United States Department of Agriculture

FINAL STUDY REPORT
NORMAN A. BERG NATIONAL PLANT MATERIALS CENTER, BELTSVILLE, MD

Plants Tolerant of Poultry Farm Emissions in the Chesapeake Bay Watershed

Shawn V. Belt, Horticulturist

Abstract

A relatively low cost technology capable of mitigating dust, odor and ammonia emissions resulting from poultry farms, vegetative environmental buffers (VEBs) improve air quality in a variety of ways. This study's objective is to expand the variety of plants, to make successful VEBs. The palette of new plants included in this study is 40 species (9 grasses, 27 deciduous shrubs/trees and 4 evergreens).

Studies were conducted from 2010 – 2014 at 14 different test farms to evaluate survival near sidewall, single and double tunnel ventilation fans. A minimum of 10 plants, three seasons of performance for woody plants or two for grasses were required before being recommended. Survival and size evaluations took place each autumn, at only one farm were controls also planted and monitored.

Results

Plant Survival: Fifteen of the 40 different plants tested (38%) had survival percentages above 60% over a two (grasses) or three year period (woody). Eight of the forty species tested (20%) had survival percentages below 60% are intolerant of poultry farm emissions. Seventeen plants (43%) require further testing to determine emission tolerance.

Ventilation fan type: Twenty-one different plants tolerate single tunnel fan emissions, 6 different plants tolerate double fan emissions and 5 different plants tolerate side wall fan emissions.

Distance between fans and plantings: Plants survive and grow only 20' from single bank, double bank and side wall ventilation fans. This allows producers additional land for cultivation and potentially more ammonia absorption.

Conclusion

This study confirmed that 15 plant species are successful for use in VEBs ameliorating air and water quality concerns. Confirming that poultry planners have additional options when considering plants for poultry emission mitigation.

Contents

Abstract 1
Results 1
Conclusion 1
1 Introduction 3
1.1 Benefits 4
1.2 Drawbacks 4
1.3 Considerations 4
1.4 Ventilation Fans 5
1.5 Resource Concerns 6
1.5.1 Ammonia 6
1.5.2 Odors and Dust 6
2 Design 8
3 Results 10
3.1 Distance between Fans and Plantings 10
3.2 Double Fan Banks 11
3.3 Plant Performance 11
Table 1: Test farm information 12
3.4 Grasses 13
3.5 Deciduous Trees and Shrubs 13
3.6 Evergreen Trees and Shrubs 14
Table 2: Plant survival results **15**
4 Conclusions 23
References 23

1 Introduction

This progress report pertains to MD, DE, PA and VA hedgerow (422) and windbreak establishment (380) practice standards. Practice 422 is the primary practice currently used near poultry houses as it allows woody and herbaceous plants, whereas 380 allows only woody plants.

The Chesapeake Bay Watershed has considerable concentrations of poultry farms (Figure 1). Maryland was ranked the 10th largest poultry farming state in 2010 producing nearly 300 million chickens representing 40 percent of the state's farm revenue. With rising public awareness of the health of the Chesapeake Bay, Mid-Atlantic poultry producers and integrators are leading the country in implementing practices decreasing their environmental impact while efficiently producing food for a growing population.

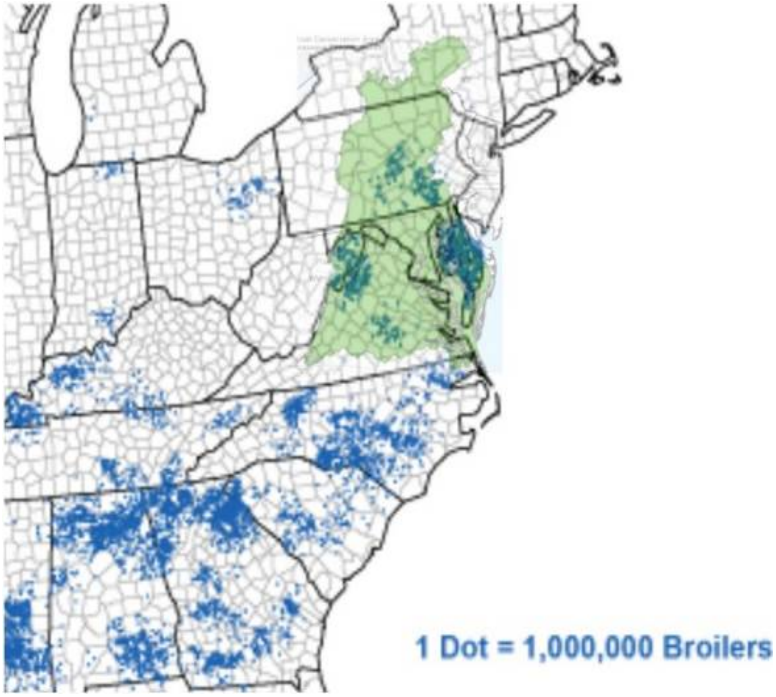

Figure 1: 2007 Broiler production in the Chesapeake Bay Watershed (highlighted in green) and eastern U.S. (National Agricultural Statistical Service).

Over ten years ago, Delmarva peninsula poultry producers began planting strategically placed trees, shrubs and grasses around their farms , based on the idea that windbreaks or hedgerows – also known as vegetative environmental buffers (VEBs) (Figure 2) -- capture ammonia, dust, odors and viruses and/or decrease their dissemination into the environment. The challenging conditions near poultry house exhaust fans hinder or kill some plants while stimulating growth in others.

Figure 2: This broiler farm's 4-year-old vegetative environmental buffer is a cost-effective way to improve aesthetics while addressing air and water quality concerns.

1.1 Benefits

The following benefits were identified:

- Filter and trap dust, reduce odors by 57% (Parker, 2011) and ammonia by 29 to 67% at 9 – 14.6 meters from the exhaust fans (Malone, 2004; Malone et al., 2006) by slowing exhaust fan air speed. (Patterson, 2008)
- Filter water, nutrients and sediments by slowing and/or buffering roof, road and barnyard runoff.
- A reasonably inexpensive technology that may have increased effectiveness over time.
- Flexible stemmed grasses and hybrid willows do not compromise fan performance and actually improve performance by blocking cross winds (H. Li and W. Brown, personal communication, 2014).
- Sequesters carbon

1.2 Drawbacks

- May take 3 – 5 years to become effective.
- May need a significant amount of land to provide optimum benefits.
- May harbor rodents and other pests.

