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Biowaste Utilisation for Improving Soil Health and Crop Productivity in North Eastern India

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Abstract

Efficient utilisation of bio-wastes could be an important strategy for meeting the growing demand of nutrients and improving the soil health and crop productivity in north-eastern India, where there is abundant availability of bio-wastes (such as crop residues, weed biomass, forest litter, animal dung *etc*.), and use of chemical fertilisers is traditionally minimal. Production of weed biomass in north-eastern India is estimated to be in the range of 5-20 t/ha. Around 9 Mt of crop residues are produced annually in the region. Considering even half of these residues to be available and 40% loss of nutrients contained therein, the potentially available crop residues can add up to 10,000 tonnes of N, 2,000 tonnes of P_2O_5 and 35,000 tonnes of K_2O to soil. Around 15 Mt of animals' dung produced annually can also supply substantial amount of nutrients. Additionally, these bio-wastes can improve soil organic carbon, moisture retention capacity, buffering capacity and many other desirable attributes of soil quality. These bio-wastes can also be utilised for production of quality organic manure in a short period of 50-80 days using earthworms and cellulose decomposing microorganisms, either alone or in combination. On the whole, efficient utilisation of the available bio-wastes has great potential to improve the soil health and crop productivity, and therefore needs to be promoted on priority basis. This will also help in mitigating the likely impacts of climate change on soil health and crop productivity in north eastern India.

1. Introduction

Nutrient requirement in agriculture has been rising, and is likely to increase further to boost the agricultural productivity in order to keep pace with the growing food demand of India, especially in context of climate change (Kumar, 2011a and b; Kumar *et al*., 2011a, b and c; Rakshit *et al*., 2012). Chemical fertilisers have been indiscriminately used to meet the growing nutrient demand over the past half-a-century which, of course, boosted agricultural productivity, but not without its deleterious impact on soil health and future sustainability of crop production. Further, economic and environmental considerations associated with the overuse of chemical fertilisers make it imperative to search for an alternative which can reduce over-dependence on chemical fertilisers and increase soil health and crop productivity. Efficient utilisation of bio-wastes could be a prudent option towards this end, particularly in context of north-eastern agriculture where there is abundant availability of bio-wastes (such as crop residues, weed biomass, forest litter, animal dung *etc*.) and use of chemical fertilisers is traditionally minimal, and more so in *Jhum*-cultivated areas (Rajkhowa and Kumar, 2013).

2. Soil Related Constraints in North-Eastern India

Soil degradation is a major threat to food and environmental security. Soils of the North-Eastern Region are highly susceptible to various kinds of degradation owing to its topographical and edapho-climatic conditions. Status of soil degradation in North-Eastern Hill Regions of India is shown

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in table 1. The degradation is primarily due to prevalence of shifting cultivation with short *Jhum* cycle, over exploitation of forest resources, improper land use practices and unmindful exploitation of natural resources to meet the growing needs expanding population, infra-structure development and mining activities, which ultimately result in the poor soil health (Singh *et al*., 2014a; Choudhury *et al*., 2017). Soil water erosion, which ranges between 5-83 t/ha, is the main agent of land degradation across the NEH. Loss of top fertile soil from the limited cultivated lands caused many farmers to abandon their traditionally cultivated land and move on to other marginal lands. The existing community/ private land system has been excessively exploited for survival and realisation of short-term objective without taking care of soil health. Major cropland areas of hill agriculture are eroding faster than natural process and have been significantly degraded. Deterioration of soil health is the cumulative result of soil fertility loss, increase in erodibility and exposure of compact sub-soil of poor physico-chemical properties.

