Potential of Surplus Crop Residues, Horticultural Waste and Animal excreta as nutrient source in Central and Western Region of India

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ABSTRACT
In the recent past yield stagnation in major cropping systems of India, along with declined soil fertility and soil health have emerged as a prime threat to sustainable food security. Moreover ever-increasing population is also accelerating the food demand from the limited land resources. This current situation has led to a huge gap between the availability of nutrients and the demands to sustain food security. It has thus become the need of the hour to recover and recycle the nutrients that have been mined from soil. Henceforth, recycling of surplus crop and horticultural residues and animal excreta seems to be viable option to minimize the nutrient gaps. However, the cumulative estimated data of availability of unutilized crop and horticultural residues and animal excreta is rare in Indian context. The exhaustive review has thus attempted to give an estimation of recyclable bio-waste in the Central and Western states of India that could be utilized as baseline information by the future policy makers.

Key words: *Surplus, Crop residue, Vegetable waste, Fruit waste, Annimal excreta,*

INTRODUCTION

A material is only a waste unless it is recycled or converted in to a value added product. When it's converted to valuable resources, it rather becomes a form of wealth. Skyrocketing growth of human population, its consumption pattern, subsequent urbanization, industrialization and agricultural intensification have resulted in the generation of enormous quantity of urban and rural waste. Crop residues have been referred to as "wastes" but also considered to be "potential black gold" as a natural and valuable resource [1] as it provides significant quantities of nutrients for crop production. Organic wastes generated by agriculture, commercial and industrial activities are often disposed on the soils. The biodegradable wastes available in India such as crop residues (from cereals, legumes, pulses, oilseeds, sugar cane, cotton etc.), animal waste (from cow, buffalo, goat, sheep, poultry etc.), agro industrial wastes and city garbage have wide C/N ratio ranging from 80-110, and low concentration of available plant nutrients particularly N, P and K. On the basis of crop production levels, it is estimated that ten major crops (rice, wheat, sorghum, pearl millet, barley, finger millet, sugar cane, potato tubers, pulses and oil seeds) of India generate approximately about 679.32-686 million tons (MT) of crop residues [2], in which 226MT are actually available that has nutrient potential of about 5.6MT of nitrogen, phosphorus and potassium (NPK). The availability of all animal excreta is about 369 MT of which 101 MT are actually available that can potentially supply 3.474 MT of NPK [3]. Per capita waste generation rate in India was estimated to be 0.34 Kg day^{-1}in 2012 and it will reach up to 0.71Kg day^{-1}in 2025 [4]. In a recent survey, it is estimated that about 64.8MT of city wastes are generated every year from different cities of India that have nutrient potential of about 0.285 million tons of NPK. It is further estimated that one million ton increase in food grain production will produce 1.2-1.5 million tons of crop residues and one million increases in cattle population will provide additional 1.2 million tons of dry dung per annum. Thus, the estimated NPK supply from all the wastes including crop residues is 5.0, 6.25 and 9.25 million tons, respectively during the year 1991, 2011 and 2025 [5].

In spite of their huge nutrient potential, the wastes are being disposed regularly without being recycled. Most of the crop residues are burnt in Northern India and some parts of Central India and only one third part of residue are being utilized for cattle manure. Similarly two third part of animal wastes are being used as fuel cake and remaining one third part is being channelized for manure production. However, under ordinary storage condition tremendous losses of plant nutrients takes place either by uses as fuel cake or by leaching or volatilization when manure remains exposed to sun and rain. These scenarios thus again highlights the significance of composting in a scientific way to bring back the much needed organic and mineral matters to the soil.

Apart from this the present day agriculture is facing major challenges like yield stagnation in crop production, declined fertilizer response ratio, emergence of secondary and micro nutrient deficiency and deterioration of soil quality. At present level of crop production, annually there exists a negative balance of 10 million tons between the nutrient (NPK) removal by crops from soil and addition through fertilizers. The stagnation in fertilizer consumption and higher negative nutrient balance are posing a threat to soil health and sustainable agriculture [6]. Fertilizer consumption in India is generally imbalanced, tilted more towards N followed by P and K, mainly due to intensive crop production as well as Govt. subsidy system. In many areas in India the imbalanced fertilization is the root cause of poor crop yield [7].The negative yield trends were observed under long-term imbalanced N and NP fertilizer application in rice-wheat-jute, soybean-wheat and sorghum-wheat system in Inceptisol, Alfisol and Vertisol, respectively [8]. Continuous application of imbalanced NPK fertilizers alone minimized the crop yield and soil quality parameters. It was observed that decline in yield is more pronounced with concomitant decrease in SOC content under imbalanced fertilizer application. Long-term application of NPK and NPK+FYM (farm yard manure) maintained or improved SOC content over initial [9,10]. Therefore, to maintain soil organic matter as well as to supplement nutrient requirement for crop production, recycling of crop residues, horticultural wastes and animal excreta is of utmost importance. Keeping in view the facts discussed above, we have thus reviewed the availability of wastes generated in the from crop residues, horticultural waste, animals excreta in the central and western states of India i.e from Madhya Pradesh, Chhattisgarh, Rajasthan, Gujarat, Maharashtra, and Goa and further computed the surplus, their nutrient potential and feasible recycling options to achieve sustainable crop production, soil health and economy.

