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Impact of balanced fertilization on nutrient acquisition, fibre yield of jute and soil quality in New Gangetic alluvial soils of India

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ABSTRACT

Balanced fertilization not only enhances crop growth and yield but also improves its quality and soil health. This study was conducted to determine the best approach of fertilization for jute production in New Gangetic alluvial soils of India. The experiment comprising seven fertilizer treatments was laid out in a randomized block design with three replications during three consecutive crop seasons of 2010, 2011 and 2012. The treatments were: T_1 – control (no fertilization), T_2 – farmyard manure at 5 t ha^{-1}, T_3 – farmers practice of fertilizer use (23:60:60 kg N:P_2O_5:K_2O ha^{-1}), T_4 – conventionally recommended dose of fertilizers (80:40:40 kg N:P_2O_5:K_2O ha^{-1}), T_5 – soil test based inorganic fertilizers (127:40:61 kg N:P_2O_5:K_2O ha^{-1}) for targeted fibre yield of 3.5 t ha^{-1}, T_6 – soil test based inorganic fertilizers (117:36:57 kg N:P_2O_5:K_2O ha^{-1}) plus farmyard manure (5 t ha^{-1}) for targeted fibre yield of 3.5 t ha^{-1} and T_7 – soil test based inorganic fertilizers (161:48:74 kg N:P_2O_5:K_2O ha^{-1}) for targeted jute fibre yield of 4.0 t ha^{-1}. It was found that application of soil test based inorganic fertilizers for targeted fibre yield of 3.5 t ha^{-1} (T_5) and 4.0 t ha^{-1} (T_7) achieved the yield with deviations of –6.0% (3.29 t ha^{-1}) and –6.75% (3.73 t ha^{-1}), respectively, in the experimental field. Treatment T_7 significantly ($p \leq 0.05$) increased crop growth, fibre yield, nutrient uptake, available P and K in soil in comparison to the other treatments. Treatment T_5, T_6 and T_7 increased fibre yield of jute by 8.94, 15.6 and 23.5% respectively, over conventionally recommended dose of fertilizers. However, microbial counts, microbial biomass carbon, soil enzymes, strength and fineness of jute fibre were found highest in T_6. The highest soil quality index (0.94) was recorded with T_6 followed by T_7 (0.86) and the lowest in control (0.67). The average contribution of minimum data set (MDS) towards the SQI was in the descending order of soil organic carbon (36.5%) > urease activity (20.2%) > *Azotobacter* (10.1%) > available P (7.4%) > microbial biomass carbon (6.5%). Correlation between SQI and fibre yield was significant suggesting prominent influence of balanced fertilization based on soil test and targeted yield upon fibre yield of jute. Fibre yield of jute showed significantly positive relationship with available N ($R^2 = 0.98$, $P = 0.0001$), available K ($R^2 = 0.83$, $P = 0.01$), urease activity ($R^2 = 0.94$, $P = 0.01$) and acid phosphatase activity ($R^2 = 0.91$, $P = 0.02$).

1. Introduction

Jute is an important bast fibre crop. *Corchorus capsularis* and *Corchorus* olitorius are the prominent jute species cultivated for jute fibre in New Gangatic alluvial soil of the country. In India, annual production of raw jute was 11.42 million bales of 180 kg per bale occupying 0.87 million ha area that works out to be 0.45% of the total gross cropped area during 2013–14. The share of Indian jute goods export to the global market was around 30% contributing significantly to the national exchequer (18,806.3 million INR) during 2013–14 (http://jutecomm.gov.in). Jute, a biodegradable cellulolytic raw material, is used for making diversified products depending upon the fibre quality. While ordinary jute fibre is used for making various types of bags, wools, ropes, sacks and covers. The superior quality jute fibre is used for making carpets, twine, curtains, cloth etc. Jute sticks, the byproduct, are used as fuel, fencing and raw materials for paper pulp and hardboard. Jute leaves, rich in vitamins, carotinoids, calcium, potassium and dietary fibers are used in soup preparation and folk medicine for the treatment of fever, chronic cystitis, cold and

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tumours. Jute leaves are also used as cattle feed. Apart from its diversified uses, cultivation of this crop enriches soil fertility by adding huge amount of green biomass through leaves, twigs, and thinned out plant which contains appreciable amount of macro and micro nutrients (Alam et al., 2011; Majumdar et al., 2014).

Fertilizer application is the most effective and often the most expensive among the management practices implemented in order to attain higher productivity and sustainability of crops. In India, recommendations for fertilizer applications are generally made on the basis of agro-climatic zones assuming them as homogenous units. They are not based on the soil types. Soils within an agro-climatic zone often vary widely in texture, mineralogy, organic matter content and reaction. Crop response to fertilizers is greatly influenced by soil types and spatial variability resulted from complex geological and pedological processes. Spatial variations of soil properties decrease the use efficiency of uniformly applied fertilizers at the field scale (Ramamurthy et al., 2009). Hence, under both high and low levels of soil fertility, the applied nutrients often prove to be a wasteful expenditure. Imbalanced fertilization may not only limit crop growth but also affect fertilizer use efficiency, microbial activities and metabolic processes sustaining necessary ecosystem services (Chaudhry et al., 2012; Chinnadurai et al., 2014). At the same time, there is an increasing pressure to reduce excess fertilization in commercial agriculture and minimize non-point sources of pollution in surface and ground waters. There is an absolute need to apply fertilizers in right quantity, sources and combination at the right time using the right method.

