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A Preliminary Investigation on the Use of Warm-Season Grasses as Vegetative Environmental Buffers to Capture Particulate Matter from Manure Pit Exhaust Fans Associated with a Swine Finishing Facility

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Abstract

Airborne Particulate Matter (PM) released through exhaust fans from livestock barns can be environmentally objectionable resulting in enhanced odors and the release ammonia and harmful microbes. While large trees and woody shrubs have been recommended as Vegetative Environmental Buffers (VEB) for capturing PM from exhaust from off the ground ventilation fans in livestock barns, grasses due to their smaller vegetative size may be more suitable for capturing PM from exhaust from ground level manure pit fans often unique to swine barns. Since there is limited information on the use of grasses as VEB in animal barns, we developed this preliminary investigation to determine if warm season grasses (*Panicum virgatum* L. 'Northwind', *Miscanthus sinensis* Anderss. 'Zebrinus', and *Andropogon gerardii* Vitman 'Blackhawk') could capture air borne particulates (PM10 and PM2.5) from ground level manure pit exhaust fans located at a swine finishing facility near Lancaster, Pennsylvania (USA). We observed that all three grass species accumulated PM on their leaves with the more pubescent leafed species (Miscanthus and Andropogon) tending to capture more PM on their leaves than the non-pubescent leafed Panicum. Additional research evaluating a larger number of plants and species is needed for more accurate interpretation of results and to further refine and improve the conclusions and recommendations on the use of warm season grasses as VEB for PM in these facilities.

Keywords: Windbreaks, Particles, Swine barn

Abbreviations: VEB: Vegetative Environmental Buffers; PM: Particulate Matter; PM10: Inhalable Particles, with diameters that are generally 10 μm and smaller, PM2.5: Fine Inhalable Particles, with diameters that are generally 2.5 μm and smaller.

Introduction

Vegetative Environmental Buffers (VEB) or windbreaks have been recommended by the US Natural Resource Conservation Service since 2007 [1] as a best management practice for animal production barns (primarily for poultry) to mitigate the release of air borne Particulate Matter (PM) from the barns that can result in odors and dust [2]. Poultry operations produce large quantities of PM due to their dry litter manure, while swine operations typically produce the most offensive odors of all livestock operations [3]. While ventilation fans from livestock barns are typically located elevated off the ground, manure pit exhaust fans uniquely associated with swine facilities are located at the ground level.

Previous studies with poultry facilities and windbreaks have evaluated evergreen trees or shrubs for VEB due to their tall/larger size to intercept the exhaust from the off the ground ventilation fans at the end of the barns. Tree buffers have been reported to lower PM counts and odorous gas emissions by 40% and 60%, respectively [4] and reduced air velocity by 99%, dust by 49%, and ammonia by 46% downwind during the summer [5]. Vegetation planted 75 to 100 m from the facility was most effective for PM collection [6].

Many swine barns have under-barn concrete manure pits [7] that the roots of trees planted near the barn could potentially penetrate, threatening the structural integrity of the manure pit and contaminating groundwater. Falling limbs from trees near the barns could also damage roofs and harm livestock within the barns. While grasses may not grow adequately tall to create windbreaks or VEB for the higher ventilation fans at the end of swine barns, tall growing, bunch grasses could provide the optimal height to intercept air flow from the ground level manure pit exhaust fans and not threaten the manure pits or barn roofs. Currently there is limited research on the use of grasses as VEB or windbreaks in swine facilities.

We suggest that grasses utilized as buffers should be relatively hardy, tall growing, and drought and heat resistant due to the constant exposure to air flow that could cause accelerated evapotranspiration and/or other negative physiological plant responses. The grasses we chose for this preliminary evaluation and their vegetative characteristics that could contribute to their PM filtering were the following:

Panicum: *Panicum virgatum*, switchgrass, is native to North America and is commonly used in conservation as well as biofuel operations. It can grow to 0.5 to 2 m tall and has rhizomes which provide the potential for a formation of sod from a single or few plantings of Panicum [8]. Panicum also produces tillers which provides extra lateral growth for a single plant. Except for the small patch of hairs at the base of the leaf blade, the leaves of Panicum are completely glabrous.

Andropogon: *Andropogon gerardi,* big bluestem, is a native plant to North America that can be grown for forage. It has numerous basal leaves as well as culms and can grow to 1 to 2 m in height [8]. The leaf sheath of Andropon is hairy, and the leaf blade has silky pubescent hairs dispersed across the blade.

Miscanthus: *Miscanthus sinensis,* Chinese silvergrass, is native to eastern Asia and is widely cultivated as an ornamental plant in the US. It is disease and pest resistant and salt tolerant. It is an erect clumping grass growing upwards to 1 to 3 m with terminal inflorescence in finger-like racemes and is noted for its horizontally banded foliage [9]. Miscanthus has pubescent leaves from the base of the blade to the tip, 15mm wide and 1 m long.

Materials and Methods

This research was conducted at a commercial swine finishing facility near Lancaster, Pennsylvania (USA). Two plants of the three species of grasses evaluated (*Panicum virgatum* L. 'Northwind', *Miscanthus sinensis* Anderss. 'Zebrinus', and *Andropogon gerardii* Vitman 'Blackhawk') were purchased from a local plant nursery in 4L pots at the same approximate size and appropriate growth stage for transplanting to the field. Each plant was removed from the pots on 15th of May 2020 and placed into the soil surrounding the swine barn 3 meters from manure pit exhaust fan and 1 meter apart from the other grass plant. After transplanting, temporary exhaust shields made of plywood were placed between the fans and the grasses to protect the grasses from the stress of the air emitted from the exhaust fans while they became established in the field. Plants were irrigated as needed and the shields were removed one month after transplanting and the grasses were then exposed to the exhaust air from the manure pit fans of the swine barn until termination of the experiment.