Availability of crop residues in Central and Western states of India

In central and western India, approximately 342.82 MT of crop residues are produced every year (Table 1). Among different crops, sugarcane generates the highest (154 MT) residues, followed by cereals(87 MT),cotton (67 MT), chickpea and pigeon pea (17.4 MT) and soybean and groundnut (16.8 Mt). Irrespective of crops, the highest residue is generated from Maharashtra followed by Gujarat and Madhya Pradesh. Furthermore, Maharashtra stood first in terms of sugarcane residue (130.10 Mt) whereas Madhya Pradesh is dominant in pulse and oil seed crop residues (5.61, 6.66 Mt, respectively). Rajasthan ranked first in cereal residue generation which is closely followed by Madhya Pradesh. Percent contribution of different crops in residue generation has been depicted in Fig 1.

Availability of vegetable and fruit waste in Central and Western states of India

In central and western India, approximately 61.63 MT of vegetable and fruit wastes are produced every year (Table 2; data period 2010-11). The highest vegetable and fruit wastes are being generated in Maharashtra, followed by Gujarat. Tomato, potato, onion, brinjal, okra, cabbage, cauliflower are the main contributing vegetable waste; whereas mango, banana, citrus, guava, papaya, sapota, grapes and pomegranate are the major contributors of fruit waste. Maharashtra produces the highest amount of tomato and onion waste; however, Gujarat ranked first in potato, brinjal , cabbage , cauliflower and okra waste production. Similarly, among the different fruit wastes, highest mango wastes (1.09 MT) are produced by Gujarat; whereas Maharashtra dominates in banana, citrus, papaya, guava, pomegranate, sapota and grapes waste production. Percent contribution of different vegetables and fruits in residue generation has been illustrated in Fig 2 and Fig 3.

Central and western states of India cumulatively produce 135.86 MT (Table 3) of animal excreta, out of which major portion is contributed by cattle, followed by buffalo and goat. The highest quantity of animal excreta is being generated by Rajasthan, followed by Madhya Pradesh. The highest cattle excreta is produced by Madhya Pradesh, whereas the highest amount of buffalo and pig excreta are produced by Chhattisgarh. Rajasthan ranks first in goat and sheep excreta production, whereas Maharashtra contributes the largest quantity of poultry excreta. Percent contribution of different states in animal excreta production has been delineated in Fig 4.

Surplus of crop residues in Central and Western India

In the central and western states of India approximately 114.27 MT (Table 1) crop residues remain surplus after different uses of crop residues such as cattle feed, domestic fuel, bedding material for animals etc. Maharashtra produces the highest amount of surplus residues (58.60 Mt), followed by Gujarat (23.88 MT). The major portion of the total surplus residue is being contributed by sugarcane. It is followed by total cereals, cotton, bengal gram and pigeon pea (5.79 MT) and soybean and ground nut. Percent contribution of different crops in generation of surplus residue has been portrayed in Fig 1.

Surplus of vegetable and fruit wastes in Central and Western India

In addition to the crop residues, approximately 15.73 MT vegetable wastes and 15.03 MT (Table 2) fruit wastes are available as surplus for recycling. Maharashtra dominates in both the vegetable (7.99 MT) and fruit (8.58 MT) wastes surplus as compared to other states in central and western India. Gujarat ranks second with respect to vegetable and fruit wastes surplus for recycling. Percent contribution of different vegetables and fruits in generation of surplus waste has been delineated in Fig 2 and Fig 3.

Nutrient potential of crop residues and its recycling

Crop residues are potential source of plant nutrients and their beneficial effect on soil fertility and productivity could be harnessed by recycling them in to the soil (Table 4).Thus, it's continuous removal and burning can lead to net losses of nutrients which ultimately will lead to higher nutrient cost input in the short term and reduction in soil quality and productivity in the long term. Estimates showed that on average 30–35% of applied N & P and 70–80% of K accumulated in the crop residues of food crops. About 40% of the N, 30-35% of the P, 80-85% of the K, and 40-50% of the S taken up by rice remain in the vegetative parts at maturity [11]. Similarly about 25-30% of N and P, 35-40% of S, and 70-75% of K uptake are retained in wheat residue [12].Moreover, crop residues are the primary source of organic matter (as C constitutes about 40% of the total dry biomass) [13]which is indispensable for sustaining agricultural ecosystems. However, soil conditions, crop management, variety as well as season determine the nutrient concentration in crop residues.

In the central and western states of India total nutrient potential (cumulative NPK content) of different surplus crop residues is 2.22 MT, surplus vegetable wastes is 0.066 MT, surplus fruit waste is 0.068 MT and of surplus animal excreta is 3.90 MT (Table 5). Among different states, Maharashtra has the highest cumulative nutrient potential from crop residues, horticultural wastes as well as animal excreta.

The annual nutrient cycling in the plant-soil ecosystem is essential in maintaining a productive agricultural system. The crop residue management has important implications for the total amounts of nutrients removed from and returned to the soil. The dynamics and bio-availability of main plant nutrient elements are also improved by SOM. Moreover, the amount, diversity and activity of soil fauna and microorganisms are directly related to SOM content and quality. Carbon compounds in the residue are the fuel or energy sources for the soil microbes and fauna responsible for biological recycling of these inorganic plant nutrients. During microbial decomposition of crop residues, mineral nutrients are released into the immediate environment that may be utilized by living plants or organisms. Carbon-enriched crop biomass becomes the primary food source for soil microorganisms and fauna and as a result "nurtures" nutrient cycling.

Furthermore, management practices such as fertilization and the amount of residue remaining after harvest determine the extent of cycling and plant availability of nutrients from crop residues. Henceforth, the shift from conventional to conservation tillage systems necessitates new research to determine the rate of cycling and plant nutrient availability.

