

Chapter 2

Intensification of Aerobic Processing of the Organic Wastes into Compost

A. N. Ivankin, Urja Pandya and Meenu Saraf

Abstract The review is devoted to modern achievement in area of the aerobic processing of the organic wastes in compost for improvement of an ecological condition of the environment and purposeful use at intensification of the agriculture. The methods of reception and characteristic of products of microbiological transformation household, agricultural and industrial wastes are considered.

Keywords Aerobic · Bioprocess · Organic matter · Pathogens · Waste treatment · Kinetics · Animal manure

2.1 Introduction

As a result of ability to live of the person the significant amount of waste of different structure is formed. These wastes demand the subsequent destruction or reception from them the products, capable to find of the further application in various areas. The simplest way of destruction of waste is their burning. However in some cases these wastes have a liquid consistence and are not capable to ignition. During their burning such quantity of toxic substances which neutralization demands the expenses which are not compensated by the offered kind of processing can be allocated (Neklyudov and Ivankin 2003). A way of waste processing having popularity increase from years of composting. As a rule, it consists in natural biological decomposition of organic substance of waste by means of various kinds of microorganisms. The end-product of decomposition is humus substance which with success

A. N. Ivankin (✉)
Moscow State University of Forest, Mytishchi,
Moscow oblast, 141005 Russia
e-mail: aivankin@mgul.ac.ru

U. Pandya · M. Saraf
Department of Microbiology and Biotechnology,
University School of Sciences, Gujarat University,
Ahmedabad 380009, Gujarat, India

can be used, first of all, as the means stimulating restoration soil properties and in the second—as organic fertilizer.

Many pathogenic microorganisms do not maintain a competition to other microorganisms collecting during composting. Besides warmly, allocated at reception compost, promotes final destruction pathogens. Inorganic waste, glass for example, metals and plastic, separate more often before biochemical processing organic waste, and then if necessary recycle (Weber et al. 2007; Bustamante et al. 2008; Kuba et al. 2008; Hort et al. 2009; Ben et al. 2010). It is known also, that now there are the special enterprises which are engaged both composting, and release of the equipment necessary for these purposes. Such manufactures as has shown an expert, are profitable enough, as compost, received at these enterprises as already it was marked earlier, is widely used at reclamation arable lands in rural, garden and park facilities (Neklyudov and Ivankin 2003).

Process of composting is known since deep times. Still ancient Egyptians have found out that agricultural crops considerably increased after animal manures in fields. They revealed that fresh manure renders essentially smaller influence on ground, and even can sometimes harm in comparison with the manure preliminary mixed with silt or the vegetative rests. In many cases the increase in efficiency of such mix needed long enough time, its maturing sometimes reached year and more (Lima et al. 2004; Zmora-Nahum et al. 2005; Smith 2009; Raj and Antil 2011; Gabhane et al. 2012). In the further it has appeared, that at correctly picked up parity of components reception of fertilizers for ground can be carried out for shorter terms (Neklyudov and Ivankin 2006).

However only after opening the fact of existence of microorganisms and creations of new scientific discipline—of microbiology became clear features of reception of similar fertilizers. It has appeared, that efficiency of a method is defined by participation of various microorganisms and entirely depends on their activity (Marr and Facey 1995; Neklyudov and Ivankin 2006). Process proceeded essentially more quickly increase in aeration of processed components and consequently it began to name aerobic decomposition of organic substances, or composting (Marr and Facey 1995; Smith 2009). With growth of animal industries, increase in an intensification of agricultural crops, development of cities and occurrence of the increasing quantity of waste composting became one of effective means of their processing and improvement of structure not only the ground, but also a condition of an environment (Miller 1996; Tognetti et al. 2011).

The purpose of the review—consideration of publications for last years, the organic waste devoted to aerobic decomposition for reception of composts, the analysis of methods of reception and properties received compost.

