Stable Fly, House Fly (Diptera: Muscidae), and Other Nuisance Fly Development in Poultry Litter Associated with Horticultural Crop Production

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ABSTRACT Poultry litter usage in horticultural crop production is a contributor to nuisance fly populations, in particular stable flies (*Stomoxys calcitrans* L.) and house flies (*Musca domestica* L.). Extrapolation of adult emergence data suggests that ≈1.5 million house flies and 0.2 million stable flies are emerging on average from every hectare of poultry litter applied as a preplant fertilizer for vegetable production in Perth, Western Australia. To a lesser extent, sideband applications to established crops may allow for the development of 0.5 million house flies and 45,000 stable flies per hectare. However, up to 1 million house flies, 0.45 million lesser house flies, *Fannia cannicularis* L., and 11,000 stable flies per hectare may be produced from surface dressings of poultry litter associated with turf production. Other nuisance flies present in poultry litter included the false stable fly, *Muscina stabulans* (Fallén), bluebodied blowfly, *Calliphora dubia* Hardy, black carrion fly, *Hydrotaea rostrata* Robineau-Desvoidy, Australian sheep blowfly, *Lucilia cuprina* Wiedemann, and flesh flies (Sarcophagidae). Only house flies developed in poultry litter for the first 4 d after application in the field. Stable flies were not present in poultry litter until 4–7 d after application, and were the only fly species developing in litter >9 d after application.

KEY WORDS flies, poultry manure, horticulture, turf, vegetable

POPULATIONS OF THE stable fly, *Stomoxys calcitrans* L., and the house fly, *Musca domestica* L., have increased along the Swan Coastal Plain around Perth, Western Australia (Cook et al. 1997). Furthermore, since the late 1980s, the stable fly has become an economic threat to the local beef and dairy cattle and horse industries. In cattle, as few as 20 flies per animal can reduce daily weight gain and affect marketing plans (Campbell et al. 1987; Catangui et al. 1993). In several localities along the Swan Coastal Plain, up to several hundred stable flies per animal have been recorded, causing severe animal distress and on occasion leading to animal deaths (unpublished data). Cattle bunch together when attacked by the stable fly, which causes both heat stress and reduced feeding (Wieman et al. 1992, Catangui et al. 1997). Stable fly outbreaks in the rural–urban fringe areas of the Swan Coastal Plain have forced cattle owners and recreational and thoroughbred horse owners to relocate their animals away from affected areas. Human lifestyle also has been seriously affected in rural residential areas. Large numbers of house flies constitute a public nuisance as they invade dwellings and are capable of transmitting numerous diseases (Wall and Shearer 1997).

Flies as a group exploit an enormous range of breeding habitats. Many fly species are associated with either manure or other by-products of animal husbandry. The most common breeding medium is rotting vegetable matter, in which larvae feed on microorganisms decomposing the vegetable matter rather than on the substrate itself (Ferrar 1987). *S. calcitrans* develops in a range of animal manures (Bishopp 1913), spilled feed (Scholl et al. 1981), rotting organic material (King and Lenert 1936; Meyer and Petersen 1983), hay stacks (Bishopp 1913), hay bales (Hall et al. 1982) and lawn clippings (Ware 1966). *S. calcitrans* rarely develops in pure poultry manure; however, poultry litter, which is a combination of poultry manure and organic matter produced as a byproduct of the poultry meat industry, provides an ideal medium for immatures (Sutherland 1978; Boire et al. 1988). The house fly develops in human, horse, cattle, pig, poultry, sheep, and kangaroo dung; rotting vegetable matter; kitchen refuse; lawn clippings; and carrion (Pont 1973).

Approximately 150,000 m^3 of poultry litter is produced annually by the chicken meat industry along the Swan Coastal Plain (Agriculture Western Australia, unpublished data). The vast majority of this litter is used as a fertilizer and soil conditioner by horticultural industries, principally in vegetable, strawberry, and turf production. The litter is applied either by incorporating it into the soil before planting (preplant), or placed either beside existing plants (side-

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band) or on the surface of turf. On the sandy soils typical of the Swan Coastal Plain, this litter is regularly watered (up to 2 times daily) as part of normal horticultural practices. In addition, growers often accumulate large amounts of poultry litter on their properties in stacks (10 to several hundred cubic meters). Often the litter is either delivered wet from the broiler sheds, or becomes wet from either rain or nearby sprinklers. These sources of moist poultry litter provide an ideal environment for nuisance fly breeding. The objective of our study was to determine the numbers of stable flies and other nuisance flies developing from poultry litter when it is used in horticultural production.