1.3 Considerations

- Careful design is needed to avoid snow deposition on roads, buildings etc.
- Not a silver bullet eliminating the need for other technologies and practices.
- Irrigation, weed control and maintenance are essential, particularly during the first 2-4 growing seasons.

1.4 Ventilation Fans

Figure 3: A five-year-old 'Valley Forge' American elm growing near two side wall fans. Faster growth was observed for this tree compared to elms not exposed to ventilation fans.

There are two different types of ventilation fans: sidewall and tunnel. They vary with farm type (broiler, egg, or turkey) and farm age. Select plants for the discharge area based on the ventilation fan type. Outside this area, plants are largely unaffected. Fan operation is staged, running sequentially on temperature and humidity thresholds.

Sidewall fans (Figure 3) are generally three feet in diameter, occur periodically along the length of the house. Operate primarily when birds are young, discharge concentrated emissions and have received the least amount of plant testing.

Tunnel fans (Figure 4, bottom) are typically more than four feet in diameter and are located at the ends of houses. In comparison to sidewall fans, tunnel fans discharge more air. However the air contains a lower concentration of contaminants.

Producers are concerned that VEBs impede fan performance and air flow. Recent tests (H. Li and W. Brown, personal communication) show that flexible stemmed grasses and deciduous trees actually improve fan performance by blocking cross winds.

1.5 Resource Concerns

1.5.1 Ammonia

Ammonia is a "sticky" gas which tends to adhere to surfaces. It is captured by plant leaves (Krupa 2003) and volatilizes quicker at higher temperatures (Sommer 1991). Increased foliar nitrogen in plants outside of fan-ventilated poultry houses and decreased atmospheric ammonia around VEBs suggest that ammonia dissipates with distance and plants reduce ammonia concentration through their presence (Adrizal et al., 2006 and Patterson et al 2008). VEB field studies yielded ammonia reductions of 29 – 67% 9 – 14.6 meters from ventilation fans (Malone, 2004; Malone et al., 2006) Different plants capture ammonia at varying rates (Patterson et al 2008). Tomatoes, pines, cucumbers, conifers, soybeans, and fescue are killed (Van der Eerden et al., 1998). Elm, switchgrass and giant cane (Figures 3 and 4) grow quicker when exposed to air with higher ammonia concentrations. Broiler farms discharge higher amounts of ammonia compared to egg farms due to litter being removed less frequently.

Figure 4: Effects of ammonia on plant growth. Soybeans (top left) 60 feet from tunnel fans and fescue turf (top right) exhibit ammonia phytotoxicity. Giant cane (*Arundinaria gigantea*) and Timber germplasm switchgrass (bottom) grow more quickly. Staged dominant fans on the right, may provide higher ammonia concentrations resulting in increased growth.

1.5.2 Odors and Dust

Odors generated in a poultry house exit through the fans and travel downwind to neighboring properties. Odor is carried on dust particles. Therefore reducing dust also reduces odors. Dust, also known as particulate matter (PM), is classified according to size, as either 2.5 ($PM_{2.5}$) or 10 (PM_{10}) microns. Dusts (both $PM_{2.5}$ and PM_{10}) are regulated by the U.S. Environmental Protection Agency (EPA).

Plants potentially abate odor by several mechanisms:

- Dilute and mix upward forced odors (figure 5).
- Reduced wind speeds cause odor bearing particles to settle out (figure 5).
- Intercept and collect dusts and particles on leaves and other plant surfaces (figure 8).
- Leaves absorb and adsorb odors.

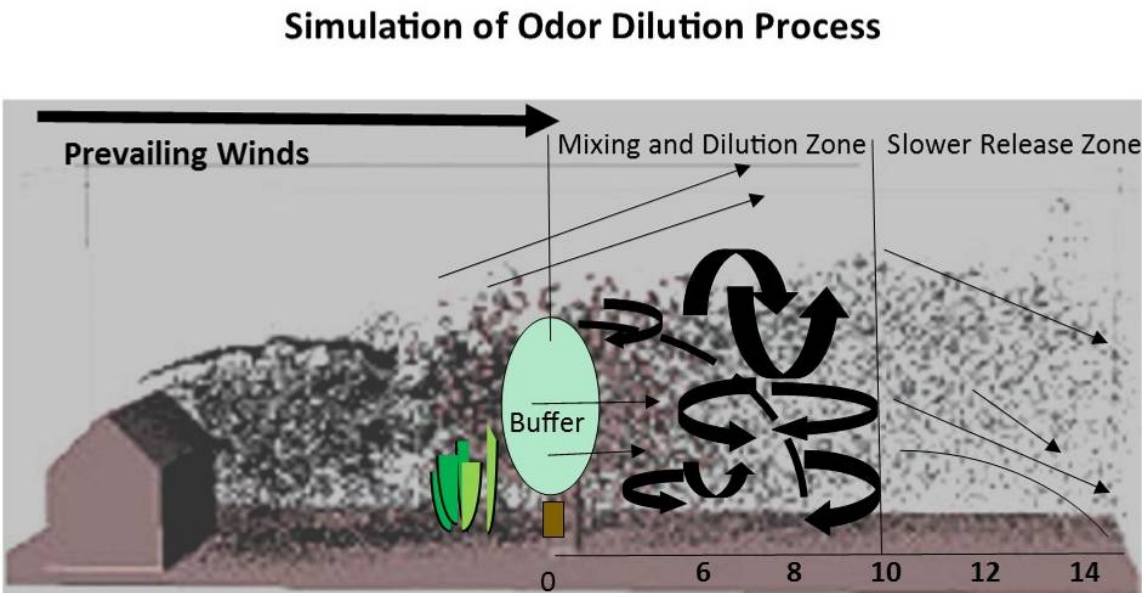

Figure 5: This diagram simulates the distribution of dust and odors. Deposition primarily occurs at a distance greater than 10 times the height of the buffer (not to scale). Research is underway quantifying and defining this model. (Adapted by Raine (1974) and used in McNaughton (1988) Computer simulation by Lammers et al 2001.)

