High Temperature Composting of Cattle Feedlot Manure Kills Weed Seed

A. F. Wiese, J. M. Sweeten, B. W. Bean, C. D. Salisbury, E. W. Chenault

Abstract. *The temperature and exposure period required to kill seed of johnsongrass, (*Sorghum halepense*); pigweed, (mixture of* Amaranthus *sp. primarily* hybridus *and Palmeri); kochia, (*Kochia scoparia *(L.) Schrad); barnyardgrass, (*Echinochloa crus-galli *(L.) Beauv); sorghum, (*Sorghum bicolor *L. Moench 'DeKalb 42Y'), and field bindweed, (*Convolvulus arvensis *L.) buried in compost during laboratory experiments or compost manufacturing process was determined. When buried in compost, seed of all species except field bindweed were killed with three days or more exposure at 49°C (120°F). It required seven days of exposure at 83°C (180°F) to kill all field bindweed seed in compost. In dry air, rather than compost, all species survived 60°C (140°F) for 30 days. All seed except field bindweed were killed in dry air by 72°C (160°F) for three days. It took seven days of exposure at 83°C (180°F) to reduce viability of field bindweed from about 30 to 7% in dry air. At 83°C (180°F) viability was reduced only to 5% with 30-day exposure. Seed of all species except field bindweed were killed in a three-day composting process where temperature was maintained at 72°C (160°F) or higher. Field bindweed seed were killed with a 12-day exposure in an outside storage pile of compost. Compost manufactured at this location is probably free of viable weed seed and would be suitable for lawns, nurseries, and agricultural land.*

Keywords. *Weed seed germination, Feedlot manure, Compost.*

Under natural conditions seed of some weeds persist for a long time in the soil seed bank (Darlington and Steinbauer, 1961; Lewis, 1973; Stoller and Wax, 1974). It follows that using manure containing weed seed may increase the problem. However, the number of weed seed added with manure was small compared to seed from weeds growing in a field or from adjacent uncultivated areas (Mt. Pleasant and Schlather, 1994; Hume and Archibold, 1986). These authors add that noxious perennial weed seed in manure can create a problem that persists for many years. Timmons (1949) stated at least 30 years of careful observation and control would be required to rid a field of field bindweed seed. Field bindweed seed remained viable for 50 years in dry storage (Brown and Porter, 1942). Johnsongrass viability remained almost 100% after 5.5 years of burial from 8 to 38 cm in a sandy loam soil in Mississippi (Egley and Chandler, 1983).

The threat of introducing weed seed to cropland has prevented many farmers from using manure as a source of fertilizer. Because of this, many researchers have studied the effect of animal digestive systems on viability of weed seed. Some seed were killed and others pass through animals with little or no reduction in viability (Atkeson et al., 1934; Harmon and Keim, 1934). Storage in manure piles killed seed of some species but not others. The digestive systems of chickens destroyed seed of sweet clover, smooth dock, smartweeds, wild rose, and peppergrass. Only 2% of bindweed seed survived. Whereas, about 12% survived in sheep and horses and 23% in cattle and hogs (Harmon and Keim, 1934). Grinding weed seed in a hammer mill with a 1 mm (0.04 in.) screen destroyed about 99% of weed seed but intact seed were viable (Zamora and Olivarez, 1994). Weed seed may persist in processed and pelleted feeds (Beach, 1908). Ensiling and rumen digestion killed some weed seed but not all (Blackshaw and Rode, 1991).

In California, composting dairy manure greatly reduced, but did not eliminate weed seed from manure (Cudney et al., 1992). Manure collected from six dairies contained 21% mustard species, 21% yellow foxtail, 17% bermudagrass, 10% annual bluegrass, 7% barnyardgrass, and 5% pigweed species. Viable weed seed per ton varied from 10 million in uncomposted dairy manure to as low as 323,000 in composted. Weed seed in composted manure from five dairies varied from 323,000 to 4 million per ton indicating different composting methods were used. In the same study, manure in pens of dry cows had 16 million weed seed per ton and pens of milking cows averaged only 4 million. Dry cows received lower quality feed which would have more weed seed.

