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SOIL SCIENCE

Effect of Inherent Soil Nutrients on Yield and Quality of Ramie (*Boehmeria nivea* L.) Fibre

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Abstract

Ramie (*Boehmeria nivea* L.) is one of the most valuable sources of natural fibre known to human civilization from ancient times. The yield and fiber quality of ramie are affected by soil nutrients, particularly nitrogen (N), phosphorus (P) and potassium (K). Variation in organic carbon content of soil influences the fibre quality as it acts as a natural buffer. In the present study, we aimed to correlate the influence of inherent soil nutrients on yield and fiber quality of ramie fibre. Six ramie lines (R-1424, R-1415, R-67-34, R-1411, R-1418, R-1427) were grown in North Eastern hilly regions of India, under normal fertilizer dose was studied to evaluate for differences in plant height, stem diameter, filament length, yield and fiber quality of ramie. It was found that available nitrogen and potassium had significant effect on plant growth, yield, and fiber quality, whereas available phosphorous had strong positive correlation with fineness, strength and length of fibre.

Highlights

- Contribution of soil towards fibre yield of six different ramie lines
- Correlation of fibre quality with soil nutrients for production of textile grade ramie fibre

Keywords: Ramie, Available N, P, K, Organic carbon, Fibre quality

Ramie or (*Boehmeria nivea* L. Gaudich.) is one of the most valuable bast fibre yielding crops of the world. Ramie fibre is much more superior than other commonly used plant fibres like jute, cotton, flax, etc. in terms of bundle tenacity, strength of wet fibre, fineness, ultimate fibre length and length to breadth ratio. Ramie fabrics transmit heat, absorb moisture and have higher resistance to mildew than other cellulosic fibres (Pandey, 2007). It is one of the strongest but stiffest bast fibre due to high cellulose to hemicellulose ratio which favor a high degree of cellulose crystallinity (Sarkar *et al.*, 2010). Besides having the unique physical properties, the silk-like appearance and anti-microbial property of the fibres as well as the medicinal value and antioxidant property of the ramie leaves make the plant utmost valuable in the International market. China is the chief ramie producer followed by Brazil and Phillipines. In India there is a huge scope to exploit this fibre economically to get maximum benefit. The sandy loam soil with slopping land and hot-humid weather conditions that are required for ramie cultivation is available in Indian North Eastern parts. The foothills of Himalaya and the Brahmaputra valley of Assam, along with Western Ghats and Arunachal Pradesh, Manipur, Meghalaya have great natural resource to promote ramie cultivation (Satya *et al.*, 2010). There is a great demand of ramie fibre in the market but the production is not enough to meet the need. In the present study, the yield and fibre qualities of ramie plant with respect to available soil nutrients was studied in the pre-existing plot of Ramie Research Station, Sorbhog, Assam.

Materials and Methods

A field experiment was conducted at Ramie Research Station, Sorbhog, Assam to study the effects of soil inherent properties on the yield and quality of ramie fibre in the year 2014. The experiment was laid out in randomized block design (RBD) with three replications. The dimension of plots were 10 m x 5 m. Spacing = 60 cm x 50 cm. In each plot there were approximately 144 plant samples.

Experimental location

Ramie plants were grown in Ramie Research Station, Sorbhog which is situated between 26.4904° N, 90.8842° E at an elevation of 50 metre, in Barpeta district of Assam, India. It experiences a humid subtropical climate characterized by temperature between 33°C during summer and 12°C during winter. Periodic dry spells occur during October to March. The meteorological data of 2014 of Sorbhog showed that the average temperature of the year was 24.6°C and annual precipitation recorded was 1832.99 mm.

Ramie sample collection

Rhizome or underground stem was used as planting material. The fertilizer dose of 30:15:15 N-P-K was administered after 2 months of planting for sole ramie cultivation, i.e., without intercropping. The ramie samples for the present study were collected from the pre-existing plots of Ramie Research Station, Sorbhog, Assam. Six different ramie lines were chosen for the present study, viz., R-1424, R-1415, R-67-34, R-1411, R-1418, R-1427. The six different plots corresponding to these six different lines are designated as P1, P2, P3, P4, P5 and P6 respectively.

Soil analysis

The soil samples were collected from Ramie Research Station, Sorbhog, and analysed in the laboratory of ICAR-National Institute of Research on Jute and Allied Fibre Technology, Kolkata, West Bengal. The soil samples were collected from a depth of 15cm in the farm. The samples were transported to the laboratory, air-dried and sieved through a 2 mm pore size sieve. Soil texture determined by the relative quantities of sand, silt and clay by pipette method. Organic carbon of soil was estimated by wet oxidation method of Walkley and Black method (Jackson, 1967). Available nitrogen was determination by distilling the soil with alkaline potassium permanganate solution and determining the ammonia liberated (Tandon, 1993). For determining plant available P in soil, Bray and Kurtz method was used for the acidic soil Sarbhog, Assam (Tandon, 1993). 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).

