WATER APPLICATION METHOD FOR COMPOSTING COTTON GIN WASTE

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Abstract

Cotton gins generate large quantities of waste material, called cotton gin waste (CGW). Because of environmental concerns, incineration as a disposal method recently became outlawed across the Cotton Belt. Disposing of CGW by other means is costly for many gins. Spreading CGW on farm land has been proposed as the most acceptable method. Composting alleviates most concerns about spreading raw CGW. Bulk density of CGW from seed cotton cleaners was found to be 7.7 lb/ft^3 (123 kg/m^3). A small composting experiment showed that, without mixing the pile, composting was slow compared with past reports. Calculations showed that varying the flow of water used to wet CGW in response to the gin's CGW flow was unnecessary. Two systems were constructed, at two gins with auger-conveyor piling devices, for injecting surfactant into water to be applied to CGW. One system shut off the water flow automatically when the gin was not running. Both systems worked well. However, though pilot-scale experiments showed that surfactant speeded the uptake of water by CGW, the effect was not evident in a test at a commercial gin. This is assumed to be the result of extended mixing time and extra agitation in the enclosed auger portion in which water mixes with CGW.

The Cotton Gin Waste Problem

Generation

Since the advent of mechanical cotton harvesting, gins no longer have removed just the fiber (lint) from the seed. They now also separate a large amount of foreign matter from the seed cotton and the lint. Foreign matter requiring disposal is called cotton gin trash (CGT) or cotton gin waste (CGW). The latter term, CGW, is used herein.

Quantities

The quantity and makeup of CGW depend primarily on harvesting method. Two mechanical methods, selected according to regional amounts of rainfall and wind and thus the types of cotton grown, are used: spindle (or picker) harvesting, and stripper harvesting, which is predominant only in West Texas and Oklahoma. For each 500-lb (227-kg) bale of ginned lint, picker-harvested seed cotton contains from 81 lb (37 kg) (Pendleton and Moore, 1967) to 325 lb (147 kg) (Reeves, 1977) of CGW. In most cases, 100 to 150 lb/bale (45 to 68 kg/bale) must be handled. When stripper-harvested seed cotton is ginned, from 524 lb/bale (238 kg/bale) (Pendleton and Moore, 1967) to 1476 lb/bale (670 kg/bale) (Kolarik et al., 1978) is separated. A commonly used value for wastes in stripper-harvested cotton is 700 lb/bale (320 kg/bale). If 75% of U.S. cotton was picker-harvested (letting CGW from picker-harvested cotton be 100 lb/bale) in the 1994 growing season, in which approximately 20 million bales were ginned, it can be estimated that 2.5 million tons (2.3 billion kg) of CGW were produced nationwide.

Properties of CGW

Griffin (1974) reported that leaf material makes up about 20% of CGW from Mid-south machine-picked cotton, about 35% is sticks, stems, and hulls, and about 40% is lint (Table 1). At gins that reclaim some of the waste fiber ("motes"), the lint portion is less than that reported by Griffin. Kolarik, et al. (1978) gave an average bulk density of 7 lb/ft^3 (112 kg/m^3) for dry CGW. Rook (1960) listed the organic contents of CGW from stripper-harvested cotton (Table 2). Schacht and LePori (1978) stated that the volatile-matter content (Table 3) of CGW from stripper-harvested cotton was 85% with ash content equal to 15%. Griffin (1974) determined that, for picker-harvested cotton, the ash content was 10%.

Costs of Disposal

The disposal of CGW is an economic problem for ginners and cotton producers. A survey of Texas South Plains gins by Kolarik et al. (1978) revealed that about two-thirds of the CGW produced cost the gins money for disposal. Recently, four common methods to dispose of CGW have been used: incineration, land filling, spreading on soil, and feeding to livestock. During the 1965-66 ginning season 37% of all CGW was burned, 58% was returned to the farm to spread on the soil, and 5% was disposed of by another method (Reeves, 1976). According to the Texas South Plains survey by Kolarik et al. (1978), only 1% of the CGW was incinerated, 42.5% was spread on land, 36.7% was used as livestock feed, 19.2% was dumped in a land fill, and 0.6% was disposed of otherwise. In a survey of Midsouth gins (Thomasson et al., 1991), about 33% of CGW was being spread on farm land, 23% was incinerated, 17% was given away for personal use as a mulch, 11% was dumped in some type of land fill, and most of the rest was either composted in some fashion, fed to cattle, or hauled away by a contractor for disposal. Land-filling was reportedly the most expensive method, followed by contract hauling, spreading on farm land, feeding to cattle, composting, and incineration. An overall cost per bale for the entire Midsouth, made up of labor and other operating expenses, was estimated at 80 cents.

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Current Options

Only a few Midsouth states allowed CGW incineration in recent years, and now each has phased out this practice. The decline in incineration was caused chiefly by governmental pollution regulations. No CGW burning occurs presently because incinerators that could meet emission requirements are prohibitively expensive. Land-filling was an option as long as inexpensive dump sites were available. This is typically not so any longer. Feeding CGW to livestock can be a useful option, but the use of chemicals in cotton farming limits its applicability. Finally, spreading raw CGW on the soil has benefits, but there are also concerns.