The southern Great Plains has the largest concentration of cattle feed lots in the world, producing 25 to 30% of cattle fed for slaughter in the United States. As many as 2.4 million head are on feed at one time in open unsurfaced lots, and a total of 8 million head are fed annually in Texas alone (Hunset, 1993). This many cattle produce tremendous quantities of manure and a difficult disposal problem. Manure production in a feedlot averages 1 ton per head during a 9 mo feeding period (Butchbaker et al., 1971). One

Article was submitted for publication in February 1998; reviewed and approved for publication by the Soil & Water Div. of ASAE in May 1998.

This article is a contribution from Texas Agricultural Experiment Station, 6500 Amarillo Blvd. West, Amarillo, Texas.

The authors are **Allen F. Wiese,** Professor Emeritus, **John M. Sweeten,** ***ASAE Fellow Engineer***, Professor and Research Director, **Brent W. Bean,** Associate Professor, **Clay D. Salisbury,** Assistant Professor, and **E. W. Chenault,** former Research Scientist, Texas A&M University, Texas A&M Res. & Ext. Center, 6500 Amarillo Blvd. West, Amarillo, TX 79106. **Corresponding author:** Allen F. Wiese, 5 Painted Daisy Place, Amarillo, TX 79106; tel/fax: (806) 467-7238.

feedlot in the Texas Panhandle area has a manure pile 15 ha at the base and 12 m high (40 acres × 40 ft).

Previous research shows that composting manure appears to be the most effective way of reducing viable weed seed. Interest in composting has grown as a means of improving manure quality and making it more marketable (Sweeten, 1985). Our research used a combination of laboratory and field experiments to determine the temperature, moisture, and time requirements necessary to produce compost free of viable weed seed.

Materials and Methods

Laboratory and field experiments were used to determine if a mechanically mixed and temperature controlled composting process used in a plant near Hereford, Texas, killed seed of six common species. Laboratory experiments were conducted in dark ovens at the USDA Conservation and Production Research Laboratory near Amarillo, Texas. Field studies involved burying weed seed in compost being manufactured from cattle feedlot manure. Seed of field bindweed, johnsongrass, pigweed (mixture of *Amaranthus sp.* primarily *hybridus* and *Palmer*), kochia, and barnyardgrass were gathered from local fields for both types of experiments. Untreated seed of grain sorghum was used for comparison.

Seed viability was determined from three replications in rag doll tests at room temperature (table 1). A rag doll test was done by scattering seed on dampened paper towels placed on clear plastic wrap. The towels and wrap were rolled and the ends rubber-banded to prevent water loss. Viability was determined after two weeks of incubation. Non-viable seed molded in the rag dolls and were discarded. Germinated and dormant seed remaining were considered viable. In order to have any germination, field bindweed seed had to be soaked in concentrated sulfuric acid for 30 min (Steinbauer and Grigsby, 1959). Johnsongrass seed germination was 13% with no treatment and 75% when seed coats were pricked with a needle. Unpricked seed were used in subsequent experiments. Seed were measured rather than counted. A 4 mL (1 teaspoon) measure was used for all weed seed except pigweed and kochia where 2 mL (1/2 teaspoon) was used. The average number of seed in these measures are given in table 1.

Table 1. Germination obtained from rag doll tests of seed used in subsequent experiments

Weed	Seed in Rag Dolls* (no.)	Germinated Seed (no.)	Germination (%)
Field bindweed†	90	55	61
Johnsongrass‡	127	95	13 (75)‡
Pigweed	176	96	54
Kochia	95	57	60
Barnyardgrass	163	28	17
Sorghum	72	57	79
LSD 0.05§			13

* Seed in 4 mL (1 teaspoon) except for pigweed and kochia which was 2 mL (1/2 teaspoon).

† Treated with concentrated H_2SO_4 for 30 min.

‡ Johnsongrass seed pricked with needle to rupture seed coat to insure viability.

§ LSD 0.05 = Least significant difference at the 5% level of probability.

In all subsequent laboratory and field experiments, the measured amount of seed was sown into 5 × 5 cm, 60 mesh/cm (150 mesh/in.) nylon packets. After various studies were conducted, seed were retrieved and viability determined. Percent viability was calculated based on the average number of seed that had been measured.