Fertilizer consumption vs. nutrient potential of surplus waste in central and western states of India

A comparative assessment between fertilizer consumptions and the nutrient (NPK) potential of surplus wastes has been projected in the Figure 5. The figure has been compiled from the data derived from Fertiliser Statistics 2012-13 [14] and from the table 5.The highest fertilizer consumption as well as the highest NPK potential of surplus wastes is found in Maharashtra and the lowest was noticed in Chhattisgarh. Fertilizer consumption and the highest NPK potential of surplus wastes of Goa are negligible as compared to other states, thus, it is not considered here. The projection depicts a promising prospect as the surplus waste recycling can cumulatively contribute to narrow down fertilizer consumption of the states; still it's not enough to fulfil the entire nutrient demand for sustainable crop production. If the whole amount of surplus wastes is composted, still it can't meet the nutrient requirement for single crop season, as only 30-40 % of the composted nutrient release during first year of application. However, in economic terms recycling of surplus waste could save almost 6483.74 crore government money that has been spent in term of fertilizer subsidy (Figure 5B). .

Management of wastes (crop residues, vegetable and fruit waste and animal excreta)

In-situ decomposition of crop residues

Surface retention, incorporation (*in-situ*) and composting (*ex-situ*) are the promising on-farm management options to address the issue of burning as well as maintaining soil health and long-term sustainability of crop productivity. To achieve the *in- situ* decomposition different recent technologies have been coming up. Such as, *in- situ* decomposition of rice and wheat residue where 4000 kg fresh cow dung slurry along with 37 kg urea, 50 kg molasses, 25 kg curd, 1.7 kg mycelial mat (cellulolytic fungi) and 34 L of microbial inoculum (lingo-cellulolytic bacteria and actinomycetes) were added and spread over the residues. One irrigation was applied immediately after spreading the consortia followed by thorough mixing and incorporation into the soil by a tractor drawn rotavator. The, second irrigation was given after 15 days of incorporation and the residue decomposition was complete after one month. The same technology was also successful to decompose the sugar cane trash with 45 days. This technology is the brain child of ICAR-IISS, Bhopal [24 [15]. Another technological innovation for *in-situ* residue management is the latest version of the Turbo Happy Seeder [16, 17]. A straw management system (SMS) named as Super-SMS has been developed and commercialized by Punjab Agricultural University, Ludhiana, to equip the combine harvesters with mechanized straw spreaders [18, 19]. In this technology, SMS can be attached with in all existing combines for paddy harvesting and spreading of straw uniformly *in-situ* for facilitating the subsequent operation of Happy seeder for sowing of wheat crop, that is operated through tractor.

***Off-situ* Composting**

The potential of composting to turn on-farm waste materials into a farm resource makes it an attractive proposition. Composting is a microbiological, non-polluting and environmentally safe method for disposal and recycling of these wastes by converting them into organic fertilizer.

Apart from this, another important aspect of composting is the stability or maturity of compost. The term stability and maturity are often used interchangeably to describe the degree of decomposition and transformation of the organic matter in compost [20].There are different physico-chemical indicators to validate compost stability and also rapid tests used at composting plants to track compost stabilization during the process. Loss of CO_2-C, content of NH_4-N and NO_3-N, pH, EC and total humic substances (humic and fulvic acid) serve as the physico-chemical indicators of compost stability. The self-heating test on the un-dried, sieved samples is another stability test as recommended by the [21]. The maximum temperature (T_{max}) reached is used to evaluate the rotting degree of the compost from I (fresh material, T_{max}> 60°C) to V (mature compost, T_{max}<30°C). Composts are considered as finished when temperature did not exceed 40°C during the test (Rotting degree IV and V). For preparing of good quality compost from waste it is necessary for the organics to go through "Seven Stage of Composting" (Fig 6)

The history of composting dates back to the history of early agriculture, however, the contemporary composting initiated in India with the innovation of Indore method of composting. In India, the rural wastes (farmyard waste, household waste, agricultural wastes etc) and city waste are usually composted following either pit/ heap or trench method (Fig 7) which takes about six-seven months to mature with 2-3 turnings at 15 days intervals. Range of methods, including traditional to modern, manual to mechanical, that are scientifically designed and tested are being implemented to produce good quality compost which represents a completely decomposed brown homogeneous humic product in about three months. The compost resembles the traditional FYM in appearance and properties. The average nutrient content of compost prepared by this method is 0.5-0.8 % N, 0.3-0.5% P_2O_5 and 1-1.5% K_2O. Some scientific methods of composting along with their salient features are discussed below.

Phospho-sulpho-nitro-compost (PSNC) technology

This method employs both the fortification and the acceleration strategy by using rock phosphate, pyrites, micas etc., urea nitogen, and lignicellulolytic microbes so that the end product contains more nutrients per unit weight. For production of a ton of P-S-N Compost, waste-1000kg, cow dung-200kg, rock phosphate-333kg, pyrites-120kg, urea-13kg and soil-50 kg are required. Matured P-S-N compost after 110 days of decomposition contain approximately 3.2-4.2 % P and 1.5-2.3 % N.

Organo-mineral compost

In this method, the preparation of P,K, and S enriched compost is being prepared by pit method using wheat straw, cattle dung, rock phosphate,waste mica and mineral gypsum.The compost that gets ready after 4 months of decomposition contains about 1% N,1% total P , 2.1 % total K 1.7 % S. Moreover,it can substitute 24% of chemical fertilizers in terms of P requirement and would be more cost-effective to apply insoils prevalent in large part of Rajasthan, and most of the Indo Gangetic plainshaving low available phosphorus and organic carbon.