Table 1: Status of soil degradation in NEH Regions of India [approximation is based on 1:250,000 soil resource mapping. Figures represent the area (,000 ha)]

State	Water erosion	Wind erosion	Water logging	Salinity/ alkalinity	Soil acidity	Complex problems	Total degraded area	Total geo. area of the state	Degraded area (%)
Arunachal Pradesh	2372	-	176	-	1955	-	4,503	8,374	53.8
Mizoram	137	-	-	-	1050	694	1,881	2108	89.2
Manipur	133	-	111	-	481	227	952	2233	42.6
Nagaland	390	-	-	-	127	478	995	1658	60
Assam	688	-	37	-	612	876	2213	7844	28.2
Tripura	121	-	191	-	203	113	628	1049	59.9
Sikkim	158	-	-	-	76	-	234	710	33
Meghalaya	137	-	07	-	1030	34	1208	2243	53.9
All India	93,680	9,483	14,299	5,994	16,033	7,381	146,820	328602	

(Source: NBSSLUP, 2004)

Soil acidity, which is already the most important impediment to crop productivity in the region, is likely to further amplify under the influence of climate change (Kumar, 2010), with an associated rise in plant phosphorus and micronutrients' requirement as well (Kumar *et al*., 2012a). This will further aggravate the acidity induced fertility constraints in soils such as phosphorus deficiency, Al toxicity, inadequate availability and uptake of various plant nutrients and many other associated problems which are already afflicting north eastern agriculture (Awomi *et al*., 2012; Kumar *et al*., 2012b; Singh *et al*., 2014b). In the North East, out of a total geographical area of 26 mha, more than 21 mha (>80% of TGA) is occupied by acid soils having pH<6.5 and more than 50% of India's acid soils below pH 5.5 belongs to this region (Kumar, 2015). The toxicity of soil Al has been recognized as one of the important factors limiting the productivity of crops on acid soils with pH less than 5.5. Reclamation of such type of soils for agriculture is the national priority. As such, the restoration of soil health is a formidable challenge before us to ensure higher productivity, profitability and food security.

Although, the soils of north-eastern hills (NEH) contain high amount of organic matter, it does not reflect the correct estimate of available N (Bordoloi *et al*., 2013). The critical limit of organic carbon for such soils has been found in the range of 1.5-2.4 %, below which response of crops to N fertilizer would be more (Prasad *et al*., 1981). Although the soils of this region has high reserve of P, the existing soil P is strongly bound to amorphous oxides of aluminium and iron, which render it unavailable to plants. Further, the phosphorus requirement of soils in north-eastern India has recently been reported to be much higher than the conventionally understood (Kumar, 2015). The deficiency of K occurs on sandy, degraded drained and highly reduced valley soils. In upland crops, its deficiency occurs due to loss of top fertile soils from terraces and sloppy lands by runoff water. The response of rice to potassium is well documented in the soils of Meghalaya (Patiram *et al*., 1996). The deficiency of Zn, B, Mo and other trace elements is also becoming pronounced at some places which must be addressed for sustainable enhancement of the crop productivity in acidic soils of north eastern India (Khan *et al*., 2016; Kumar *et al*., 2016)

Fertiliser consumption in the region is far below the national average with low use efficiency and hence crop production is mainly dependent on native soil fertility. In many areas no use or imbalanced use of fertilizer has also affected agricultural productivity and caused soil degradation. Of late, there has been a growing realization that the adoption of ecological and sustainable farming practices can only reverse the declining trend in the global productivity and environmental security. There is also possibility of reduction in soil organic carbon due to faster decomposition in the event of rising temperature (Kumar, 2010). The deficiency of both major- and micro-nutrients is widespread in the region (Kumar, 2015; Kumar *et al*., 2014 & 2016). Organic manure improves the physical, chemical and biological properties of soil as well as release of nutrients after decomposition, affecting plants growth favourably (Kumar *et al*., 2012; Verma *et al*., 2020). The application of organic manure eliminates the aluminium toxicity in acidic soils by forming organo-Al complexes and increases soil pH, organic carbon, available nutrient and soil CEC (Patiram, 1996). Large scale production and use of organic manure have a direct bearing on improvement of soil health of the already degraded soil resources by improving soil physico-chemical properties, biological health and improving moisture retention capacity besides providing plant nutrients.