Across the Cotton Belt alternative CGW disposal methods that are economically feasible are essential to the continued operation of the ginning industry. Thomasson (1990) conducted an exhaustive literature review of practices and research in CGW disposal, showing that many different methods have been attempted. However, the practice of returning CGW to the soil is considered to be the most generally acceptable method of disposal. Spreading CGW on farm land rids the gin of its disposal problem and utilizes the CGW in a beneficial way, returning this organic matter to the land from which it came. Thomasson and Anthony (1990) and Anthony et al. (1992) recommended four methods that gins might use to handle CGW and return it to the soil: (1) spreading raw CGW as it comes from the gin; (2) composting raw CGW in a well managed fashion and spreading on farm land; (3) using an auger-conveyor to form a pile for later spreading; and (4) compressing, moving, and storing for later spreading. The utility of each depends on a gin's circumstances regarding space and labor.

There likely never will be one method of returning CGW to the soil that is suitable in all applications. Harvesting method, amount of cotton ginned, and location relative to other gins and urban areas are factors involved in deciding the appropriate practice for a particular gin. However, some worries exist concerning spreading raw CGW on farm land: (1) increased weed pressure on the land caused by possible live weed seed in the CGW, (2) increased insect pressure caused by possible live insects harbored in the CGW, (3) an increase in disease problems from possible disease organisms in the CGW, (4) possible problems from chemicals applied to the CGW, and (5) the difficulty in transporting and spreading such a large volume of material.

Composting in some form results in the most valuable end-product, and it can alleviate some of the worry associated with raw CGW. Allen (1981) claimed that composted CGW demonstrated through a test market that its value was quickly recognized and accepted by farmers. A ginner could conceivably even profit from a composting operation by selling his product as a mulch or potting soil ingredient in bagged form or by the truckload. This paper thus will concentrate on composted CGW.

Literature Review

Effects of CGW Compost

Several studies have shown composted CGW to be generally beneficial to plant growth and yield of various plants when used in place of peat as a potting soil ingredient, when mixed with soil, and when applied on top of the soil (Seiber et al., 1982; Williams et al., 1982; Pessarakli and Tucker, 1985; and Pinckard, 1982). As long as CGW application rates have been kept below 5 tons/acre (11 Mg/ha), reductions in germination have not been found to be a problem (Pettygrove and McCutcheon, 1982). Probably the main contributor to increased yields is the increased water holding capacity of the soil. Previous studies have shown that raw CGW applications greatly increased soil water storage (Fryrear, 1979), reduced soil temperatures to a depth of 30 inches (76 cm) (Fryrear and Koshi, 1974), reduced soil bulk density and increased hydraulic conductivity, air porosity, total porosity, and organic matter content (Koshi and Fryrear, 1973). According to Pessarakli and Tucker (1985), CGW compost similarly improves the physical condition of the soil. They concluded that nutrients in the form of composted CGW were more effective for plant growth than those in the form of commercial fertilizer.

Producers have long had concerns about possible infestation problems from adding uncomposted CGW to the soil. However, certain studies have shown that applying even uncomposted CGW to soil was not associated with increased problems from weeds, diseases, and insects (Box and Walker, 1959; Fryrear, 1979). Furthermore, several researchers have found that composting destroys some common fungal disease organisms and all weed seeds studied (Sterne et al., 1979; Parnell et al., 1980; Hills et al., 1981; Griffis and Mote, 1978B; Cudney et al., 1982).

According to Seiber et al. (1979), Miller et al. (1975), and Hills (1982), a few of the agricultural chemicals found in CGW at the time of the studies were stable in open storage (DEF, Toxaphene, Paraquat, Sodium chlorate, "Supracide" organophosphate insecticide, Omite, and Kelthane). Composting generally had the effect of breaking down chemicals more rapidly than under ambient conditions. The only exceptions were Kelthane and DEF, which were partially degraded, and Paraquat, which was quite stable during composting. According to Winterlin et al. (1986), when composted CGW was amended to field soil, residue levels were generally very low to undetectable in the soil, suggesting little potential hazard for a compost and amendment operation. The decline of residues during composting, coupled with the dilution factor when composted waste is incorporated into the soil, led to soil residues less than 0.5 PPM and generally less than 0.1 PPM just after incorporation. Winterlin et al. (1986) concluded that it is unlikely that toxicity to germinating and developing seedlings will result at these levels, or that residue transfer to subsequent crops will result from typical incorporation rates, because the few chemicals that survive composting are not systemic.

Composting Process

Composting involves converting organic wastes into lignoproteins (humus) by thermophilic organisms (Reddell et al., 1975). The primary factors affecting composting rates are moisture content (m.c.), aeration, carbon to nitrogen ratio (C/N), phosphorus and potassium content, and the content of materials such as heavy metals which are toxic to microorganisms (Reddell et al., 1975). Composting begins when the temperature of the waste material reaches 113°F (45°C) (lower limit for thermophilic organisms), and is complete when the temperature will no longer remain above 113°F (45°C) (Reddell et al., 1975). Mote and Griffis (1978) reported that the optimum temperature for microbial decomposition of cellulose is 122°F (50°C), but temperatures in a compost pile will reach 165°F (74°C). Composting can reduce dry matter weight by 50% and volume by 60% (Parnell et al., 1980).

