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Organic nutrient management packages as soil policy for upgrading cropping system to restore soil productivity in Sikkim

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ABSTRACT

The indigenous farming system in the state are by and large, organically practiced. Organic farming system facilitate the build-up of soil organic matter, reducing risk of erosion, runoff and enhancing nutrient store house in soils for plant. Rapid developments in organic farming promotion necessitated continuous flow of technology to meet day-to-day challenges. Farm yard manure, compost and green manure are the most important and widely used bulky organic manures. Manuring with different short duration legumes is suitable for maintenance of soil quality in terms of adding nitrogen to soil. Sustainable quantity of potassium can be maintained by vegetative mulching with crop residues. Use of balanced dosages of mixed compost @ 5-10 t/ha along with 2 t/ha dolomite increase yield of maize, rice, mustard and soybean in the state. In spite of fairly high available soil organic carbon status in the state as a whole, the available nitrogen is low (<280 kg/ha) in 28.0% of cultivated area in South Sikkim, 25.1% cultivated area of North Sikkim, 19.1% of cultivated area of West Sikkim and 16.1% of cultivated area of East Sikkim district. The organic package of practices for major crops has been taken into consideration by the ICAR Sikkim Centre, Gangtok. This article briefly describe about the integrated organic nutrient management as soil policy for upgrading cropping system to restore soil productivity in Sikkim.

1. Introduction

Sikkim enjoys a wide range of climate, physiographic, geology and vegetation that influence formation of different kinds of soils. Hills of Sikkim mainly consist of gneissose and half-schistose rocks, producing generally poor and shallow brown soils. The soil is coarse, with large concentrations of iron oxide; ranges from neutral to acidic making it lacking in mineral nutrients. This type of soil tends to support evergreen and deciduous forests (NBSS&LUP 2004). Rock consists of phyllites and schists, which is much younger in age and is highly susceptible to weathering and erosion. This combined with the state's heavy rainfall, causes extensive soil erosion and the loss of soil nutrients through leaching. Soils of Sikkim belong to 3 orders, 7 suborders, 12 great groups and 26 subgroups. It is observed that inceptisols are dominant (42.84%) followed by entisols and mollisols occupying 42.52% and 14.64% respectively. Percentage area under Zn deficiency (<0.6 mg kg-1) in Sikkim is 15.69% (202.35 sq. km) of the geographic area having highest Zn deficiency in South Sikkim district (82.07 sq. km, 19.1% of TGAD) followed by East (56.84 sq. km, 13.3% of TGAD), West (48.91 sq. km, 15.7 of TGAD), and North (14.53 sq km, 11.8% of TGAD). Percentage area under Mn deficiency (<3.5 mg kg-1) in Sikkim is 10.16% (131.02 sq. km) of the geographic area having highest Mn deficiency in South Sikkim (48.72 sq. km, 11.3 of TGAD) followed by East (34.52 sq. km, 8.1% of TGAD), North (28.82 sq. km, 23.13% of TGAD) and West (18.96 sq. km, 6.1% of TGAD). Total degraded area in Sikkim is 60 thousand ha (9% of TGA); of which West Sikkim is highly degraded, followed by South Sikkim and North Sikkim (NBSS&LUP 2016). Erosional hazard has affected about 2 thousand ha (0.28% of TGA of the state). South Sikkim is worst affected district, followed by West Sikkim and North Sikkim.

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Sikkim being hilly state practicing terraced agriculture on an extensive scale could successfully control soil erosion.

