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Agronomy

Quality Attributes of North-East Himalayan Soil for Cultivation of Ramie (*Boehmeria nivea* L. Gaudich.)

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Abstract

Ramie (*Boehmeria nivea* L. Gaudich.) is one of the most valuable and oldest fibre crop grown in the world. China is the chief producer of ramie in the international market. Being a perennial crop, ramie cultivation helps in soil conservation and due to its unique properties its demand is always higher than production. In this scenario, ramie cultivation in India is utmost important to the farmers. This plant has a wide adaptation power and can survive at any place. But for commercial production of cultivated varities of ramie, some specific soil and climatic factors are required. The North Eastern parts of India, especially, Assam is noted for ramie cultivation in wide scale. The soil from Ramie Research Station (RRS), Sorbhog, Assam was considered as standard soil for ramie cultivation. The chemical and physical properties of this soil was studied carefully and the fibre samples from plants grown in this soil was analyzed. It was found that the quality of fibre depends on available nutrient status of soil. The best quality of fibre was available when the quantity of available nitrogen, phosphorus and potassium in the pre-existing plots were 460.60 – 474.05 kg/ha, 140.36 – 143.88 kg/ha and 49.72 – 63.16 kg/ha respectively.

Highlights

- Cultivation of ramie is best suited in North Eastern Himalayan soil in India
- Gum content and physical properties of ramie fibre depends on soil nutrient parameters and climate

Keywords: Ramie, soil parameters, fibre quality, North-East Himalayan soils

Among the soil conservation practices, the introduction of perennials in crop rotations has been proposed as a viable opportunity to improve the long-term sustainability and productivity (Bene *et al.* 2011). This lead to a considerable improvement in soil organic matter and nutrient cycling as well as the overall physical and biological health of the soil. In this context, ramie [*Boehmeria nivea* (L.) Gaud.], a herbaceous member of the Urticaceae family, may represent a classic bast fibre yielding crop for India, due to its perennial cycle and its noticeable agronomic benefits in terms of weed competition, and reduced use of chemicals and soil disturbance (Angelini *et al.* 2000). Ramie is widely cultivated for fibre production in China (Yangtze valley and southern areas of China) and several other Asian countries having sub-tropical climatic zones (Liu *et al.* 2001). But due to its wide range of adaptation capacity, it can also be successfully grown in other parts of the world also. Ramie was used in Egypt during the period of 5000-3000 B.C. for wrapping mummies (Ray *et al.* 2014c). It is reported that at present, there is an increasing demand for textiles made from natural fibres, obtained by organic and/or sustainable agriculture techniques, in European countries (Mussig, 2010). As ramie produces one of the strongest, longest and very expensive bast fibres, with a shiny, almost silky appearance (Banerjee *et al.* 2015 b; Xu *et al.* 2001; Nishino *et al.* 2004; Liu *et al.* 2005; Lu *et al.* 2006) and having anti-microbial properties, it fully satisfies the growing demand for natural textiles and fibre reinforced composite products (Shihong *et al.* 1994; Angelini *et al.* 2000; Lodha and Netravali, 2002; Chen *et al.* 2005; John and Thomas, 2008; Cengiz and Babal k, 2009). Thus, ramie could profit from this trend better than annual fibre crops, such as cotton and hemp.

However, despite its excellent fibre properties and diverse applications, ramie remains unexploited due to its high gum content, which mainly constitutes of pectin and hemicelluloses. There is a constant hunt for developing low-gum-genotypes of ramie among the researchers. Soil plays a vital role in ramie cultivation and affects the plant height, leaf area index, growth rate, yield and quality of fibre. There are several studies indicating that ramie is characterized by a high nitrogen requirement like all other Urticaceae plant species, and by a high potassium necessity (Angelini *et al.* 2000; Sarno and Leto, 2001; Singh, 2001; Beni *et al.* 2009; Tavarini *et al.* 2009). In India ramie is grown mainly in North Eastern Part of the country mainly in Brahmaputra valley. ICAR has developed Ramie Research Station (RRS) at Sorbhog, Assam to promote ramie cultivation for research and industrial purpose (Ray *et al.* 2014b). Despite its immense economic value the fibre has not been exploited properly and there is no relational studies on soil attributes towards the production of this valued fibre. Therefore, the aim of this study was thus to study the quality attributes of soil parameters of North East Himalayan areas mainly in lower Brahmaputra valley for drawing a conclusion to establish such relationship.