According to Reddell et al. (1975), aerobic decomposition leads to the formation of oxidized end products such as carbon dioxide, water, sulfates, etc. They stated that the process usually has a musky, sweetish odor, and that the compounds produced are stable and relatively nonoffensive. Parnell (1977) reported that aerobically composted CGW was almost black, almost odorless, and did not resemble CGW except for a few undecomposed sticks.

Reddell et al. (1975) reported that anaerobic decomposition yields partly oxidized compounds and reduced chemicals such as fatty acids, aldehydes, alcohols, hydrogen sulfide, etc., which are capable of continued biochemical decomposition. They also stated that these end products can be a serious nuisance. Parnell (1977) reported that anaerobically composted CGW was brown and gave off an offensive odor.

Composting Procedure

Microorganisms required for composting are present in raw CGW, and no starter or inoculant is necessary (Alberson and Hurst, 1964; Parnell et al., 1980). Griffis and Mote (1978A) stated that CGW will compost successfully without inoculation and without added nitrogen. They stated that water will be a limiting factor for about one month, beyond which time the pile should be provided with better aeration through turning or another means.

Aeration. Parnell et al. (1980) suggested stirring or mechanical aeration for uniform air and moisture distribution, and to prevent anaerobic decomposition. Reddell et al. (1975) recommended that a pile should be turned 3 times during the 1st week, twice during the 2nd week, once during the 3rd week, and once during the 4th week. Parnell (1977) reported that three good stirrings are necessary. Hills (1982) recommended 7-day mixing frequency.

Wetting. Parnell (1977) concluded that aeration is required and it would not be practical to store CGW on the ground and merely add water. However, Mote and Griffis (1980) claimed that compost could be made from windrows of CGW by doing nothing more than adding water. They stated that maintaining windrow moisture by over-the-surface spraying at 5.6×10^{-4} gal/hr per lb (4.7 mL/kg) initial dry trash, at frequencies of 1 to 4 sprays per hr for the duration of the process, will allow the entire windrow to compost. They further said that composting can be initiated by running a water-maintenance spray system continuously until enough water has been added to bring the dry CGW to 60% m.c., wet basis (w.b.).

Alberson and Hurst (1964) stated that 70 to 75% m.c. w.b. is desirable. Reddell et al. (1975) cautioned that m.c. levels above 75% will result in lower temperatures and thus require longer to process. They also said that high water concentrations may leach soluble constituents from the compost, and that if the m.c. is too high, anaerobic conditions are produced. While they suggested 60 to 70% m.c. w.b. as optimal, Parnell (1977) suggested 60%. Hills (1982) recommended 60% m.c. w.b. Griffis and Mote (1978A) stated that CGW with an initial m.c. w.b. of 40% will compost satisfactorily.

Reddell et al. (1975) stated that CGW may be difficult to wet, and recommended that one tablespoon of detergent dissolved in a gal (3.8 L) of water sprayed over the material before adding water will enhance wetting without affecting decomposition rates. Mote and Griffis (1980) reported that adding surfactant at 0.5% by volume to the water used to initially wet CGW in the windrow can increase the rate of temperature rise over the use of plain water.

Time Requirements. Alberson and Hurst (1964) claimed that usable compost can be produced in 3 weeks if the CGW is aerated and kept wet. Hills et al. (1981) stated that composting CGW requires roughly 5 weeks, but later Hills (1982) said it takes about 7 weeks. If placed in pit silos or ground surface enclosures with no aeration but thoroughly watered, CGW will decompose in about 3 months (Alberson and Hurst, 1964). Parnell (1977) also reported that about 90 days would be required to obtain some good-looking compost. Reddell et al. (1975) recommended stockpiling finished compost for about 9 weeks for curing and final degradation.

Facility Requirements. Reddell et al. (1976) estimated that a 5000 bale-per-year stripper-cotton gin would need 26 land acres (10.5 ha), 2 million gal (7.6 ML) of water for initial wetting, and another 1 million gal (3.8 ML) during composting. Anthony et al. (1992) gave related numbers for picker cotton: 3.3 acres (1.3 ha) and 375,000 gal (1.42

ML) total. They noted that each inch of rain during composting could reduce this requirement about 25,000 gal (95 kL).

Inferences from the Literature and Experience

Composting CGW before spreading on farm land addresses the worries that have existed regarding spreading raw CGW. Weed seeds are destroyed during composting. Insects are not likely to survive composting, and no incidences of increased insect pressure related to field application of composted CGW have been found in the literature. Some common pathogenic fungi are destroyed during composting. Most farm chemicals are broken down altogether or more quickly during composting, and tests have shown that, at standard rates of application, post-spreading soil residues of all chemicals are negligible. Finally, composting reduces the volume of material that must be spread by as much as 60%. These facts, taken together, show composted CGW to be a preferable product to raw CGW for spreading on crop land.