Optimum fertilizer recommendations for targeted yield approach was given by Troug (1960) and further modified by Ramamurthy et al. (1967) on the basis of theoretical and experimental proof that Liebig's law of the minimum operates equally well for N, P and K. The quantitative idea of fertilizer needs is based on yield and nutritional requirement of the crop, percent contribution of the available nutrient in soil and that of the applied fertilizer. The targeted yield concept is superior to other approaches as it not only indicates fertilizer doses but also the level of yield that the farmer can hope to achieve.

Farmyard manure, the most common organic sources of nutrients, has shown its potential to increase soil organic matter and thereby soil quality. It is well known that organic amendments improve in soil physical and biological properties. Previous researchers addressed different aspects of biology of soils amended with organic matter, i.e., number of microorganisms (Chang et al., 2007), biomass of bacteria and fungi (Nannipieri et al., 2003) and enzymes activities (Herencia et al., 2008; Chivenge et al., 2011). All these reports suggested that soil test based fertilizer recommendations should be preferred to achieve precision in farming to maximize crop production, maintain soil health and to minimize fertilizer misapplication. Considering all these facts, a field experiment was carried out on jute crop with the following objectives: (1) to achieve the targeted yield of jute fibre with the application of balanced fertilizers on the basis of initial soil test values, (2) to compare the effect of balanced fertilization based on initial soil test values and targeted yields with conventionally recommended dose of fertilizer and farmers practice in respect of fibre yield, soil quality and nutrient status of soil and (3) to determine the impact of farmyard manure (FYM) application together with balanced fertilization, i.e., to examine whether FYM application can reduce the doses of N, P and K fertilizers without significant reduction in crop yield.

Table 1
Initial properties of soil recorded before the initiation of the experiment

Parameters	Values (0–15 cm soil layer)	Methods employed
pH (soil:water, 1:2)	6.8	Jackson (1973)
EC (dS m^{-1})	0.21	Jackson (1973)
Oxidizable SOC (g kg^{-1})	7.20	Walkley and Black (1934)
Total N (g kg^{-1})	0.62	Wet digestion method
Available N (mg kg^{-1})	166.0	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Available P (mg kg^{-1})	34.2	0.5 M $NaHCO_3$ extractable P (Olsen et al., 1954)
Extractable K (mg kg^{-1})	84.4	1N NH_4OAc (Jackson 1973)
CEC (c mol^+ kg^{-1})	21.8	Jackson (1973)
Sand (%)	54.4	Hydrometer method
Silt (%)	27.3	
Clay (%)	18.3	
Texture	Sandy clay loam	

EC: electrical conductivity, CEC: cation exchange capacity.

2. Materials and methods

2.1. Experimental location, treatments and design

A field experiment was carried out at Central Research Institute for Jute and Allied Fibres, Kolkata, West Bengal, India (88° 26′E, 22° 45′N at an altitude of 9 m above mean sea level) for three consecutive crop seasons (1st week of April to 3rd week of July) during 2010, 2011 and 2012. Soil of the experimental site was non-saline and alkaline, moderately deep, well drained and sandy clay loam (Table 1), *Typic Ustocrept* according to the USDA classification system (Soil Survey Staff, 1998). Mean maximum and minimum air temperature during the crop season were 31.3 and 21.0 °C, respectively. Mean relative humidity in morning and noon were 92.7 and 62.2%, respectively. Mean annual precipitation at the experimental site was 1550 mm. The field experiment comprising seven treatments (Table 2) was laid out in a randomized block design with three replicates. Each treatment was imposed in a plot of 5 m × 5 m size. Well decomposed farm yard manure (FYM) at 5 t ha^{-1} was incorporated in the respective plots before preparation of the seed bed. The FYM contained 43% moisture, 0.60% N, 0.30% P, 0.70% K, 0.022% S, 0.185% Fe, 0.0039% Zn, 0.014% Mn and 0.00028% Cu on dry weight basis and had a C/N ratio of 56.1. Each plot was tilled separately with a power tiller to a depth of 20 cm. After field preparation, jute (var. JRO 8432) was sown in the first week of April using the seed rate of 6 kg ha^{-1} in each year (2010, 2011 and 2012) at a row spacing of 25 cm. The crop was thinned fifteen days after sowing to maintain plant to plant spacing of 5 cm. The crop was irrigated as and when required and was kept weed free by hand weeding. A workable targeted yield equations of jute (var. JRO 8432) for integrated plant nutrient supply system (IPNSS) had been developed during 2008–09 for New Gangetic alluvial soils of India (experimental site) considering the four basic parameters viz., nutrient requirement for 100 kg yield of the crop, use efficiency of nutrients available in soil, nutrient applied through inorganic fertilizers and organic sources (Ramamurthy and Velayutham, 1971). Based on initial soil test values and achievable fixed targeted yield of jute fibre, inorganic fertilizer requirement for the treatments T_5, T_6 and T_7 were calculated using the yield equations. Nitrogen was applied in three equal split doses (at the time of sowing as basal, 25 and 50 days after sowing as top dressing) through urea in the respective plots. Full dose of phosphorus and potassium fertilizers were applied at the time of sowing through diammonium phosphate and muriate of potash, respectively.