natural Fibres, Dhaka-Bangladesh*.

Harwood, J., McCormick, P., Waldron, D., & Bonadei, R. (2008). Evaluation of flax accessions for high value textile end uses. *Industrial crops and products*, 27(1), 22-28.

Hasfalina, C. M., Maryam, R. Z., Luqman, C. A., & Rashid, M. (2010). The potential use of kenaf as a bioadsorbent for the removal of copper and nickel from single and binary aqueous solution. *Journal of Natural Fibers*, *7*(4), 267-275.

Hiremath, G. M., & Hunsigi, G. (2012). Effect on Nitrogen and potash levels on concentration of nitrogen and potassium in petiole of two cotton hydrids (*Gossypium sp*.). *Karnataka Journal of Agricultural Sciences, 8*(1).

H'ng, P. S., Khor, B. N., Tadashi, N., Aini, A. S. N., & Paridah, M. T. (2009). Anatomical structures and fiber morphology of new kenaf varieties. *Asian Journal of Scientific Research*, 2(3), 161-166.

Holbery, J., & Houston, D. (2006). Natural-fiber-reinforced polymer composites in automotive applications. *Jom*, 58(11), 80-86.

Hölscher, D., Möller, R. F., Denich, M., & Fölster, H. (1996). Nutrient input-output budget of shifting agriculture in Eastern Amazonia. *Nutrient Cycling in Agroecosystems, 47*(1), 49-57.

Hosseini, S. M., Maftoun, M., Karimian, N., Ronaghi, A., & Emam, Y. (2007). Effect of zinc× boron interaction on plant growth and tissue nutrient concentration of corn. *Journal of plant nutrition, 30*(5), 773-781.

Hossain, M. D., Musa, M. H., Talib, J., & Jol, H. (2010). Effects of nitrogen, phosphorus and potassium levels on kenaf (*Hibiscus cannabinus* L.) growth and photosynthesis under nutrient solution. *Journal of Agricultural Science, 2*(2), p49.

Hossain, M. D., Hanafi, M. M., Jol, H., & Jamal, T. (2011). Dry matter and nutrient partitioning of kenaf (*Hibiscus cannabinus* L.) varieties grown on sandy bris soil. *Australian Journal of Crop Science*, *5*(6), 654.

Hossain, M. D., Hanafi, M. M., Jol, H., & Hazandy, A. H. (2013). Growth, yield and fiber morphology of kenaf (*Hibiscus cannabinus* L.) grown on sandy bris soil as influenced by different levels of carbon. *African Journal of Biotechnology, 10*(50), 10087-10094.

Hosomi, K. (2000). Utilization dried kenaf leaves to the meal. In *Proceeding of the 2000 International Kenaf Symposium, Hiroshima, Japan, Oct* (pp. 13-14).

Ho, W. M., Ang, L. H., & Lee, D. K. (2008). Assessment of Pb uptake, translocation and immobilization in kenaf (*Hibiscus cannabinus* L.) for phytoremediation of sand tailings. *Journal of environmental sciences, 20*(11), 1341-1347.

Humphries, M. (2009). Fourth edition. Fabric Reference, Pearson education, *Inc., Section Two*, pp. 14-102.

Igras, J., & Danyte, V. (2007). Potassium concentration in tissue water as an indicator of crop potassium requirement. In *Proceedings of International Conference Plant Nutrition and its prospects. Brno Czech Rep* (pp. 47-51).

Imas, P. (2013). Potassium-the Quality Element in Crop Production. *IPI International Potash Institute. ISBN* 978-3-905887-07-5.

Indran, S., & Raj, R. E. (2015). Characterization of new natural cellulosic fiber from Cissus quadrangularis stem. *Carbohydrate Polymers*, 117, 392-399.

International Jute Study Group (2009a). Progress report of kenaf (*Hibiscus cannabinus*) screening and seed multiplication programme in Bangladesh under the project (*CFC/IJSG/25*).

International Jute Study Group (2009b). Kenaf project increased production efficiency in small-holder kenaf production systems for specific industrial application (*CFC/ IJSG/ 25*). *Implementation in China from April to November*, 2009.

Iiyama, K., Lam, T. B. T., Meikle, P. J., Ng, K., Rhodes, D. I., & Stone, B. A. (1993). Cell wall biosynthesis and its regulation. *Forage cell wall structure and digestibility*, (foragecellwalls), 621-683.

IPC-TM-650 Test Methods Manual Number 2.4.18.3. *Subject: Tensile Strength, Elongation, and Modulus*, pp. 1-3.

Ismail, H., Omar, N. F., & Othman, N. (2011). The effect of kenaf fibre loading on curing characteristics and mechanical properties of waste tyre dust/kenaf fibre hybrid filler filled natural rubber compounds. *BioResources*, 6(4), 3742-3756.

Jafri, J. (2008). *Effects Of Fiber Size Modification On The Mechanical Properties Of Kenaf Fiber Reinforced Polyester Composite* (Bachelor dissertation, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka).

Jähn, A., Schröder, M. W., Füting, M., Schenzel, K., & Diepenbrock, W. (2002). Characterization of alkali treated flax fibers by means of FT Raman spectroscopy and environmental scanning electron microscopy. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 58*(10), 2271-2279.

Jai-Kashyap, J. C., Sharma, V. K., & Gupta, A. D. Taneja and J. Kashyap, 1997. Effect of Zn on growth and yield characters and uptake by different parts of two cotton cultivars. *Agric. Sci. Digest-Karnal, 17*, 83-86.