Materials and Methods

Soil and climate

The experiment was conducted in the experimental plots of Ramie Resaerch Station Sorbhog, Assam. The soils of the experimental sites was classified as medium fertile, sandy loam acidic soil, which is characterized by the presence of heavy sand and clay. The experimental site falls under subtropical climatic zone and experience heavy rainfall during the months of March to May and abrupt/scanty rainfall during rest of the year. The weather condition of crop growing period was as usual and total rainfall during cropping period was 1500 - 2500 mm. the maximum and minimum temperature recorded was 25°C to 31°C during the crop growing period. Overall, hot and humid climate prevailed during the growing phase of the plant.

Soil sampling

The soil was collected from pre-existing ramie fields of Ramie Research Station, Sorbhog, Assam. Each sampling was done using a 5 cm diameter hand auger, duplicate soil cores (30 cm depth) were taken from random positions across each plot. The samples were oven-dried at 105°C, crushed and passed through a 2-mm sieve (USDA-NRCS, 1996) prior to analysis.

Analysis of soil

The samples were analysed for: organic carbon, available nitrogen, available phosphorus and available potassium. Mechanical composition, electrical conductivity and pH was also measured. All analyses were carried out in three replicates in order to control intra-laboratory variability.

The quantity of organic carbon of the soil was estimated by the method of Walkley and Black (1934) described by Jackson, 1967. The nitrogen is available to all the plants in form of ammonia and nitrates. In this method, the nitrogen is released by alkaline permanganate solution and estimated by the usual ammonia distillate procedure, the distillate being absorbed in standard acid and the excess acid is back titrated with standard alkali (Subhaiah and Asija, 1956). The available cations were determined by extracting the soil with 1N ammonium acetate (pH 7.0), calcium and magnesium in extract were determined by versene titration method and potassium with flame photometer model.(Systronics flame photometer 128 (Jackson 1967). For determining plant available phosphorous in soil, the Bray and Kurtz method was used for acid soils (Tandon, 1993). Available potassium was determined with Flame Photometer (Systronics Flame Photometer 128) (Jackson, 1967).

Test crop

R-1415 line of ramie (*Boehmeria nivea* L. Gaudich.) was used in this experiment. The fibres from this line was collected for experimental purpose to perform the post harvest treatments and quality evaluation.

Field trial and experimental design

The field test was laid out in randomized complete block design (RCBD) with factorial design with two replications. Six plots (P1 to P6) were identified in which R-1415 line of Ramie was replicated. A control plot (C) was maintained without growing any crop as a parallel check.

Extraction of fibre

Unlike other best fibres like jute, flax, hemp, etc., ramie fibre cannot be extracted satisfactorily by the usual retting methods owing to the presence of gummy substances found in the bark of the stem. The stems are first immersed in water. The bark is then peeled off and green tissue are scraped off by oiling or mechanical means. The fibers that remain are heavily coated with gum and require further treatment before they can be used. Decortication, i.e., removal of the fibrous layer from long slender green stalks of the plant, should take place immediately after the harvest. The cortex can be stripped off in the form of ribbons. This can be done by hand or decorticator machine. The ribbons are cleaned by hand scraping and this practice is only feasible where labour costs are very low. After decortication the fibre are dried and combed to improve quality. The extent of further processing will depend on the final product that may be prepared by using the fibre.

Evaluation of fibre quality

Gum content

Gum content of fibre was determined by treating the fibre in hot alkali solution for a given period of time (Das Gupta *et al.* 1976) followed by through washing with hot and cold water and oven drying.

Hemicellulose content

Holocellulose was quantified with sodium chlorite treatment according to the procedure of Browning, 1967 with slight modification. In brief, the defatted fibres were treated with sodium chlorite in acidic condition, in a hot water bath at 70-80°C. 2g of holocellulose was treated with 18 % NaOH, washed and dried for determination of alpha and hemi-cellulose.

Pectin content

Pectin content was determined by boiling the fibre samples in 0.5% freshly prepared ammonium oxalate with for 4 hours. This pectin can be precipitated with calcium ions (Batra, 1998; Weiting, 1951).

Fineness and Single fibre strength

The tensile properties (breaking tenacity and extension at break) of different ramie fibre samples had been estimate using a Universal Strength Tester (Instron Tensile Tester, Model No. 5567 along with Bluehill software).