However, composting requires greater resources and management than simply spreading on the soil. Frequently mixing and wetting large volumes of composting CGW during, or even after, ginning season can be a burden in terms of technical feasibility, labor, land, and management. After many years of research and publications about methods and benefits of composting CGW, the cotton ginning industry apparently has decided by default that, for the time being, the value added to CGW by composting is simply not worth the expense and management involved. There are a few instances of true composting taking place around the industry, but the widespread use of the practice does not appear to be imminent.

State of the Art

Current

In the review of composting procedures, the discussion was limited to a well-managed operation with proper water, labor, and machine inputs. This is within a precise connotation of composting. Notwithstanding, many people refer to composting with regard to lower levels of management etc. We define here "unmanaged composting" as some form of piling the material, wetting it, and allowing it to decompose with little further assistance other than rainfall. This practice appears to be taking over as the most common method in the industry.

The type of system used is composed of primarily a central collection point for waste material coming from the gin plant, and a long elevated auger-conveyor. The collection point usually involves a cyclone that separates CGW from a conveying air stream. From the cyclone bottom CGW drops into the inlet on top of the auger's enclosed portion. The rotating auger then conveys the CGW along its axis to the point at which the auger bottom is open. The CGW falls to the ground when it exits the enclosed portion of the auger, and begins to pile up until the top of the pile reaches the base of the auger. At this point, the pile of CGW effectively encloses a small portion of the auger bottom, requiring additional CGW to travel further along the auger before it falls to the ground. In this way, the pile is extended the full length of the auger.

These auger systems typically are constructed in one of two configurations. In one configuration, the auger is stationary and supported by posts along its length (fig. 1). A pile of CGW is formed in a straight line, covering the support posts. This configuration requires a relatively long piece of land for a given amount of waste. The support posts inside the pile complicate access with heavy equipment, and corrosion of the posts in the compost pile is a problem. On the other hand, this configuration is the less expensive of the two.

In the other configuration, the auger is suspended on a large frame that pivots about the collection point and is supported there by a large post. The outward end of the frame rests on a circular concrete track at the edge of the pile area (fig. 2). The frame's support wheels roll on the track. When a complete, auger-length, pile has been formed, the free end of the auger is moved to a new location so that a new pile can be formed. Long piles are laid out radially from the pivot point within the available pivot angle of the auger, ordinarily about 275-300°. The piles typically merge to form one large, almost circular, pile. One commercial company constructs CGW collection systems in this configuration.

Problems and Possible Improvements

There are problems with unmanaged composting: lack of mixing and improper water application. The former can result in anaerobic decomposition and its related problems, and also uneven decomposition throughout the pile. The latter can result in wasted water, poor initial wetting, slow and poor decomposition, fires, and/or the nuisance of flies.

Without mixing, CGW at the pile's outside typically is not subjected to high temperatures. However, research in spray moisture maintenance (Mote and Griffis, 1980) showed that even the very surface of the pile rose in temperature to 120°F (49°C). This research indicates that thorough CGW composting, with elevated temperatures throughout the pile, can be achieved by merely maintaining moisture with over-the-surface spraying at 5.6 x 10^{-4} gal per hr. per lb. (4.7 mL/kg) initial dry trash, at a 0.25-hr. spray frequency throughout the process (assuming no rain). This method has yet to be tested on a large pile such as is formed with an elevated auger.

A problem that exists with large piles of biomass is the chance of fire, which can be caused by spontaneous combustion. This can occur in large piles when the m.c. of the material is at a level that will support ongoing chemical oxidation, and the temperature of the material has been elevated by biological activity to a level at which chemical oxidation will begin. These conditions can exist in piles that have a high inner m.c. and a low outer m.c.. The biological activity in the inner portion raises the temperature in its general vicinity, and the drier material toward the outside is at the proper m.c. for chemical oxidation, and has a ready supply of oxygen from the outside edge of the pile. These conditions can result in spontaneous smoldering producing a great deal of smoke, and possibly in a more hazardous open fire situation (Rynk et al., 1992; Koegel and Bruhn, 1971; Miao and Yoshizaki, 1994). Whether caused by spontaneous combustion or by a remote ignition source, fires in large piles of CGW have been and continue to be a problem involving nuisance smoke and possible equipment damage. It should be noted that CGW at 40% m.c. w.b. and above will neither spontaneously combust nor burn. Thus, a system of initially wetting the material and then maintaining the m.c. with over-the-surface spraying will prevent fires.

Another problem that exists with large piles of decaying biomass is the presence of flies. Two methods of remediation can be used. First is distance. The composting system should be located sufficiently far from any home or inhabited business to alleviate a possible nuisance caused by the presence of flies. The second method, if necessary, of remediating fly problems is applying chemicals with a spray application when needed. The state of Mississippi approved, on September 30, 1993, a "special local need" registration of Dursban 4E Insecticide (Dow Elanco) for control of flies in CGW. When necessary, direct surface application can be accomplished by injection into an over-the-surface spray system, or by manual spray application, according to the label instructions for application to refuse dumps.