Fibre analysis

Fibre fineness is expressed as tex, a unit that measures the linear mass density of fibers, yarns, threads and is defined as the mass in grams per 1000 meters. The weights of hundred 1-cm long fibers, in which these middle 1-cm sections were cut from an array of combed and aligned fibers, were taken to calculate the fineness or linear density of the fibres (ASTM D1577-96, 1999). Bundle tenacity was expressed as g/tex and was simply calculated using the bundle breaking force and the known weight of fiber bundle from samples. The tensile test was performed on single filaments according to ASTM D3379-75 (1975). 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) (Banerjee *et al.*, 2015).

Results and Discussion

The soil of Sorbhog was found to be acidic in nature and the soil falls under sandy loam (42.05% sand, 26.14% silt and 31.16% clay) category. The soil was well drained and there was no water logging problem even during the rainy seasons. The water holding capacity of the soil is a major factor affecting yield, and the yield shows a strong correlation to the soil EC. CEC of experimental plots were related to percent of clay and organic matter content in the soil. As the percent of clay and organic matter increase, the CEC also increased (Grisso *et al.*, 2009). They reported that there is a correlation between conductivity and CEC through its relationship to clay. Again, there is a relation between electrical conductivity and soil porosity. Greater the ease of conducting electricity more is the soil porosity. Soil with high clay content has more total pore space than sandy soils when other soil parameters remain constant. The electrical conductivity, pH, cation exchange capacity, bulk and pore density of the soils are presented in Table 1. From the data it is revealed that the pH of the plots were in between 5.50 to 5.75. The electrical conductivity varies from 0.13 to 0.16 dSm and the cation exchange capacity ranged 8.22 to 9.74 meq/100g. The bulk density of the soil was found in the range of 1.29 to 1.31 g/cm^3 where as particle density was found to be in between 2.56-2.62 g/cm^3.

Studies on soil organic carbon and available N-P-K

Perusal of the data presented in the Table 2, revealed that, the experimental plot P1, P2, P3, P4, P5 and P6 had no significant difference with respect to organic carbon content. All the experimental plots contained high amount of organic carbon (ranging between 0.76 to 0.91%). Muhr *et al.*, 1965 reported that higher the organic carbon, richer the soil. It is also revealed from the present data that organic carbon content in soil has a strong positive correlation with available nitrogen present in the soil. The soils of North Eastern hilly regions are rich in humic acid which in turn increases the level of organic carbon in soil (Arjumend *et al.*, 2015). The organic carbon rich soil has a direct effect on growth and yield of plant.

The value of available nitrogen in the experimental plot varied from medium to high (Medium: 280-560 kg/ha and high: above 560 kg/ha). From the statistical analysis of the results no significant difference could be achieved among the values. However the values differ in comparison to control plot against carbon content which significantly contributes towards the enrichment of the plots over time due to addition of plant biomass in the soil. P1 was significantly different with respect to available nitrogen content from all other treatments as it contains the highest amount, which again corresponds to the highest value of organic carbon found in that plot. From the correlation Table 3 we found that available nitrogen and organic carbon in soil had a strong positive correlation (+0.91). Nitrogen is present in chlorophyll molecule and affects the production of carbohydrates (Burns *et al.,* 2013). It was found that ramie line grown in plot P4 (R-1411) contains the lowest gum among all the lines while R-67-34 in plot P3 contains highest gum, as reported by Banerjee *et al.,* 2015a. One of the major quality parameters of ramie fibre is its low-gum content and hence the available nitrogen content of plot P4, i.e., 462.07 kg/ha may be taken as optimum.

The available phosphorous in the plots were much higher than the reference range of 24.60 kg/ha (Muhr *et al.,* 1965), indicating the soil was rich in available phosphorous content. The variation in available phosphorous in the soil was found to be more than any other nutrient. P3, P4; P2, P5; P6, and P1 were found to be at par with the control plot and did not differ significantly. Available phosphorous affects the height of plant, length of filament and fineness of fibre. The plant (R-1411) attains a height of 1.90 m in plot P4, where the available phosphorous is 143.96 kg/ha. The plot P2 containing plants of line

