Plant Foliar Nitrogen and Temperature on Commercial Poultry Farms in Pennsylvania

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Abstract

Trees have been planted for many years in agriculture settings for windbreaks and shade purposes. A new, but largely untested benefit may be as a visual screen for combating neighbor issues, as a barrier for flies, and as a filter for fan emissions from poultry and livestock farms. This field study sought to evaluate the potential of trees planted around commercial poultry farms to trap NH_3, the gas of greatest environmental concern to the poultry industry. Four plant species (spruce, poplar, streamco willow, and hybrid willow) were planted in front of the exhaust fans of eight commercial farms from 2003 to 2004. In 2005 because temperature (T) can be a stressor for trees, T was monitored with data loggers among the trees in front of the exhaust fans (11.4 m to 17.7 m) and at a control distance away from the fans (≥48 m) during all four seasons in Pennsylvania. Poplar and spruce foliage samples were taken in August 2005 from one turkey and two layer farms for dry matter (DM) and nitrogen (N) analysis. The two layer farms had poplar plantings and all three farms had spruce. The results showed that farm type had a significant effect on plant leaf DM but not leaf N. Although poplar had less foliage DM compared to spruce (41.3 vs. 50.1%), it contained greater N (3.43 vs. 2.46%). Plant location clearly showed greater foliar DM and N levels among those plants near the fans compared with controls, 51.0 vs. 40.4% and 3.61 vs. 2.28%, respectively. Greater foliar DM may have resulted from the plants' capacity to trap NH_3-N emitted by the exhaust fans resulting in better N status in the tissues, growth and biomass of the plant, or desiccation of the plants from the proximity of the fans. However, the difference in foliar DM and N concentrations due to species, location, and the interaction of the two factors was unlikely correlate with ambient T. Summer T were similar in front of the fans and at a control distance away from the fans on all farms (25.80 vs. 25.32C-layer 1, 25.92 vs. 25.53C-layer 2, and 25.45 vs. 25.54C-turkey) suggesting no greater T stress associated with fan proximity.

Introduction

Air emissions from poultry and livestock production are numerous and may include dust or particulate matter, odors and nitrogenous compounds including ammonia. Ammonia (NH_3) emissions can be significant. Our own data using mass balance techniques on commercial pullet, laying hen, broiler and turkey farms indicates that between 18 to 40% of feed N is lost to the atmosphere mostly as NH_3-N (Patterson and Lorenz, 1996, 1997; Patterson et al. 1998, Patterson et al., 1999). Planting trees around poultry farms has been utilized for wind breaks and for shade. Recently vegetative shelterbelts have been used as a visual screen, a barrier for fly migration and to trap emissions (odors, dust, and gases) discharged by the exhaust fans from poultry farms (Malone, 2004).

Plants have the capacity to absorb aerial ammonia (NH_3) via foliar stomata and cellular assimilation through the glutamine synthetase and glutamate synthase pathways (Yin et al., 1998). Van deer Eerden et al. (1998) reported that at the right concentrations, NH_y (NH_3 + NH_4^+) would favor plant growth, but at a critical threshold it would cause tissue necrosis, reduced growth, and greater frost sensitivity.

In chamber studies we determined that multiple plant species including red cedar, white spruce, arbovitae, honey locust, hybrid poplar, streamco willow, and reed canary grass deposited almost two-fold greater N in their leaves when exposed to continuous NH_3 at 4 to 8 ppm, compared to control chambers without atmospheric NH_3 (Adrizal et al., 2006). However, only honey locust consistently grew well and showed little foliar injury compared to other species; indicating its capacity to tolerate and utilize aerial NH_3-N.

Malone (2004) planted three plant species (4.9 m high bald cypress, 4.3 m high Leyland cypress, and 2.4 m high red cedar, 9m wide) at 9, 12.2, and 14.6 m downwind of the tunnel fans on a roaster chicken farm. During the summer, the trees reduced air velocity by 99%, dust by 50-53%, and NH_3 by 29-67% down wind of the trees. One concern faced by extension personnel sighting trees for poultry farms was that heat exhausted from the poultry barns in winter may throw plant species out of dormancy, or result in temperature and/or dehydration stress on the plants. This study was designed to evaluate the potential of trees planted around poultry house exhaust fans to trap NH_3, and the impact of tree proximity to the fans on environmental temperature and its associated stressors.

Materials and Methods

There were eight commercial poultry farms involved in this study including 3 broiler, 3 layer, 1 pullet, and 1 turkey farm. Cox tracer data loggers (Model CT-1E-D-16, Sensitech, Inc. MA, USA) were used to monitor temperature (T) on all farms at two locations. The first T logger was placed away from the buildings and fans (≥48 m, control), while the second was placed near the fans (11.4 to 17.7m) among the trees. Each logger was hung inside the wall of a propylene shield and secured horizontally to a metal post at 1.5 m high from the ground matching the height of the facing fan. All the loggers were programmed to record the T every 30 min continuously for two consecutive months in each season (winter: January to February; spring: April to May; summer: July to August; fall: October to November) in 2005.