2 Design

Plant selection and arrangement varies depending upon various factors. Every poultry farm is different. Where site conditions and funds allow, place plantings around the majority of the farm perimeter. A well designed buffer diminishes the amount of emissions that travel off the property. Buffers positioned closer to poultry houses contain or limit dispersion of more emissions than those further away (Lin et al 2006, Patterson 2008). Design buffers based on the following factors:

- Taller VEBs reduce wind speed over greater distances (figure 5).
- Effectiveness improves when bands are oriented perpendicular to prevailing winds. (figures 5 and 6) (Brandle, 1991)
- Long uninterrupted VEB's (at least 10 times as long as high) are more effective than shorter ones with gaps. (Brandle, 1991, 2009)
- Wider ("deeper") VEB's are more effective than narrower ones. (Brandle, 2009)

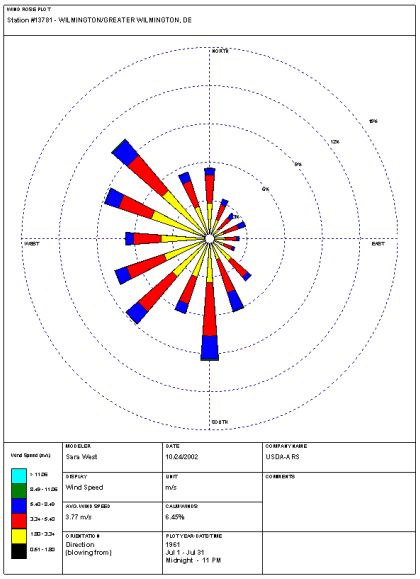

Figure 6: A wind rose shows the direction, frequency and speed of wind for Wilmington DE in July. For additional information viisit:
http://www.nrcs./windrose.html
http://www.iastate/animalhousing/siting/.html

Figure7: An aerial view of a Delmarva Peninsula poultry farm showing buffer design and the types of plants used. Grasses and deciduous trees/shrubs are primary filters while evergreens improve visual aesthetics. Figure 6 emphasizes shielding the NW, SW, and S aspects of the farm since summer winds mostly occur from those directions

Select plants based on the following factors:

- Soil type, drainage and moisture conditions.
- Mature height and spread of the plant, taller plants reduce wind speed over a greater distance. (figure 6)
- USDA plant hardiness range. http://planthardiness.ars.usda.gov/.
- Growth rate.
- Native or introduced species.
- Plants with smaller leaves trap more dust and odors than plants with larger leaves (varies with species) (Asman 2008).
- Rough leaf surfaces (leaf hairs, veins). (Figure 8)
- Low branching (shrubs and trees) or leaves extend to the ground (grasses)

Figure 8: The rough leaf surface of switchgrass (left) and large surface area of 'Streamco' willow (right) trap dust and odors, particularly when the flocks are at their largest size. Rains with time typically wash the leaves of this accumulation.

Research is currently underway determining optimal distances and plant arrangements.

It is usually best to select several different species of trees and shrubs for use in buffers. This helps prevent the loss or decline of the entire buffer due to insect pest infestation or plants diseases. Diversity also offers a better chance for survival during alternating seasons of drought and/or wet soil conditions.

To provide an effective buffer, a combination of plants with varying growth rates should be used in the overall design. Within each row, select species with similar growth rates to provide an even height. Faster growing plants which provide quick visual screening generally are short-lived and will need to be replaced sooner than slower growing plants.

3 Results

3.1 Distance between Fans and Plantings

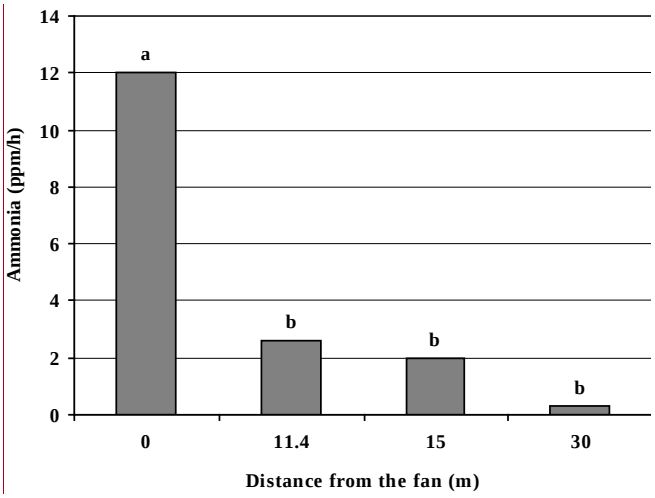

Figure 10: Ammonia levels are lower as distance from fans increases (graph Adrizal et al 2008).

Figure 11: Hybrid willows will survive growing within 20 feet from fans.

The closer the buffer is positioned to the fans, the more effective it is in trapping, and dispersing the odor, dust and ammonia (Lin et al 2006). However, plant survival and fan performance must also be considered when planting buffers near fans.

Producers want to use as little land as possible for buffers since this takes land out of production. Ammonia levels initially dissipate quickly (figure 10) due to both proximity of the planting and plant uptake (Adrizal et al., 2008a, Adrizal et al., 2008b).

Standards currently place VEBs at distances over 10 times the total tunnel fan width. Recent testing shows that some plants are capable of growing within 20 feet from ventilation fans (figures 4 (bottom), and 11). Updating the standards to allow a closer planting distance from the fans will result in increased ammonia absorption saving producer's land for production.

3.2 Double Fan Banks

Double fan banks have a significant impact on plant survival. Emissions from two houses contribute to high mortality rates (Figures 12). Irrigation is difficult to install but will optimize shrub and tree growth. However it is unnecessary for grass establishment.

Figure 12: Switchgrass (front), osage orange and black locust (rear) reduce emissions (denoted by blue arrows) that are pushed up and off the farm by prevailing winds. Tables 2 and 3 list other species capable of surviving in this area, the harshest growing environment on a poultry farm.