Materials and Methods

Poultry Litter. All poultry litter assessed in these trials was delivered directly from poultry sheds (meat bird production) to horticultural properties. The poultry litter consisted of raw poultry manure deposited onto wood shavings from trees of either jarrah, *Eucalyptus marginata* Donn ex Smith, or pine, *Pinus radiata* Don. Monterey P., over ≈35 d previously. The assessments of fly development followed normal grower practice, which involves using this litter within several weeks after delivery.

Emergence Cages. Standard fly emergence cages were used to identify and quantify fly development in poultry litter when used in crop production. The cages consisted of a rectangular metal frame covering 1 m^2, above which a flat pyramid of dark green shade cloth (80% solar rating) led into a circular port. A 1-liter clear plastic cylinder with a brass mesh cone pointing upward was attached to this port to collect newly emerged adult flies. Flies caught in cylinders were collected, identified to species level, and counted.

The emergence cages were placed over raw poultry litter applied as either preplant or sideband in vegetable production, or either preplant or surface application in turf production. The cages were placed on 15 different horticultural properties within a 120-km radius of Perth between October 1996 and March 1997. The cages were placed over poultry litter 4–5 d after application (when fly oviposition and larval development had commenced). The cages allowed for normal grower practice (i.e., watering, fertilizer application), but no insecticide applications were allowed while the cages were in place. The cages remained in place until all adult fly emergence had ceased. The cages were checked weekly up to 4 wk, after which the cylinder and the inside of the trap were cleared of dead flies.

Emergence Tubs. Large grab samples of potential fly breeding material (≈1 by 1 by 0.05 m deep) were collected from either stacks of poultry litter stored on horticultural properties before application, or from preplant and sideband applications of poultry litter. These samples were collected from over 70 different properties within a 12-km radius of Perth, Western Australia. The samples were placed on sand in large, self-draining, black plastic tubs (60 by 36 cm) placed under an overhead automatic watering system. Watering twice daily for 5 min kept the samples moist enough to prevent larval desiccation. After a 5-d watering regime, no more water was added to allow the sand to dry and larvae to pupate. Adult flies were trapped in clear cylinders above the tubs similar to the emergence cages. This information was used to quantify further the sites where flies develop.

Sequence of Fly Species Breeding in Poultry Litter. To determine the sequence of fly species developing in poultry litter over time, litter taken directly from chicken meat industry sheds and delivered to a vegetable growers' property was exposed to flies every 2 d after being applied as a surface dressing. This was conducted on a market garden in Mandogalup (32.207°S, 115.838°E), 20 km south of Perth, Western Australia. Plastic boxes (0.34 by 0.23 by 0.12 m deep) with the bottoms cut out were pushed into the soil around the litter and fine mesh was secured over the top to prevent fly oviposition. The boxes covering the litter were alongside a commercial vegetable crop, hence they received a watering regime typical for poultry litter applications in horticulture. At varying intervals after application (0–2, 2–4, 5–7, 7–9, 9–11, 12–14 d), the mesh lids on 6 replicate boxes were removed so that flies could oviposit in the litter. The litter was exposed to flies for 48 h, after which the litter was held under laboratory conditions (constant 22°C; a photoperiod of 14:10 [L:D] h) to allow emergence of adult flies for counting and species identification.

Results

Fly Species Trapped. The 2 major nuisance flies identified from all poultry litter collections were the stable fly and house fly. Other flies identified in the samples, previously recorded as being either economic pests or a nuisance to humans and livestock included false stable fly, *Muscina stabulans* (Fallén); lesser house fly, *Fannia cannicularis* L.; flesh flies, Sarcophagidae; Australian sheep blowfly, *Lucilia cuprina* Wiedemann; bluebodied blowfly, *Calliphora dubia* Hardy; and black carrion fly, *Hydrotaea rostrata* Robineau-Desvoidy.

Emergence Cages. There was considerable variability in the numbers of both stable flies and house flies emerging from applications of poultry litter in horticulture. Numbers of stable fly and house fly ranged from 0 to 159 and 0 to 1,046 per trap (1 m^2), respectively on preplant applications in vegetable production (Table 1). On average, 25 stable flies and 167 house flies emerged in each cage. Only 1 turf property had a preplant application of poultry litter assessed for fly development, with an average of 4 stable flies per cage. Fly numbers were similar from sideband applications of poultry litter, where 0–112 stable flies and 1–693 house flies emerged per cage. On average, 14 stable flies and 165 house flies emerged from each cage. Surface applications of poultry litter in turf production realized 0–4 stable flies and 0–198 house flies per cage (Table 1).