2. Integrated organic nutrient management practices

The major challenge in organic agriculture is the availability of huge quantities of organic inputs for satisfying the farm demand. Use of animal excreta based manure alone is not sufficient for meeting the nutrient needs of the crops. It is therefore, necessary to utilize all the sources available on and off farm effectively. The resource components available for nutrient management in organic horticulture are: farmyard manure, crop residue, weed biomass, green manures, biofertilizers, composts / phospho-compost, vermicomposting, oil cakes, mulching / cover crop, liquid manures, biodynamic preparation, botanicals, legumes in cropping sequence and certified commercial products. Maintenance of soil fertility may be achieved through organic matter recycling, enrichment of compost, vermicomposting, animal manures, urine, farm yard manure, litter composting, use of botanicals, green manuring *etc.* Use of bio-fertilizers like *Azolla, Azospirillum, Azotobacter, Rhizobium* culture, PSB *etc.* to be used. Saw dust from untreated wood, calcified seaweed, limestone, gypsum, chalk, magnesium rock and rock phosphate can be used (Avasthe *et al.,* 2014). Various sprays like vermiwash and liquid manure *etc.* can be used in crops for nourishing the soil and plant. Farm yard manure, compost and green manure are the most important and widely used bulky organic manures (IARI 2012). Partially decomposed FYM has to be applied 3-4 weeks before sowing, while, well decomposed FYM should be applied immediately before sowing. Manuring with different short duration legumes is suitable for maintenance of soil quality in terms of adding nitrogen to soil. Nitrogen addition by sunhemp (150-200 kg/ ha N) and dhaincha (125-175 Kg/ha N) is highly beneficial for the succeeding crops and even for the subsequent crops too. Crop residue can also produce 2.47 Kg N, 0.53 Kg P and 8.87 Kg K per ha. Edible oil cakes of mustard and non edible oil cakes from neem, karanj and castor can serve the dual purpose of manure and bio-pest control. Vermicompost can be used for wide variety of horticultural, ornamental and vegetable crops at any stage. Generally vermicompost is applied @ 3-5 t/ha in row zones for field crops, whereas, for fruit crops, it is preferred to use the same mixing with equal amount of FYM in periodic interval. The general recommendation dose of vermicompost is 6-8 t/ha for field crop and 3-5 t/ha for subtropical fruits (Benke *et al.,* 2009 and Crawford *et al.,* 2008). In case of soil application desired strain of biofertilizer is normally mixed with 20 times well decomposed FYM to maintain uniformity of mixture and applied in furrows. However, for seedling treatments, biofertilizer slurry is made (1: ratio) in water and roots are emerged in suspension for about 30 minutes. For cereals like, maize, baby-corn, buckwheat, upland rice and finger millet, it was suggested to apply 10-20 t/ha FYM along with 5.0 t/ha vermicompost, whereas, for low P and low K, the dosages are 6-12 t/ha FYM and 3-4 t/ha vermicompost. It is suggested that goat/pig/poultry @ 3.0 t/ha along with FYM @5.0 t/ha is a good source of organic zinc supplement in zinc deficient soils. The spices like ginger, turmeric and large cardamom, it is suggested to apply well decomposed FYM along with neem cake @ 3.0 t/ha and biofertilizer slurry in rows at planting time in variable dosages under low NPK situations. The temperate climate with high organic matter is highly suitable for fruits like mandarin, chayote, strawberry, pear, *etc.* in the state. Application of well decomposed FYM along with neem cake and vermicompost at variable dosages during land preparation and biofertilizer treatment before transplanting can be beneficial for improving fruit quality even under the stress of NPK in soils.

3. Year round cropping systems of major crops for lower and mid hills (300-2000 m amsl)

For Rainfed areas the predominant cropping systems are maize + Beans-vegetable pea; maize + beans-Barley; maize + beans-rajmash; maize + beans-buckwheat; maize + beans-toria; soybean-buckwheat; soybean-toria. For Irrigated areas the predominant cropping systems are maize (green cobs)-pahenlo dal-buckwheat; maize-vegetable pea; rice-vegetable pea-maize (green cobs); rice-fenugreek (leafy vegetable)-baby corn; rice-sunflower-dhaincha (green manuring); rice-vegetable pea. Important vegetable cropping system under low cost plastic tunnels are broccoli-spinach-coriander-broccoli-coriander system; broccoli-coriander-cabbage-radish-coriander system; coriander-radish-fenugreek-spinach-coriander system; cabbage-local rayo sag-broccoli-coriander system; cabbage-spinach-broccoli-coriander system; coriander-radish-fenugreek-cauliflower-pakchoi system. Important vegetable cropping sequence for low cost plastic rain shelter are tomato-pea-tomato system; bitter gourd-pea-tomato system; bottle gourd-capsicum-pea system; sponge gourd-pea-tomato system. Important vegetable cropping sequence for low cost polyhouse are cucumber-cabbage-tomato system; capsicum-broccoli-tomato system; cucumber-cauliflower-tomato system. Important vegetable cropping sequence for open condition are okra-pea-cole crops system; okra-cole crops-local rayo sag/leafy vegetables system; dalley chilli + local rayo sag/leafy vegetables as intercrop; okra-garlic-local rayo sag/leafy vegetables system; ginger-pea system;