One final problem that can exist with such a composting system is puddling of water around the pile, which can cause anaerobic decomposition of organic material in the puddles. This situation can produce foul "rotten egg" odors and can exacerbate the fly problem. Therefore, the ground on which the system is placed should be built up to be high and dry and sloping away from the center, with no holes or low places. The base under the waste pile should be composed of free draining sand (see the standard, ASTM D2487; American Society of Testing and Materials, 1993).

Objectives

It was believed possible to reduce problems related with current unmanaged composting systems for large quantities of CGW by regulating the initial water applied according to the ginning rate and possibly by adding an appropriate wetting agent, and by operating a spray moisture-maintenance system. The spray system was beyond the scope of this research. The scope of this work was to establish and test a method of applying water to CGW that will provide the proper amount of initial moisture for composting. Part of this work involved determining the efficacy of adding surfactants in CGW collection systems. Thus, the specific objectives were (1) to conduct a pilot-scale composting study with CGW to establish time, moisture, and temperature relationships; (2) to determine the necessity of regulating the initial application of water according to the CGW flow rate; (3) to construct and test a flow-regulating, venturi-type surfactant-injection system for wetting CGW at a commercial gin; (4) to construct and test a water-driven, proportional surfactant-injection system for wetting CGW at a commercial gin; (5) to conduct a pilot-scale evaluation of the efficacy of wetting agents in improving water uptake by CGW; and (6) to conduct a commercial-scale evaluation of the efficacy of a wetting agent in improving water uptake by CGW. The work conducted for each specific objective is reported as a separate part (i.e., Parts 1-6) in the Methods and Materials section and in the Results section.

Methods and Materials

All work herein was conducted in picker-harvesting areas. Where not specified otherwise, general assumptions are made that an average of 100 lb (45 kg) of CGW, including moisture, is generated per bale of cotton, and that the initial m.c. w.b. of the CGW is 10%. The ideal m.c. w.b. for initiating composting is taken as 60%. All references to moisture content herein are wet basis unless specified otherwise, so we will refer to m.c. w.b. as simply m.c.

Part 1

Seed cotton on hand at the U.S. Cotton Ginning Laboratory (USDA-Agricultural Research Service, Stoneville, Mississippi) was ginned, and waste from the seed cotton cleaners was collected. About 70 lb (32 kg) of this CGW, which would correspond to that of a commercial gin that reclaimed motes, was dumped unpacked into semi-conical containers. Volume occupied in the containers was calculated, and the contents were weighed so that bulk density could be found.

The entire 70 lb (32 kg) of CGW was piled on a covered paved storage area. According to the recommendations of Reddell et al. (1975) one tablespoon of powdered laundry detergent was added to each gal of water to wet the CGT. On the first day, 9.5 gal (36 L) were added. This amount was expected to bring the CGT to roughly 55% m.c. The water was applied with a hand-pump spray tank and wand. Turning of the pile with a seed fork was required between each 2.5-gal (9.5-L) application to keep water from running off.

On most days over a 17-day period, samples from the pile were collected, and temperature of the pile was monitored with a hand-held thermocouple probe. Oven moisture analyses were performed on the samples from the pile.

Water was added periodically in an attempt to maintain the m.c. above 40%.

Part 2

Calculations were made to determine the necessity of regulating flow in a manner other than on or off according to operation of the gin. From the following equations we found how much water was required to bring 100 lb (45 kg) of CGW to 60% m.c.

$$m = \frac{M}{M + D} \qquad \textbf{(1)}$$

where m = m.c. w.b.
M = mass of moisture in CGW
D = mass of dry matter in CGW

From the assumptions, we have

$$0.6 = \frac{M}{M + 90} \qquad \textbf{(2)}$$

Solving, we have M = 135 lb (61.2 kg). Thus, added water required per bale ginned is 135 - 10 = 125 lb (56.7 kg), or about 17 gal (64 L). We assumed that to initiate composting, the m.c. of the material should be between 40 and 70%. To find the range of CGT flow rates that would fit in this range, we made the following calculations:

$$m = \frac{125 + 0.1D'}{125 + 0.1D' + 0.9D'} \qquad \textbf{(3)}$$

where D' = total mass of CGW per bale
0.1 D' = mass of initial moisture in CGW
0.9 D' = D

Solving for D' we have

$$D' = \frac{125(1 - m)}{m - 0.1} \qquad \textbf{(4)}$$

Part 3

A flow-regulating, venturi-type surfactant-injection system was installed on the CGW collection/composting system at Burdette Gin, Burdette, MS. The system was of the pivoting-auger type, and a water supply had been installed previously for wetting the CGW in the enclosed portion of the auger. The water flowed at one rate to three fittings in the top of the auger's enclosed portion. The bucket-and-stopwatch method was used, taking three samples of approximately 1 min in duration, to find that the flow rate was 2.3 gal/min (8.7 L/min). The maximum ginning rate was 25 bales/hr, so the CGW generation rate was assumed to be 2500 lb/hr (1130 kg/hr), or 41.7 lb/min (18.9 kg/min). Therefore, 52.1 lb/min (23.6 kg/min) or 7.0 gal/min (26 L/min) additional water would be required to bring the CGW to 60% m.c. The 2.3-gal/min (8.7-L/min) rate provided was not, by itself, adequate to achieve an acceptable m.c. to initiate composting; It increased m.c. to only 36%. However, our desire here was to show the feasibility of controlling the flow and adding surfactant to aid in wetting.