Emergence Tubs. High numbers of house flies (159–225/m^2) developed from preplant, sideband,

Table 1. Numbers of stable flies and house flies (mean ± SEM) in emergence cages placed over preplant, sideband, and surface applications of poultry litter used for vegetable and turf production, Perth, Western Australia

Property	Preplant application		Sideband application		Surface Application	
	Stable flies (n)	House flies (n)	Stable flies (n)	House flies (n)	Stable flies (n)	House flies (n)
Vegetable production						
1	0.3 ± 0.2 (20)	<0.1 ± <0.1 (20)	0.9 ± 0.4 (20)	398.0 ± 104.9 (20)	—	—
2	0 (20)	0.1 ± 0.1 (20)	0.2 ± 0.2 (10)	1.0 ± 0.7 (20)	—	—
3	159.0 ± 27.9 (10)	0 (10)	2.1 ± 0.8 (10)	11.1 ± 1.8 (10)	—	—
4	1.1 ± 0.4 (10)	4.8 ± 1.9 (10)	0 (20)	178.0 ± 22.8 (20)	—	—
5	4.5 ± 2.3 (10)	4.5 ± 1.2 (10)	5.5 ± 1.1 (10)	222.0 ± 27.3 (10)	—	—
6	0.6 ± 0.4 (20)	1.5 ± 0.6 (20)	0.4 ± 0.3 (10)	4.1 ± 1.0 (10)	—	—
7	1.0 ± 0.4 (15)	47.1 ± 17.1 (15)	0.2 ± 0.1 (10)	5.4 ± 1.1 (10)	—	—
8	0 (10)	91.8 ± 23.3 (10)	0 (10)	0.5 ± 0.4 (10)	—	—
9	0.2 ± 0.1 (10)	1046.0 ± 37.8 (10)	0 (10)	693.0 ± 120.0 (10)	—	—
10	20.1 ± 8.4 (10)	206.0 ± 43.9 (10)	112.0 ± 61.9 (15)	46.4 ± 23.1 (15)	—	—
11	110.0 ± 30.4 (10)	57.8 ± 25.5 (10)	3.6 ± 1.7 (10)	68.8 ± 25.1 (10)	—	—
12	0 (10)	386.0 ± 42.1 (10)	NC	NC	—	—
13	2.2 ± 1.7 (10)	51.2 ± 24.0 (10)	NC	NC	—	—
14	67.2 ± 15.7 (20)	69.7 ± 11.4 (20)	NC	NC	—	—
15	0.1 ± 0.1 (20)	716.0 ± 80.5 (20)	NC	NC	—	—
16	64.8 ± 18.5 (20)	132.0 ± 30.0 (20)	NC	NC	—	—
Mean	25.1 ± 2.8	167 ± 18.6	13.5 ± 3.0	165 ± 17.4	—	—
Turf production						
1	3.7 ± 2.2 (10)	0 (10)	—	—	1.6 ± 0.6 (20)	198.0 ± 45.9 (20)
2	NC	NC	—	—	3.7 ± 0.6 (10)	0 (10)
3	NC	NC	—	—	0 (10)	141.0 ± 53.4 (10)
4	NC	NC	—	—	0.9 ± 0.6 (10)	177.0 ± 80.1 (10)
5	NC	NC	—	—	0 (10)	2.3 ± 1.9 (10)
Mean					1.3 ± 0.2	119 ± 11.2

n, number of emergence cages; NC, not conducted on growers' property.

and surface applications of poultry litter in vegetable and turf production. The highest numbers of stable flies developed from preplant applications of poultry litter (43/m^2), followed by wet stacks (29/m^2) (Table 2). A range of other nuisance flies developed in the poultry litter. The highest number that developed was *F. cannicularis* from surface applications associated with turf production (14/m^2) and preplant applications (8/m^2). *M. stabulans* developed from all sources of poultry litter, in particular sideband applications of poultry litter (4/m^2). Species of the family Sarcophagidae developed mostly in preplant applications of poultry litter (5/m^2). In all instances, the nuisance flies listed in Table 3 represented <4% of the total fly populations developing from each poultry litter source. The only exception was *F. cannicularis,* which represented 30% of all flies developing from surface applications of poultry litter in turf production (Table 3).