2.2 Raw-material Base of Compost Reception

As raw material for reception of composts any waste containing organic substances can practically serve: manure of agricultural animals and birds, dirtiness, silt, firm and liquid organic waste from sewage, city waste, a grass, leaves, hay, straw, waste

Table 2.1 Raw sources of reception of composts

Household organic wastes	Agricultural and a garden-kitchen garden organic wastes	Commercial and industrial organic wastes
Waste of fruit and vegetables	Leaves	Agro industrial waste of beer, tobacco, cotton
Shell of eggs and nuts	Scraps of a grass	Waste from industrial reservoirs (seaweed, water hyacinths), deposits from sewage and drainage systems
Waste of tea and coffee	Scraps of trees and bushes	Various kinds of city dust
Wood ashes, Flowers, garden plants, the vegetative rests, Toilet paper, packing paper, brown, paper and so forth	The fallen down fruit, Waste from the markets, The rests of agricultural crops (roots, stalks, shanks, Straw, Vegetative waste, from lawns and parks	Waste of paper and timber manufacture
Food waste Manure and laying for pets contents of toilets	Various kinds of manure of agricultural animals and birds	Waste from agricultures and farms
Various kinds of house dust	Corpses of the dead animals and birds	Waste of the food- processing industry

of a sugar beet, a cotton, fat, paper, wood and the brewing industries. This raw-material base can be presented in the form of a Table 2.1 (Benito et al. 2006). It is possible to add other kinds of waste which quantity on literary data annually increases in 2–3 times (Aviani et al. 2010; Hartley et al. 2010).

Waste contained up to 60–80 % of the most various organic substances, the main things from which are such high-molecular connections, as fibers, polysaccharides and lignine. If fibers rather easily are exposed biochemical decomposition and the subsequent mineralization cellulose and especially lignine are split essentially worse and at them composting there are the greatest difficulties (Marr and Facey 1995; Tuomela et al. 2000). Many of these waste have high microbic infection, promoting after activation of microorganisms occupying them to synthesis of corresponding enzymes which split and partially saline the organic connections containing in them necessary as for development on them corresponding microflora, and for biosynthesis of biologically active substances. Essential lack composting waste of all kinds is duration of the process composting, sometimes proceeding during many months. It is no wonder therefore, that the basic purpose of many publications—consideration of ways of acceleration of process composting on the basis of deeper understanding of process, identification of microorganisms participating in it, allocation and studying of the enzymes promoting splitting and a mineralization of organic connections.

2.3 Key Parameters of Aerobic Composting

The main key parameters of aerobic composting include such as temperature, a degree of aeration, moisture content and value pH in a punched mix.

2.3.1 *Temperature*

One of the major parameter provides efficiency composting. It essentially varies during composting due to thermal effect which appears as a result of oxidizing degradation of covalent bond at decomposed substances. It is known, that any process of composting has 3 basic temperature stages—mesophilic, thermophile and a stage of cooling, or final maturing compost. Duration of all of 3 stages depends on structure of a mix of the organic waste intended for composting, and a degree of aeration of this mix. Usually mesophilic the stage begins in the beginning composting or after some period necessary for microorganisms for their adaptation and growth (Walsh et al. 1991). The temperature mesophilic can vary phases from 40 up to 55 °C. In opinion of many researchers, at this stage there is the most active oxidizing degradation of organic waste (Mahimairaja et al. 1995; Tuomela et al. 2000). This temperature is characteristic and for thirds of stage composting—stages of cooling of a punched mix when it is observed final destruction organic connections. Thermophile the stage can proceed from 5 up to 25 day and more, the temperature at this stage composting can reach 70 °C and above. As a rule, at this stage there is an active destruction of pathogenic microorganisms and the highest losses of flying organic substances (Mahimairaja et al. 1995). Last stage can proceed within many weeks and even months and comes to the end, when the temperature of a punched mix will achieve an ambient temperature (Boldrin et al. 2010; Paradelo et al. 2011; Dilek and Yasemin 2013; Serramib et al. 2013).

2.3.2 *Aeration*

Aeration of a punched mix is closely connected with temperature. For example, with increase of temperature the output of harmful connections and a poisoning of the air environment increase. Such connections formed during composting, sulfur, odorous components are CH_4 , methanol. Usually in this case methanol and 2-butanol is the cores admixture of air. However issue of odorous substances of type dimethyl sulfide amplifies at increase in the contents of sulfur-containing substances in raw material, thus high concentration of methane, ammonia and sulfurs in air usually testify to bad aeration during process composting (Skajaa and Hannibal 1991). There are three kinds of aeration of punched mixes: the compulsory aeration which is carried out by forcing of air in clamps, compost heaps or corresponding devices for aerobic process; the passive aeration which is carried out by a special arrangement horizontal clamps in a direction of a wind rose and a lining inside of punched clamps of special pipes with punching, providing passive receipt of air inside of a processed mix, and at last, a method composting with natural aeration, without use of any adaptations, but in view of a wind rose (Imbeah 1998; Aviani et al. 2010).