The cross-head speed and gauge length were fixed at 20 mm/min and 20 mm respectively. The gravimetric fineness method was used to measure the linear mass density (tex) of the fibres, where 1 tex is defined as the mass in grams per 1000 metre of a single fibre. The stress-strain curves and tensile properties were calculated using the Bluehill software supplied by the Universal Tensile Tester instrument. The stress is expressed in tenacity and the unit is cN/tex; and the extension at break is expressed in percentage.

Results and Discussion

Climate during period of study

Ramie plantation is mainly found in tempareate and tropical climatic zones (Ray *et al.* 2014 a).The weather of North-Eastern state of India, especially, Assam, is extremely humid. Between the months of March and May the rainfall of Assam is most distinguished feature. Assam's weather can be very simply classified into two seasons, namely, Cold and Rainy. Cold climatatic conditions prevail between October to February and the rest months are known as rainy season (www.assamspider.com). The average annual rainfall of Assam is around 2431.9 mm of which 1550.0 mm occurs during the months of June to September. Cherapunji and 'Mawsynram comes under this region and known for receiving highest rainfall in the world. The average temperature of this region never goes beyond 35-38°C. Ramie growth is best suited in this type of hot and humid climatic conditions.

Soil and available nutients

North-Eastern parts of India is located on the foothills of the majestic Himalaya and soil of this region has derived from the mountain region. These soils are deposited here by hilly rivers and their numerous tributaries. Three types of soils are mainly found in Assam, viz. Red Loam Soil, Alluvial Soil and Lateritic Soil. Red Loam Soil is found in Garo, Mizo Hills, Cachar (part of), Khasi-Jaintia Hills and Sibsagar of Assam. Part of Shibsagar, Jaintia Hills, Khasi Hills, Cachar (part of) and Nowgaon - is the region where Lateritic Soil found. Alluvial Soil covers entire Darrang, Kamrup, Lakhinpur, Goalpara, Sibsagar and part of Garo Hills (www.assamspider.com). Main composition of the alluvial soil is sand, clay and silt and they are very rich in humus. The soil texture of Ramie Research Station, Sorbhog, is mainly sandy loam. The highly porous nature of the soil inhibits water-logging condition in rainy season which makes it suitable for ramie cultivation. Due to severe leaching by rainwater and presence of humus, the soils are acidic which favours growth of ramie plant.

In the present investigation, seven plots (P1 to P6 and one control plot C) of size 10m × 5m were selected for ramie cultivation. The mechanical composition of the experimental plots reveal the presence of moderate amount of sand and clay and comparatively less amount of silt (Table 1). The plot P6 contains highest amount of sand (50.34%) while silt and clay is about 21.50% and 28.16 % respectively. Sloppy land with good drainage system, i.e., soils having no water logging problem is the primary requirement for ramie cultivation, with high percentage of sand the probability of water logging become minimum.

Table 1: Mechanical composition of Sorbhog soil

Soil mechanical composition			
Experimental Plots	Sand(%)	Silt(%)	Clay(%)
P1	42.45	26.19	31.36
P2	48.54	18.30	33.16
P3	44.31	26.43	29.26
P4	41.84	27.79	30.37
P5	38.50	34.31	27.19
P6	50.34	21.50	28.16
C	45.53	22.11	32.36

The available nutrients present in the experimental plot is depicted in Table 2. It is clearly evident from the Table that the soil reaction of different plots varied from 4.40 to 4.74, i.e., soils were acidic. This natural acidic type of soil promotes ramie growth in the North Eastern provinces. The salt concentration (E.C.) of the plots varied from 0.60 – 0.13 dS/m. The plots under study were rich in organic carbon (O. C.) and the O. C. level is as high as 0.90 in plot P1. Due to the presence of high amount of humus in the soil of Sorbhog, organic carbon level is very high. From table 2 it is evident that the plots P1 to P6 have high amount of available nitrogen which is related to plant height and ultimate fibre length. Available phosphorous and potassium range was found to be 23.67 kg/ha to 143.88 kg/ha and 44.35 kg/ha to 148.38 kg/ha respectively. Balancing nitrogen and phosphorus with adequate potassium improve length, strength and fineness of fiber in both cotton and ramie (Tartar *et al.* 2010). Available potassium in soil was responsible for ramie production to obtain higher yield (Shengxian, 1998).