3. Scope of Bio-waste Utilization in North East India

The agro-climatic conditions of the region favours production of enormous bio-waste such as crop residues, weed biomass, forest litter *etc*. under different land use systems (Table 2-3) which are potential sources of organic carbon and plant nutrients. The biomass production in weeds roughly ranges from 5- 20 t/ha depending upon the weed species, season and growing conditions (Rajkhowa *et al*., 2005; Rajkhowa and Kumar, 2013). Proper utilization of weeds itself can contribute significantly to enhance the income of poor farmers by reducing the cost of cultivation, more particularly weeding and other intercultural operational cost, enhancement of soil health and ecosystems sustainability. Weed biomass in general contains considerable quantity of plant nutrients and may be a potential source of plant nutrients and organic matter, if properly utilized. Of late, growing demand for organic manure and reduced availability of conventional source of organic manures like FYM, animal dung *etc*. also necessitates the exploitation of other alternative sources of organic manure for their large scale use for sustaining soil health and improving crop productivity. This is more relevant for the NEH region since majority of the cultivated area have been suffering from one or the other forms of land degradation and soil health deterioration.

Table 2: Nutrient content (%) of crop residues, weed and other manures

Crop residues	N	P	K
Rice straw	0.36	0.08	0.71
Maize stover	0.42	1.57	1.65
Groundnut stover	1.6	0.23	1.37
Pulses stover	0.72	0.18	0.53
Oilseeds stover	0.30	0.13	0.33
Weed biomass			
Eupatorium odoratum	3.36	0.10	0.82
Eicchornia crassipes	3.01	0.90	0.15
Ipomea sp.	2.01	0.33	0.40
Ambrossia artimisifolia	3.15	0.11	0.79
Lantana camara	2.41	0.08	1.37
Mikania micrantha	2.94	0.18	1.71
Azolla carolliniana	2.38	0.51	2.75

Source: Hazarika *et al.* (2006)

Table 3: Potential weed biomass available in NEH Region for organic manure production

Name of weeds	Biomass per year (t/ha/year)
Ipomea carnea	15-20
Eichhornia crassipes	6-8
Mikania micrantha	8-10
Cassia occidentalis	5-8
Cassia tora	6-8
Mimosa invisa	10-12
Lantana camara	10-12
Chtromalaena odorata	10-12
Ageratum conyzoides	5-6
Mixed weed biomass	3-5

Source: Rajkhowa *et al*. (2005)

The availability of animal dung, crop residues, weed biomass in the region and the potential nutrient availability from these bio-wastes are presented in table 2-5. Around 9 million tonnes of crop residues (rice, maize, pulses and oilseeds) are produced annually in north-eastern region. Even considering the half of these residues to be available and 40% loss of the nutrients contained therein, the potentially available crop residues can add up to ~10,000 tonnes of N, ~2,000 tonnes of P_2O_5 and ~35,000 tonnes of K_2O to soil (Hazarika *et al*., 2006; Rajkhowa and Kumar, 2013). Around 15 Mt of animals' dung produced annually can also supply substantial amount of nutrients to the soil. Besides their nutrient supply capacity, these bio-wastes can also improve the soil organic carbon, moisture retention capacity, buffering capacity and many other desirable attributes of soil quality. In fact, these benefits of crop residues (through mulching or in-situ incorporation) have been witnessed in many studies undertaken in different rice and maize-based cropping systems of north-east India. These bio-wastes can also be utilised for production of quality organic manure within a short period of 50-80 days using earthworms and cellulose decomposing microorganisms, either alone or in mixture. Such methods need to be standardized and popularised among the farming community. Further, development of appropriate techniques for in-situ utilization of such bio-waste is also necessary for improving soil health under hilly situation. Improvement of compost through mineral amendments or microbial culture may also be popularised. One of the possible ways of improving nutrient content in the compost is by inoculating nitrogen fixing microorganisms and phosphate solubilizing microorganisms. The culture of efficient strains of nitrogen fixing bacteria such as *Azotobacter*, *Azospirillum*, *Pseudomonas etc*. can be inoculated in the compost either during composting or in the final compost to increase the nitrogen content in the compost. Similarly, phosphate solubilizing microorganisms such as *Aspergillus awamori* are inoculated to enhance P content in the compost. Inoculation of compost with *Azotobacter* and phosphate solubilizing culture along with 1 % rock phosphate is beneficial to obtain good quality compost rich in nitrogen and phosphate.