Laboratory Experiments

Seed packets of each weed were placed in covered 946 cc steel soil moisture cans and placed in an oven. Seed were suspended from covers of empty cans to simulate dry conditions. In other cans seed were buried in compost with 35% moisture on a wet weight basis. This was the moisture content of compost determined from 12 samples taken during manufacturing. Cans with compost were weighed every second day and water added by weight as needed to maintain 35% moisture. Seed of the six species were incubated at 1, 3, 7, or 30 days at 49, 60, and 72°C (120, 140, and 160°F) and viability determined with rag doll tests. Field bindweed seed were incubated at 60, 72, and 83°C (140, 160, and 180F) for the various periods. There were three replications for each temperature and time.

Field Experiments

To manufacture compost, manure from cattle pens at a feedlot was ground and deposited in a bin that was about 3 m wide, 3 m high, and 30 m long (10 × 10 × 100 ft). During the grinding process, enough water was sprayed on the manure to raise the moisture to 35%. To prevent molding, temperature of the mix was maintained at 72 to 83°C (160 to 180°F) by drawing air through the pile with large fans at 5 m (16 ft) intervals near the bottom of the bin. Thermocouples were placed at various locations in the bin to activate the fans. After three days, compost in the bin was rewet if needed and mixed with the electrically driven power mixer. The process was continued for another three days. Then the material removed from the composting bin was put in a large static pile for 30 days before grinding and bagging for sale. Temperature was not monitored in the large pile.

Seed of the six species were buried for three days in the compost bin immediately after grinding and wetting until the pile was reground and turned. Two packets of seed were placed 0.3, 0.6, and 1.6 m (1, 2, and 5 ft) from an outside wall at depths of 0.3, 0.6, and 1.0 m (1, 2, and 3 ft). The process was repeated at three locations in the bin. Seed packets were removed just before turning. Half of the packets were taken to the laboratory to check viability, and the other half were reburied in the mixed compost for an additional three days until the composted manure was moved to the large holding pile. Seed were then taken for viability testing.

Three replications of seed packets of field bindweed were buried 0.6 m (2 ft) deep in the large holding pile for 12, 19, and 26 days. Other species had been killed at all locations in the composting bin, so were not included in this experiment. Temperature measurements were not taken.

Results and Discussion

Laboratory Experiments

Percent viable seed of johnsongrass, pigweed, kochia, barnyardgrass, and sorghum after exposure to 49, 60, and 72°C (120, 140, 160°F) in an oven are shown in tables 2, 3, and 4, respectively. When buried in compost, all species were killed with three days of exposure to 49°C (120°F) or higher temperatures. Kochia was killed with only one day exposure to 49°C (120°F) in compost. Seed of the five species tolerated 49 and 60°C (120 and 140°F) in the dry air of the oven regardless of length of exposure up to 30 days. Seed of all five species were killed at 72°C (160°F) in dry air after three days of exposure.

Seed of field bindweed were more difficult to kill (table 4). Exposure to 60 and 72°C (140 and 160°F) in and out of compost did not reduce viability. Seed in compost were killed after seven days of exposure at 83°C (180°F). In air, viability of field bindweed seed was reduced to 7% from about 30% by exposure for seven days at 83°C (180°F).

Field Experiments

All seed except field bindweed were killed at any location in the composting bin after three days of exposure (table 5). Temperatures must have exceeded 60°C (140°F) at all locations in the bin. This is in agreement with laboratory experiments that showed all seed except field bindweed were killed in compost after three days of exposure to 60°C (140°F).

Field bindweed viability was reduced compared to the 30% in laboratory experiments at all locations in the bin, but not all were killed after three days. When field bindweed seeds were reburied for an additional three days during the second half of the manufacturing process, seed buried 0.3 m (1 ft) deep were not all killed but viability was reduced to 6% or less. Only 1% of seed were viable when buried 1.0 m (3 ft) deep and 0.6 m (2 ft) from the edge of the bin. Seed buried in the center of the bin or 1.6 m (5 ft) from the edge, were killed regardless of burial depth indicating temperatures in that part of the bin must have been at least 83°C (180°F). This was the temperature required to kill bindweed seed in compost with seven days of exposure in laboratory experiments. Temperature in other parts of the bin must have been less in order for some field bindweed to survive.