An electric-solenoid type, flow regulating water valve, a venturi-type surfactant-injection system, and a backflow prevention valve were acquired. An appropriate 24-VDC power supply was selected to drive the solenoid valve. These items together cost less than $200. A weather-proof box was constructed and mounted on top of the enclosed portion of the rotating auger. Inside the box, the power supply, the solenoid valve, surfactant-injection system, and backflow prevention valve were housed. The power supply was connected to a ground-fault-interrupt circuit fed from the feed-control switch inside the gin. The feed-control switch controls the flow of cotton into the gin stands. Thus, the solenoid valve was driven to the open position only when cotton was being ginned. Appropriate piping connected the solenoid valve to the existing water supply for wetting the CGW, and connected the surfactant-injection system to the surfactant reservoir, which was mounted next to the weather-proof box. Water with added surfactant went from the injection system to the fittings in the enclosed portion of the auger. At this point, the water/surfactant mixture was incorporated into the CGW by the churning motion of the auger.

Adjustment and calibration of the surfactant-injection rate were accomplished by opening a valve to route the necessary amount of water through a by-pass, to which the venturi hose was connected. Increasing the opening of the valve allowed more water through the by-pass, increased the venturi-effect suction on the hose, and drew more surfactant from the reservoir. Conversely, decreasing the valve opening reduced the surfactant-injection rate.

Part 4

A water-driven proportional surfactant-injection system was installed at Minter City Gin, Minter City, MS. This gin could process 25 bales/hr. The composting/collection system was of the straight-line, fixed-auger type. A water supply had been installed previously for wetting the CGW through six nozzles in the enclosed portion of the auger. The water flow rate was about 6 gal/min (23 L/min). Based on general assumptions of CGW flow rate and initial m.c., this water flow was expected to produce a m.c. in the wet CGW of about 56%. This was an acceptable amount for initiating composting. However, some water noticeably drained from the inlet end of the enclosed portion of the auger, so not all of the water was being absorbed by the CGW. A water-driven proportional injection pump was added to the water supply. The injection pump had a visible gauge, showing the volumetric percentage of the material being injected, and allowing the adjustment valve to be turned to vary the surfactant-injection rate as desired.

Part 5

Ninety CGW samples of 50 g were immersed in water/surfactant mixtures of six different surfactant concentrations (0%, 1/4%, 1/2%, 1%, 2-1/2%, and 5%) for five different durations (1, 5, 10, 30, and 60 seconds). The CGW used in this experiment included lint waste. This CGW corresponds to that of a gin that does not reclaim "motes." Carefully weighed samples were placed in perforated metal cans and immersed in the various solutions for one of the given durations. Excess water was wiped from the outside of the cans, and the cans were reweighed. These data were collected with three replications. The data were analyzed by calculating water added as the amount of increase in sample weight, and by plotting water added vs. time at different surfactant levels.

Part 6

After the surfactant-injection system at Minter City Gin had been installed, and during a period in the 1994 ginning season in which large blocks of fairly uniform seed cotton were coming through the gin, an experiment was conducted concerning the effect of different surfactant levels on the final m.c. of CGW collected at the auger. Since, as noted for Part 4, not all the water was being absorbed by the CGW, it was expected that the addition of surfactant to the water would increase the absorption, and thus the m.c.. Four treatments consisting of no water, water only, water with 1/4% surfactant, and water with 1/2% surfactant, were executed in random order with three replications. During each replication, seed cotton from only one farmer, and in only one field or in two adjacent fields, was ginned. Either a half or a whole module of seed cotton was ginned for each experimental unit. During sampling for an experimental unit, six replicate samples of seed cotton at the module, and of CGW at the auger, were collected. Fractionation analyses were conducted in triplicate on the seed cotton samples to determine the percentage of foreign matter by mass. Oven m.c. tests were performed in triplicate on the CGW samples. Doing three analyses on each sample was expected to give a stable mean value for each sample.

Data were analyzed by looking at moisture added to the CGW, and also by looking at moisture added per unit mass of CGW. The former data were calculated by subtracting the m.c. dry basis (d.b.) of the no-water samples from that of the samples with water added. The latter data accounted for the inherent amount of seed-cotton foreign matter by using the fractionation analysis results. From the fractionation data, equivalent to percent foreign matter in the seed cotton, estimates of the amount of CGW produced per bale were calculated for each experimental unit. In this way, any variation in m.c. caused by variation in CGW flow rate could be taken into account. For example, a given amount of water will increase the m.c. of a bale's worth of CGW from clean seed cotton much more than from dirty seed cotton, because the dirty seed cotton contains much more CGW per bale. Analysis of variance was performed with the SAS procedure PROC ANOVA (SAS Institute, 1985) to find out whether adding surfactant affected moisture uptake.

