Crop Residues Management for Composting

User Manual

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Crop Residues Management for Composting

Efficient use of Crop Residues: Animal Feed Vs Conservation Agriculture Research Project

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Introduction

Crop residues are the parts of plants left in the field after the crops have been harvested and threshed. Crop residues are not a waste but rather tremendous natural resources. They are good sources of plant nutrients where about 25% of nitrogen (N) and phosphorus (P), 50% of sulfur (S), and 75% of potassium (K) uptake by cereal crops are retained in crop residues. They are also the primary source of organic matter added to the soil, and thus knowledge about residue decomposition is essential for management of agro-ecosystems.

Throughout the tropics there is little recycling of crop residues in the field since they are either harvested for fuel, animal feed, or are burned in the field due to the lack of awareness of farmers about their value and/or absence of proper technology for in situ incorporation of residues. In Ethiopia, crop residues are used mostly as animal feed and sometimes as energy source; whereas very little amount is left on the land as mulch or being incorporated to the soil. In this regard, some farmers in some localities still practice the traditional soil fertility maintenance in that they leave the wheat and barley stubble on the land for some months and they incorporate it to the soil when they plough the land for the next cropping season. Therefore, in order to make and implement sound decisions about crop residue management, it is necessary to scientifically understand the short- and long-term effects of different crop residue management and develop residue management technologies that provide agronomic benefit in a cost-effective and environmentally acceptable fashion.
Crop Residue Management

There are a number of options for managing crop residues, which include being removed from the field as feed or bedding for animals, a substrate for composting, biogas generation or mushroom culture, or as a raw material for industry and left on the soil surface to be used as mulch, or incorporated into the soil or burned in situ. The above uses of crop residues are discussed in detail as under.

Crop residues as animal feed

In many parts of the world (particularly in areas with low yield potential), crop residues are essential for feeding to animals. Animals are left to graze freely on harvested fields or straw is collected off the land and taken to feeding trough to feed livestock and prepare bedding. Yet, because of their low nutritional content, especially N, high cell wall and slow digestion, animals kept on sole crop residues such as wheat and barley straw diet cannot maintain their N balance especially for growing animals. Therefore, supplementation from other sources such as concentrates and other cakes are required.

Burning of crop residues

With the intention of having stubble free and ease of field preparations, some farmers normally burn large quantities of crop residues, particularly in areas with high yield potential. Disposing the crop residues such as maize stover by burning is a cost effective method and helps to eliminate pests and disease population residing in the residue biomass. Yet, burning of these residues also leads to the following:

- air pollution, particularly due to the release of carbon dioxide, nitrous oxide, ammonia, and ash particulate in the atmosphere,
which harms environment and contributes to global climate change.

- burning of crop residues causes substantial loss of precious nutrient resources and organic matter in the soil, especially nitrogen is lost as ammonia when it is burned in the field.
- the ash left on the soil surface after burning crop residues causes an increase in urease activity and may cause N losses from soil and applied fertilizer

- deterioration of soil physical properties. As crop residues are organic materials, improve soil structure and fertility, whereas burning residues could result in loss of soil fertility
- reduction in number and activity of beneficial soil microorganisms

**Using crop residue as a mulch**

The complete removal of straw from the field is practised in areas where the straw is highly demanded for animal feed, fuel, or house thatching, causing large nutrient export from those fields. Therefore, retaining of the crop residues on the field enables to provide sufficient ground cover to protect the soil surface from the direct erosive effects of wind and rain and incorporating to the soil allows in returning almost all the nutrients in the straw to the soil. Thus mulching is one of the different crop residue management that could be used to conserve our soil and water, coupled with conservation tillage practices such as zero-tillage and minimum tillage.

**Advantages of mulching crop residues**

When appropriately managed, mulching of the soil with crop residue suppresses the weeds through its physical presence on the soil surface; by restricting solar radiation reaching below the mulch layer; by direct suppression; and by controlling N availability. It also prevents soil erosion by wind and water erosion, improve the soil organic matter content, and maintain the fertility of the soil by increasing water-holding capacity, reducing surface crusting, and maintaining soil structure.
Crop Residue Decomposition

Decaying of crop residues starts as soon as the residues meet the soil. The process of decomposition is controlled by the interaction of three components: the soil organisms or biological processes, the quality of crop residues, and the physical and chemical environment.