Microbial-enriched compost

In this technique, a consortium of bio-inoculum has been used to enhance the decomposition process to recycle city garbage by pit or windrow method and compost may be ready for field application after 1.5 to 2 months. Fungal culture is added at 500 g mycelial mat per tonne of material. Initially, at 1-5 days bioinoculum such as *Aspergillus heteromorphus*, *Aspergillus terrus*, *Aspergillus flavus* and *Rhizomucor pusillus* is added and owing to a high initial temperature (55 to 70^{o}C) at the thermophilic stage, the bioinoculum is again added after 30 days of decomposition. A microbial enriched compost technology has, thus, been developed using cellulolytic organisms to accelerate the process of decomposition and to increase the manurial value as compared to existing MSW compost

Vermicompost

Vermicomposting is a very effective method of converting wastes into useful manure with the help of earthworms to recycle decomposable organic wastes such as animal excreta, kitchen waste, farm residues, forest litters, etc. The species of epigeic earthworms, only a few are known to be used for vermicomposting. These are (i) *Eisenia foetida* (ii) *Eudrilus eugeniae* (iii) *Perionyx excavatus* and (iv) *Decogester bolaui*. The first two are exotic and the last two are indigenous to India. These species are most suited because these are prolific breeders with high multiplication rate, have short life cycles with less mortality and are voracious feeders which excrete high quality vermicasts. They are easy to handle, have lifespan of 1 to 1.5 years, are sturdy and survive very well throughout the year under varying weather conditions. Such species are easily available and economically feasible for vermicomposting.

Rapid compost

Rapid composting is the need of the hour for reducing the time required for obtaining good quality compost. This technology is especially suitable for recycling of kitchen waste and vegetable wastes. The unique ness of this technology is to inoculate thermophilic lignocellulolytic microbes at thermophilic stage of composting to accelerate decomposition rate and reduce the time frame. For the preparation of 100 kg compost, 150 kg waste material, 50 kg fresh cow dung, 1.1 kg urea, and consortia of fungi bacteria and actimiycetes are required. It would produce compost within 1-1.5 months.

Status of composting

Among different states of central and western India, the highest quantity of rural compost is produced in Chhattisgarh and urban compost in Rajasthan. However, huge quantity of FYM is being produced by Gujarat, followed by Rajasthan (Table 6).Case studies on the impact of phosphor-sulpho-nitro-compost (PSNC) application on yield potential and fertiliser substitution represented that application of 10 tonnes PSNC can substitute 99-100% of recommended fertiliser dose in ground nut and green gram, whereas 5 tonnes of PSNC can replace 98 % of recommended fertiliser dose in soybean (Table 7). Similarly, 10 tonnes vermicompost can substitute 100% of recommended fertiliser dose in pearl millet and 5 tonnes can replace 85 % of recommended fertiliser dose in chick pea [3].

Challenges of waste recycling

The success of waste recycling depends upon mainly four pillars: technology availability, accessibility, affordability and technology diffusion. SWOT analysis revealed that most of the challenges of waste management concern the lack of suitable facilities such as equipment and infrastructure, underestimation of waste generation rates, inadequate management and technical skills. In comparison to developed countries Indian scenario depicts that it is not actively involved in the recycling process, recycling plans, and techniques [22,23]. Moreover little involvement of private sector, inappropriate choice of methods for waste recycling, lack of holistic policy measures and inadequate incentives/subsidies made the outcome poor [23].Furthermore, Ministry of Environment, Forest and Climate Change (MoEF)/ Pollution Control Boards/ states do not have a complete data about all the various kinds of waste being generated in India. Risks to health/ environment had not also been adequately assessed by MoEF/states. Rare instances of the polluter being held responsible for unsafe disposal and absence of a single body taking ownership of waste issues in India made the recycling more difficult. Public attitudes towards waste are also a major barrier to improving waste management in India.

In case of agriculture sector on field burning of crop residues of aapproximately 15.78-21.92 MT [24] is a greatest threat against recycling them into field.Unavailability of labour, high cost in removing the residues, lack of requisite machinery to incorporate crop residues in soil and use of combine harvesters in rice, wheat and sugarcane based cropping system made the problem more stringent.

Scope of future research

- Indian states are generating huge amount of wastes in terms of crop residues, horticultural wastes and animal excreta. There is a trade-off between different competing uses of wastes depending upon the need of the people. Lack of management knowledge are causing loss of huge amount of waste material and in turn resulting in environmental pollution. Moreover, the lack of quantitative data base about the amount of wastes generated, used and surplus in different states of India making this more problem more acute. Therefore, a study to generate a database of waste material at national scale is of utmost importance for future research and policy development.

- Waste recycling could play instrumental role in Integrated Nutrient Management for sustaining crop productivity.
- Whether recycling of waste is really improving fertilizer use efficiency in long term?
- Composting is beneficial way to recycle surplus waste; however, composts generated in India are of low quality. Thus compost fortification with externally added nutrient and microorganisms could enrich the low grade compost for better utilization.
- Though the crop residue recycling is already recommended as an integrated part of conservation agriculture, farmers are facing major challenge of slower decomposition of crop residues which is leading to burning of crop residues in Indo-Gangetic Plain. Thus, further pilot scale research on in-situ decomposition/management as well as soil organic carbon enrichment is the need of the time.