Jawaid, M. H. P. S., & Khalil, H. A. (2011). Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review. *Carbohydrate Polymers*,*86*(1), 1-18.

Juliana, A. H., Paridah, M. T., & Anwar, U. M. K. (2012). Properties of three-layer particleboards made from kenaf (*Hibiscus cannabinus* L.) and rubberwood (*Hevea brasiliensis*). *Materials & Design*, 40, 59-63.

Joffe, R., Andersons, J., & Wallström, L. (2003). Strength and adhesion characteristics of elementary flax fibres with different surface treatments. *Composites Part A: Applied Science and Manufacturing, 34*(7), 603-612.

Jones Jr, J. B. (2001). *Laboratory guide for conducting soil tests and plant analysis*. CRC press.

Kabata-Pendias, A. (2010). *Trace elements in soils and plants*. CRC press.

Kaldor, A. F. (1989). Preparation of kenaf bark and core fibers for pulping by the Ankal method. *Tappi journal, 72*(9), 137-140.

Kanking, S., Niltui, P., Wimolmala, E., & Sombatsompop, N. (2012). Use of bagasse fiber ash as secondary filler in silica or carbon black filled natural rubber compound. *Materials & Design*, 41, 74-82.

Kano, T. (1997). Development and prospect of kenaf board. *Reference No. 47 of the kenaf society of Kochi and economic reports of Ehime*, *25*, 44.

Kanwal, S., Rahmatullah, Maqsood, M. A., & Bakhat, H. F. S. G. (2009). Zinc requirement of maize hybrids and indigenous varieties on Udic Haplustalf. *Journal of plant nutrition, 32*(3), 470-478.

Kasim, W. A. (2007). Physiological consequences of structural and ultra-structural changes induced by Zn stress in Phaseolus vulgaris. I. Growth and photosynthetic apparatus. *International Journal of Botany*, *3*(1), 15-22.

Katyal, J. C., & Singh, B. (1992). Availability of boron in the soil and its uptake by rice as influenced by soil moisture regimes. *Oryza, 29*, 384-384.

Katyal, J. C., & Randhawa, N. S. (1983). Micronutrients (FAO Fertilizer and Plant Nutrition Bulletin 7). *FAO, Rome, Italy*.

Kawahara, H., de Cheveigné, A., Banno, H., Takahashi, T., & Irino, T. (2005, September). Nearly defect-free F0 trajectory extraction for expressive speech modifications based on STRAIGHT. In *Interspeech* (pp. 537-540).

Kawai, S., Sasaki, H., & Yamauchi, H. (2001). Bio-mimetic approaches for the development of new wood composite products. In *1st Wood Mechanics Conference, Lausanne* (pp. 503-514).

Khalina, A., Nazri, A.M., and Hasniza, M.Z. (2008). Simulation studies of fiber reinforced plastic composite on injection molding processing for automotive application. Proceedings Colloquium of Kenaf Research output 1-2 December 2008, Seremban, Negeri of the Sembilan Malaysia Universiti Putra Malaysia.

Khalil, H. A., Yusra, A. I., Bhat, A. H., & Jawaid, M. (2010). Cell wall ultrastructure, anatomy, lignin distribution, and chemical composition of Malaysian cultivated kenaf fiber. *Industrial Crops and Products, 31*(1), 113-121.

Khalil, H. A., & Suraya, N. L. (2011). Anhydride modification of cultivated kenaf bast fibers: morphological, spectroscopic and thermal studies. *BioResources, 6*(2), 1121-1135.

Khalil, H. A., Hossain, M. S., Rosamah, E., Azli, N. A., Saddon, N., Davoudpoura, Y., ... & Dungani, R. (2015). The role of soil properties and it's interaction towards quality plant fiber: A review. *Renewable and Sustainable Energy Reviews, 43*, 1006-1015.

Khanom, S., Hosssain, S., & Hossain, S. A. (2012). Effects of N, P, K and S application on yield and quality of white jute (*Corchorus capsularis* L.) var. BJC-2197. *Dhaka University Journal of Biological Sciences, 21*(2), 109-116.

Kiaei, M. (2014). Investigation on Biometrical Properties and Mineral Content of Rice Residues and its Application in Pulp and Paper Production. *Advances in Environmental Biology*, 8(13), 952-959.

Killinger, G. B. (1969). Kenaf (*Hibiscus cannabinus* L.), a multi-use crop. *Agronomy Journal, 61*(5), 734-736.

Kipriotis, E., Alexopoulou, E., Papatheohari, Y., Moskov, G., & Georgiadis, S. (2007). Cultivation of kenaf in north-east Greece: Part II-Effect of variety and nitrogen on growth and dry yield. *Journal of Food Agriculture and Environment*, 5(1), 135.

Kukcinavičiūtė, J., Jonaitienė, V., & Abromavičius, R. (2007). Influence of Roving on Semi-wool and Wool Yarn Quality. In *Magic World of Textile Conference* (pp. 35-38). In "Comparitive Investigation of Mechanical Indices of Sheep's Wool and Dog Hair Fibre." *Fibres & Textiles in Eastern Europe* (2012).

Kuo, S. (1996). Phosphorus. In: Sparks DL (ed) Methods of soil analysis. *Part 3 Chemical methods. SSSA and ASA. Madison, W.I.* pp. 869-920.