Table 2: Properties of soil taken from experimental plots

Soil parameters						
Study Area	pH	E.C. dS/m	O.C. %	N kg/ha	P_2O_5 kg/ha	K_2O kg/ha
P1	4.76	0.12	0.90	616.70	117.88	122.30
P2	4.68	0.06	0.86	563.70	23.67	148.38
P3	4.74	0.06	0.78	474.05	140.36	49.72
P4	4.40	0.12	0.76	460.60	143.88	63.16
P5	4.45	0.11	0.80	510.70	43.32	88.70
P6	4.65	0.09	0.88	590.70	75.57	44.35
C	4.51	0.13	0.84	537.20	86.86	100.80

** P1 to P6 is experimental plots, C is control plot

From the available data it was found that the most of the plots were at par with their nutrient status when normal dose of fertilization occurred. In figure 1, it is shown that the plot P3 and P4, P5 and P2, P1 to P6 were identified as replica plots. In these plots R-1415 was planted. The plants were denoted as I, II, III with respect to the plots P3-P4, P5-P2 and P1-P6. Same line of plant with different soil properties show variation in fibre qualities as well. It was found that fibres produced by the line R-1415 (I) was superior among the three replicas chosen. Although the Plot P3 and P4 were lower in nutrient status compared to other experimental plots as well as control, it was found that the soil of P3 and P4 plots with available N-P-K in the range of 460.60 – 474.05 kg/ha, 140.36 – 143.88 kg/ha and 49.72 – 63.16 kg/ha respectively is most suitable for producing good quality fibre.

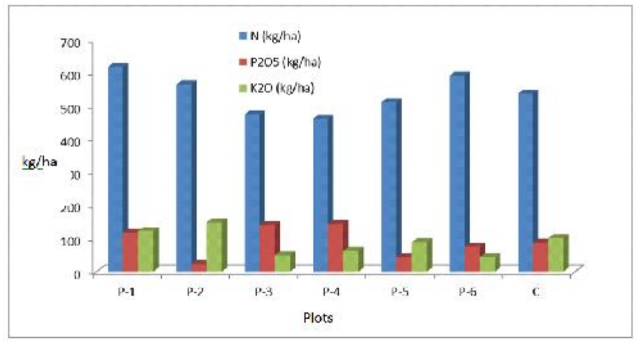

Fig. 1: Plots P1 to P6 and C (left to right) and available NPK

Analysis of fibre quality

R-1415 line of ramie in replica were chosen from pre-existing plots and fibre quality of each line in their existing location were analyzed. It was found that due to differences in quantity of available N-P-K the properties of fibre of each line varies. This experiment is a preliminary research to show that soil affects the quality of fibre of ramie. Proper soil amendments can improve fibre quality to a certain limit.

It was revealed that the fibre from R-1415 (I) is the finest fibre with highest single fibre tenacity and lowest gum content (Table 3). The quality of ramie fibre is primarily determined by the percentage of gum. Generally, Indian variety of ramie contains 19 -28 % of gum. Lower the percentage of gum, better is the fibre quality. From Table 3, it is evident that due to different soil nutrient status, the gum content of fibre varies to a considerable limit. Ramie produces one of the finest and strongest fibre with silky appearance. Due to higher percentage of gum, the fineness of the fibre increases decreasing the bundle strength and single fibre tenacity. In our findings, R-1415 (I) possesses the highest bundle tenacity of 28.80

g/tex and single fibre strength of 35.32 CN/tex. R-1415 (II) shows the highest gum content among the replicates and therefore has least fineness and strength. The differences in chemical and physical properties of the fibre arise due to different soil parameters. Along with the differences in soil properties, environmental factors like rainfall, temperature during the growing season, humidity, etc. Also affect the quality of ramie fibre (Banerjee *et al.* 2014 a).