3.3 Plant Performance

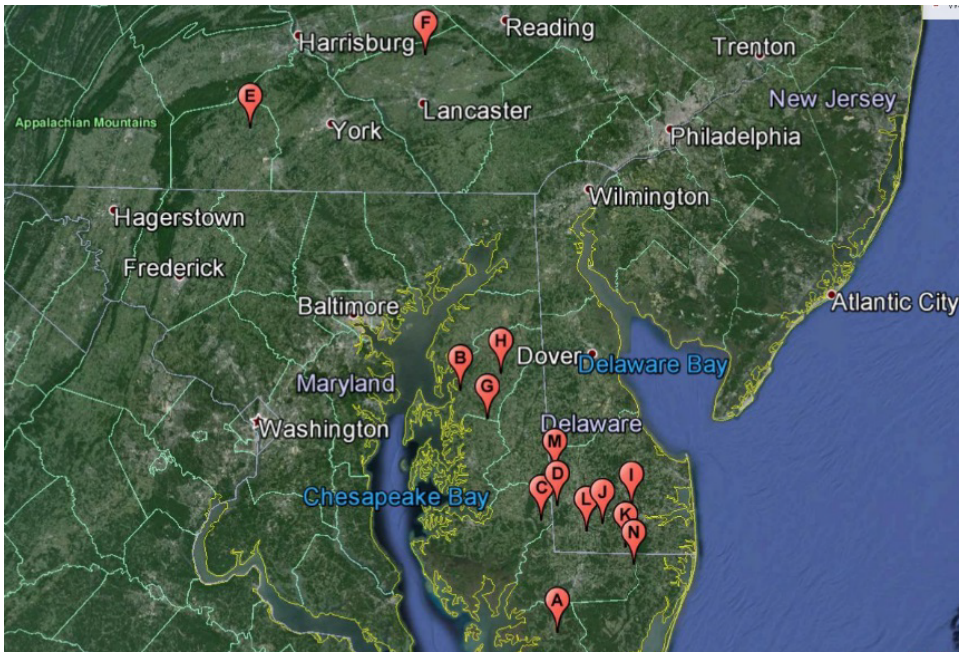

Figure 13: Map of the 14 different MD, DE and PA test farms.

The Norman A. Berg National Plant Materials Center, Delmarva Poultry Industry (DPI), Pennsylvania State University and Big Flats Plant Materials Center planted VEBs on 14 test farms from 2009 – 2011 (figure 13).

These VEBs were planted in the late summer/early autumn which lessened the need for irrigation. It was determined that a minimum of 10 plants and two growing seasons of survival were needed before recommending grasses and three seasons of survival were needed for deciduous shrubs/trees and evergreens. A number of factors which influence plant survival -- including irrigation, fan type and distance (degree of emission exposure), soil type and the degree to which the producer maintained the VEB -- made it challenging to distinguish which factor(s) caused plant death.

Table 1: Test farm information

Farm*	Year Planted	Location	Type	Fan type(s)**	Irrigation/type	Soil Classification
A	2002	Somerset Co., MD	Broiler	T	none	Othello silt loam (0-2% slope)
B	2007	Queen Anne Co., MD	Broiler	SW, T	none	Matapeake silt loam (0-2% slope)
C	2009	Dorchester Co., MD	Broiler	T^2	none	Ingleside sandy loam (0-1% slope)
D	2010	Sussex Co., DE	Broiler	T, T^2	none	Rosedale loamy sand (0-1% slope)
E	2010	Adams Co., PA	Egg	T	Tape	Penn Silt loam (3-8% slope)
F	2011	Lancaster Co., PA	Broiler	T	Drip, Tape	Lindside silt loam (0-2% slope) Bedington silt loam (3-16% slope)
G	2011	Talbot Co., MD	Broiler	T	none	Mattapex sandy loam(0-2% slope)
H	2011	Queen Anne Co., MD	Broiler	T, T^2	none	Mattapex-Butlertown silt loams (0-2% slope)
I	2011	Sussex Co., DE	Broiler	T	none	Pepperbox-Rosedale complex (0-2% slope)
J	2011	Sussex Co., DE	Broiler	SW, T, T^2,	Drip	Pepperbox-Rosedale complex (0-2% slope)
K	2011	Sussex Co., DE	Broiler	SW	Drip	Klej-Galloway complex (0-5% slope)
L	2011	Sussex Co., DE	Broiler	SW	Drip	Hammonton sandy loam (0-2% slope)
M	2011	Sussex Co., DE	Broiler	SW, T	Drip	Woodstock sandy loam (0-2% slope)
N	2011	Wicomico Co., MD	Broiler	T, T^2	Drip	Hurlock sandy loam (0-2% slope)
*See figure 13 for locations				**SW side wall fans, T tunnel fans, T^2 double fans		

3.4 Grasses

Grasses are generally planted in the band closest to the fans (Figure 7). Durable, inexpensive, they are increasingly popular with poultry producers. For drier, sunnier, hotter sites, warm-season grasses perform well (switchgrass, figure 8). Delmarva Peninsula well water (south of Georgetown, DE) is frequently high in dissolved minerals (hard water). Water conditioners correct this problem but discharge saline water. Smooth and saltmarsh cordgrasses tolerate these saline sites (figure 14).

Figure 14: Saltmarsh cordgrass tolerates both tunnel fan and water conditioner discharge areas. Smooth cordgrass also tolerates this saline site. Photo courtesy Jim Passwaters Delmarva Poultry Industry.

Grasses have the following attributes:

- Warm-season grasses grow during the summer when the tunnel fans are most active and ammonia volatizes quicker.
- Deer resistant.
- High dust and odor filtering ability. (Figure 8)
- Most efficient when used with subsequent bands of trees and evergreens.
- Perform best in full sun, may become shaded and stunted if planted to closely to fast growing trees (especially willows).

3.5 Deciduous Trees and Shrubs

Shrubs and trees' height is key to concentrating fan emissions downward into the buffer (figure 15). They filter emissions during the growing season when the fans are operating (Figure 8 right). Deciduous plants, however, drop leaves in the autumn when the fans are not as active. They will then leaf out in the spring, repeating this process. They tolerate heat, desiccation and other environmental factors, however their growth rate, mature size and longevity are probably depressed by these stresses.

Figure 15: Three bands of plants combine providing effective emission mitigation. Hackberries are tough, adaptable to dry, wet or infertile soils, and low branching which make them ideal for these situations.

3.6 Evergreen Trees and Shrubs

Figure 16: Producers are reluctant to sacrifice land for VEBs, sometimes installing one band of evergreens or placing them too closely to tunnel fans. Planting grasses and deciduous plants ahead of the evergreens would remedy this.

Figure 17: 'Manhattan' Euonymus is one of the few evergreens to capable of growing directly behind tunnel fans. These Eastern Shore plants are only 20 feet from tunnel fans. Slow growing and relatively free of pests and diseases; they eventually reach ten feet in height and spread.