At compulsory aeration speed of receipt of air usually makes 0.20–1.33 l/min kg of dry flying substances for composting city dust and deposits of sewage and 0.87–

1.9 l/min kg of dry flying substances at processing mixes which structure includes manure. At passive aeration speed of receipt of air in compost heaps is insignificant and makes 0.04–0.08 l/min kg of dry flying substances (Bernal et al. 1993; Haines 1995). Passive aeration can essentially reduce the price of process in comparison with compulsory or active aeration. Passive aeration demands for the realization special aeration channels and appropriate calculation of speeds of the air streams created due to a difference in temperature between the punched mix and air. To establish the similar interrelation, modes of temperature have been studied and convection a stream of air in is punched mixes with 3 kinds loading: wooden shavings, hay and straw and also 3 levels of the contents of humidity: 60, 65 and 70%. All experiments were spent in a passive and active mode of aeration. For experiments laboratory reactors in volume 105 l have been used.

2.3.3 Humidity

Passive humidity of 60–70% had the temperature peak arising between 2 and 6 day of composting. After 6 day of composting the moisture content did not render any influence on a temperature mode of process because of loss of moisture in a mix. The interrelation between number Grasholff (GR—the relation of buoyancy to force of internal friction) and speed convection an air stream has been established. Generally speed convection an air stream varied from 1.5 up to 0.7 mg of dry air/kg s of dry material compost from 0 up to 20 day accordingly for all samples compost. This speed of a stream of air was provided aeration with the channels made inside compost of heaps for passive aeration. In comparison with straw where speed of an air stream fell below a level of number GR, wood shavings and hay have appeared are more effective as loading. At use of these substances speed of a stream of air increased constantly together with GR (Altieri and Esposito 2010; Sato et al. 2010; Yu et al. 2011; Pane et al. 2013). On the other hand, advantage of compulsory aeration is higher speed composting and an opportunity of partial regulation of temperature of process; lack—significant losses of flying organic substances at carrying out composting (Brinton and Brinton 1994).

Influence of compulsory aeration on a degree of formation of ammonia was studied at composting waste of housekeeping on pilot installation. It is shown, that significant clearing NH_3 occurred at the first stages of degradation of fibers and amplified with increase in speed of aeration during this period. Good correlation between change of temperature, clearing CO_2 and allocation NH_3 was observed (Atkinson et al. 1996). In this connection separate researchers recommend to spend composting at passive or natural aeration which though proceeds with slower speed, but provides fuller maturing compost and does not demand high monetary expenses (Hemmat et al. 2010; Jolanun and Towprayoon 2010; Bustamante et al. 2011; Turrión et al. 2012). Parallel experiments on influence of various kinds of aeration on quality compost have shown, that any processes of artificial aeration reduce time composting, however on occasion, can worsen quality compost. It is most

effective, in comparison with other kinds, aeration of section type lengthways horizontally laid composting ledge by means of the compressor if speed of aeration is supervised in conformity with speed of process of decomposition of an organic material. Besides the gases departing at controllable section aeration compost ledge, contain smaller quantity bed smelling and flying substances.

Various methods aerobic composting are discussed in works (Mahimairaja et al. 1995; Bustamante et al. 2011). From the considered methods it becomes clear, that the most suitable are methods of physical and microbiological processing in aerobic thermophile conditions. The basic problem at such kinds of processing—foaming during process. Methods which can solve this problem are offered. Aerobic thermophile composting is a simple and inexpensive method which can resolve problem decontamination on farms where the given way is constantly used for waste disposal. The content of water in punched mixes has essential value for reception high-quality of compost. Usually process proceeds effectively enough at the maintenance of water in a punched mix of 35–65 % (Walsh et al. 1991). To support these values especially important at compulsory aeration when water leaves together with departing air (Doublet et al. 2010; Yu et al. 2011; Cellier et al. 2012; Mostafid et al. 2012; Angin et al. 2013). For understanding of interrelation between humidity, temperature, and microbial activity have been carried out researches at composting mixes of firm oozy deposits from city sewage. Microbial activity was defined, how speed of consumption of oxygen, mg/kg s. Moisture load was the dominating factor influencing microbial activity of the punched mix. Humidity of 50 %, apparently, is that minimal limit below which it should not fall. In this case activity of microorganisms above, than 1.0 mg/kg s. The temperature also was the important factor at composting mixes of waste. However it rendered smaller influence, than moisture content. In particular, increase of activity of the microorganisms, caused by increase in temperature; it was possible to reach one increase in humidity.