Table 2. Percent viable seed of Johnsongrass and pigweed after exposure to several oven temperatures in and out of compost*

		Johnsongrass		Pigweed	
Temperature† (°C)	Exposure Time (d)	Compost	No Compost	Compost	No Compost
		Viable Seed (%)			
49	1	3(±2)	58(±6)	7(±1)	46(±1)
	3	0	85(±2)	0	85(±4)
	7	0	34(±5)	0	26(±5)
	30	0	70(±2)	0	61(±8)
60	1	0	25(±5)	0	53(±5)
	3	0	24(±7)	0	50(±3)
	7	0	24(±2)	0	60(±7)
	30	0	30(±2)	0	41(±4)
72	3	0	0	0	0
	7	0	0	0	0
	30	0	0	0	0

* Numbers in parentheses are SE.
† 49, 60, and 72°C = 120, 140, and 160°F.

Table 3. Percent viable seed of kochia and barnyardgrass after exposure to several oven temperatures in and out of compost*

		Kochia		Barnyardgrass	
Temperature† (°C)	Exposure Time (d)	Compost	No Compost	Compost	No Compost
		Viable Seed (%)			
49	1	0	44(±1)	21(±1)	25(±2)
	3	0	42(±5)	0	23(±3)
	7	0	37(±2)	0	20(±3)
	30	0	32(±2)	0	18(±3)
60	1	0	24(±1)	0	15(±4)
	3	0	27(±2)	0	20(±2)
	7	0	35(±3)	0	20(±2)
	30	0	48(±6)	0	24(±4)
72	3	0	0	0	0
	7	0	0	0	0
	30	0	0	0	0

* Numbers in parentheses are SE.
† 49, 60, and 72°C = 120, 140, and 160°F.

Table 4. Percent viable seed of sorghum and field bindweed after exposure to several oven temperatures in and out of compost*

		Sorghum		Field Bindweed	
Temperature† (°C)	Exposure Time (d)	Compost	No Compost	Compost	No Compost
		Viable Seed (%)			
49	1	7(±2)	83(±6)	- ‡	-
	3	0	59(±10)	-	-
	7	0	55(±11)	-	-
	30	0	73(±10)	-	-
60	1	0	80(±10)	34(±5)	34(±3)
	3	0	74(±3)	27(±3)	31(±7)
	7	0	74(±7)	38(±3)	31(±2)
	30	0	68(±4)	25(±2)	31(±3)
72	3	0	0	23(±3)	27(±3)
	7	0	0	28(±2)	26(±3)
	30	0	0	30(±5)	32(±5)
83	1	-	-	21(±7)	34(±4)
	3	-	-	2(±2)	16(±5)
	7	-	-	0	7(±2)
	30	-	-	0	5(±2)

* Numbers in parentheses are SE.
† 49, 60, 72, and 83°C = 120, 140, 160, and 180°F.
‡ No data were obtained for these temperatures.

Table 5. Percent viable seed of field bindweed following placement in compost bin at manufacturing plant*†

		Viable Seed		
		Depth of Seed Packet (m)		
Exposure Time	Location from Wall (m)	0.3 (%)	0.6 (%)	1.0 (%)
3 d‡	0.3	7(±3)	8(±2)	16(±1)
	0.6	10(±3)	6(±1)	3(±1)
	1.6	10(±2)	3(±1)	10(±1)
6 d§	0.3	3(±2)	6(±1)	1(±1)
	0.6	0	0	1(±1)
	1.6	0	0	0

* Seed of Johnsongrass, pigweed, kochia, barnyardgrass, and sorghum were killed at all locations in the bin in three days.
† Numbers in parentheses are SE.
‡ Seed were buried for three days before turning compost in bin.
§ Seed were reburied for a second three days before compost was piled outside.