Evergreens planted around the farm perimeter (figure 7) provide year-round visual screening. Choosing the right species and planting them at the proper distance from fans are important considerations for selecting evergreen plants. If dust does not easily wash off leaves, they can become overloaded and the plant eventually die. For example, arborvitae can be an effective dust-trapping species. But it chokes to death with dust – trapping so much that respiration and photosynthesis are reduced resulting in plant death (figure 16). It should also be noted that a curved planting is easier to cultivate and offers a more pleasing appearance than one with squared corners.

'Manhattan' Euonymus tolerates dust and ammonia and can be planted directly behind ventilation fans (figure 17), conserving land for production. A slow growing plant, it has somewhat limited use by producers. White and loblolly pines are not tolerant of high ammonia levels, although they may be an option for use in non-discharge areas.

Table 2: Plant survival results

Farm[1]	Name[2]	Botanical Name	Variety	Fan Dist. (ft.)	Fan Type[4]	Survival %	# tested	# lived	Notes/Results
E	Big Bluestem	*Andropogon gerardii*		30	T	87	15	13	
F	Big Bluestem	*Andropogon gerardii*	Niagara	45	T	42	73	31	Poor performance behind fans.
G	Big Bluestem	*Andropogon gerardii*		20	T	25	8	2	
H	Big Bluestem	*Andropogon gerardii*		20	T	53	15	8	
	Total					**49**	**111**	**54**	**Poor Performer**
C	Emoryi's Sedge	*Carex emoryii*		30	T^2	0	5	0	
D	Emoryi's Sedge	*Carex emoryii*		30	T	0	6	0	
H	Emoryi's Sedge	*Carex emoryii*		20	T	0	6	0	
	Total					**0**	**17**	**0**	**Poor Performer**
E	Coastal panicgrass	*Panicum amarum var. amarulum*	Atlantic	30	T	100	24	24	Good establishment but dead after 3 yrs., wet soil.
	Total					**100**	**24**	**24**	**Good Performer T (dry sites)**
F	Switchgrass	*Panicum virgatum*	Timber	20	T, T^2	100	22	22	Limited commercial availability.
C	Switchgrass	*Panicum virgatum*	Kanlow	30	T, T^2	92	84	77	
E	Switchgrass	*Panicum virgatum*	Northwind	30	T, T^2	89	81	72	Stiff stemmed ornamental.
E	Switchgrass	*Panicum virgatum*	Thundercloud	30	T, T^2	73	30	22	Tallest switchgrass variety tested. Plant variety protected against open propagation.
	Total					**89**	**217**	**193**	**Good Performer T, T^2**

[1]Farm Location in figure 13
[2]Grasses in red, Trees/shrubs in blue and Evergreens in green with hot links to additional information
[3]Nonnative plant
[4]SW side wall fans, T tunnel fans, T^2 double fans

Farm[1]	Name[2]	Botanical Name	Variety	Fan Dist. (ft.)	Fan Type[4]	Survival %	# tested	# lived	Notes/Results
C	Florida Paspalum	*Paspalum floridanum*	Mid-Atlantic	20	T^2	0	4	0	Established well but declined quickly.
D	Florida Paspalum	*Paspalum floridanum*	Mid-Atlantic	20	T^2	0	3	0	
E	Florida Paspalum	*Paspalum floridanum*	Mid-Atlantic	20	T	0	14	0	
F	Florida Paspalum	*Paspalum floridanum*	Mid-Atlantic	20	T	0	13	0	
	Total					**0**	**34**	**0**	**Poor Performer**
H	Silver Plumegrass	*Saccharum alopecuroides*		20	T, T^2	0	2	0	
M	Silver Plumegrass	*Saccharum alopecuroides*		20	T, T^2	0	2	0	
	Total					**0**	**4**	**0**	**Further Testing Necessary T, T^2**
F	Prairie Cordgrass	*Spartina pectinata*	Southampton	20	T	100	7	7	
J	Prairie Cordgrass	*Spartina pectinata*	Southampton	20	T	100	12	12	
	Total					**100**	**19**	**19**	**Good Performer T**
C	Eastern gamagrass	*Tripsacum dactyloides*	Highlander	20	T^2	75	4	3	
H	Eastern gamagrass	*Tripsacum dactyloides*	Pete	20	T^2	0	6	0	
	Total					**30**	**10**	**3**	**Further Testing Necessary**
F	Sea Oats Grass	*Uniola paniculata*		45	T	0	5	0	
H	Sea Oats Grass	*Uniola paniculata*		20	T	0	5	0	
M	Sea Oats Grass	*Uniola paniculata*		20	T	0	5	0	
	Total					**0**	**15**	**0**	**Poor Performer**
A	Red maple	*Acer rubrum*		25	T, T^2	100	3	3	

[1]Farm Location in figure 13
[2]Grasses in red, Trees/shrubs in blue and Evergreens in green with hot links to additional information
[3]Nonnative plant
[4]SW side wall fans, T tunnel fans, T^2 double fans

Farm[1]	Name[2]	Botanical Name	Variety	Fan Dist. (ft.)	Fan Type[4]	Survival %	# tested	# lived	Notes/Results
E	Red maple	*Acer rubrum*		30	T	100	8	8	Deer browse problematic.
	Total					**100**	**10**	**10**	**Good Performer T, T[2]**
B	Hazel Alder	*Alnus serrulata*	Panbowl	25	T[2]	0	2	0	
C	Hazel Alder	*Alnus serrulata*	Panbowl	25	T[2]	0	2	0	
D	Hazel Alder	*Alnus serrulata*	Panbowl	25	T[2]	67	3	2	Mesic to wet soil.
F	Hazel Alder	*Alnus serrulata*	Panbowl	30	T	0	8	0	
G	Hazel Alder	*Alnus serrulata*	Panbowl	30	T	50	2	1	
H	Hazel Alder	*Alnus serrulata*	Panbowl	25	T[2]	0	3	0	
	Total					**15**	**20**	**2**	**Poor Performer except wet sites**
F	Chinkapin	*Castanea pumila*	Golden	30	T	100	2	2	
	Total					**100**	**2**	**2**	**Further Testing Necessary T**
F	Netleaf Hackberry	*Celtis laevigata var. laevigata*		24 - 35	T	8	8	8	
	Total					**100**	8	8	**Good Performer T**
I	Common Hackberry	*Celtis occidentalis*		25	T	100	3	3	
	Total					**100**	**3**	**3**	**Good Performer T, T[2]**
C	Dwarf Hackberry	*Celtis tenuifolia var. pumila*		25	T[2]	100	1	1	
G	Dwarf Hackberry	*Celtis tenuifolia var. pumila*		30	T	100	2	2	
H	Dwarf Hackberry	*Celtis tenuifolia var. pumila*		30	T	100	3	3	
I	Dwarf Hackberry	*Celtis tenuifolia var. pumila*		25	T	100	3	3	
J	Dwarf Hackberry	*Celtis tenuifolia var. pumila*		30	T	100	3	3	