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Table 1 Generation, surplus and burning of CR (in MT yr^{-1}) in central and western states of India

States	Residue generation[a]	Residue surplus[b]	Residue burned[c]	Residue burned[d]
Chhattisgarh	10.49	3.50	1.84	0.83
Goa	0.26	0.09	0.08	0.04
Gujarat	71.65	23.88	6.69	3.81
Madhya Pradesh	46.52	15.51	3.46	1.91
Maharashtra	175.81	58.60	6.27	7.41
Rajasthan	38.11	12.70	3.58	1.78
India	**342.82**	**114.27**	**21.92**	**15.78**

#[Source: a. Fertiliser Statistics 2012-13 [14], b. Anonymous, [25]; b.Bhardwaj, KKR. [26]. c. Based on IPCC coefficients, d. Pathak et al. [24]]

Table 2 Generation, and surplus of vegetable and fruit wastes ($MTyr^{-1}$) in central and western states of India

	Vegetable		Fruit	
States	Waste generation[a]	Waste surplus[b]	Waste generation[a]	Waste surplus[b]
Chhattisgarh	3.14	1.57	0.90	0.45
Goa	0.00	0.00	0.04	0.02
Gujarat	9.05	4.53	7.98	3.99
Madhya Pradesh	2.65	1.32	3.71	1.86
Maharashtra	15.97	7.99	17.17	8.58
Rajasthan	0.64	0.32	0.39	0.19
India	**31.45**	**15.73**	**30.18**	**15.09**

#[Source: a. b. Modified from Anonymous, [25]; Manna et al. [3]; Indian Horticulture database-2013, [27] data period 2010-11]

Table 3. Contribution different animals in total excreta production (MT) in central and western states of India

Livestock	Excreta Production (Mt)	%
Cattle	75.03	55.23
Buffalos	52.02	38.29
Sheep	2.08	1.53
Goats	5.81	4.27
Pigs	0.30	0.22
Horse & Ponies	0.06	0.04
Mule & Donkeys	0.09	0.07
Camels	0.29	0.21
Poultry (Backyard + Farm+ Hatcheries)	0.19	0.14
Total	**135.86**	

#[Source: 19th Live stock cencus-2012 All India Report, [28]]

Table 4. Nutrient potential of different crop residues in India

	N (%)	P_2O_5 (%)	K_2O (%)	Total	Tonne / Tonne residue
Rice	0.61	0.18	1.38	2.17	0.0217
Wheat	0.48	0.16	1.18	1.82	0.0182
Sorghum	0.52	0.23	1.34	2.09	0.0209
Maize	0.52	0.18	1.35	2.05	0.0205
Pearl millet	0.45	0.16	1.14	1.75	0.0175
Barley	0.52	0.18	1.30	2.00	0.0200
Finger millet	1.00	0.20	1.00	2.20	0.0220
Pulses	1.29	0.36	1.64	3.29	0.0329
Oilseeds	0.80	0.21	0.93	1.94	0.0194
Groundnut	1.60	0.23	1.37	3.20	0.0320
Sugarcane	0.40	0.18	1.28	1.86	0.0186
Potato tuber	0.52	0.21	1.06	1.79	0.0179

#[Source: Tandon[29]]

Table 5. Nutrient budget (MT) in terms of total ($N+P_2O_5+K_2O$) of different wastes available in the central and western states of India

States	Crop residues*	Vegetable waste*	Fruit waste*	Animal excreta*	Total$
Chhattisgarh	0.08	0.001	0.002	0.39	**0.48**
Goa	0.002	0.000	0.000	0.00	**0.00**
Gujarat	0.44	0.019	0.019	0.76	**1.24**
Madhya Pradesh	0.34	0.005	0.009	0.99	**1.34**
Maharashtra	1.12	0.032	0.037	0.75	**1.94**
Rajasthan	0.24	0.001	0.001	1.01	**1.26**
Total	**2.22**	**0.066**	**0.068**	**3.90**	

[Source: Manna et al. [3], Fertiliser Statistics 2012-13[14];Anonymous, [25]; Bhardwaj, KKR. [26] Indian Horticulture database-2013, [27] data period 2010-11; 19th Live stock cencus-2012 All India Report, [28]; Tandon[29]]

*Nutrient potential = Surplus crop residues/Vegetable waste/Fruit waste/Animal excreta (Mt) × % of nutrient (N/ P_2O_5/ K_2O)

$ Cumulative nutrient potential of crop residues, vegetable waste, fruit waste and animal excreta in terms of $N+P_2O_5+K_2O$.

Table 6. Organic manure produced (MT) in different states of central and western India

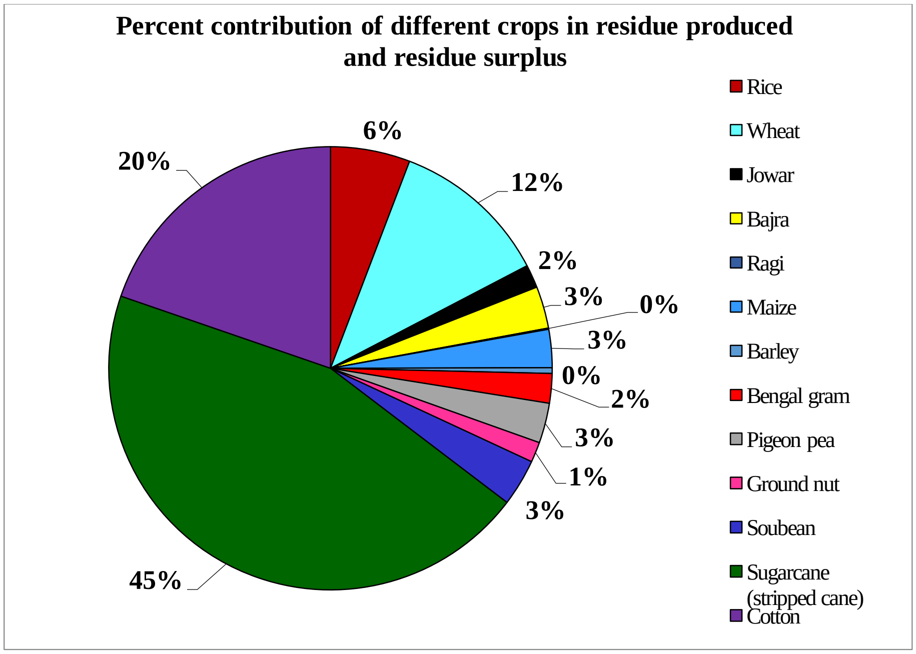
State	Rural compost	Urban compost	FYM	Vermi-compost
Madhya Pradesh	4.50	0.35	8.55	0.20
Chhattisgarh	8.03	0.32	3.60	0.20
Rajasthan	1.97	1.51	25.25	.0036
Gujarat	-----	------	35.80	.05
Maharashtra	-----	------	------	.017
Goa	1.57	.002	-------	.002