Seed of field bindweed buried 0.6 m (2 ft) deep in the outside holding pile were killed when buried for 12, 19, or 29 days. Seed of other species were not buried in this holding pile because they were all killed in the first three days of the initial composting process. These results indicate temperature 0.6 m (2 ft) deep in the holding pile was about 83°C (180°F). In the laboratory, field bindweed buried in compost were killed with seven days or more exposure at 83°C (180°F). Unfortunately, seed of field bindweed were not buried at shallower depths in the pile where temperatures most likely were lower.

Conclusion

In these experiments the process used to manufacture compost in bins from cattle feedlot manure killed most seed of six species including johnsongrass and field bindweed, both noxious perennial weeds. Consequently the compost would be safe to use on lawns, nurseries, and agricultural land without fear of introducing troublesome weeds. Laboratory experiments showed that a composting process will kill all common weed seed if temperature is maintained at least 83°C (180°F) for longer than three days. Reaching and maintaining this temperature in bins would be easy to achieve. Small composting operations that do not meet these temperature and exposure time requirements may kill most annual weed seed but not all noxious weed seed like field bindweed.

References

Atkeson, F. W., H. W. Hulbert, and T. R. Watten. 1934. Effect of bovine digestion and manure storage on viability of weed seed. *Agron. J.* 26: 390-397.

Beach, C. L. 1908. Viability of seed seeds in feeding stuffs. *Vermont Agric. Exp. Stn. Bull.* 138: 11-20.

Blackshaw, R. E., and L. M. Rode. 1991. Effect of ensiling and rumen digestion by cattle on weed seed viability. *Weed Sci.* 39: 104-108.

Brown, E. O., and H. Porter. 1942. The viability and germination of seeds of *Convoluvulus arvensis* L. and other perennial weeds. *Iowa Res. Bull.* 294: 473-504.

Butchbaker, A. F., J. E. Garton, G. W. A. Mahoney, and M. D. Paine. 1971. Evaluation of beef feedlot waste management alternatives. In *Livestock Waste Management and Pollution Abatement. Proc. Int'l Symp. Livestock Wastes*. St. Joseph, Mich.: ASAE.

Cudney, D. W., S. D.Wright, T. A. Schultz, and J. S. Reints. 1992. Weed seed in dairy manure depends on collection site. *California Agric.* 46: 31-32.

Darlington, H. T., and G. P. Steinbauer. 1961. The 80 yr period for Dr. Beal's seed viability experiment. *Am. J. Bot.* 48: 321-325.

Egley, G. H., and J. M. Chandler. 1983. Longevity of weed seeds after 5.5 years in the Stoneville 50-year buried seed study. *Weed Sci.* 31: 264-270.

Harmon, G. W., and F. D. Keim. 1934. The percentage and viability of weed seeds recovered in the feces of farm animals and their longevity when buried in manure. *Agron. J.* 26: 762-767.

Hume, L., and O. W. Archibold. 1986. The influence of weedy habitat on the seed bank of an adjacent cultivated field. *Canadian J. Bot.* 64: 1879-1883.

Hunset, M. A. 1993. Livestock statistics. In *USDA, Agricultural Statistics*, 235. Austin, Tex.: USDA, Texas Dept. of Agriculture.

Lewis, J. 1973. Longevity of crop and weed seed after 20 years in soil. *Weed Res.* 13: 179-191.

Mt. Pleasant, J., and K. S. Schlather. 1994. Incidence of weed seed in cow manure and its importance as a weed source for cropland. *Weed Technol.* 8: 304-310.

Steinbauer, G. P., and B. Grigsby. 1959. Methods of obtaining field and laboratory germination of seeds of bindweeds, lady's thumb, and velvet leaf. 1959. *Weeds* 7: 41-46.

Stoller, E. E., and L. M. Wax. 1974. Dormancy, and the fate of some annual weed seeds in the soil. *Weed Sci.* 22: 151-155.

Sweeten, J. M. 1989. Composting manure and sludge. Texas Agric. Ext. Serv. L-2289. College Station, Tex.: Texas A&M University.

Timmons, F. L. 1949. Duration of viability of bindweed seed under field conditions and experimental results in the control of bindweed seedlings. *Agron. J.* 41: 130-133.

Zamora, D. L., and J. P. Olivarez. 1994. The viability of seeds in feed pellets. *Weed Technol.* 8: 148-153.