[1]Farm Location in figure 13
[2]Grasses in red, Trees/shrubs in blue and Evergreens in green with hot links to additional information
[3]Nonnative plant
[4]SW side wall fans, T tunnel fans, T[2] double fans

Farm[1]	Name[2]	Botanical Name	Variety	Fan Dist. (ft.)	Fan Type[4]	Survival %	# tested	# lived	Notes/Results
	Total					**100**	12	12	**Good Performer T**
M	Redosier dogwood	*Cornus sericea*		25	T	0	3	0	
	Total					**0**	3	0	**Further Testing Necessary**
D	Spreading Euonymus[3]	*Euonymus kiautschovicus*	Manhattan	20	T	100	10	10	
G	Spreading Euonymus[3]	*Euonymus kiautschovicus*	Manhattan	40	T	100	8	8	
	Total					**100**	18	18	**Good Performer T**
M	Honeylocust	*Gleditisia triancanthos var. inermis*		30	T^2	100	3	3	Root suckering.
	Total					**100**	3	3	**Good Performer** T^2 (Adrizal et al 2006)
M	Yaupon	*Ilex vomitoria*		30	T^2	100	1	1	
	Total					**100**	1	1	**Further Testing Necessary**
D	Osage orange	*Maclura pomifera*	Whiteshield	25	T^2	75	4	3	
F	Osage orange	*Maclura pomifera*	Whiteshield	24 - 35	T	50	4	2	
	Total					**63**	8	5	**Further Testing Necessary T,** T^2
K	Dawn Redwood[3]	*Metasequoia glyptostroboides*		25	SW	100	8	8	
J	Dawn Redwood[3]	*Metasequoia glyptostroboides*		25	SW	100	10	10	
	Total					**100**	18	18	**Good Performer SW**
C	Wax Myrtle	*Morella cerifera*		25	T^2	0	1	0	Questionable winter hardiness.
G	Wax Myrtle	*Morella cerifera*		30	T^2	0	1	0	
	Total					**0**	2	0	**Poor Performer when paired with Northern Bayberry results**

[1]Farm Location in figure 13
[2]Grasses in red, Trees/shrubs in blue and Evergreens in green with hot links to additional information
[3]Nonnative plant
[4]SW side wall fans, T tunnel fans, T^2 double fans

Farm[1]	Name[2]	Botanical Name	Variety	Fan Dist. (ft.)	Fan Type[4]	Survival %	# tested	# lived	Notes/Results
C	Northern bayberry	*Morella pennsylvanica*		25	T[2]	0	1	**0**	
D	Northern bayberry	*Morella pennsylvanica*		25	T[2]	50	2	1	
E	Northern bayberry	*Morella pennsylvanica*		30	T	88	9	8	minimal growth
F	Northern bayberry	*Morella pennsylvanica*		30	T	0	5	0	
H	Northern bayberry	*Morella pennsylvanica*		30	T[2]	0	2	0	
N	Northern bayberry	*Morella pennsylvanica*		30	T	100	1	1	
	Total					**50**	**20**	**10**	**Poor Performer**
A	American Sycamore	*Platanus occidentalis*		20	SW, T	100	3	3	Roots extending to foundations may become problematic with age.
J	American Sycamore	*Platanus occidentalis*		40	T	100	1	1	
	Total					**100**	**4**	**4**	**Further Testing Necessary** SW, T **(large areas)**
E	hybrid Poplar[3]	*Populus deltoides x nigra*	Spike	45	T	100	7	7	Stunted size, additional testing necessary.
I	hybrid Poplar[3]	*Populus deltoides x nigra*	Spike	25	T	100	1	1	
	Total					**100**	**1**	**1**	**Further Testing Necessary**
E	Black Cherry	Prunus serotina		20	T	100	1	1	Plants started by seed deposited by birds.
M	Black Cherry	*Prunus serotina*		20	T	100	1	1	Plants started by seed deposited by birds.
	Total					**100**	**2**	**2**	**Further Testing Necessary**

[1]Farm Location in figure 13
[2]Grasses in red, Trees/shrubs in blue and Evergreens in green with hot links to additional information
[3]Nonnative plant
[4]SW side wall fans, T tunnel fans, T[2] double fans

Farm[1]	Name[2]	Botanical Name	Variety	Fan Dist. (ft.)	Fan Type[4]	Survival %	# tested	# lived	Notes/Results
A	Swamp white oak	*Quercus bicolor*		25	SW, T, T[2]	100	6	6	
	Total					**100**	**6**	**6**	**Further Testing Necessary** SW, T, T[2]
E	Chestnut Oak	*Quercus montana*		34	T	0	4	0	
F	Chestnut Oak	*Quercus montana*		24 - 35	T	100	4	4	
	Total					**50**	**8**	**4**	**Further Testing Necessary**
F	Northern red oak	*Quercus rubra*		24 - 35	T	100	4	4	
	Total					**100**	**4**	**4**	**Further Testing Necessary** T
C	Black Locust	*Robinia pseudoacacia*	Steiner	25	T[2]	0	1	0	
D	Black Locust	*Robinia pseudoacacia*	Steiner	25	T[2]	100	1	1	Some root suckering.
E	Black Locust	*Robinia pseudoacacia*	Steiner	34	T	64	11	7	
F	Black Locust	*Robinia pseudoacacia*	Steiner	24 - 35	T	100	4	4	
G	Black Locust	*Robinia pseudoacacia*	Steiner	30	T	50	2	1	
H	Black Locust	*Robinia pseudoacacia*	Steiner	25	T	100	1	1	
I	Black Locust	*Robinia pseudoacacia*	Steiner	25	T	100	1	1	
	Total					**72**	**21**	**15**	**Good Performer T**, T[2]
E	Purpleosier willow	*Salix purpurea*	Streamco	34	T	100	51	51	
	Total					**100**	**51**	**51**	**Good Performer T**
F	Japanese pagoda tree[3]	*Staphnolobium japonicum*		24 - 35	T	100	4	4	Deer browse problematic.