[Modified from Fertiliser Statistics 2012-13 (2013) [14]]

Table 7. Comparative effectiveness of composts and recommended dose of fertilizers on crop productivity in different soils of India

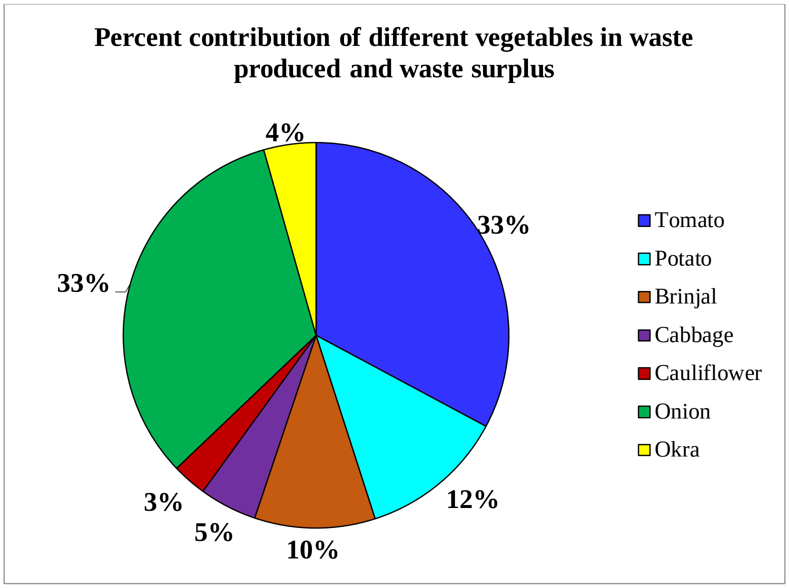
Soils and crops	Treatment		Crop yield (tha^{-1})
	Input	Rate ($t\ ha^{-1}$)	
Black soil (Groundnut, 1 yr)	100% NPK	-	1.75
	PSNC	10.0	1.75
Black soil (Soybean, 5 yrs)	100%NPK	-	0.953
	75%NPK+ PSNC	5.0	11.1
	75% NPK+Poultry manure	1.5	10.9
Black soil (Soybean, 3 yrs)	100%NPK	-	2.94
	PSNC	5 .0	2.91
Black soil (Wheat, 3 yrs)	100 % NPK	-	5.19
	50 % NPK + residual effect of 5t $ha^{-1}yr^{-1}$ PSNC after Soybean	-	4.52
Alluvial soil (Greengram, 1 yr)	100% NPK	-	1.041
	PSNC	10	1.032
Black soil (Soybean, 2 yrs)	100% NPK	-	2.62
	PSNC + mustard straw	5	2.08
	PSNC + city garbage	5	2.45
Sandy-loam (Chickpea)	100%NPK	-	3.4
	Vermicompost	5	2.89
Alkali soil (Sugarcane)	100%NPK		70.2
	75% fertilizer N+ 25% N as pressmud		71.3
	50% fertilizer N+ 25% N as vermicompost + *Azotobacter* +PSB		70.5
Sandy loam (pearlmillet)	100%NPK	-	82.9
	Vermicompost	10	84.2

NPK: Recommended dose of fertilizer; PSNC: Phospho-sulpho-nitro-compost PSB: P-solubilising bacteria [Source: Manna et al. [3]]



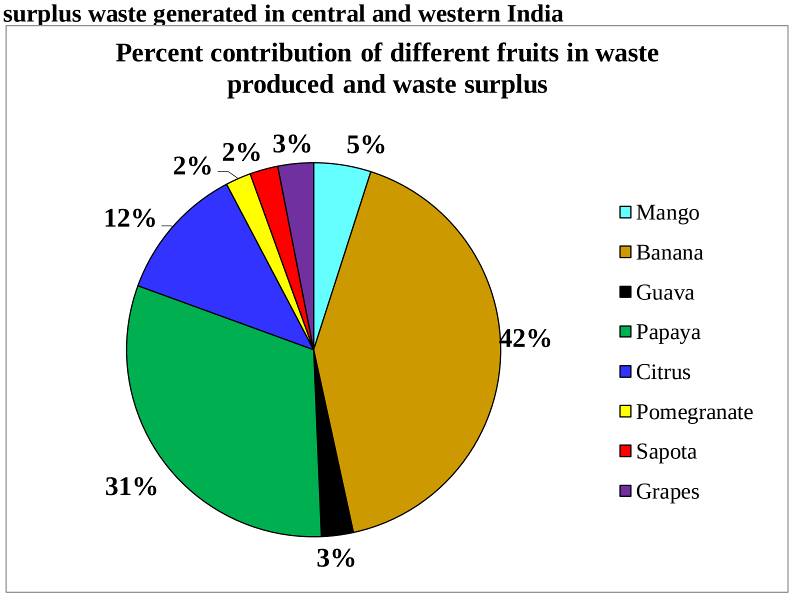
[Source:Fertiliser Statistics 2012-13[14]; Anonymous, [25]; Bhardwaj, KKR. [26]]