The experiment was terminated on the 22nd of August 2020, and each plant was cut approximately 1cm above the soil surface for determinations of PM on the foliage and plant growth characteristics of height (from cut surface to terminal leaf) and mass. A 150-gram sample of vegetation from each plant was rinsed with 200mL of deionized water and brushed with a bannister brush twice to remove PM from the leaf surfaces. The wash water and particles for each sample were collected into 1000mL plastic bottles and transferred for PM analysis to the Penn State Agriculture Analytical Laboratory at the Penn State University Campus, University Park, Pennsylvania (USA).

Laboratory analysis for PM was determined from samples collected based on procedures of [10] and [11]. During this process, 10μm and 2.5μm filters were placed in separate Büchner funnels to capture PM10 and PM2.5 particulates (as defined by the US EPA), respectively. The funnels were attached to a vacuum to force 2.5 mL of the collection sample through the filters. Filters were weighed before and after sampling to determine the post-filtration mass of particulates (PM10 or PM2.5 depending on which filter had been used) and expressed as mg /L of PM captured per sampled wash water. Two particulate determinations were done for each collection sample and averages calculated.

Dry mass of the grass samples was determined by oven drying at 60°C to a constant weight (approx. 1 week of drying). All data were analyzed by ANOVA using Stats. Blue (https://stats.blue/index.html). Since there was a limited number of individuals evaluated within plant species (and the resulting small number degrees of freedom in the analysis of variance) we felt it was more descriptive for discussion in this preliminary investigation to list the calculated P-values for the dependent variables rather than choosing significance to only exist at a P-value of 0.05 or some other chosen P-value [12, 13]. P-values are measures of the probability that observed differences could have occurred just by random chance [14]. Therefore, the lower the P-value, the greater the statistical significance of observed differences.

Conclusions

We observed that warm season grasses grown near the low-level manure pit fans from the swine barn appeared to collect PM on their leaves from the fan air flow [Table 1]. All three species evaluated had similar accumulated PM10 on their vegetation (P-value = 0.484) though Miscanthus had numerically more particles. There was also no difference among the grass species in their PM2.5/ PM10 (P-value = 0.551), suggesting a common source of the particulates in the fan exhaust that originating from the indoor air of the barn to the VEB. Previous model estimated emission rates of PM2.5 and PM10 from a swine barn were 0.14 and 0.55 g/pig/day, respectively [15] or a PM2.5/PM10 of 0.255. [16] suggested that the main sources of PM2.5 in swine barns to be blowing dust, feed, mineral particles, and outside smoke, while increased bird activity and ventilation rates in turkey barns positively impacted both PM10 emission rate and concentration [17].

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Table 1: Growth characteristics and accumulated particulate matter (PM) by grass species evaluated as vegetative environmental buffers at a swine barn.

	Growth Characteristics		Accumulated Particulate Matter (PM)			
Grass Specie	Mass(g)	Height(cm)	PM10 (mg/L)	PM2.5/ PM10(ratio)	PM10 by Growth Characteristic	
					(PM10/Mass)	(PM10/Height)
Miscanthus	139.9	61.7	1860	0.211	13.252	30.493
Andropogon	158.6	56.6	1155	0.41	7.002	21.61
Panicum	507.3	61.6	990	0.419	1.952	16.487
P-value	<0.001	0.717	0.484	0.551	0.143	0.625

PM10 = Particles with diameters that are 10 μm and smaller; PM2.5 = Particles with diameters that are 2.5 μm and smaller.

While all the grasses were comparable sized in appearance at planting, there were differences in vegetative mass among the grass species (P-value = < 0.001) at the termination of the experiment. Panicum had the greatest vegetative mass and Andropogon and Miscanthus has less weight than Panicum and were numerically comparable to each other. Miscanthus had the greatest PM accumulated per plant mass and Panicum the least (P-value = 0.143). Previous investigations [18] concluded that smaller leaves and leaves with more trichomes or hairs on the leaf surface captured more atmospheric PM and pollution. While Miscanthus and Panicum generally have the same width leaves of about 15mm, Miscanthus leaves were more pubescent and a had waxier cuticle than Panicum. This is similar to previous observations with urban trees and shrubs where PM was lodged in the cuticle of leaves [11]. In the present investigation, we observed little differences in final plant height (P-value = 0.717) or in accumulated PM per plant height (P-value = 0.625) among the grass species.

In summary, the three warm season grasses evaluated in this preliminary study (*Panicum virgatum* 'Northwind', *Miscanthus sinesis* 'Zebrinus', and *Andropogon gerardi* 'Blackhawks') appeared to capture air borne particulates (PM10 and PM2.5) from ground level manure pit exhaust fans located at a swine finishing facility. The more pubescent leafed species (Miscanthus and Andropogon) tended to have more PM on their leaves than the non-pubescent leafed Panicum. Additional research evaluating a larger number of plants and species is needed to further refine and improve recommendations on the use of warm season grasses as VEB for PM in swine barns. We also suggest that future evaluations should include grass plantings not located near exhaust fans to compare with results from plantings near the fans and to also employ mechanical PM samplers both inside and outside of the barns to compare instrument measurements of PM to the VEB results.

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Conflict of Interest

The authors report no conflict of interest.

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