Köleli, N., Eker, S., & Cakmak, I. (2004). Effect of zinc fertilization on cadmium toxicity in durum and bread wheat grown in zinc-deficient soil. *Environmental Pollution, 131*(3), 453-459.

Lai, C. Y., Sapuan, S. M., Ahmad, M., Yahya, N., & Dahlan, K. Z. H. M. (2005). Mechanical and electrical properties of coconut coir fiber-reinforced polypropylene composites. *Polymer-Plastic Technology and Engineering*,*44*(4), 619-632.

Lamy, B., & Baley, C. (2000). Stiffness prediction of flax fibers-epoxy composite materials. *Journal of materials science letters, 19*(11), 979-980.

Lee, S. C., & Mariatti, M. (2008). The effect of bagasse fibers obtained (from rind and pith component) on the properties of unsaturated polyester composites. *Materials Letters*, *62*(15), 2253-2256.

Leigh, R. A., & Wyn Jones, R. G. (1984). A hypothesis relating critical potassium concentrations for growth to the distribution and functions of this ion in the plant cell. *New Phytologist, 97*(1), 1-13.

LeMahieu, P. J., Oplinger, E. S., & Putnam, D. H. (2003). Kenaf. *Alternative Field crops Manual. http://www. corn. agronomy. wisc. edu/FISC/Alternatives/Kenaf. htm*.

Liu, F., Li, F., Du, G., & Xiao, F. (2013). Balanced fertilization improves fiber yield and quality of winter flax (*Linum usitatissimum* L.).

Liu, W., Drzal, L. T., Mohanty, A. K., & Misra, M. (2007). Influence of processing methods and fiber length on physical properties of kenaf fiber reinforced soy based biocomposites. *Composites Part B: Engineering*, *38*(3), 352-359.

Liu, F., Liang, X., Zhang, N., Huang, Y., & Zhang, S. (2001). Effect of growth regulators on yield and fiber quality in ramie (*Boemheria nivea* (L.) Gaud.), *China grass. Field Crops Research, 69*(1), 41-46.

Li, X., Du, G., Wang, S., & Meng, Y. (2015). Influence of Gender on the Mechanical and Physical Properties of Hemp Shiv Fiber Cell Wall in Dioecious Hemp Plant. *BioResources*, *10*(2), 2281-2288.

Liang, K., Shi, S. Q., & Wang, G. (2014). Effect of Impregnated Inorganic Nanoparticles on the Properties of the Kenaf Bast Fibers. *Fibers, 2*(3), 242-254.

Lips, S. J., & van Dam, J. E. (2013). Kenaf fibre crop for bioeconomic industrial development. In *kenaf: A multi-purpose crop for several industrial applications* (pp. 105-143). *Springer London.*

Lubin, M., & Ennis, H. L. (1964). On the role of intracellular potassium in protein synthesis. *Biochimica et Biophysica Acta (BBA)-Specialized Section on Nucleic Acids and Related Subjects, 80*(4), 614-631.

Lomov, S., Verpoest, I., & Robitaille, F. (2005). Manufacturing and internal geometry of textiles. Design and manufacture of textile composites.*Woodhead Publishing Limited and CRC Press*, *200*, 1-61.

Lomov, S. V., Huysmans, G., Luo, Y., Parnas, R. S., Prodromou, A., Verpoest, I., & Phelan, F. R. (2001). Textile composites: modelling strategies. *Composites Part A: applied science and manufacturing*, *32*(10), 1379-1394.

Loomis, W. D., & Durst, R. W. (1992). Chemistry and biology of boron.*BioFactors (Oxford, England)*, *3*(4), 229-239.

Lv, S. M. (1993). The Standard and Examination of Bast Fibers, *Fiber Branch of China Association for Standardization, Beijing*, pp. 81-90. In: Balanced Fertilization Improves Fiber Yield and Quality of Winter Flax (*Linum usitatissimum* L.).

Macarayan, O. B. (2005). Harvesting cycle and nitrogen requirement of three ramie (*Boehmeria nivea* L. Gaud.) cultivars, 13-1. *USM Journal, University of Southern Philippines, The Philippines.*

Mahjoub, R., Yatim, J. M., Sam, A. R. M., & Hashemi, S. H. (2014). Tensile properties of kenaf fiber due to various conditions of chemical fiber surface modifications. *Construction and Building Materials, 55*, 103-113.

Malik, M. N. A., Makhdum, M. I., Mirza, M. B., & Chaudhry, F. I. (1989). Preliminary observations on potassium nutrition of cotton crop in silt and clay loam soils. *Pakistan Cottons* (Pakistan).

Mamatha, N., & CHANNAL, H. (2007). Effect of sulphur and micronutrients (iron and zinc) on yield and quality of cotton in a vertisol. *Department of soil science and agricultural chemistry college of agriculture, Dharwad University of agricultural sciences, dharwad-580, 5*.

Marschner, H. (1995a). *Mineral nutrition of higher plants*, 2nd edn. Academic, San Diego, CA. In: Importance of Boron for Agriculture Productivity: A Review.

Marschner, H. (1995b). Functions of mineral nutrients: macronutrients. *Mineral nutrition of higher plants, 2*, 379-396.

Marschner, H. (2011). *Marschner's mineral nutrition of higher plants*. Academic press.

Matthews, G. A. (1972). Effects of nitrogen, sulphur, phosphorus and boron on cotton in Malawi. *Experimental Agriculture, 8*(03), 219-224.