okra-potato-local rayo sag/leafy Vegetables system. Table 1 represents the organic nutrient available in Sikkim from all possible sources.

4. Nutrient management in major crops of Sikkim

Maize (*Zea mays* L.): Application of dolomite @ 2 t/ha+ mixed compost 2.5 t/ha+ neem cake @ 0.5 t/ha + vermicompost @ 2.5 t/ha (ICAR Sikkim, 2011). Apply FYM @15 t/ha 20 days before planting along with 150 kg rock phosphate. Neem cake @150 kg/ha for nutrient supply and control of soil-borne insect pests. Green manuring: sunnhemp, dhaincha another alternative. Seed inoculant: Azospirillum, Azotobacter & PSB @ 20 g/kg seed.

Rice (*Oryza sativa* L.): Apply FYM @ 10 t/ha to supplement recommended dose of N+P+K for maintaining soil fertility. Practice of raising a pre-kharif crop like green gram, cowpea, sunhemp or Sesbania for use as green manure. Biofertilizers (blue-green algae or Azolla) capable of providing 20-25 kg N/ha. Neem cake 150 kg/ha provides protection against soil borne diseases and improves nutrition of rice crops. 5 t FYM + 2 t vermicompost + green manures/weed biomass before 20 days transplanting and 250-300 kg neem cakes during transplanting of rice crop is best nutrient management options. Mixed compost @ 15 t/ha + neem cake @1 t/ha (ICAR Sikkim, 2011). Green manure crops like dhaincha, sunhemp and cowpea capable of accumulation of 4-5 t/ha of dry biomass and 100 kg N_2/ha in 50-60 days.

Rapeseed and Mustard (*Brassica* sp.): Apply FYM 10 t/ha or vermicompost @ 5 t/ha during last field preparation Vermicompost along with Azotobacter and PSB considerably enhances mustard yield. Apply different oil cakes @ 0.5 to 1.0 t /ha to meet demand of micro nutrient and S demand of the crop. Mixed compost @ 5 t/ha + vermicompost @ 1.0 t/ha + neem cake @ 1.0 t/ha + dolomite 1.0 t/ha was recommended (ICAR Sikkim, 2011).

Soybean (*Glycine max*) (L.) Merr.: Being a leguminous crop, require less N than other crops. Apply FYM @ 5-10 t/ha & incorporate into soil during final land preparation. Apply neem cake @ 1 t/ha + mixed compost 2.5 t/ha + dolomite 1 t/ha (ICAR Sikkim, 2011). Seed inoculation with Bradyrhizobium japonicum culture (500 g/75 kg seed) + PSB/PSM (6.5 g/ kg seed).

Buckwheat (*Fagopyrum esculentum* Moench.): Application of vermicompost @ 1.5 t/ha recorded the higher grain yield of buckwheat. Efficient crop in extracting phosphorus of low availability from the soil. Azophos seed treatment (APST) + mixed compost @ 5 t/ha + neem cake @ 0.5 t/ha (ICAR Sikkim, 2011).

Baby corn (*Zea mays* L.): Well-decomposed FYM @ 10 t/ha should be applied 20 days before sowing of crop. Baby corn should be inoculated with N fixing non-symbiotic microorganism like Azospirillum, Azotobacter *etc.* and PSB @ 20 g/kg seed.

Finger millet (*Elusine coracana*): Apply 5 t FYM/ha 15 days prior to sowing of the crop. Bio-fertilizers like *Azospirillum brasilense* (N-fixing) and *Aspergillus awamori* (P-solubilizing) apply @ 25 g/kg seed.