Figure 1. Percent contribution of different crops in residue production and surplus residue generated in central and western India



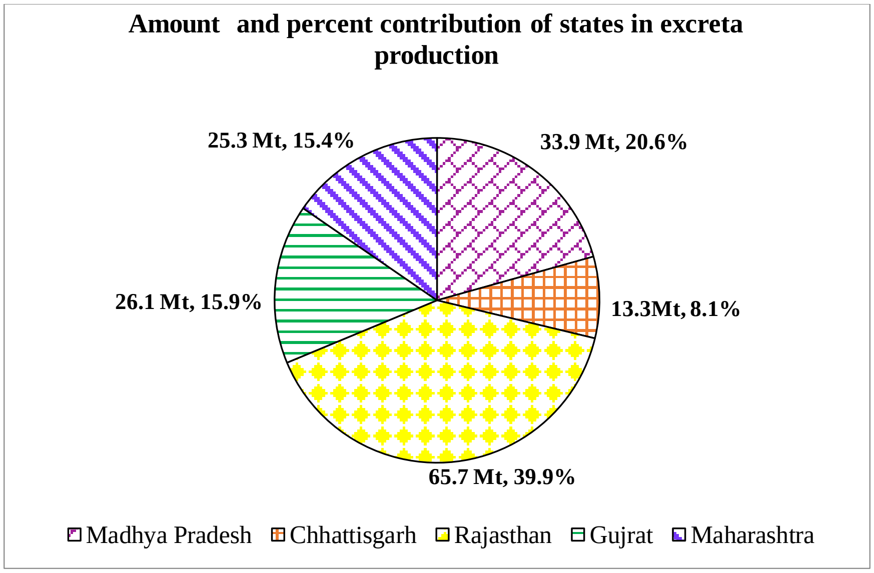
[Modified from Anonymous, [25]; Manna et al. [3]; Indian Horticulture database-2013, [27] data period 2010-11]

Figure 2. Percent contribution of different vegetables in waste production and surplus waste generated in central and western India



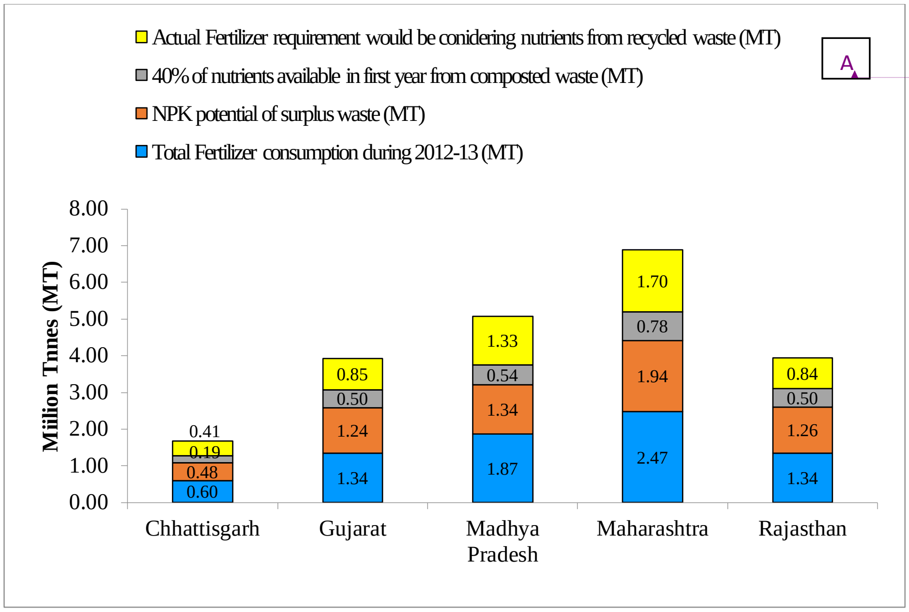
[Modified from Anonymous, [25]; Manna et al. [3]; Indian Horticulture database-2013, [27] data period 2010-11]

Figure 3. Percent contribution of different fruits in waste production and surplus waste generated in central and western India

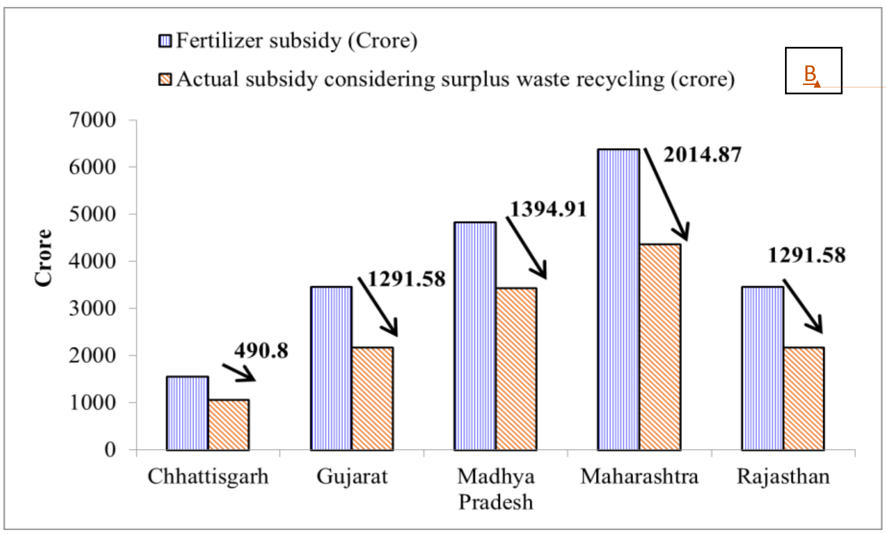


[19th Live stock cencus-2012 All India Report, [28];Jain and Kumar [30]]