Mengel, K. and E.A. Kirkby. (1987). Principles of Plant Nutrition, Fourth edition, p. 427-453. In: Effects of Different Fertilizer Application Level on Growth and Physiology of *Hibiscus cannabinus* L. (Kenaf) Planted on BRIS Soil.

Mikshina, P., Chernova, T., Chemikosova, S., Ibragimova, N., Mokshina, N., & Gorshkova, T. (2013). Cellulosic Fibers: Role of Matrix Polysaccharides in Structure and Function. In *Cellulose–Fundamental Aspects* (pp. 91-113). Rijeka: InTech.

Mukherjee, P. S., & Satyanarayana, K. G. (1986). An empirical evaluation of structure-property relationships in natural fibres and their fracture behaviour. *Journal of materials science*, *21*(12), 4162-4168.

Mukherjee A.B. (2005). An overview of boron: sources, uses and uptake by plants. *International Workshop "Fate and Impact of Persistent Pollutants in Agroecosysterns*" 10 - 12 March 2005, lUNG, Pu/awy. Poland. In: Plant-mineral nutrition: macro- and micro nutrients, uptake, functions, deficiency and toxicity symptoms, pp. 1-31.

Mullins, G. L., Schwab, G. J., & Burmester, C. H. (1999). Cotton response to surface applications of potassium fertilizer: a 10-year summary. *Journal of production agriculture, 12*(3), 434-440.

Musa, M.J., Denamany, G., Syed, Kamaruddin, S.W. (1992). Secondary and Micronutrient in cocoa production- An Appraisal. H.A.H Sharifudih., P Vimala and H Aminudin (ed.) *Secondary and Micronutrients in Malaysian Agriculture. Pub; Malaysian Society of Soil Science*. In: Importance of Boron for Agriculture Productivity: A Review

Murphy, B. C., & Lancaster, J. D. (1971). Rt esponse of Cotton to Boron. *Agronomy Journal, 63*(4), 539-540.

Mogea, J., Seibert, B., & Smits, W. (1991). Multipurpose palms: the sugar palm (Arenga pinnata (Wurmb) Merr.). *Agroforestry Systems*, *13*(2), 111-129.

Mohanty, A. K., Misra, M., & Drzal, L. T. (Eds.). (2005). *Natural fibers, biopolymers, and biocomposites*. CRC Press.

Mohanty, A. K., Misra, M., & Hinrichsen, G. (2000). Biofibres, biodegradable polymers and biocomposites: an overview. *Macromolecular materials and engineering*, *276*(1), 1-24.

Mohamad, W., & Hazira, W. (2007). *The physical and mechanical properties of kenaf-reinforced polypropylene composites treated with compatibilizers/Wan Hazira Wan Mohamad* (Doctoral dissertation, Universiti Teknologi MARA).

Mohamed, A., Bhardwaj, H., Hamama, A., & Webber, C. (1995). Chemical composition of kenaf (*Hibiscus cannabinus* L.) seed oil. *Industrial crops and products, 4*(3), 157-165.

Moreau, J. P. (1995). Mechanical processing of kenaf for nonwovens. *TAPPI J*, 78(2), 96-105.

Mossello, A. A., Harun, J., Resalati, H., Ibrahim, R., Shams, S. R. F., & Tahir, P. M. (2010). New approach to use of kenaf for paper and paperboard production. *BioResources*, *5*(4), 2112-2122.

Mousavi, S. R., Galavi, M., & Rezaei, M. (2013). Zinc (Zn) importance for crop production–A review. *International Journal of Agronomy and Plant Production, 4*(1), 64-68.

Mwaikambo, L. Y. (2009). Tensile properties of alkalised jute fibres. *BioResources, 4*(2), 566-588.

Nabulo, G., Black, C. R., & Young, S. D. (2011). Trace metal uptake by tropical vegetables grown on soil amended with urban sewage sludge. *Environmental Pollution, 159*(2), 368-376.

Nascimento, J., Do, A., & Athayde, M. L. F. (1999, September). Effects of lime and of potassium fertilizer on technological properties of cotton fibers. In *Annual Brasilian Congress of Cotton, 2nd, Ribeirao Preto, SP, Brasil* (pp. 5-10).

Needles, H. L. (1986). *Textile fibers, dyes, finishes, and processes: a concise guide*. Noyes Publications.

Neckář, B., & Das, D. (2006). Mechanics of Parallel Fiber Bundles. *Fibers & Textiles in Eastern Europe*, *14*(3), 57.

Neil Curtis, (n.d.). Plant nutrition and soils. *New Zealand Institute of Chemistry*, pp. 1-18.

Ng, S.K., Tan, Y.P., Chan, E., & Cheong, S.P. (1974). Nutritional complexes of oil palm planted on peat in Malaysia. II. Preliminary results of copper sulphate treatments. *Oleaginous 29*: 445-456. In: Importance of Boron for Agriculture Productivity: A Review.

Nishimura, N., Izumi, A., & Kuroda, K. I. (2002). Structural characterization of kenaf lignin: differences among kenaf varieties. *Industrial Crops and Products, 15*(2), 115-122.

Norton, A. J., Bennett, S. J., Hughes, M., Dimmock, J. P. R. E., Wright, D., Newman, G., ... & Edwards ‐ Jones, G. (2006). Determining the physical properties of flax fibre for industrial applications: the influence of agronomic practice. *Annals of Applied Biology, 149*(1), 15-25.