2.3.4 *pH Value*

Value pH in a mix—one of parameters of efficiency of process composting. Usually sizes pH vary from sub-acidic up to neutral and alkalescent values due to formation of ammonium, i.e., in an interval pH 4.5–8.1. As a rule, these values are closely connected with activity of microorganisms which participate during composting (Bustamante et al. 2011; Carbonell et al. 2011; Mostafid et al. 2012). Composting in a mode pH-controlled it has been shown on various kinds of city dust. In pH-controlled process to compost added lime to neutralize pathogenic microorganisms and to prevent downturn pH below 7.0, in particular at early stages composting. Speed of decomposition of organic materials was above in pH-controlled a reactor in comparison with a reactor without the control pH. The quantity of losses of nitrogen in pH-controlled rose, but the degree of transformation of nitrogenous components remained low. Also pH-dependence of the micro-sorbents participating in composting components. Optimum value pH for activity of the microorganisms

Table 2.2 Nutrient contents of animal manure composition

Name of Animals	Nutrient contents (%)			
	H ₂ O	Organic substances	Nitrogen	P ₂ O
<i>Horned Livestocks</i>	81	16	0.4	0.2
<i>Hens</i>	57	29	1.5	1.3
<i>Ducks</i>	54	25	1.0	1.4
<i>Horses</i>	73	22	0.5	0.4
<i>Pigs</i>	78	17	0.5	0.4
<i>Rabbits</i>	75	23	1.1	1.2
<i>Sheeps</i>	64	31	0.7	0.4

participating in reception compost, in particular in degradation of fibers, was value pH 7.0–8.0 whereas the greatest speed of degradation of the carbohydrates, observed at early stages of maturing compost, happened at pH 6.0–9.0 (Glenn 1990).

Change of time composting for processing house waste due to initiation of a phase of low value pH at the control mesophilic temperatures has been investigated at an initial stage composting house waste until value pH did not reach some constant value. For this purpose pH value was measured in a condensate received after cooling compost of gas. The assumption has been put forward, that activity of microorganisms at low value pH suppresses with fast growth of temperature. The sharp increase in value pH due to decomposition of fat acids, apparently, is a good marker of the termination of the temperature control (Ohins 1994).

2.4 Types of Various Substrates for Compost and their Importance

Composting with immense importance in agriculture is concern under uses of various substrates. These substrates are following:

2.4.1 Composting Manure of Agricultural Animals

As already it was marked earlier, reception of fertilizers from manure of agricultural animals is known from an extreme antiquity. Some concepts about structure of manure of agricultural animals and birds can be gathered in Table 2.2 (Walsh et al. 1991; Neklyudov and Ivankin 2003), and also from works of other authors (Logsdon 1993). Apparently from Table 2.2, manure contains a lot of necessary nutrients for plants: significant amounts of carbon and nitrogen, and 80–85% are necessary on organic connections of these substances (Walsh et al. 1991; Logsdon 1993) and also significant amounts of phosphorus. Besides phosphorus (Table 2.2), manure contains significant amounts of potassium and magnesium and practically all the microcells necessary for growth and development of plants (Logsdon 1993).

Apparently from Table 2.2, the relation of carbon to nitrogen which is the most important parameter of quality compost, has values 19–25 for manure of various kinds of poultry and rabbits, for pigs and ruminants higher parameters are characteristic: 34–44, i.e., the smaller contents of amount of nitrogen. However these parameters below parameters of relation C:N at other kinds of organic waste which can achieve the values 50–60 and even 200–300 at lignine cellulose materials.