Table 3: Comparative properties of physical and chemical properties of ramie fibre

Chemical Components	R-1415 (I)	R-1415 (II)	R-1415 (III)
Gum content	23.21 %	24.85 %	24.67
Moisture content of defatted fibre	13.63 %	12.78 %	13.78 %
Holocellulose content	91.68 %	94.10 %	93.56 %
α-cellulose with respect to holocellulose	81.96 %	85.45 %	84.34 %
Hemicellulose content	7.95%	8.47%	8.01 %
Physical properties	**R-1415 (I)**	**R-1415 (II)**	**R-1415 (III)**
Ultimate fibre length	23. 15 mm	22.87 mm	21.90 mm
Bundle tenacity	28.80 g/tex	26.00 g/tex	25.75 g/tex
Single filament strength	35.32 CN/tex	31.00 CN/tex	29. 06 CN/tex
Fineness	0.66 tex	0.75 tex	0.84 tex

Conclusion

Ramie is an economically important fibre yielding crop which is cultivated popularly in North Eastern Provinces of India. Ramie can be grown on the plain lands also due to its wide range of adaptation capacity. But the quality of fibres may differ in different soil and climatic conditions. Although ramie is best suited in Assam considering all the environmental parameters, still there is variation in fibre qualities when the available N-P-K varies. In this study an optimum N-P-K ratio for yielding the best quality of fibre has been depicted.

References

Angelini, L.G., Lazzeri, A., Levita, G., Fontanelli, D. and Bozzi, C. 2000. Ramie [*Boehmeria nivea* (L.) Gaud.] and Spanish Broom [*Spartium junceum* L.] fibres for composite materials: agronomical aspects, morphology and mechanical properties. *Industrial Crops and Products* **11**:145–161.

Banerjee, P., Ray D. P., Biswas, P. K., Satya, P., Mitra, S. and Sharma, A. K. 2014 a. Studies on the variation of the fibre quality of ramie grown in two different soil regimes, ***In:*** Invited Lectures and Book of Abstracts in International Conference on Natural Fibres, organized by TINFS, August 1-3, 2014, Kolkata: 137.

Banerjee, P., Ray, D.P., Satya, P., Debnath, S., Mondal, D., Saha, S.C. and Biswas, P.K. 2015b. Evaluation of Ramie fibres quality: A Review, *International Journal of Bioresource Science* **1**(2): 65-69.

Batra, S.K. 1998. Other Long Vegetable Fibre – Abaca, Banana, Sisal, Henequen, Flax, Ramie, Hemp, Sunn, and Coir, ***In:*** *Handbook of Fibre Chemistry,* Revised and Expanded, Second Edition, International Fibre Science and Technology Series/15 (ISBN 0-8247-9471-0), edited by Lewin M. and Pearce E. M., Marcel Dekker, Inc., New York, Basel, p. 528.

Beni, C., Marconi, S., Aromolo, R., Pierandrei, F., Diana, G., Neri, U., Sturchio, E., Boccia, P. and Servadio, P. 2009. Ramie cultivation: nutrients need in open field and nursey propagation. ***In:*** Proceedings "Le filiere delle colture da fibra: aspetti tecnicoscientifici e sperimentazione correlata alla produzione e all'impiego dei loro prodotti in ambito agricolo, industriale ed energetico" , Viterbo, Italy, University of Tuscia, 16 February 2009, Amaro (UD): Cirmont vol. CD ROM, ISBN: 978-88-903361-1-9.

Browning, B.L. 1967. Holocellulose preparation, *Method of wood chemistry,* Vol. II, 1. Edition, New York, p. 396.

Cengiz, T.G. and Babal k, F.C. 2009. The effects of ramie blended car seat covers on thermal comfort during road trials. *International Journal of Industrial Ergonomics* **39**: 287–294.

Chen, Y., Sun, L., Chiparus, O., Negulescu, I., Yachmenev, V. and Warnock, M. 2005. Kenaf/ramie composite for automotive headliner. *Journal of Polymers and the Environment* **13**: 107–114.

Das Gupta, P.C., Sen, K. and Sen, S.K. 1976. Degumming of decorticated ramie for textile purposes. *Cellulose Chemical Technology* **10**: 285-29.

http://assamagribusiness.nic.in/RAMIE.pdf., 24 November, 2015-11-26

Jackson, M.L. 1967. Soil Chemical analysis. Prentice Hall of India, Pvt. Ltd., New Delhi : 498.

John, M.J. and Thomas, S. 2008. Biofibres and biocomposites, *Carbohydr. Polymer* **71**: 343–364.

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

Liu, F., Liu, Q., Liang, X., Huang, H. and Zhang, S. 2005. Morphological, anatomical, and physiological assessment of ramie [*Boehmeria nivea* (L.) Gaud.] tolerance to soil drought. *Genetic Resources and Crop Evolution* **52:** 497–506.