Ochi, S. (2008). Mechanical properties of kenaf fibers and kenaf/PLA composites. *Mechanics of materials, 40*(4), 446-452.

Ochi, S. (2009). Tensile properties of kenaf fiber bundle. *SRX Materials Science, 2010*.

Oksman, K. (2001). High quality flax fibre composites manufactured by the resin transfer moulding process. *Journal of reinforced plastics and composites, 20*(7), 621-627.

Qiao, X., He, Y., Wang, Z., Li, X., Zhang, K., & Zeng, H. (2014). Effect of foliar spray of zinc on chloroplast β-carbonic anhydrase expression and enzyme activity in rice (*Oryza sativa* L.) leaves. *Acta Physiologiae Plantarum, 36*(2), 263-272.

Oosterhuis, D. M. (2002). Potassium management of cotton. *Potassium for Sustainable Crop Production*, 331-346.

Othman, A. R., & Haron, N. H. (1992). Potensi industri kecil tanaman enau. *Forest Research Institute of Malaysia (FRIM) Report. FRIM Press, Kepong, Malaysia.*

Öztürk, S. (2010). Effect of Fibre Loading on the Mechanical Properties of Kenaf and Fiberfrax Fibre-reinforced Phenol-Formaldehyde Composites. *Journal of Composite Materials*.

Paridah, M. T., & Khalina, A. (2009). Effects of soda retting on the tensile strength of kenaf (*Hibiscus cannabnius* L.) bast fibres. *Project Report Kenaf EPU*, 21.

Paridah, M. T., Hafizah, A. N., Zaidon, A., Azmi, I., Nor, M. M., & Yuziah, M. N. (2009). Bonding properties and performance of multi-layered kenaf board. *Journal of Tropical Forest Science*, 113-122.

Paridah, M. T., Basher, A. B., SaifulAzry, S., & Ahmed, Z. (2011). Retting process of some bast plant fibres and its effect on fibre quality: A review. *BioResources, 6*(4), 5260-5281.

Pan, N., Hua, T., & Qiu, Y. (2001). Relationship between fiber and yarn strength. *Textile Research Journal*, *71*(11), 960-964.

Panhwar, Q. A., Radziah, O., Khanif, Y. M., & Naher, U. A. (2011). Application of boron and zinc in the tropical soils and its effect on maize (*'Zea mays'*) growth and soil microbial environment.

Parikh, D. V., Calamari, T. A., Sawhney, A. P. S., Blanchard, E. J., Screen, F. J., Warnock, M., ... & Stryjewski, D. D. (2002). Improved chemical retting of kenaf fibers. *Textile research journal*, *72*(7), 618-624.

Peck, A. W., & McDonald, G. K. (2010). Adequate zinc nutrition alleviates the adverse effects of heat stress in bread wheat. *Plant and soil*, *337*(1-2), 355-374.

Petrini, C., Bazzocchi, R., & Montalti, P. (1994). Yield potential and adaptation of kenaf (*Hibiscus cannabinus*) in north-central Italy. *Industrial Crops and Products*, *3*(1), 11-15.

Pettigrew, W. T., Meredith, W. R., & Young, L. D. (2005). Potassium fertilization effects on cotton lint yield, yield components, and reniform nematode populations. *Agronomy journal, 97*(4), 1245-1251.

Pettigrew, W. T., Heitholt, J. J., & Meredith, W. R. (1996). Genotypic interactions with potassium and nitrogen in cotton of varied maturity. *Agronomy Journal, 88*(1), 89-93.

Pervez, H., Ashraf, M., & Makhdum, M. I. (2005). Influence of potassium rates and sources on seed cotton yield and yield components of some elite cotton cultivars. *Journal of plant nutrition, 27*(7), 1295-1317.

Phillips, W. A., Srinivas, C. R., & Dao, T. H. (1989). Nutritive value of immature whole plant kenaf and mature kenaf tops for growing ruminants. *Proceed Association Advancement of Industrial Crops*, 19-22.

Prasad, M.N.V. (2002a) Zinc is the friend and foe of life. Zeszyty Naukowe PAN 33, Com. "Man and Biosphere". *Eds:A. Kabata-Pendias and B. Szteke, Warsaw*, p.49-54. In: Plant-mineral nutrition: macro- and micro nutrients, uptake, functions, deficiency and toxicity symptoms, pp. 1-31.

Prasad, M.N.V. (2002b) Zinc transporting genes in plants. Zeszyty Naukowe PAN 33, Com. "Man and Biosphere". *Eds: A. Kabata-Pendias and B. Szteke, Warsaw*, p. 363-366. In: Plant-mineral nutrition: macro-and micro nutrients, uptake, functions, deficiency and toxicity symptoms, pp. 1-31.

Prasad, R. (2003). Protein-energy malnutrition in India. *Fertiliser News, 48*(4), 13-26. In: Relative efficiency of zinc-coated urea and soil and foliar application of zinc sulphate on yield, nitrogen, phosphorus, potassium, zinc and iron biofortification in grains and uptake by basmati rice (*Oryza sativa* L.).

Prasad, R., Shivay, Y. S., & Kumar, D. (2014). Agronomic biofortification of cereal grains with iron and zinc. *Advances in Agronomy*, *125*, 55-91.

Primacenko, B. M., Privalov, S. F., & Agamov, F. C. (2002). Analysis of technical purpose wool blend composition for condenser spinning. *Tekstilnaja promyshlennostj*, 12, 34-36. In "Comparitive Investigation of Mechanical Indices of Sheep's Wool and Dog Hair Fibre." *Fibres & Textiles in Eastern Europe* (2012).