Table 1: General soil parameters of experimental plots

Plots	pH	EC (dSm)	CEC (meq/100 g)	BD (g/cm^3)	PD (g/cm^3)
P1	5.69	0.13	9.20	1.31	2.62
P2	5.65	0.14	9.51	1.30	2.57
P3	5.75	0.16	9.74	1.32	2.61
P4	5.50	0.13	8.83	1.31	2.56
P5	5.55	0.14	8.97	1.29	2.56
P6	5.66	0.13	8.83	1.30	2.60
SEm (±)	5.51	0.13	8.22	1.30	2.56
CD (0.05)	0.05	0.007	0.019	0.01	0.02
CV (%)	0.15	0.02	0.057	0.05	0.07

(All data are average of three replications)

Table 2: Soil nutrient status of experimental plots along with fibre quality and yield

Plots	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Plant height (m)	Yield of fibre (q/ ha/yr)	Fineness (tex)	Bundle tenacity (g/tex)	Single fibre tenacity (cN/tex)
P1	0.91	627.67	119.48	123.74	1.81	17.75	0.56	27.05	53.30
P2	0.88	537.08	34.75	148.43	1.74	17.61	0.51	24.29	46.29
P3	0.78	485.51	142.13	53.65	1.84	17.23	0.63	22.32	50.34
P4	0.8	462.07	143.96	50.27	1.9	17.00	0.65	27.04	47.17
P5	0.82	519.86	46.67	63.03	1.78	17.31	0.52	22.69	40.47
P6	0.87	555.37	77.41	86.65	1.78	17.34	0.55	24.67	34.66
Control	0.76	538.19	88.40	117.41	0.05	0.38	0.008	0.45	3.05
SEm (±)	0.02	22.87	3.74	4.511	0.17	1.51	0.03	1.37	8.12
CD (0.05)	0.06	69.36	11.33	13.68	6.38	4.40	3.06	3.71	7.45
CV (%)	4.12	7.44	6.94	8.51	1.81	17.75	0.56	27.05	53.30

(All data are average of three replications)

R-1415 attained the least height among all the plants and the available phosphorous content of this plot was found to be 34.75 kg/ha.

Available potassium in the experimental sites was found to low to medium in range. According to Muhr *et al.*, 1965, below 108 kg/ha, potassium content is low while 108-280 kg/ha available potassium depicts high range of potassium content in soil. P3, P4, P6; P2, P5 and P1, control were found significantly similar in terms of available potassium. The single fibre tenacity of plot P1 (R-1424), P2 (R-1415) are found to be much higher (53.30 cN/tex and 46.29 cN/tex respectively) than other lines of ramie indicates the role of potassium towards the tenacity of fibre. The plots P1 and P2 contains 123.74 kg/ha and 148.43 kg/ha of available potassium and plot P5 contains the lowest amount of available phosphorous and the single fibre tenacity of this fibres obtained from this plot is 34.66 cN/tex.

Study of fibre yield and quality of ramie

The height of ramie plant varies among the plots from 1.74m to 1.91m. Ramie is the only fibre yielding plant which can attain this height with minimum lignin content unlike other fibre crops (Ray *et al.*, 2013a; Banerjee *et al.*, 2015b). The yield of ramie fibre varies from17.00 quintal/hectare/year to 17.75 quintal/ hectare /year. Ramie yields one of the finest fibre one the world (Ray *et al.*, 2014; Banerjee *et al.*, 2015b). Less the value of fineness more is the single fibre tenacity and more is the bundle strength. The fineness values of ramie ranges from 0.51-0.63 tex as shown in Table 2. The bundle strength and single fibre tenacity of the ranges from 22.69-27.05 g/tex and 34.66-53.30 cN/tex respectively (Table 2). The results of plant height, fibre yield, fineness, bundle tenacity and single fibre tenacity are presented in Table 2.

The correlation (Table 3) between organic carbon and available N-P-K of soil with fibre yield and quality showed that available nitrogen is strongly related to organic carbon content of the soil, which in turn had positive effect on yield of fibre. Drewink, 2006 reported that as nitrogen plays a key role in metabolic activities of plant, thus it affects the plant growth and fibre yield and quality. Bundle tenacity (+0.32) and single fibre tenacity (+0.11) bears a positive correlation with the available nitrogen content of soil. The increase in nitrogen content of the fiber had a positive effect on the cell wall of the fibre and also it has been significantly affected to increase fresh and dry fiber yield as reported by Salih *et al.*, 2014a. Nitrogen content has positive effect on the fiber quality and mechanical properties in the ramie fiber. Similar results were obtained from our experiment. Muchow (1990) reported that the photosynthetic capacity of kenaf increased with increasing rate of nitrogen in leaf while Hossain *et al.* (2010) who reported that in kenaf, plant height and photosynthesis were decreased due to nitrogen, phosphor and potassium deficiency and also it leads to decrease biomass accumulation. The high occurrence of herbage yield from our