Table 4: Production and nutrient supply from crop residues in NEH region

Crop	Available residue for use* (10^6 t)	Potential nutrients (10^3 t)			Probable nutrients** (10^3 t)		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
Rice	4.0	14.4	0.32	28.4	8.64	0.198	17.04
Maize	0.18	0.76	2.82	29.7	0.46	1.7	17.82
Pulses	0.09	0.65	0.16	0.48	0.39	0.10	0.29
Oilseeds	0.17	0.61	0.22	0.56	0.37	0.13	0.34

50% of total produce; ** 40% loss of potential nutrients; Source: Hazarika *et al.* (2006)

Table 5: Total production of manures and actual availability of nutrients (000' tones) for use in NEH region

Source/Commodity		Annual production	Probable loss (%)	Actually available for use		
				N	P_2O_5	K_2O
Cattle	Dung (Wet)	43,631	30	45.82	30.54	15.27
	Urine	28,403	75	4.73	0.18	4.73
Goat/Sheep	Dung (Wet)	574	50	0.63	0.28	0.29
	Urine	574	80	0.02	0.01	0.02
Pig	Dung	380	20	0.15	0.08	0.08
	Urine	320	50	0.32	0.14	0.28
Poultry	Excreta	1,083	30	8.33	1.51	9.09
Total	Animals	-	-	60.0	32.74	29.76
	Compost	117	-	0.52	0.17	0.47
	Green manure	700	-	0.14	0.02	0.04
	Forest litter	-	-	3.42	2.28	5.74
Total Organic Sources		-	-	64.08	35.21	36.01
Nutrients (kg ha^{-1}) (organic source)		-	-	13.07	7.18	7.34

Source: Hazarika *et al.* (2006)

In a recent study by Rajkhowa *et al*. (2019), a refined method was presented for bioconversion of agricultural waste for its efficient utilization in the hilly regions of Northeast India. They used pits in terrace lands and filled them with chopped plant biomass (rice straw, maize stover and mixed weed biomass) with alternate layers of cow dung at 3:2 ratios. For conversion of plant biomass into organic manure they used treatments including control (plant biomass + cow dung), plant biomass + cow dung + earthworm (*Eisenia fetida*) (with or without poly lining in the pit) and plant biomass + cowdung + earthworm + cellulose-degrading microorganism (*Pseudomonas* sp.) (with or without poly lining in the pit). They found that combined inoculation of *E. fetida* and *Pseudomonas* sp. with poly lining in the pit significantly enhanced compost recovery, cellulase activity and the C:N ratio. Significant improvement in yield components and nutrient status in soil was also observed after combined application of compost with 50% recommended dose of fertilizer. Based on this very useful study, Rajkhowa *et al.* (2019) concluded that dual inoculation of *E. fetida* and *Pseudomonas* sp. with poly lining in the pit could be a suitable technology for faster decomposition and effective bioconversion of agricultural waste into quality organic manure. In a similar study, Mahanta *et al*. (2012) employed microbial consortia for vermicomposting using different plant biomasses and recorded their positive effect on rice (*Oryza sativa* L.) growth and soil fertility. The same group of researchers (Mahanta *et al*., 2014) successfully isolated and evaluated the native cellulose degrading microorganisms for efficient bioconversion of weed biomass and rice straw.

4. Conclusion

In view of the elaborations made in the article, it's amply clear that there exists a huge abundance of waste biomass in north-eastern hilly region of India, which presents a lucrative potential source of plant nutrients and organic carbon. Technologies to convert them into organic manures are also available; though there remains considerable scope to refine them further. Considering the scope and imperatives of bio-waste utilization in NEH region, there is a need for production of quality organic manures from these bio-wastes and their popularisation among the farming community for improving soil health and crop productivity in north-eastern India.

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