Table 1. Organic nutrient available in Sikkim from all possible sources

Sl. No.	Animal	Livestock Population Sikkim (19th livestock census 2012)	Manure production rate per animal per day in kilograms	Amount of Manure produced per day (in Kilograms)	Manure/ Year (tons)	Manure/year on dry weight basis (in tons)
1	Cattle	140467 CB-126519 Ind.-13948	25-30	3511675-4214010	1281761.375-1538113.65	384528.4125-461434.095
2	Buffalo	703	25-30	17575-21090	6414.875-7697.85	1924.4625-2309.355
3	Sheep	2634	2-3	5268-7903	1922.82-2884.595	576.846-865.3785
4	Goat	113364	2-3	226728-340092	82755.72-124133.58	24826.716-37240.074
5	Pig	29907	5	149535	54580.275	16374.0825
6	Yak	4036	25	100900	36828.5	11048.55
7	Poultry	451966	0.6	271179.6	98980.554	29694.1662
Total				4282860.6-5104709.6	1563243.9-1863219	468973.17-558965.7

Black gram (*Vigna mungo* L.): FYM or mixed compost @ 5 tonnes/ha enhances the yield. Seed inoculation with *Rhizobium* strains increases seed yield & uptake of nutrients. Additional nutrient may be supplied through *water soluble organic granules @ 5 kg/acre* mixed with FYM, vermicompost or mixed compost.

Large cardamom *(Amomum subulatum Roxb.):* If the land is not terraced, soil base may be made by cutting top soil from upper half and placed on lower half followed by mulching. At plant base, mulching with easily degradable organic materials is good for conserving both moisture and soil. Mulching improve soil physical condition and fertility. Dried organic matter, leaves, weeds *etc.* can be used as mulch. During planting pits are filled with topsoil mixed with FYM @ 1-2 kg/pit. FYM/compost @ 5 kg/plant at least twice a year in April-May and August-September is beneficial.

Ginger (*Zingiber officinale* L.): Well-decomposed and dried cattle manure or compost @ 25-30 t/ha + neem cake @ 2 t/ha + biofertilizer (Azospirillum+PSB) @ 5-6 kg/ha helps in reducing incidence of rhizome rot of ginger and increases yield. Two months after planting, vermicompost @ 5t/ha should also be applied for better growth and production. Since edible part is rhizome, prior to planting of seed rhizome in soil, a half foot layer (6'') of leaf increases production of ginger by loosening soil texture around seed rhizome at later stages.

Turmeric (*Curcuma longa* L.): Needs heavy manuring. Apply FYM @ 15-20 t/ha along with 250 kg neem cake or vermicompost @ 10 t/ha. Integrated application of FYM @ 10 t/ha and vermicomposting 5t/ha along with 250 kg neem cake. O.M. along with biofertilizers like Azospirillum and Bacillus for better nutrition. Dolomite @ 2 t/ ha to ameliorate soil acidity

Mandarin (*Citrus reticulata* Blanco.): Young plants manured once/year, bearing plants twice/year (June-July and after harvesting in December-January) @ 10-20 kg FYM/tree or 2-2.5 kg vermicompost/tree. Micronutrients through foliar sprays of water soluble organic sources or nano-fertilizers @ 0.2 %. Dolomite @ 100-200 g /plant for every second year. Neem cake @ 2 t/ha during active growth stage in July-August. Kiwi fruit (*Actinidia chinensis*): Plants are heavy nitrogen feeders. Apply well-decomposed FYM@ 25-30 t/ha & neem cake @ 2 t/ha after vines have several inches of new growth during early spring. During active fruit growth stage, vermicompost @ 2 kg/plant should also be given for better growth, production and fruit quality.

Cole crops (*Brassica* spp.): Well-decomposed FYM or compost should be applied @ 5.0 kg/m² along with neem cake @ 200 g/m² at the time of final land preparation. Root dipping of seedlings in Azospirillum +PSB (20%) for 15 minutes at the time of planting. Additional application of vermicompost in cole crops @ 1 kg/m² further improves production.