Sequence of Fly Species Breeding in Poultry Litter. House flies developed exclusively in poultry litter for the 1st 4 d after application and overhead watering in the field, with an average of 600–700 adult flies developing from each 800 cm^2 of litter (Fig. 1). Progressively fewer house flies developed from the poultry litter at each additional aging period, such that after 9–11 d exposure, no house flies developed in the litter (Fig. 1). There was a significant linear decline in the proportion of house flies developing in the litter (Y) over time after application (x) ($Y = -10.924x + 113.48$) ($F = 52.84$; df = 1, 4; $P = 0.0019$). Stable fly development was not evident in poultry litter until 4–7 d after application, with a maximum number developing in litter after 9–11 d. Stable flies were the only fly species developing in poultry litter >9 d after application. There was a significant linear increase in the proportion of stable flies developing in the litter (Y) over time after application (x) ($Y = 10.924x$–13.482) ($F = 52.84$; df = 1, 4; $P = 0.0019$).

Table 2. Numbers of stable fly and house fly (mean ± SEM) developing from ≈1-m^2 samples of poultry litter (used in horticultural crop production) reared in emergence tubs

Sample	Stable flies	House flies	n^a
Stacks	28.7 ± 11.2	37.7 ± 16.5	72
Preplant application	42.8 ± 18.5	158.6 ± 57.8	14
Side-banding	9.4 ± 3.5	224.6 ± 51.2	28

[a] Number of properties sampled.

Table 3. Numbers of other nuisance flies (mean ± SEM) developing from ≈1-m^2 samples of poultry litter (used in horticultural crop production) reared in emergence tubs

Species	Source of poultry litter			
	Stacks	Sideband	Surface[a]	Preplant
F. cannicularis	0.3 ± 0.3	<0.1 ± <0.1	13.8 ± 3.9	7.5 ± 1.9
C. dubia	0	<0.1 ± <0.1	0.6 ± 0.3	<0.1 ± <0.1
M. stabulans	2.6 ± 2.6	3.5 ± 1.0	<0.1 ± <0.1	1.6 ± 0.6
H. rostrata	2.2 ± 1.8	0	0.9 ± 0.9	0
Sarcophagidae	0	0.5 ± 0.3	0.3 ± 0.2	5.0 ± 1.6
L. cuprina	<0.1 ± <0.1	0	0	0
Sample size[b]	34	60	32	69

[a] Applies only to turf farms.
[b] Number of properties sampled.

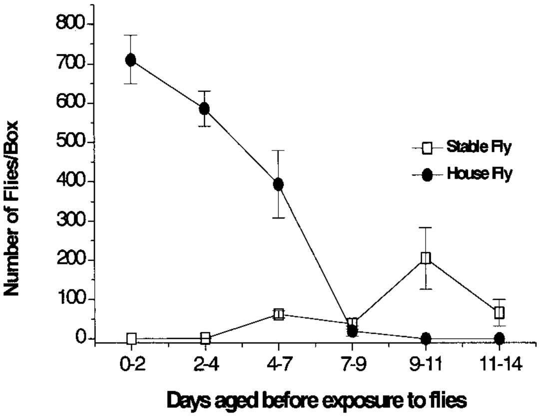

Fig. 1 Numbers of stable flies and house flies emerging from poultry littler removed from storage stacks and exposed to flies for 48-h intervals over a range of 0–14 d after application.

Discussion

With the encroachment of horticulture into traditional livestock areas and urban development in rural areas, *S. calcitrans* and *M. domestica* have become an increasing problem on the Swan Coastal Plain (unpublished data). Measures of adult fly emergence conducted in this study (emergence cages and tubs) revealed that use of poultry litter can produce large numbers of house flies and stable flies (Table 1). Extrapolation of the emergence cage data suggests that ≈1.5 million house flies and 225,000 stable flies are emerging on average from every hectare of poultry litter applied as a preplant fertilizer in vegetable production (assuming 90% coverage per hectare). With sideband applications of poultry litter to already established vegetable crops, the data suggests that ≈0.5 million house flies and 45,000 stable flies are emerging on average from every hectare of vegetable production (assuming 33% coverage per hectare). Production of turf also contributes to nuisance fly populations, with surface dressings of poultry litter estimated to allow the development of ≈1 million house flies, 0.45 million lesser house flies, and 11,000 stable flies per hectare (assuming 90% coverage per hectare).