The amount of organic substances (OS), containing in manure of a horse, the cow, a pig, a sheep, a goat, the rabbit, chickens and an ostrich, the general contents of carbon (CC), total of nitrogen (CN), ratio $C_{CC}:N_{CN}$, amount of soluble organic carbon (SOC), amount of organic nitrogen (AON), a ratio of carbohydrates to AON, carbon of ulmification acids (CUA), carbon fulvo acids (CFA), an index of ulmification ($C_{CUA}/C_{CC}100$), relation of C_{CUA}/C_{CFA} and a ratio of nitrogen NH_4^+/NO_3^- is certain (Logsdon 1993). An unduly high content of water in manure in some cases prevents effective composting firm dry substances (Lopez-Aranda et al. 2002; Guanzon and Holmer 2003). However, on occasion, this lack can be eliminated, adding to manure various loading (Guanzon and Holmer 2003), that promotes allocation of hotbed gases (Wallace et al. 1992). Practical examples similar composting are resulted below.

Allocation of hotbed gas (CO_2 , CH_4 , N_2O) in containing manure a laying for pigs (a storage time 113 day during a winter season) defined quantitatively, using an awning with which covered all clamp during all period of composting. Liberation of gas paid off in the form of equivalent CO_2/g of dry substance. In addition the defined time of keeping (using gas SF_6) and concentration of gases in various parts of clamp. Average time of keeping of gases in clamp was less than 2 h. Formation and allocation of methane was observed only in the central part of clamp whereas accumulation CO_2 occurred on all volume. The highest allocation of CH_4 , CO_2 and N_2O was observed in the beginning of storage manure lying in a clamp when the temperature rose and by that conditions for development thermophile microorganisms were created. It is possible to make the conclusion of these data, that thermophile microorganisms first of all influence formation of hotbed gas. It has been established, that by the most important gas determining global warming in environment, is N_2O (Wallace et al. 1992). In this connection to punched manure as already it was marked earlier, began to add loading, providing partial adsorption of allocated gases and increase in process of aeration, for example straw, sawdust, shavings, household dust and even deposits of sewage (Imbeah 1998; Walsh et al. 1991).

Intensive allocation NH_3 during composting pork manure in compost heaps without compulsory aeration was observed at an initial stage when there was a heating a punched mix. The sharp increase in amount of CH_4 happened immediately after pork manure has been collected in compost heaps, but active temperature of compost started to decrease. Speeds of allocation of each gas in compos heaps small and great volume were 112.8 and 127.4 g nitrogen of NH_3/kg of the general contents of nitrogen, 37.2 and 46.5 g nitrogen of N_2O/kg of the general contents of nitrogen and 1.0 and 1.9 g CH_4/kg of organic substances accordingly. It is shown, that the sizes of compost heaps are one of the major factors influencing for speed of allocation of gases (Maeda et al. 2011). Composting manure and waste of cattle-breeding farms.

In clamp or compost heaps, volume 0.25 m³ and height 1 m with natural aeration, it was possible to receive compost with satisfactory properties during 10–12 week carrying out of process at the contents of a dry material in the beginning of composting 17–21 % (Wetterauer and Killorn 1996). It is offered to punch also manure of cattle together with waste of a house and domestic economy as loading compost at their ratio with compost 1:1. At such method of reception compost it has appeared it is effective for restoration of the disturbed structure of the ground which is taking place at a crop rotation of agricultural crops (Guerra-Rodrigues et al. 2001).

Composting dry manure of large horned livestock with fallen down leaves of trees it was spent in a reactor for composting which have been executed from polyurethane by thickness of 3 mm. The volume of a reactor was 108.8 l. The mass ratio of components was 3:1. Composting proceeded during 103 day. The thermophile stage of composting came through 14 day and had extent during 10 day then during 20 day the temperature fell up to 20 °C. Final value pH of compost is equal 8.89. The ratio C:N in the beginning of composting was 12.86, in the end composting 13.27. Indexes of germination of seeds were the following: for ryegrass—55.35, wheats—56.56, an oats of 100 % (Schmitt et al. 1996). Considering, that pig-breeding farm last two decades especially effectively develops in many countries, processing of manure of these animals becomes not only actual, but also a necessary problem (Imbeah 1998; Antil et al. 2013). Composting manure of pigs application-dependent with its necessity preliminary of separation as initial fractions contain up to 97 % of water and only 2–3 % of firm substances (Walsh et al. 1991) and the subsequent neutralization of liquid fraction (Imbeah 1998) which can be added to a punched mix of firm waste for maintenance in them of a necessary water level (Yu et al. 2011; Bernal et al. 1993; Haines 1995; Antil et al. 2013).