Figure 4. Total excreta produced in Western states of India (MTand %)



[Fertiliser Statistics 2012-13 [14]]



Fertiliser Statistics 2012-13 [14];

* Calculation has been done taking into consideration of total fertilizer consumption of India during 2012-13 of 25.54 MT and Total central subsidy on fertilizer during 2012-13 of Rs. 65974 crore (Subsidy on imported Urea + indegenous Urea + decontrolled P and K fertilizers);

¶ Downward black arrow along with the data (in crores) indicate the savings of subsidy on fertilize

Figure 5. Fertilizer consumption vs. nutrient potential of surplus waste (A) and savings of fertilizer subsidy (B) for central and western states of India

Formatted: English (India)

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COLLECTION OF WASTE

↓

SEGREGATION

(100 mm sieve) Above 100 mm as RDF & below 100 mm for compostable

↓

WINDROW FORMATION

(2.5 M Height Max., 3.5 m wide bottom Max)

↓

CULTURE TREATMENT

(At every 50 cm layer & 50-60% Moisture maintenance)

↓

FIRST MESOPHILLIC STAGE

(Temp. below 45^{o}C, 55% moisture & time 1 week) Turning for aeration

↓

THERMOPHILLIC STAGE

Inoculation (Temp. 65-75 ^{o}C, Moisture at 50 % & time – 2 Week) Turning after a week

↓

SECOND MESOPHILLIC STAGE

(Cooling) (Temp. 45-50^{0}C, moisture at 45% & time 1 week) Turning

↓

MATURATION STAGE
(CURING)

(Degradation of lignin, lignocellulose and other recalcitrant compounds, Time 1-2weeks)

↓

SCREENING

(4 mm seive)

↓

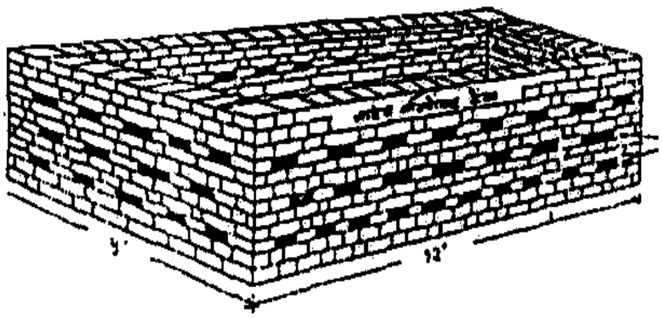
HUMIFICATION
(SYNTHESIS OF HUMUS)

Change of aliphatic compounds into aromatic compounds (high humic acid content & low fulvic acid content) high content of nutrient but no pollutants, Time 1 week, & Moisture around 20-25%)

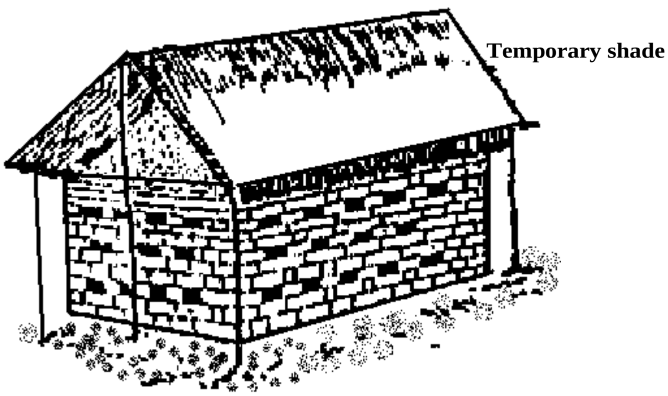
↓

QUALITY COMPOST
(AS PER FCO STANDARDS)

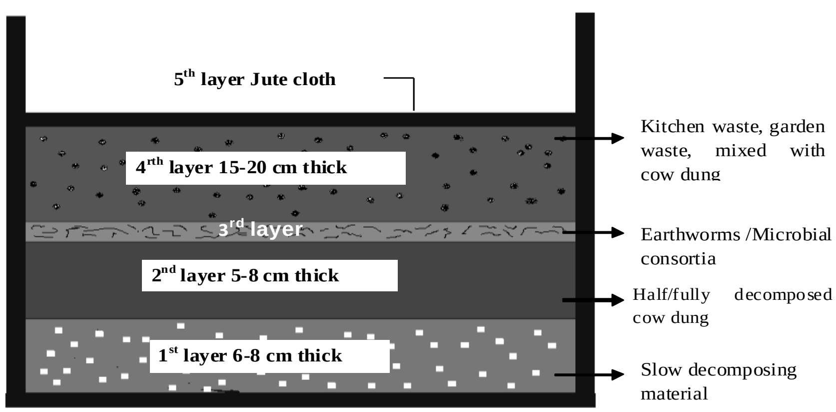
Figure 6. "Seven Stage of Composting" for preparing of good quality compost



Compost Pit



Completely filled pit



Diagrammatic presentation of successive layers to be made for composting in pit

[Source: Manna et al. [3]];

Figure 7. Diagram of compost pit