Biological factors

The accessibility of plant residues to soil microbes is of primary importance in the rate of decomposition. The particle size of the residue can provide different degrees of accessibility, which in turn affect residue decomposition rates as well as the mineralization-immobilization process. Generally, small particles decompose faster than large particles because the increased surface area and better distribution in soil will increase the susceptibility to microbial attack.

Environmental factors

Environmental conditions can affect residue decomposition rates. Generally, decomposition rates are faster in hot and humid areas and decrease as water availability and temperature decrease. Maximum activity of decomposers is near 30 to 35 °C and thus supports maximum residue decomposition in this range. Soil water content can dramatically influence crop residue decomposition and nutrient cycling. Moreover, plant residue can decompose faster and more C mineralization occurs under aerobic condition than under anaerobic conditions.

Management factors

The effect of management is predominant in controlling the amount and kind of plant residues returned to the soil and in determining
the degree of decomposition dynamics. Thus, residue placement is one factor in controlling the rate of crop residue decomposition and nutrient cycling by influencing soil temperature, and water regimes and indirectly affecting the soil microbial activity. Surface placement or heterogeneous distribution reduces the residue-soil contact as compared with a homogenous distribution (mixed into the soil). Thus, residue management practices that involve intensive tillage and incorporation of residues increase the decomposition rates resulted from greater soil-residue contact, a more favourable and stable microenvironment, particularly soil moisture regime, and increased availability of external N input for decomposition by microorganisms.

The depth of residue incorporation has also been shown to affect the decomposition of residues. Increasing the depth of residue incorporation from 50 to 200 mm resulted in a decrease in breakdown rate due to less biological activity with increasing soil depth. Thus, the decomposing residue should be incorporated within plough layer.

**Effects of Crop Residues on Nutrient Availability**

The successful utilization of crop residues as a nutrient source depends on manipulating the biological processes in the soil so as to optimize nutrient availability with respect to plant demand. By manipulating the time of crop residues application, it is possible to control nutrient release to coincide with the time course of the nutrient requirements by the crop. When low-quality crop residues (low N and P, high lignin or polyphenol contents) are incorporated into the moist soil, nutrients become available to the plants slowly and this may overlap with the plant requirement for the given nutrient in question. With high-quality residues, nutrients are initially released rapidly in excess of plant demand with a risk of
nutrients such as N being lost via leaching or denitrification or a nutrient such as P becoming chemically unavailable.

**Nitrogen availability**

Residues from cereal crops such as wheat, barley and other small grains with large C to N ratios are noted for their initial N immobilization (the conversion of inorganic N to organic form which cannot directly used by plants), which can negatively affect crop yields. Microbes using the crop residues as an energy source compete with crop plants for available N. Generally, mineralization of N (the conversion of organic N to inorganic form which is easily used by plants) from low N containing residues occurs only after 50–60% of residue is decomposed or after the C to N ratio is below 30. Therefore, such cereal residues require addition of external N for decomposition to precede, otherwise, the growing plants will starve from N deficiency at early stage of growth and yield will decrease.

**Phosphorus availability**

Phosphorus mineralization from crop residues is determined greatly by the rate of residue decomposition and microbial immobilization. Availability of P to plants in crop residue-amended soils depends on organic matter turnover, concentration of inorganic P in soil solution, and P requirements of microorganisms.

Phosphorus content of the added residue is perhaps the most important factor in regulating the mineralization of P in crop residues. In general, net immobilization of P (much of P being assimilated into the body microorganisms) occurs following addition of crop residues with less than 0.2 to 0.3% P, while net mineralization (release of P for plant uptake) occurs with higher P contents. Since, most of the crop residues have low nutrient content, it is better to use mixture of organic and artificial fertilizers than either of them alone.
Hence, it is better to use the crop residues for compost making which enhances especially the availability of P for plant use.