Pooniya, V., & Shivay, Y. S. (2013). Enrichment of Basmati rice grain and straw with zinc and nitrogen through ferti-fortification and summer green manuring under Indo-Gangetic plains of India. *Journal of Plant Nutrition, 36*(1), 91-117.

Raju, G., Ratnam, C. T., Ibrahim, N. A., Rahman, M. Z. A., & Yunus, W. M. Z. W. (2008). Enhancement of PVC/ENR blend properties by poly (methyl acrylate) grafted oil palm empty fruit bunch fiber. *Journal of applied polymer science*, *110*(1), 368-375.

Ramaswamy, G. N., Ruff, C. G., & Boyd, C. R. (1994). Effect of bacterial and chemical retting on kenaf fiber quality. *Textile research journal*, *64*(5), 305-308.

Ramaswamy, G. N., Boyd, C. R., Bel - Burger, P., & Kimmel, L. (1995). Kenaf/cotton blends for textiles. *Family and Consumer Sciences Research Journal, 24*(2), 180-190.

Ramires, E. C., & Dufresne, A. (2011). A review of cellulose nanocrystals and nanocomposites. *Tappi Journal, 10*(4), 9-16.

Rassmann, S., Paskaramoorthy, R., & Reid, R. G. (2011). Effect of resin system on the mechanical properties and water absorption of kenaf fibre reinforced laminates. *Materials & Design*, *32*(3), 1399-1406.

Rathinavel, K., Dharmalingam, C., & Paneerselvam, S. (1999). Effect of micronutrient on the productivity and quality of cotton seed cv. TCB 209 (Gossypium barbadense L.). *Madras Agricultural Journal*, *86*(4/6), 313-316.

Reddy, N., & Yang, Y. (2005). Structure and properties of high quality natural cellulose fibers from cornstalks. *Polymer*, *46*(15), 5494-5500.

Roberts, R. K., Gersman, J. M., & Howard, D. D. (2000). Soil-and foliar-applied boron in cotton production: an economic analysis. *Journal of Cotton Science, 4*(3), 171-177.

Roggatz, U., McDonald, A. J. S., Stadenberg, I., & Schurr, U. (1999). Effects of nitrogen deprivation on cell division and expansion in leaves of *Ricinus communis* L. *Plant, Cell & Environment, 22*(1), 81-89.

Rouison, D., Sain, M., & Couturier, M. (2004). Resin transfer molding of natural fiber reinforced composites: cure simulation. *Composites Science and Technology, 64*(5), 629-644.

Rowell, R. M., & Stout, H. P. (1998). Jute and kenaf. *Handbook of fiber chemistry*, 466-502.

Rowell, R. M., Han, J. S., & Rowell, J. S. (2000). Characterization and factors effecting fiber properties. Natural Polymers and Agrofibers Bases Composites. *Embrapa Instrumentacao Agropecuaria*, P. O. Box 741, Sao Carlos, 13560-970 SP, Brazil, 2000., 115-134.

Ryan, J., Singh, M., & Yau, S. K. (1998). Spatial variability of soluble boron in Syrian soils. *Soil and Tillage Research, 45*(3), 407-417.

Saba, N., Jawaid, M., Hakeem, K. R., Paridah, M. T., Khalina, A., & Alothman, O. Y. (2015). Potential of bioenergy production from industrial kenaf (*Hibiscus cannabinus* L.) based on Malaysian perspective. *Renewable and Sustainable Energy Reviews*, 42, 446-459.

Sadegh, A. N., Rakhshani, H., Samariha, A., Nemati, M., & Khosravi, E. (2011). The influence of axial position on fiber features of cotton stems. *Middle-East J Sci Res*, *10*(4), 447-449.

Sahari, J., Sapuan, S. M., Zainudin, E. S., & Maleque, M. A. (2012). Sugar palm tree: a versatile plant and novel source for biofibres, biomatrices, and biocomposites. *Polymers from Renewable Resources*, *3*(2), 61-77.

Saleem, M. F., Bilal, M. F., Awais, M., Shahid, M. Q., & Anjum, S. A. (2010). Effect of nitrogen on seed cotton yield and fiber qualities of cotton (*Gossypium hirsutum* L.) cultivars. *Journal of Animal & Plant Science, 20*, 23-27.

Saleem, M., Khanif, Y. M., Ishak, F., Samsuri, A. W., & Hafeez, B. (2011). Importance of boron for agriculture productivity: a review. *International Research Journal of Agricultural Science and Soil Science, 1*(8), 293-300.

Salit, M. S. (2014). Tropical Natural Fibres and Their Properties. In *Tropical Natural Fiber Composites* (pp. 15-38). *Springer Singapore.*

Samad, M. A., Sayeed, M. A., Hussain, A. M., Asaduzzaman, M., & Hannan, M. A. (2002). Mechanical properties of kenaf fibres (*Hibiscus cannabinus*) and their spinning quality. *Pakistan journal of biological science*, *5*(6), 662-664.

Sangakkara, U. R., Frehner, M., & Nösberger, J. (2000). Effect of soil moisture and potassium fertilizer on shoot water potential, photosynthesis and partitioning of carbon in mungbean and cowpea. *Journal of Agronomy and Crop Science, 185*(3), 201-207.