Table 3: Correlation between soil and fibre parameters

	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Yield of fibre (q/ha/yr)	Fineness (tex)	Bundle tenacity (g/tex)	Single fibre tenacity (cN/tex)	Plant height (m)
Organic carbon (%)	1								
Available N (kg/ha)	0.908895727	1							
Available P (kg/ha)	-0.412257579	-0.2444	1						
Available K (kg/ha)	0.871903177	0.700664	-0.5169	1					
Yield of fibre (q/ha/yr)	0.870403085	0.893247	-0.40925	0.88953	1				
Fineness (tex)	-0.648357182	-0.56719	0.932935	-0.6692	-0.67767	1			
Bundle tenacity (g/tex)	0.456321966	0.325381	0.37206	0.249297	0.13952	0.249078	1		
Single fibre tenacity (cN/tex)	-0.000946218	0.109202	0.544785	0.173026	0.272051	0.392154	0.300156	1	
Plant height (m)	-0.594481084	-0.51493	0.894471	-0.69584	-0.6835	0.94824	0.400055	0.376157	1

experimental plots indicated the conformation with these findings.

Table 4: Plant height, filament length, stems diameter and fineness of ramie

Treatments	Plant height (m)	Length of the filament (cm)	Stem diameter (mm)	Fineness (tex)
P1	1.81	20.36	11.07	0.56
P2	1.74	19.57	11.75	0.51
P3	1.84	24.44	10.93	0.63
P4	1.9	24.98	10.27	0.65
P5	1.78	19.57	13.11	0.52
P6	1.78	19.98	11.27	0.55
SEm (±)	0.05	0.72	9.72	0.008
CD (0.05)	0.17	2.20	10.57	0.03
CV (%)	6.38	6.83	9.73	3.06

(All data are average of three replications)

Available potassium had a positive correlation with the fibre yield (+0.88) as shown in the Table 3. Similar type of results was observed by Liu *et al.* (2000), who reported that potassium has positive and significant correlation with fiber yield of the crop. Stem wood was rich in potassium concentration compared to other parts of ramie plants. Glass (2003) and Parry *et al.* (2005) also supported the fact that four factors viz., nitrogen, phosphorus, potassium and water are critical for healthy development of plant and obtain higher yield economically (Rakshit *et al.*, 2015).

Salih *et al.* (2014b) and Tatar *et al.* (2010) reported that potassium fertilization has the significant effects on the plant height and stem yield in the kenaf and ramie plants. Fibre fineness was found to be dependent of organic carbon (+0.65) and available phosphorous (+0.93) content of soil from the correlation table. This observation was at par with the findings of Geitmann and Ortega, 2009; Ping *et al.* 2004 who stated that soil phosphorous content affects the fibre fineness, length, uniformity and strength, elongation percentage of plant.

Table 5: Correlation between fibre qualities

	Plant height (cm)	Length of the filament (cm)	Stem diameter (mm)	Fineness (tex)
Plant height (cm)	1			
Length of the filament (cm)	0.905839549	1		
Stem diameter (mm)	-0.693549314	-0.715093862	1	
Fineness (tex)	0.948239845	0.975516311	-0.787261052	1

The plant height is positively related with phosphorous content of soil and plant height is directly proportional to length of the filament and fineness as showed in the Table 3. Van Brunt and Sultenfuss (1998) observed that potassium required for many processes of plant growth. It works to increase crop yields due to increasing protein content in plants, building cellulose, improves translocation of sugars and starch and reduce lodging.

From the Tables 4 and 5 it is found that the plant height and length of the filament (+0.90) have a positive correlation between them, which in turn affects the fineness of the fibre (0+0.95). But stem diameter of plant is negatively correlated with plant height (-0.69) and filament length (-0.71). This is may be due to the better elongation of fibre bundles during the developmental stage.

Conclusion

Ramie has a prolonged history of cultivation in the North Eastern hilly region of India and from our experiment it is found that the fibre yield and fibre quality of plants of this region is much higher in the plots with proper agronomic management practices than to the control plots. The organic carbon rich soil of North Eastern hilly regions of India has a direct effect on growth and yield of plant. Available nitrogen and organic carbon in soil had a strong positive correlation (+0.91). Available potassium had a positive correlation with the fibre yield (+0.88). Fibre fineness was found to be dependent of organic carbon (+0.65) and available phosphorous (+0.93) content of soil. Moreover, the soil reaction for proper growth of ramie fibre must be acidic with the average EC of 0.14 dSm, CEC 9.18 meq/100 g and bulk density of 1.30 g/cm^3. Ramie had a wide range of tolerance towards the agro-climatic conditions and with proper soil amendment cultivation of ramie can be practised in plains also.

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