**Potassium availability**

Crop residues contain large quantities of potassium, and their recycling can markedly increase K availability in soils. Recycling of crop residues can improve crop yields at low rates of K application and reduce K fertilizer requirement. Potassium is not bound in any organic compound in the plant material, and thus its release does not involve microorganisms.

**Sulfur availability**

Sulfur is a critical nutrient for crop growth, and its deficiency is observed in soils of the tropics by intensive agricultural practices, less use of organic manures, removal of crop residues, and leaching of SO$_4$ by heavy rains. It is generally accepted that plants assimilate S almost entirely in the form of SO$_4$, which is produced by the mineralization of organic S. Unlike phosphates, sulphates are easily leached. Thus, incorporating crop residues into the soil is one way of reducing S losses by leaching.

**Micronutrients availability**

Much of the essential micronutrients are taken up by the plants from the soil and crop residues are reported to have a significant amount of these nutrients. About 50 to 80% of Zn, Cu, and Mn taken up by rice and wheat crops can be recycled through residue incorporation. Therefore, recycling of crop residues can help improve the availability of micronutrients in soil.
Effects of Crop Residues on Soil Properties

Soil organic matter

In tropical soils, soil organic matter (SOM) plays a major role in soil productivity because it represents the dominant reservoir and source of plant nutrients. It also influences pH, cation exchange capacity, anion exchange capacity, and soil structure. Its level in soil was used as a general indicator of soil productivity. A major factor contributing to the level of SOM is annual input of plant residues. Residue management impacts on SOM and long-term fertility are becoming more relevant in the context of soil quality in tropical environments.

Soil organisms use residues as a source of energy and nutrients, thereby releasing CO$_2$, inorganic compounds, and some molecules, which contribute to the formation of soil humus. Thus, decomposition of crop residues releases about 55–70% of the C to the atmosphere as CO$_2$, 5–15% is incorporated into microbial biomass, and the remaining C (15–40%) is partially stabilized in soil as new humus.

Soil physical properties

Crop residues play an important role in improving soil physical characteristics. Recycling of crop residues improve soil structure, crusting, bulk density, moisture retention, and water infiltration rate and help to reduce adverse effects of hardpan formation in heavy clay soils especially, when cultivated by machinery.
Soil microbial biomass

Soil microbial biomass acts as a reservoir of plant nutrients and is a major determinant for governing the nutrient (like N, P, and S) availability in soils. Although soil microbial biomass values are only a small portion of total C and N in soils, this living portion of soil contains a substantial amount of nutrients needed for crop growth. The amount of microbial biomass and microbial activity depends on the supply of organic substrates in soil. Therefore, regular addition of a sufficient amount of organic materials such as crop residue is important in the maintenance of microbial biomass and improvement of soil fertility.

Plant Pathogens and Crop Residues

Incorporation of crop residues to the soil or leaving it on the soil surface has its own impact in crop disease cycle. With conservation tillage practice which involves little soil disturbance and retention of 20-90% residue cover after planting, some plant disease may concentrate in the plow layer and lead to poor seed germination and growth performance. Pathogens like *Rhizoctonia solani*, which uses plant residue as food source, can cause serious problem on emerging seedlings. Different fungal diseases are reported to affect crop yields of the next season especially those, which reside on wheat and barley stubbles. Therefore, in order to efficiently control the occurrence of disease associated with using crop residue, disking or deep plowing the infested residue, and using crop rotation system to break the disease cycle can be adopted. However, the most effective means of avoiding the problem is to use such residues in compost making.
Crop Residue Composting

Composting is a natural process of involving controlled decomposition of organic materials such as crop residues, animal wastes, food garbage, and some municipal wastes with the help of microorganisms. When the process is complete, the organic matter can be used as natural fertilizer. This organic fertilizer boosts the biological, physical, and chemical properties of the soil. It is already mentioned in the introductory part that crop residues are the non-economic plant parts that are left in the field after harvest. The harvest refuses include straws, stubble, stover, and haulms of different crops. Crop remains are also from thrashing sheds or that are discarded during crop processing. These residues have greatest potential to be used as organic fertilizer. However, they need composting before being used as manure.