In several instances, very few flies emerged from applications of poultry litter. The emergence traps in the majority of these situations were set during October to November, when fly populations around Perth are low. Typically, stable fly and house fly populations around Perth are at their peak from December to March (Agriculture Western Australia, unpublished data).

The emergence cage data were further supported by random collections of poultry litter used in vegetable and turf production and reared under laboratory conditions (emergence tubs). Stacks of poultry litter stored on horticultural properties for several weeks and allowed to get wet (either delivered wet from the poultry shed, or wet from sprinkler drift and rainfall) were an important source of stable fly development and to a lesser extent house flies. Presumably this is because the poultry litter had aged while being stored on the property. As predicted from the sequence of fly species emerging from aging poultry litter, both stable flies and house flies developed in this litter.

Flies respond to variations in the physical and chemical properties of manure, where larval survival correlates with levels of phosphorus and adult emergence correlates with moisture content (Barnard and Harms 1992). Brues (1946) speculated that differences in the pH of rotting materials was a major factor in determining the species of fly larvae found within the material. The author suggested that stable flies developed in acidic materials such as rotting straw or lawn clippings, whereas house flies preferred a more alkaline environment. d'Amato et al. (1980) postulated that face flies, *Musca autumnalis* DeGeer, and horn flies, *Hematobia irritans* L., are associated with fresh cattle dung, whereas house flies and stable flies are associated with fermenting materials. This study demonstrated that stable flies clearly prefer to develop in a more aged and fermented litter (>4–7 d old), whereas house flies did not use poultry litter that had aged for >9 d. Similarly, house flies prefer fresh cattle manure (>2 d old) as a larval medium, whereas stable flies do not breed in the manure until it is at least 19 d old (Broce and Haas 1999).

Poultry litter used as a fertilizer and soil conditioner by horticultural industries is regularly watered on the sandy soils around Perth, producing an ideal environment for fly development. The total area of vegetable production in the Perth metropolitan area and Gingin areas is ≈3,000 ha (unpublished data). Approximately two-thirds of vegetable growers in and around Perth use poultry litter to fertilize their crops (Burt et al. 1998), hence ≈2,000 ha of vegetable production involves the use of poultry litter. If 2.5 vegetable crops are grown per hectare per year (unpublished data), there is considerable potential for high levels of house flies and stable flies to be produced as a result of poultry litter use associated with vegetable production in and around Perth.

In addition to vegetable production, flies also may be produced from rotting vegetable matter associated with horticultural production. Either crop residue (stalks, leaves, fruit) in the paddock, or harvested waste (damaged and rejected produce, processing scraps) dumped in pits or fed out to livestock from crop residues, can be a significant source of both stable fly and house fly production (unpublished data). There are ≈200 ha of turf production around Perth, where all growers apply poultry litter as a fertilizer at 2.5t/ha on average every 6 wk. Therefore, the turf industry potentially contributes to the production of large numbers of house flies, lesser house flies, and stable flies.

House flies are commonly associated with either poultry facilities (Williams et al. 1985) or accumulated poultry manure (Lysyk and Axtell 1987). Watson et al. (1998) demonstrated that large numbers of house flies develop when manure from poultry egg production is incorporated into the soil. The level of house fly development from poultry litter in this study is of major concern because this fly can be a significant potential vector of human and livestock pathogens (Wall and Shearer 1997). House flies acquire and carry many pathogens either internally or externally on their mouthparts and legs (Williams et al. 1985). In addition, house flies often constitute a nuisance to both livestock and humans.

Previous studies under laboratory conditions have ranked potential breeding materials for stable flies based on mean larval and pupal mortality and average pupal weight, respectively (Sutherland 1978, Boire et al. 1988). Similarly, Fye et al. (1980) listed potential sites where *S. calcitrans* could develop without any measure of fly production. In this study, stable flies and house flies were free to choose their oviposition substrate in the field, and survival from egg to adulthood was used as the measure of the relative contribution of each developmental medium to the stable fly and house fly population. The great numbers of house flies and stable flies produced from use of poultry litter as a horticultural crop supplement underscores the need for alternative uses for the disposal and/or utilization of poultry litter in the Perth metropolitan area. A number of composting and chemical techniques to reduce the level of fly development from poultry litter are currently being assessed. If these techniques are unsuccessful, a ban on the use of raw poultry litter for land application in Western Australia will be enforced (Paulin et al. 1998).

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