Santos, G. C. G. D., Rodella, A. A., Abreu, C. A. D., & Coscione, A. R. (2010). Vegetable species for phytoextraction of boron, copper, lead, manganese and zinc from contaminated soil. *Scientia Agricola, 67*(6), 713-719.

Sawan, Z. M., Mahmoud, M. H., & El-Guibali, A. H. (2008). Influence of potassium fertilization and foliar application of zinc and phosphorus on growth, yield components, yield and fiber properties of Egyptian cotton (*Gossypium barbadense* L.). *Journal of Plant Ecology, 1*(4), 259-270.

Schumann, A. W., & Sumner, M. E. (2004). Formulation of environmentally sound waste mixtures for land application. *Water, Air, and Soil Pollution, 152*(1-4), 195-217.

Shanmugham, K., & Bhatt, J. G. (1991). The effect of potassium on the fiber properties of high quality cotton varieties. *J. Indian Soc. Cotton Improvement*, *16*, 31-35.

Sharma, C. P. (2006). *Plant micronutrients*. Enfield, NH: Science Publishers.

Shengxian, Z. (1999). Beneficial effects of potassium application on upland soils of Hunan Province. *Better Crops International, 13*(2), 11.

Shinoj, S., Visvanathan, R., Panigrahi, S., & Kochubabu, M. (2011). Oil palm fiber (OPF) and its composites: A review. *Industrial Crops and Products*, *33*(1), 7-22.

Shivay, Y. S., Prasad, R., Singh, R. K., & Pal, M. (2015). Relative Efficiency of Zinc-Coated Urea and Soil and Foliar Application of Zinc Sulphate on Yield, Nitrogen, Phosphorus, Potassium, Zinc and Iron Biofortification in Grains and Uptake by Basmati Rice (*Oryza sativa* L.). *Journal of Agricultural Science, 7*(2), p161.

ShuLi, F. (1999). Effects of nitrogen phosphorus and potassium on the development of summer cotton boll. *Acta Gossypii Sinica (China)*.

Shorrocks, V. M. (1991). Boron--a global appraisal of the occurrence, diagnosis and correction of boron deficiency. In *International Symposium on the Role of Sulphur, Magnesium and Micronutrients in Balanced Plant Nutrition/sponsors, the Potash and Phosphate Institute of Canada...[et al.][Sam Portch, editor]*.

Smook, G. A. (2002). *Handbook for pulp & and paper technologists*. Angus Wilde Publ.

Suriyajantratong, W., Tucker, R. E., Sigafus, R. E., & Mitchell, G. E. (1973). Kenaf and rice straw for sheep. *Journal of Animal Science, 37*(5), 1251-1254.

Summerscales, J., Dissanayake, N. P., Virk, A. S., & Hall, W. (2010). A review of bast fibres and their composites. Part 1–Fibers as reinforcements. *Composites Part A: Applied Science and Manufacturing*, *41*(10), 1329-1335.

Swietlik, D. (1995). Interaction between zinc deficiency and boron toxicity on growth and mineral nutrition of sour orange seedlings. *Journal of plant nutrition, 18*(6), 1191-1207.

Swingle, R. S., Urias, A. R., Doyle, J. C., & Voigt, R. L. (1978). Chemical Composition of Kenaf Forage and its Digestibility by Lambs and. *Journal of Animal Science, 46*(5), 1346-1350.

Sydenstricker, T. H., Mochnaz, S., & Amico, S. C. (2003). Pull-out and other evaluations in sisal-reinforced polyester biocomposites. *Polymer testing, 22*(4), 375-380.

Symington, M. C., Banks, W. M., West, D., & Pethrick, R. A. (2009). Tensile testing of cellulose based natural fibers for structural composite applications.*Journal of composite materials*.

Tahery, Y., Shukor, N. A. A., & Abdul-Hamid, H. (2013). Growth characteristics and biomass production of kenaf. *African Journal of Biotechnology*, *10*(63), 13756-13761.

Taiz, L., & Zeiger, E. (1991). Plant Physiology Benjamin. In: Nitrogen, potassium and plant growth retardant effects on oil content and quality of cotton seed.*Grasas Y Aceites*, *58*(3), 243-251.

Tao, W., Calamari, T. A., Shih, F. F., & Cao, C. (1997). Characterization of kenaf fiber bundles and their nonwoven mats. *Tappi journal, 80*(12), 162-166.

Tao, W., Moreau, J. P., & Calamari, T. A. (1995). Properties of nonwoven mats from kenaf fiber. *Tappi journal (USA)*.

Tatar, Ö. Z. G. Ü. R., Ilker, E. M. R. E., Tonk, F. A., Aygün, H. A. M. D. I., & Caylak, O. (2010). Impact of different nitrogen and potassium application on yield and fiber quality of ramie (*Boehmeria nivea*). *Int. J. Agric. Biol, 12*, 369-372.

Tavallali, V., Rahemi, M., Eshghi, S., Kholdebarin, B., & Ramezanian, A. (2010). Zinc alleviates salt stress and increases antioxidant enzyme activity in the leaves of pistachio (*Pistacia vera* L.'Badami') seedlings. *Turkish Journal of Agriculture and Forestry, 34*(4), 349-359.

Textile Handbook. Hong Kong (2001). The Hong Kong Cotton Spinners Association. In: Potentiality of utilising natural textile materials for engineering composites applications, 359–368.

Tisdale, S.L., Nelson, W.L., Beaten, J.D. (1984). Zinc In soil Fertility and Fertilizers. *Fourthedition, Macmillan Publishing Company, New York*; 382-391. In: Role of Zinc in Plant Nutrition- A Review, pp.374-391.