More than 2000 plants (Norway spruce [*Picea abies*], hybrid willow [*Populus sp*.], and streamco willow [*Salix purpurea*]) were planted in rows on the all poultry farms from 2003 to 2004 (Table 1). In 2005, monitoring for T began in August, and foliage samples from three plants of each species were taken from the selected farms based on row position and distance from the exhaust fans.

Table 1. Characteristics of commercial poultry farms and trees.

Farm	House type	Birds & houses	Farm issues	Trees
Broiler 1	litter	21,000/house	Visual screen, snow load, odors and dust	2 rows Norway spruce 1 row hybrid willow 1 row streamco willow
Broiler 2	litter	50,000/2 houses	Dust , odors and snow load	1 row Norway spruce 1 row hybrid willow 1 row streamco willow
Broiler 3	litter	20,000/house	Dust and odors	1 row streamco willow
Layer 1	high-rise	125,000/house	Dust, odors, flies and visual screen	2 rows Norway spruce 2 rows hybrid poplar
Layer 2	high-rise	475,000/3 houses	Dust, odors and flies	2 rows Norway spruce 1 row hybrid poplar 1 row streamco willow
Layer 3	high-rise	1,000,000/8 houses	Visual screen, dust and odors	2 rows Norway spruce
Pullet	high-rise	83,000/house	Visual screen, snow load, energy conservation, and urban encroachment	2 rows Norway spruce 1 row hybrid willow
Turkey	litter	40,000/2 houses	Dust, odors, water quality, feathers and truck traffic	2 rows hybrid willow 10 rows Norway spruce

An incomplete randomized block design was applied in this study where farms were considered as a block. The two mathematical models employed were Model 1 for the analysis of T and Model 2 for the analysis of foliar DM and N data using Proc GLM of SAS followed by Bonferroni test for plant significance (SAS Institute, 1999). The foliar percentage DM and N data were transformed to arc sin before the analysis. The two models are described below:

$X_{ijk} = \mu + F_i + L_j + \varepsilon_{ijk}$ ….. (Model 1)

$X_{ijkl} = \mu + F_i + S_j + L_k + (S\times L)_{jk} + \varepsilon_{ijkl}$ ….. (Model 2)

where X_{ijk} is the observed value, μ is the overall mean, F_i is the i-th farm, L_j is the j-th location where the temperature was monitored (Model 1), S_j is the j-th plant species, L_k is the k-th location where the plants were planted (Model 2). $(S\times L)_{jk}$ is the species by location effect at j- and k-th combination, and ε_{ijk} or ε_{ijkl} is the residual errors for Model 1 and Model 2, respectively.

Results

Farm type had a significant effect on plant foliar DM ($P\leq 0.001$) but not on foliar N concentration (Table 2). The average DM concentrations of plants from the two layer farms were greater than that from the turkey farm.

Plant species and location showed significant effects on both foliar parameters (Table 2). Poplar was found to have less DM in its leaves than spruce (41.3 vs. 50.1%; $P\leq 0.05$), but greater foliar N levels (3.43 vs. 2.46%; $P\leq 0.05$). Planting location clearly showed greater foliar DM and N levels in those plants located near the exhaust fans compared with controls with 51.0 vs. 40.4% DM and 3.61 vs. 2.28% N, respectively. There was a significant species by location interaction with greater tissue DM again near the fans in both species, and a similar trend with tissue N levels, although not significantly so.

Table 2. Foliar DM and N (%) of hybrid polar (*Populus sp*) and Norway spruce (*Picea abies*) sampled at commercial poultry farms.

	DM (%)	N (%, DM)
Farm:		
Layer 1	47.2[a]	3.16
Layer 2	53.7[a]	2.91
Turkey	36.3[b]	2.77
Species:		
Poplar	41.3[b]	3.43[a]
Spruce	50.1[a]	2.46[b]
Location:		
Control	40.4[b]	2.28[b]
Fan	51.0[a]	3.61[a]
Species × Location		
Poplar × Control	31.9[b]	2.68
Poplar × Fan	50.6[a]	4.19
Spruce × Control	48.8[a]	1.88
Spruce × Fan	51.4[a]	3.03
SEM	4.4	0.34
Sources of variances:	--------------Probabilities	---------------
Farm	0.001	0.484
Species	0.008	0.001
Location	0.001	0.0001
Species × Location	0.009	0.696

[a-b]Means in a column with no common superscripts differ significantly ($P\leq 0.05$).