Potato (*Solanum tuberosum* L.): Proper soil fertility management alone accounts for 20.7% of all yield contributing factors. Well-decomposed and dried cattle manure or compost @25-30 t/ha & neem cake @ 2 t/ha should be applied.

5. Identified crops for marketing outside state from Sikkim

The most important crops which have been identified in Sikkim as commercial crop for marketing outside state are large cardamom, ginger, turmeric, buckwheat, cymbidium (flower) and tea. Table 2 represents the marketing of organic produce in Sikkim.

Table 2. Marketing of organic produce in Sikkim

Agency	Jurisdiction of marketing	Products
Sikkim Marketing Federation (SIMFED)	Within and outside Sikkim	Sikkim mandarin, Kiwi, Ginger, Turmeric, Buckwheat, Rajma & Vegetables
Farmers' Producers Organizations	Within Sikkim	Vegetables
Nature's Gift (private entity)	Outside Sikkim	Ginger, Turmeric, Buckwheat

6. Strategies for increasing organic farm productivity in Sikkim

Single-cropping should be avoided and preferably 2-3 crops should be grown together. If for any reason it is not possible to grow mixed or intercrops, then grow different crops in adjacent plots to maintain diversity. At any given time legumes must occupy at least 30% of total cropping area. The legumes are nitrogen-fixing and can also be good source of mulching from the crop residues. High yielding varieties require high nutrient inputs; they should be replaced with improved varieties suitable for organic management. The same crop or same cropping sequence should not be repeated in the same field in two consecutive seasons/years (except for some legume crops such as moong bean or cowpea) and the field must be rotated every 2-3 years.

Adoption of conservation tillage practices for improving soil quality and conserving soil moisture. Cover cropping, *in situ* residue management and restoration of degraded lands for soil moisture conservation and improved C-sequestration should be practiced (Das 2014). Integrated farming systems and watershed development with animal, fishery and suitable cropping for soil and moisture conservation and nutrient recycling should be practiced. Popularization of water saving and nutrient saving technologies *viz.* system of rice cultivation (SRI) and aerobic rice. Rain water harvesting: *in-situ* (land configuration, mulching with locally available biomass *etc.*) and *ex situ* (ponds, micro water harvesting structures like *jalkund etc.*) for ensuring year round high value crop production. Adoption of conservation irrigation practices like drip, sprinklers *etc. in situ* biomass management in shifting cultivation instead of biomass burning for improving soil carbon economy and hydrology should be practiced. Adoption of low cost plastic tunnels, low cost plastic rain shelters and greenhouse (low cost) for year round production of high value low volume vegetable crops should be promoted. Sufficient application of organic matter is crucial for soil fertility management especially for achieving satisfactory yields with good quality product. Integration of integrated farming system is necessity for organic farming. Strengthening the animal husbandry section with main emphasis on poultry and piggery because majority population consume meat (Das *et al.,* 2014). Besides, both are more profitable ventures. Composting of locally available biomass and construction of vermibeds for vermicomposting is also essential. cultivation/cooperative farming should be encouraged. Need-based crop diversification which allows more crops per unit area per unit time and per drop of water with due consideration of market demand should be enhanced. Introduction of new oilseeds and pulse crops which have yield potentials to meet the pulses and oil seed requirement of the region should be promoted. Recycling of all kinds of biomass and crop residues for minimizing the dependence of nutrient requirement from outside should be practiced (Schoenau and Davis 2006). Adoption of soil conservation measures, careful soil cultivation that does not lead to soil erosion and conserves the soil moisture should be practiced. Integrated organic nutrient management strategies should be adopted. Uses of biofertilizers, green manuring and concentrated organic manures like neem cake should be used for proper nutrition. Preventive measures should be adopted to manage pests, diseases and weeds. Awareness should be created for off-season vegetable production on scientific lines. Adoption of cool transport chain, pre-cooling units, packing houses, short and long term cold stores *etc.* for minimizing the post-harvest losses. Strengthen extension network for dissemination and monitoring the adoption of appropriate knowledge/technologies. Agri Export Zone should be identified by the Government for export of organic products and contract cultivation/cooperative farming should be encouraged.

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