Tomczak, F., Satyanarayana, K. G., & Sydenstricker, T. H. D. (2007). Studies on lignocellulosic fibers of Brazil: Part III–Morphology and properties of Brazilian curauá fibers. *Composites Part A: Applied Science and Manufacturing, 38*(10), 2227-2236.

Usherwood, N. R., & Segars, W. I. (2001). Nitrogen interactions with phosphorus and potassium for optimum crop yield, nitrogen use effectiveness, and environmental stewardship. *The Scientific World Journal, 1*, 57-60.

Van de Velde, K., & Kiekens, P. (2001). Thermoplastic pultrusion of natural fibre reinforced composites. *Composite Structures, 54*(2), 355-360.

Van Brunt, J. M., & Sultenfuss, J. H. (1998). Better crops with plant food. *Potassium: Functions of Potassium, 82(3), 4-5.*

Ververis, C., Georghiou, K., Christodoulakis, N., Santas, P., & Santas, R. (2004). Fiber dimensions, lignin and cellulose content of various plant materials and their suitability for paper production. *Industrial Crops and Products, 19*(3), 245-254.

Venkatakrishnan, S. S., Sudalayandy, R. S., & Savariappan, A. R. (2003). Assessing in vitro solubilization potential of different zinc solubilizing bacterial strains. *Braz. J. Microbiol, 34*, 121-125.

Voulgaridis, E., Passialis, C., & Grigoriou, A. (2000). Anatomical characteristics and properties of kenaf stems (*Hibiscus cannabinus*). *IAWA Journal*, *21*(4), 435-442.

Wang, J., & Ramaswamy, G. N. (2003). One-step processing and bleaching of mechanically separated kenaf fibers: Effects on physical and chemical properties. *Textile research journal*, *73*(4), 339-344.

Wang, W. M., Cai, Z. S., & Yu, J. Y. (2008). Study on the chemical modification process of jute fiber. *Journal of Engineered Fibers and Fabrics, 3*(2), 1-11.

Webber, C. L. (1993). Crude protein and yield components of six kenaf cultivars as affected by crop maturity. *Industrial Crops and Products, 2*(1), 27-31.

Webber III, C. L. (1996). Response of kenaf to nitrogen fertilization. *Progress in new crops. Wiley, New York*, 404-408.

Webber III, C. L., Bledsoe, V. K., Bledsoe, R. E., Janick, J., & Whipkey, A. (2002a). Kenaf harvesting and processing. *Trends in new crops and new uses, 9*, 340-347.

Webber III, C. L., Bhardwaj, H. L., & Bledsoe, V. K. (2002b). Kenaf production: fiber, feed, and seed. *Trends in new crops and new uses*, 327-339.

Welford, T. (1996). The textile student's manual, Sixth edition, published by Sir Isaac and Sons Ltd. London, pp: 6. In: Mechanical properties of kenaf fibres (*Hibiscus cannabinus*) and their spinning quality, *5*(6), 662-664.

Wong, C. C., Daham, M. M., & Abdullah, O. (2008). Effects of defoliation (cutting) on forage yield and quality of selected kenaf accessions. *J. Trop. Agric. and*

Fd. Sc, 36(1), 21-28.www.bio.miami.edu. *The Molecules that Make Plant Cells...Different*.

Xue, Y., Du, Y., Elder, S., Sham, D., Horstemeyer, M., & Zhang, J. (2007, May). Statistical tensile properties of kenaf fibres and its composites. In *9th International Conference on Wood & Biofiber Plastic Composite* (Vol. 22).

Zainudin, E. S. (2009). *Effects of Banana Pseudostem Filler and Acrylic Impact Modifier on Thermo-Mechanical Properties of Unplastisized Polyvinyl Chloride Composites*. In: Tropical Natural Fibres and Their Properties (pp. 15-38). Springer Singapore.

Zampaloni, M., Pourboghrat, F., Yankovich, S. A., Rodgers, B. N., Moore, J., Drzal, L. T., ... & Misra, M. (2007). Kenaf natural fiber reinforced polypropylene composites: A discussion on manufacturing problems and solutions. *Composites Part A: Applied Science and Manufacturing*, *38*(6), 1569-1580.

Zeng, Q. F. (1996). Researchers on the effect of zinc applied to calcareous soil in cotton field. *China Cottons, 23*, 21.

Zhang, T. (2003). *Improvement of kenaf yarn for apparel applications* (Doctoral dissertation, Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Master of Science in The School of Human Ecology by Ting Zhang BS, Beijing University of Chemical Technology).

Zhu, D., Shi, L., & Liu, W. (1999). Study on the properties of different chemical boron pools in soil – Investigation on plant availability of soil boron. *J. Huazhong Agric. university, Supplement 28*: 159-165. In: Importance of Boron for Agriculture Productivity: A Review.

Zimmermann, R., Bauermann, U., & Morales, F. (2006). Effects of growing site and nitrogen fertilization on biomass production and lignan content of linseed (*Linum usitatissimum* L.). *Journal of the Science of Food and Agriculture, 86*(3), 415-419.

Zubillaga, M. M., Aristi, J. P., & Lavado, R. S. (2002). Effect of phosphorus and nitrogen fertilization on sunflower (*Helianthus annus* L.) nitrogen uptake and yield. *Journal of Agronomy and Crop Science, 188*(4), 267-274.