The temperature data presented in Table 3 showed that none of the factors (farm type or location) had an impact on the temperatures recorded throughout all four seasons (P > 0.05). However, temperature differences were realized in all seasons and followed the same pattern on all farms, ranging from -0.06 to 1.22 °C in winter, 13.56 to 16.96 °C in spring, 24.71 to 28.06 °C in summer, and 9.28 to 12.56 °C in fall

(Table 3). Summer T's were similar near the fans and at the control distance away from the fans on all three farms where plant tissues were sampled (25.80 vs. 25.32 °C [layer 1], 25.92 vs. 25.53 °C [layer 2], and 25.45 vs. 25.54 °C [turkey]). This indicated temperature stress was not an issue for trees near the fans.

Table 3. Average temperature recorded at two locations (control vs. downwind of the exhaust fans) on commercial poultry farms during the four seasons of 2005.

Farms	Winter		Spring		Summer		Fall	
(initial)	Control	Fan	Control	Fan	Control	Fan	Control	Fan
	(ºC)[1]							
Broiler 1	0.26±7.14	0.28±7.08	14.68±7.78	14.10±7.02	28.06±7.53	27.33±7.10	10.57±7.41	12.56±8.75
Broiler 2	1.22±6.55	0.60±6.07	16.69±6.37	16.9±56.40	26.20±6.03	26.81±6.41	9.85±7.29	9.89±7.17
Broiler 3	0.16±6.27	-0.27±5.84	16.57±6.99	16.96±7.24	25.24±6.21	25.79±5.89	10.70±7.48	11.40±7.66
Layer 1	-0.06±7.54	-0.67±6.94	15.41±5.81	15.37±6.24	25.32±6.11	25.80±6.56	9.66±7.13	9.28±7.46
Layer 2	-1.20±6.50	-0.22±7.06	13.78±7.15	[2]	25.53±6.18	25.92±5.55	9.44±7.18	10.16±7.30
Layer 3	0.11±4.80	0.30±4.80	15.51±7.42	16.24±7.36	24.97±6.75	24.90±5.61	9.34±7.37	9.42±7.42
Pullet	1.38±5.11	0.99±4.95	15.96±7.54	16.74±6.24	25.51±6.90	24.71±6.47	9.79±7.57	9.50±7.31
Turkey	-2.08±6.79	-0.26±8.82	[2]	13.56±8.43	25.54±7.45	25.45±6.72	11.00±8.17	[2]

[1]Data (means ± SD) were recorded with data loggers programmed to read the temperature every 30 min for two months per season (winter: January to February; spring: April to May; summer: July to August; and fall: October to November).
[2]Technical failure of the data loggers resulted in no temperatures recorded at these locations.

Discussion

Ammonia concentration at the trees located near the exhaust fans was not measured in the current study. However, previous studies have documented ammonia losses from poultry farms (Liang et al., 2005; Miles et al., 2006; Patterson and Lorenz, 1996, 1997, Patterson et al., 1998; Patterson et al., 1999). Recently, Adrizal et al., (2006) demonstrated that plants grown in environmental chambers with atmospheric ammonia at 4 to 7ppm deposited almost 2-fold more N in their leaves compared to control plants in chambers without ammonia. Significantly great tissue DM was also observed in these studies, much like what was documented on the poultry farms herein. Although, not all plant species appeared to benefit from the ammonia exposure in the chamber studies. Hybrid poplar was the species with the greatest capacity to incorporate atmospheric ammonia into foliar tissue. However, the poplar also had the greatest tissue damage and negative color scores compared to the other species, suggesting upper limits to ammonia tolerance. The tissue injuries observed on the plants exposed to NH_3 in environmentally controlled chambers, however, were not apparent among plants on the poultry farms in the current field study. This suggests greater plant tolerance to NH_3 exposure under outdoor conditions that may included rain cleansing, and lower ammonia concentrations.

Reduced air velocity, dust, and NH_3 levels have been reported by Malone (2004) downwind of trees planted in front of poultry fans. Pitcairn et al. (1998) documented fewer numbers of nitrophilus plant species at distances downwind of the fans on livestock farms. Each of these demonstrates the importance of planting distance for the capacity of plant tissues to trap aerial NH_3-N emitted by the exhaust fans, and the sensitivity of some species. Lastly, temperature results from this study demonstrated that exhausted air temperature from buildings housing commercial poultry are not a plant stressor or affect the dormancy cycle of the trees planted within 11 to 18m from the fans.

Conclusions

Environmental temperatures monitored near commercial poultry house fans (11.4 to 17.7 m) did not differ from those at control distances from the fans (≥48 m) during all four seasons in Pennsylvania. Hybrid poplar and Norway spruce foliar N and DM concentrations were greater in the foliage sampled near the fans compared to the controls plants. Under the conditions of this study, both hybrid poplar and Norway spruce were able to trap aerial NH_3-N emissions from the fans and tolerate the concentration of ammonia realized under these field conditions.

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