Why composting is necessary?

- The rejected biological materials contain complex chemical compounds such as lignin, cellulose, hemi-cellulose, polysaccharides, proteins, lipids etc.
- These complex materials cannot be used as such as resource materials.
- The complex materials should be converted into simple inorganic element as available nutrient.
- The material put into soil without conversion will undergo conversion inside the soil.
- These conversion processes take away all energy and available nutrients from the soil affecting the crop. Hence, conversion period is mandatory.

Advantages of composting

- Reduces the soil bulk density and improves the soil structure
• Loosens heavy soils with organic matter and improves root penetration
• Increases the water-holding capacity of the soil
• Protects the surface soil from water and wind erosion by improving the soil aggregate stability
• Improves soil aeration
• Helps moderate soil temperature and prevents rapid fluctuations of soil temperature, hence, providing a better environment for root growth. This is especially true of compost used as a surface mulch
• Enables soils to hold more plant nutrients and increases the cation exchange capacity (CEC)
• The nutrients from mature composts are released to the plants slowly and steadily. The benefits will last for more than one season.
• Stabilizes the volatile nitrogen of raw materials into large protein particles during composting, thereby reducing N losses.
• Provides active agents, such as growth substances, which may be beneficial mainly to germinating plants.
• Adds organic matter and humus to regenerate poor soils.
• Buffers the soil against rapid changes due to acidity, alkalinity, salinity, pesticides, and toxic heavy metals.
• Supplies food and encourages the growth of beneficial microorganisms and earthworms.
• Helps suppress certain plant diseases, soil borne diseases, and parasites
• Reduces and kills weed seeds by a combination of factors including the heat of the compost pile, rotting, and premature germination.
• Gives an opportunity to put together several waste materials such as crop residues, weeds, kitchen and household waste materials, hedge cuttings garbage etc to be used as fertilizer.
• Reduce the need for chemical fertilizers.
Disadvantages of Composting

- It requires a lot of labor to prepare and spread it over the farm
- The nutrient composition of the compost varies a great deal. It depends on the type of material used and preparation methods
- Enough vegetation may not be available to make compost in drier areas

Methods of composting

There are two types of composting methods; pit composting and aboveground pile composting. The pit composting method conserves moisture, so it is suitable for low rainfall areas having long dry season. It is also preferable in dry and cold areas, because more heat is generated in pit composting, which is very important factor in compost preparation. On the other hand, above ground pilling method is suitable to be used in high rainfall areas, as compared to pit method, which may make the compost to be waterlogged, especially when the compost making is done in rainy season.

Pit

Site selection
Suitable place for compost pit should assure the following condition

- Sunny place in very cold areas and under shade for areas with low rainfall in order to enhance decomposition process;
- The compost pit should be at least 20 meter away from living house;
- The soil on which the compost pit is dug should be in a good drainage condition; having at least 2 % slope.
• It should not be extremely exposed to wind or it should have wind break;
• It should be situated at an acceptable distance to source of compost materials such as organic materials, water and to the field where the compost is to be applied.

Residue collection
Crop residues accumulated in different locations are to be brought to compost pits. The compost pits are located in anyone corner of the farm with accessibility via good road. Water resource should also be available in sufficient quantity. The crop residues that are brought to compost yard should be heaped in one corner for further processing.

Composting material preparations
Particle size is one of the factors that influence the composting process. It affects oxygen movement into and within the compost heap as well as microbial and enzymatic access to the residue. Therefore, it is advisable to cut to smaller pieces all the crop residues that are used for composting. Shredding to particle size of 2 to 2.5 cm is recommended for quick composting. Besides, un-chopped straws should be collected for lying on the lowest portion in compost pit for better aeration and hence inhibit unnecessary odor formation.