[1]Farm Location in figure 13
[2]Grasses in red, Trees/shrubs in blue and Evergreens in green with hot links to additional information
[3]Nonnative plant
[4]SW side wall fans, T tunnel fans, T[2] double fans

Farm[1]	Name[2]	Botanical Name	Variety	Fan Dist. (ft.)	Fan Type[4]	Survival %	# tested	# lived	Notes/Results
	Total					**100**	**4**	**4**	**Further Testing Necessary T**
D	Bald cypress	*Taxodium distichum*		25	T[2]	0	2	0	Deer browse problematic.
E	Bald cypress	*Taxodium distichum*		34	T	0	4	0	
F	Bald cypress	*Taxodium distichum*		24 - 35	T	100	4	4	
G	Bald cypress	*Taxodium distichum*		30	T	100	2	2	
J	Bald cypress	*Taxodium distichum*		30	SW	100	5	5	
L	Bald cypress	*Taxodium distichum*		20	SW	100	5	5	
M	Bald cypress	*Taxodium distichum*		25	SW	100	5	5	
	Total					**78**	**27**	**21**	**Good Performer T, SW**
G	American basswood	*Tilia americana*		30	T	100	2	2	
	Total					**100**	**2**	**2**	**Further Testing Necessary**
B	American Elm	*Ulmus americana*	Valley Forge, New Harmony	40	SW	50	2	1	Carefully prune to ensure upright growth, http://www.elmpruning/.htm.
C	American Elm	*Ulmus americana*	Valley Forge, New Harmony	25	T[2]	0	6	0	Carefully prune to ensure upright growth, http://www.elmpruning/.htm.
D	American Elm	*Ulmus americana*	Valley Forge, New Harmony	25	T[2]	0	1	0	Carefully prune to ensure upright growth, http://www.elmpruning/.htm.
E	American Elm	*Ulmus americana*	Valley Forge, New Harmony	40	SW	100	17	17	Carefully prune to ensure upright growth, http://www.elmpruning/.htm.

[1]Farm Location in figure 13
[2]Grasses in red, Trees/shrubs in blue and Evergreens in green with hot links to additional information
[3]Nonnative plant
[4]SW side wall fans, T tunnel fans, T[2] double fans

Farm[1]	Name[2]	Botanical Name	Variety	Fan Dist. (ft.)	Fan Type[4]	Survival %	# tested	# lived	Notes/Results
F	American Elm	*Ulmus americana*	Valley Forge, New Harmony	24 - 35	T	100	4	4	Carefully prune to ensure upright growth, http://www.elmpruning/.htm.
G	American Elm	*Ulmus americana*	Valley Forge, New Harmony	30	SW	82	11	9	Carefully prune to ensure upright growth, http://www.elmpruning/.htm.
	Total					**75**	**41**	**31**	**Good Performer T, SW with careful maintenance (pruning/training)**
I	Arrowwood Viburnum	*Viburnum dentatum*		25	SW	100	2	2	
M	Arrowwood Viburnum	*Viburnum dentatum*		25	SW	100	2	2	
	Total					**100**	**4**	**4**	**Further Testing Necessary SW**
E	Atlantic white cedar	*Chamaecyparis thyoides*		56	T	75	10	8	
	Total					**80**	**10**	**8**	**Good Performer T**
E	Eastern red cedar	*Juniperus virginiana*		56	T	75	8	6	Variable size and growth rate.
	Total					**75**	**8**	**6**	**Further Testing Necessary T**
F	Southern Magnolia	*Magnolia grandifolia*		24, 30	T	0	14	0	
H	Southern Magnolia	*Magnolia grandifolia*		25	T , T[2]	0	14	0	May perform well at 50' from fans.
	Total					**0**	**14**	**0**	**Poor Performer T, T[2] , Further Testing Necessary**
E	Arbovitae	*Thuja occidentalis*	Affinity	56	T	100	8	8	
	Total					**100**	**8**	**8**	**Further Testing Necessary T**

[1]Farm Location in figure 13
[2]Grasses in red, Trees/shrubs in blue and Evergreens in green with hot links to additional information
[3]Nonnative plant
[4]SW side wall fans, T tunnel fans, T[2] double fans

4 Conclusions

The study confirmed 15 plant species successful and 8 species unsuccessful as VEBs for ameliorating air and water quality concerns at poultry farms. Additional evaluations are necessary for 17 plants which were tested in insufficient quantities. Poultry planners have options when considering which plants mitigate emissions in the discharge area of poultry farm fans.

References

Adrizal, A., Patterson, P., Hulet, R., Bates, R. 2006. Growth and Foliar Nitrogen Status of Four Plant Species Exposed to Atmospheric Ammonia. Journal of Environmental Science and Health. Part B Pesticides, Food Contaminants and Agricultural Wastes. 41 (6), 1001-18.

Adrizal, A., Patterson, P., Hulet, A., Bates, R., Myers, C. 2008. Vegetative buffers for fan emissions from poultry farms: 2. ammonia, dust and foliar nitrogen. Journal Environmental Science and Health Part B 2008, 43:96-103. http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1003&context=nrem_pubs (accessed January 15, 2015).

Adrizal, A., Patterson, P., Hulet, R., Despot, D., Wheeler, E., Topper, P., Anderson, D., Thompson, J. 2008. The Potential for Plants to trap Emissions from Farms with Laying Hens. 1. Ammonia. The Journal of Applied Poultry Research 17, p. 54-63. (2008a)

Adrizal, A., Patterson, P., Hulet, R., Despot, D., Wheeler, E., Topper, P., Anderson, D., Thompson, J. 2008. The Potential for Plants to Trap Emissions from Farms with Laying Hens: 2. Ammonia and Dust. The Journal of Applied Poultry Research 17, p. 398-411. (2008b)

Asman, W. 2008. Entrapment of ammonia, odour compounds, pesticide sprays and pathogens by shelterbelts. http://pure.au.dk//portal/files/42120227/djfma135.pdf (accessed February 17th 2015).