In clamp or compost heaps, volume 0.25 m³ and height 1 m with natural aeration, it was possible to receive compost with satisfactory properties during 10–12 week carrying out of process at the contents of a dry material in the beginning of composting 17–21 % (Wetterauer and Killorn 1996). It is offered to punch also manure of cattle together with waste of a house and domestic economy as loading compost at their ratio with compost 1:1. At such method of reception compost it has appeared it is effective for restoration of the disturbed structure of the ground which is taking place at a crop rotation of agricultural crops (Guerra-Rodrigues et al. 2001).

Composting dry manure of large horned livestock with fallen down leaves of trees it was spent in a reactor for composting which have been executed from polyurethane by thickness of 3 mm. The volume of a reactor was 108.8 l. The mass ratio of components was 3:1. Composting proceeded during 103 day. The thermophile stage of composting came through 14 day and had extent during 10 day then during 20 day the temperature fell up to 20 °C. Final value pH of compost is equal 8.89. The ratio C:N in the beginning of composting was 12.86, in the end composting 13.27. Indexes of germination of seeds were the following: for ryegrass—55.35, wheats—56.56, an oats of 100 % (Schmitt et al. 1996). Considering, that pig-breeding farm last two decades especially effectively develops in many countries, processing of manure of these animals becomes not only actual, but also a necessary problem (Imbeah 1998; Antil et al. 2013). Composting manure of pigs

application-dependent with its necessity preliminary of separation as initial fractions contain up to 97% of water and only 2–3% of firm substances (Walsh et al. 1991) and the subsequent neutralization of liquid fraction (Imbeah 1998) which can be added to a punched mix of firm waste for maintenance in them of a necessary water level (Yu et al. 2011; Bernal et al. 1993; Haines 1995; Antil et al. 2013).

Composting pork manure with sawdust it is reached at mixing pork manure and sawdust in compost heaps with usual and compulsory aeration. It is revealed, that time of maturing compost is identical to usual and compulsory aeration (60 day), but quality compost at compulsory aeration above. In this case there is also essentially greater destruction of pathogenic microorganisms, such as *Salmonella* sp. (Balakrishnan and Batra 2011). Composting one pork manure and other waste of animal industries with waste of wheat and food waste it was spent in an isothermal reactor in volume 10 m³. The temperature increased during processing waste up to 70 °C and above, and could remain such during 19 day even if process spent in winter conditions when the temperature of air was below 0 °C. The amount which has formed during processing of thermal energy was more, than necessary amount of the electric energy which is required for heating. Hygienic parameters of the formed product completely corresponded to sanitary requirements. Process proceeded well except for small losses of nitrogen during aerobic processing. The end-product can be used as fertilizer and for improvement of structure and quality of ground. The best results turned out at aerobic processing a mix of waste of animal industries, waste of wheat and food waste (Nandy et al. 2002).

It is investigated also composting the pork manure mixed with rice straw to determine characteristics of 3 kind's aeration systems: compulsory aeration, passive aeration and natural aeration. Results have shown that warming up of a mix during composting is enough to satisfy requirements of standards of sanitary and to provide maturing pork manure. Indexes of composting, including physical changes, such as value pH, size of the general organic carbon, the contents of organic substances in compost, size of the common nitrogen, moisture content, ratio C:N in firm particles, ratio C:N in a water-soluble part, the contents of NH₄⁺ nitrogen, the contents of anion nitrogen (NO₃⁻ + NO₂⁻) vary slightly at all 3 ways of aeration, except for a temperature structure. The economic analysis has shown, that passive aeration is most convenient for small pig-breeding farms, compulsory aeration should be spent on pig-breeding farm average and big productivity with a high degree of industrialization. For avoidance of rise in temperature during composting up to high values, it is necessary to spend the control of compulsory aeration over process (Atkinson et al. 1996). Instead of pork manure with success can be used bird's excrement which as it is visible from Table 2.2, possesses essentially higher parameters.

2.4.2 Composting of Vegetative Waste

The chemical compound and structure of the various vegetative wastes containing in the structure lignine cellulose materials, and also the microorganisms participating in their transformation, are in details stated in recently left monographies

Composting for Sustainable Agriculture

Maheshwari, D.K. (Ed.)

2014, X, 290 p. 43 illus., 16 illus. in color., Hardcover

ISBN: 978-3-319-08003-1