Mixing of green waste and brown waste
Carbon and nitrogen ratio decides the initiation of composting process. If C to N ratio is wide (100:1), composting will not take place. Thus, low quality organic materials such as maize stover or wheat and barley straws with a wide C to N ratio require fortification with nutrient rich additives and biological catalysts before they are readily composted. Therefore, narrow C: N ratio of 30:1 is ideal for composting. To get a narrow C: N ratio, carbon, and nitrogen rich material should be mixed together. Green colored waste materials like freshly harvested weeds such as parthenium, vetch, lupin, tree lucerne and sesbania leaves are rich in nitrogen,
whereas brown coloured waste material like straw, dried leaves and dried grasses are rich in carbon.

**Compost heap formation**
A minimum of 1.5m height compost heap should be maintained for composting. In any composting process, these carbon and nitrogen rich materials are to be mixed, together to make the composting quicker rather than putting green wastes alone or brown colored wastes alone for composting. Animal dung is also a good source of nitrogen. Thus, while heaping the compost in pit, alternative layers of carbon rich material, animal dung and nitrogen rich materials should be heaped to get a quicker result in composting. After heap formation, the material should be thoroughly moistened.

**Bio-inputs for crop residue composting**
If the composting process is allowed to proceed by itself, natural microorganisms establish on the waste material and do the composting work. Nevertheless, this process takes long time for the composting process to be completed. Hence, external source of inoculums should be added for the microbial activity to be started earlier and to shorten the composting period. Therefore, Cow dung slurry should be added to the decomposing organic waste, as it is a good source for microbial inoculum, which accelerates the decomposition process. For 1 ton crop residues 40 kg fresh cow dung is required. This 40 kg fresh cow dung is mixed with 100 liters of water and it should be thoroughly poured over the waste material.

**Checking compost temperature**
Biological activity is monitored by pushing a stick into the middle and sides of the compost heap. The stick is pulled periodically, and felt by hand for any temperature changes. Within one week after compost pilling, much heat is generated from the center of the heap and the stick driven in the compost heap should indicate the same. This is an indication of biological activity in the compost.
Compost moisture maintenance
The optimum moisture content for composting is 40 to 60% as too much water interferes with oxygen accessibility leading to slowed decomposition process. On the other hand, the compost heap should not be allowed to dry. If the material becomes dry, all the microorganisms present in the crop residues will die and the compost process gets affected. Thus, it is recommended to sprinkle enough water on the heap during turning particularly when conditions are dry.

Aerating the compost material
Sufficient quantity of oxygen should be available inside the compost heap. For this external air should be freely get-in and comes-out of the heap. Normally to allow the fresh air to get inside, to ensure proper mixing and wetting, the compost heap should be moved to the next pit once in 15 days. In this process, top layer comes to bottom and bottom layer goes to top. This process also activates the microbial process and compost process is hastened. In some cases air ventilating pipe maybe inserted vertically and horizontally, to allow the air to pass through. The wood chip that is available as waste in wood processing industry may also be used as bulking agent in the composting process. This bulking agent gives more air space to the compost material. Compost turning should be continued until the heaped materials turned dark gray.

Procedure for fortified compost making

Step 1. Begin with laying straws at the bottom of the heap in about 5 cm thickness, which is important for good ventilation;

Step 2. Spread the chopped materials to a thickness of 25 cm; sprinkle some water in this layer

Step 3. At every 30 cm layer, evenly broadcast 0.75 to 3.75 kg DAP (or any other N bearing fertilizer) for fortification and lowering the C: N ratio from 80 to about 12;
Step 4. Put on the next layer farmyard manure or chicken manure in 15 cm thickness;

Step 5. Add thin layer (5 cm) of ash. The ash contains a valuable mineral including potassium, phosphorus, calcium, and magnesium. It also neutralizes acids produced during decomposition, especially by animal manure.

Step 6. Apply 5 cm of organic soil or garden soil uniformly as a "starter inoculant." Sprinkle water on every layer to enhance dissolution of fertilizers and to moisten the compost heap for microbial activity.