Results and Discussion

Part 1

Bulk density calculations on two containers of CGW resulted in a value of 7.70 lb/ft^3 (123 kg/m^3), with a difference of only 0.01 lb/ft^3 (0.16 kg/m^3) between the two. This is close to the value of 7 lb/ft^3 (112 kg/m^3) reported by Kolarik et al. (1978). The temperature and m.c. data for the compost pile are reported against time in fig. 3. It can be seen that while m.c. generally was maintained above 40%, temperature dropped fairly steadily after reaching its initial peak of 133°F (56°C). The relatively small size of the pile probably limited the maximum temperature acheived as well as its duration. At the end of the 17 days, it was readily apparent that the composting process was a long way from completion; large burr pieces were readily visible. With literature reports of complete composting in three to seven weeks, it can be surmised that the process used herein is not the most efficient, that mixing of the pile and more frequent water applications would speed the process. On the other hand, piles allowed to sit during the ginning season and beyond often have six to nine months to complete the process. In that case, if water is applied properly, time can serve as a substitute for mixing.

Part 2

From eq. 4, we found that when m = 0.4, D' = 252 lb (114 kg); when m = 0.7, D' = 63 lb (29 kg). Thus, if the water flow rate for initial wetting is 17 gal (64 L) per bale, which is designed to bring 100 lb (45 kg) of CGW to 60% m.c., CGW flow rates of 63 to 252 lb (29 to 114 kg) per bale of cotton would be wetted to acceptable m.c. to initiate composting. This range of CGW flow rates encompasses virtually any that would be encountered in picker-harvested cotton. A ginning rate of 25 bales/hr would require a water application rate of 7 gal/min (26 L/min).

Part 3

Part 3 effectively demonstrated the feasibility and inexpensiveness of controlling the flow and varying the water/surfactant mixture upon CGW in an auger-type collection system. The solenoid valve worked well in turning the water supply either on or off depending on whether cotton was flowing in the gin. Although the water supply in place did not provide adequate water for an acceptable initiation of composting, the surfactant-injection system worked well in mixing surfactant with the water used to wet the CGW.

Part 4

Part 4 showed the practicality of using a water-driven proportional injection pump to inject surfactant into a water application system for CGW. The pump also worked well in mixing surfactant with the water used for initial wetting. In addition, the pump allowed easy adjustments of surfactant-injection rate without calibrating, as was required with the venturi-type system.

Part 5

In Part 5 the amount of moisture added increased with duration of immersion. The amount of moisture added also increased with increasing surfactant concentrations. When moisture added was plotted against log time, it tended to follow fairly straight but distinct lines varying according to surfactant concentration. Increasing concentrations, up to about 1/2%, increased the slope of the line (fig. 4). Adding surfactant beyond the 1/2% level was of little benefit in increasing the rate of moisture addition.

Part 6

The analysis of variance did not show any significant effect on water uptake from adding surfactant, at any injection rate, to water used to wet CGW for composting. This was true when looking at only percent moisture added per bale, and when looking at percent moisture added per unit mass of CGW. While the results of Part 5 showed surfactant increased the rate of water uptake by CGW, the results of Part 6 indicated that the total amount of water uptake was unaffected by adding surfactant. The most likely explanation for this discrepancy is that the length of time the CGW spent in the enclosed portion of the auger where water was applied, along with the churning motion provided by the auger, was adequate to allow the CGW to take up almost all the water applied even without surfactant.

Conclusions

In Part 1 a CGW bulk density of 7.7 lb/ft^3 (123 kg/m^3) was found. During 17 days of composting an initially 70-lb (32-kg) pile of CGW, temperature peaked at 133°F (56°C) on the third day and decreased fairly steadily after that, while the m.c. was maintained above 40%. It was concluded that much more time would be required to compost CGW in this manner, which is without mixing. Based on the calculations in Part 2, it was concluded that, for initially wetting CGW from picker-harvested cotton, it is unnecessary to regulate the flow of water according to the CGW flow rate. Merely setting the water flow rate at 17 gal (64 L) per bale of cotton would be adequate to bring CGW at virtually any flow rate to an acceptable m.c. to initiate composting. The only necessity in regulating water flow rate is in stopping the water flow when cotton is not flowing through the gin. Part 3 demonstrated two things: the feasibility of using a solenoid valve to turn the water supply on or off depending on whether cotton was flowing in the gin, and the feasibility of using a venturi-type injection system to mix surfactant with water to wet CGW in an auger-type collection/composting system. Part 4 demonstrated the feasibility of injecting surfactant with a water-driven proportional injection pump. This system made it easy to adjust the injection rate without recalibration. Part 5 showed that adding surfactant to water to wet CGW does increase the rate of moisture addition. Varying concentrations from 0 to 1/2% showed that increasing surfactant concentration speeds the uptake of moisture. For concentrations over 1/2%, this did not hold true. The data analyses in Part 6 provided no evidence that addition of any level of surfactant increased water uptake by CGW in the system. From the seemingly conflicting results of Parts 5 and 6, it was concluded that, while wetting CGW (not to mention maintaining the m.c.) is critical, no surfactant is required to do an adequate job of water application to initiate composting, as long as water is applied in an adequate-length enclosed portion of the conveying auger.