Brandle, J.R., Finch, S. 1991. How windbreaks work. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska- Lincoln. http://digitalcommons.unl.edu/natrespapers/121/ (accessed February 20, 2015).

Burley, H., Adrizal, A., Patterson, P., Hulet, R., Lu, H., Bates, R., Martin, G., Myers, C., Atkins, H. 2011. The potential of vegetative buffers to reduce dust and respiratory virus transmission from commercial poultry farms. http://japr.oxfordjournals.org/ (accessed January 15, 2015).

Carley, B., Saving the American Elm, 'Valley Forge' and 'New Harmony' American Elms pruning guide. http://www.elmpost.org/2007-01.htm (accessed February 16th 2015).

Harmon, J., Hoff, S., Rieck-Hinz, A. 2014. Animal Housing – Landscaping, Application: to reduce emissions from buildings and manure storage. https://store.extension.iastate.edu/Product/Animal-Housing-Landscaping-Overview (accessed January 7 2015).

Krupa, S. 2003. Effects of Atmospheric Ammonia on Terrestrial Vegetation. http://nadp.sws.uiuc.edu/nh4ws/Krupa/Krupa.pdf (accessed March 4, 2015).

Lammers, P., Wallenfang, O., Boeker, P. 2001. Computer modelling for assessing means to reduce odour emissions. ASAE Annual International Meeting, Sacramento CA. Paper number: 01-4042.

Lin, X.J., Barrington, S., Nicell, J., Choiniere, D., Vezina, A. 2006. Influence of Windbreaks on Livestock Odour Dispersion Plume in the Field. Agriculture, Ecosystems and Environment-2778. 10p.

Malone, G., VanWicklen, G., Collier, S., Hansen, D. 2006. Efficacy of Vegetative Environmental Buffers to Capture Emissions from Tunnel Ventilated Poultry Houses. Proceedings of the Workshop on Agricultural Air Quality: p. 875-878.

Malone, G. 2004. Using Trees to Reduce Dust and Odor Emissions from Poultry Farms. Proceedings of the Poultry Information Exchange, Surfers Paradise, Queensland, Australia: p. 33 – 38.

McNaughton, K. 1988. Effects of Windbreaks of Turbulent Transport and Microclimate. Agriculture, Ecosystems and Environment, 22/23: p 17-39.

Parker, B., Malone, G., Walter, W. 2011. Vegetative Environmental Buffers for Reducing Downwind Odor and VOCs from Tunnel-Ventilated Swine Barns. ASABE Annual International Meeting, Louisville, KY. Paper number: 1110791.

Patterson, P., Adrizal, A., Bates, C., Myers, C., Martin, C., Shockey, R., van der Grinten, M. 2006. Plant Foliar Nitrogen and Temperature on Commercial Poultry Farms in Pennsylvania. Proceedings of the Workshop on Agricultural Air Quality. p. 453-457.

Patterson, P., Adrizal, A., Hulet, R., Bates R., Myers C., Martin G., Shockey R., van der Grinten M. 2008. Vegetative buffers for fan emission from poultry farms; 1 temperature and foliar nitrogen. J Environ Science Health (accessed February 20th, 2015).

Raine, J. 1974. Modelling the Natural Wind: Wind Protection by Fences. Ph.D. diss., University of Canterbury, Christchurch New Zealand.

Sommer, S., Olesen, J., Christensen, B., 1991. Effects of temperature, wind speed and air humidity on ammonia volatilization from surface applied cattle slurry. Journal of Agricultural Science 117: p. 91-100.

Tyndall, J., Vegetative Environmental Buffers & Air Quality. http://nac.unl.edu/documents/multimedia/windbreakconf/7_26_pm/M-AirQuality/17-Tyndall_Thur.pdf (accessed February 23 2015).

Van der Eerden, L., de Visser, P., Van Dijk, C. 1998. Risk of damage to crops in the direct neighborhood of ammonia sources. Environ. Pollution 102 (S1): 49-53.

Author

Shawn V. Belt, Horticulturist
USDA-NRCS Norman A. Berg National Plant Materials Center
8791 Beaver Dam Rd., Bldg. 509, BARC-East
Beltsville, MD 20705
(301) 504-8516 ● Shawn.Belt@md.usda.gov

This document should be cited as:
Belt, S. Plants Tolerant of Poultry House Emissions in the Chesapeake Bay Watershed. Maryland Plant Materials Final Report. 2015. USDA-NRCS Norman A. Berg National Plant Materials Center, Beltsville, MD.

The U.S. Department of Agriculture (USDA) prohibits discrimination against its customers, employees, and applicants for employment on the bases of race, color, national origin, age, disability, sex, gender identity, religion, reprisal, and where applicable, political beliefs, marital status, familial or parental status, sexual orientation, or all or part of an individual's income is derived from any public assistance program, or protected genetic information in employment or in any program or activity conducted or funded by the Department. (Not all prohibited bases will apply to all programs and/or employment activities.)

If you wish to file an employment complaint, you must contact your agency's EEO Counselor (PDF) within 45 days of the date of the alleged discriminatory act, event, or in

the case of a personnel action. Additional information can be found online at http://www.ascr.usda.gov/complaint_filing_file.html.

If you wish to file a Civil Rights program complaint of discrimination, complete the USDA Program Discrimination Complaint Form (PDF), found online at http://www.ascr.usda.gov/complaint_filing_cust.html, or at any USDA office, or call (866) 632-9992 to request the form. You may also write a letter containing all of the information requested in the form. Send your completed complaint form or letter to us by mail at U.S. Department of Agriculture, Director, Office of Adjudication, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, by fax (202) 690-7442 or email at program.intake@usda.gov.

Individuals who are deaf, hard of hearing or have speech disabilities and you wish to file either an EEO or program complaint please contact USDA through the Federal Relay Service at (800) 877-8339 or (800) 845-6136 (in Spanish).

Persons with disabilities who wish to file a program complaint, please see information above on how to contact us by mail directly or by email. If you require alternative means of communication for program information (e.g., Braille, large print, audiotape, etc.) please contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

For any other information dealing with Supplemental Nutrition Assistance Program (SNAP) issues, persons should either contact the USDA SNAP Hotline Number at (800) 221-5689, which is also in Spanish or call the State Information/Hotline Numbers.

For any other information not pertaining to civil rights, please refer to the listing of the USDA Agencies and Offices for specific agency information.