Lodha, P. and Netravali, A.N. 2002. Characterization of interfacial and mechanical properties of "green" composites with soy protein isolate and ramie fiber. *Journal of Materials Science* **37:** 3657–3665.

Lu, Y., Weng, L. and Cao, X. 2006. Morphological, thermal and mechanical properties of ramie crystallites–reinforced plasticized starch biocomposites. *Carbohydrate Polymers* **63:** 198–204.

Mussig, J. 2010. Industrial Applications of Natural Fibres: Structure Properties and Application, John Wiley & Sons Ltd., West Sussex, UK.

Nishino, T., Matsuda, I. and Hirao, K. 2004. All-cellulose composite, *Macromolecules* **37:** 7683–7687.

Ray, D.P., Banerjee, P., Mondal, S.B., Satya, P. and Mitra, S. 2014b. Ramie degumming through novel chemical process, *Jute & Allied Fibres Issues and Strategies*, Eds: Nag, D., Ray, D.P., Ganguly, P.K., Kundu D.K., Ammayappan L., Roy A.N., Satpathy S., Satya, P., Mitra, S., Banik, S., Bose, G. and Nayak, L.K. The Indian Natural Fibre Society, Kolkata (ISBN No. 978-93-81274-41-5): 15-20.

Ray, D.P., Banerjee, P., Satya, P., Mitra, S., Ghosh, R.K. and Mondal, S.B. 2014a. Degumming of decorticated ramie fibre through novel chemical process. *Indian Journal of Natural Fibres* **1**(1): 125 – 129.

Ray, D.P., Satya, P., Banerjee, P. and Ghosh, R.K. 2014c. Degumming of ramie: challenge to the queen of fibres. *International Journal of Bioresource Science* **1**(1): 37-41.

Sarno, R. and Leto, C. 2001. Ramie (*Boehmeria nivea* (L.) Gaud.) *In:* Baldoni, R., Giardini, L. (Eds.), Coltivazioni erbacee – Piante oleifere, da zucchero, da fibra, orticole e aromatiche. Patron Edtiore, Bologna, Italy, pp. 239–243.

Shengxian, Z. 1998. Potassium supplying capacity and high efficiency use of potassium fertilizer in upland soils of Hunan Province. *Better Crops - International* **12:** 16-19.

Shihong, L., Benlian, Z., Qiyun, Z. and Xianrong, B. 1994. A new kind of super-hybrid composite material for civil use-ramie fibre. *Al. Composites* **25:** 225–228.

Singh, D.P. 2001. Ramie (*Boehmeria nivea*), ICAR-Central Research Institute for Jute & Allied Fibres.

Subbaiah, B.V. and Asija, G.L. 1956. A rapid procedure for determination of available nitrogen in soils. *Current Science* **25:** 259 – 260.

Tandon H.L.S. 1993. Method of analysis of soils, plants, water and fertilizers. Fertilizer Development and Consultation Organization 204-204A. Bhanot Corner, 1-2 Pamposh Enclave, New Delhi 110048 (India).

Tatar, Ö., Ilker, E., Aykut Tonk, F., Aygün, H. and Çaylak, Ö. 2010. Impact of different nitrogen and potassium application on yield and fiber quality of ramie (*Boehmeria nivea*). *International Journal of Agriculture and Biology* **12:** 369-372.

Tavarini, S., Lupo, S. and Angelini, L.G. 2009. Macronutrient uptakes by ramie [*Boehmeria nivea* (L.) Gaud.] crops. *In:* Proceedings of the Conference on "Le filiere delle colture da fibra: aspetti tecnico-scientifici e sperimentazione correlate alla produzione e all'impiego dei loro prodotti in ambito agricolo, industrial ed energetico" , Viterbo, Italy, University of Tuscia, 16 February 2009, Amaro (UD): Cirmont Vol. CD ROM, ISBN: 978-88-903361-1-9

USDA-NRCS, 1996. *Soil Survey Laboratory Methods Manual*. Soil Survey Inv Rep N.42, version 3.0. USDA, Washington, DC.

Weiting, G.C. 1951. Paper chromatography of flax fibre polyuronide hemicelluloses, *Nature* **168:** 833-834.

www.assamspider.com, 22 November, 2015

Xu, R., Xu, W., Fan, Y. and Luo, L. 2001. Mechanical properties of ramie/LLDPE laminate, Fuhe Cailiao Xuebao/Acta Materiae. *Compositae Sinica* **18:** 23–28.