Step 7. Repeat steps 2 to 6 until the heap reaches 1.5 m in height (Figure 1)

Step 8. To complete the heap formation, cover it with a layer of top soil of about 10 cm thick, which prevents plant nutrients from escaping from the compost pit.

Figure 1. Fortified compost heap set up
Step 9. Take a long, sharp, pointed stick and drive it to the pit at an angle so that passes through the heap from top to bottom. Whenever the stick is pulled out and it is felt warm, this is an indication that the decomposition process is in good condition.

Step 10. Pull the stick periodically from composting pit to check the progress of composting. You can notice from the stick whether the compost heap is dry or wet. It should be moist but not wet.

Step 11. Sprinkle water on the heap occasionally (about every 3 days, depending on the weather). If it has been raining, it is not necessary to add water.

Step 12. After two weeks, turn the compost heap from one pit to another. Do not add any fresh materials except water this time. The compost heap should be turned, if the temperature testing stick feels cold or if it has a white substance on it, as this shows that the decomposition has stopped. If it feels warm when pulled out of the heap, it is still decomposing and the process is not completed.

Pile Method

Step 1. Dig a shallow pit of about 30 cm deep. Put the soil in one side as it is to be used later. The place for composting should be sheltered from wind, rain, sun, and runoff.

Step 2. Measure a rectangle of 1.2 m wide and 1.5 m or more long (the length depends on how much composting material is available). Do not make the rectangle wider than 1.2m in order to work on the compost without stepping on it.

Step 3. Build a pile above ground, using the same method as in the pit method. The compost pile must not get either very dry or very wet.

Step 4. Lastly, cover the whole pile with dry vegetation such a banana or enset leaves to reduce moisture loss through evaporation.
Do's
- Choose sheltered site for the compost pile
- Chop up long stems and big leaves
- Sprinkle some water on every layer, and ensure that the compost is moist all the time
- Turn the pile every 2 weeks
- Protect the finished compost from the sun, wind and rain

Don'ts
- Don’t use materials that contaminate the soil
- Don’t step on the pile
- Don’t use waxy leaves (such as eucalyptus leaves)
- Don’t over water the compost pile
- Don’t compact the layers
- Don’t use materials that do not decompose

Compost maturity
When the composting process has completed, the thermometer stick should be cool (at ambient temperature) indicating that all the potentially harmful organisms and by products have been eliminated. Finally, volume reduction, black color, earthy odor, reduction in particle size, contain no grass, leaves and animal manure are all the physical factors to be observed for compost maturity. Other, quality indicators of compost include pH (6-8), C: N ratio 10-15:1 and do not have phyto-toxic compounds. After satisfying with the compost maturity index, the compost heap can be disturbed and spread on the floor for curing. After curing for one day, the composted material is sieved through 4 mm sieve to get uniform composted material. The residues collected after composting has to be again composted to finish the composting process.

Compost enrichment
The harvested compost should be heaped in a shade, preferably on a hard floor. The beneficial microorganisms like Azotobacter or Azosphirillum, Pseudomonas, Phosphobacteria (0.2%) and rock phosphate (2%) have to be inoculated for one ton of compost. Forty per cent moisture should be maintained for the maximum growth of inoculated microorganism. This incubation should be allowed for 20
days for the organism to reach the maximum population. Now the compost is called as enriched compost. The advantage of enriched compost over normal compost is the quality manure with higher nutrient status with high number of beneficial microorganisms and plant growth promoting substances.

**Compost application**

Organic fertilizers such as compost are highly regarded as good source of material to maintain soil health and increasing soil organic carbon content. Compost cannot be equated with inorganic fertilizers. However, it delivers all the nutrients to the soil but with little quantity. Thus, to fulfill the crop demand of nutrients, it could be applied in combination with chemical fertilizers. As a very crude recommendation, for one hectare of land, 5 tons of enriched bio-compost could be used. It can be added as basal application in the field at least 1 week before carrying out planting work.

**References**


Singh Yadvinder, Bijay Singh and J Timsina, 2005. Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics. *Advances in Agronomy*. 85: 270-342