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Table 1. Pounds of CGW for Mid-south machine picked cotton.*

	Leaf	Sticks, Stems, & Hulls	Lint	Total
Expelled by gin machinery	21	35	42	98
As dry material	18	29	38	84

*from Griffin (1974)

Table 2. Organic contents of cotton gin trash.*

Material	Percent of waste
Pectic matter	1.6
Oil and aromatic tars	3.0
Tannin and attendant surgars	8.0
Unidentified gums (water soluble)	8.0
Pentosan sugars	16.5
Lignin	18.5
Cellulose	23.0
Moisture	10.0
Inorganics	11.4

*from Rook (1960)

Table 3. Volatile matter content (dry basis) of cotton gin trash.*

Material	Percent of waste
Volatile Matter	85.0
Carbon	42.0
Hydrogen and attendant sugars	5.4
Nitrogen	1.4
Sulfur	1.7
Oxygen and Error	34.5

* from Schacht and LePori (1978)

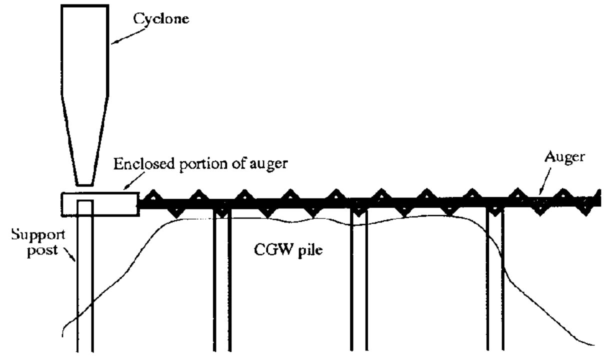

Figure 1. Straight-line auger with support posts in pile.

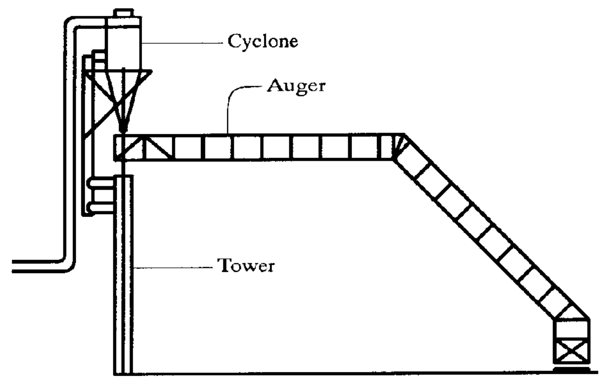

Figure 2a. Side view of pivoting-auger collection system.

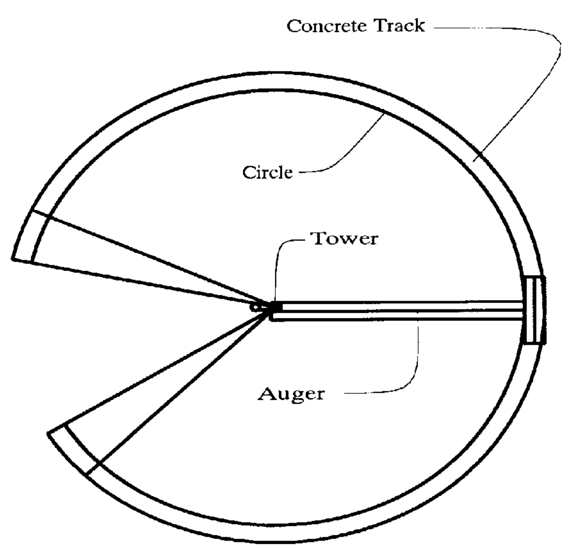

Figure 2b. Top view of pivoting-auger collection system.

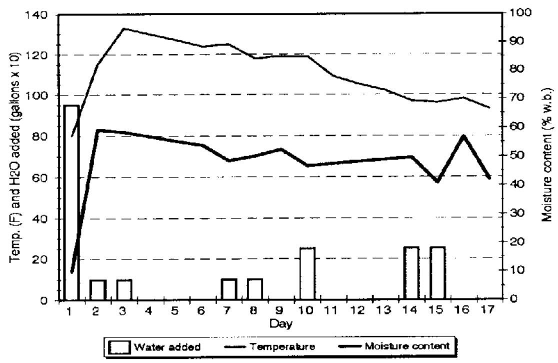

Figure 3. Temperature and moisture content of compost pile vs. time.

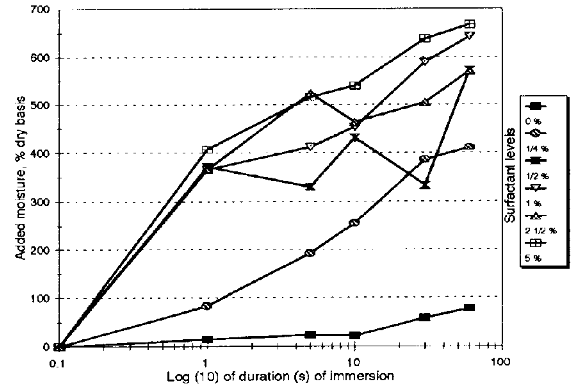

Figure 4. Moisture uptake vs. log time with varying surfactant concentrations.