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CONTROL OF HOUSE FLIES, *MUSCA DOMESTICA* (DIPTERA: MUSCIDAE), WITH IMIDACLOPRID WG 10 IN PIG FARMS (GERMANY)

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Abstract In fly control, the development of new insecticidal compounds with oral action encourages the development of baits. Imidacloprid, which belongs to the chloronicotinyl class of compounds, is most active when it is ingested and it is used in fly control as a granule for application as scatter bait (QuickBayt®1 Granular Fly Bait).

A 10% imidacloprid water dispersible, sugar based formulation, which can be applied as spray and paint-on, was developed as further option for fly control in livestock facilities. In contrast to residual contact insecticides imidacloprid WG 10 (QuickBayt®1 Spray) must not be applied to every suitable surface, but only to areas, which are preferred by the flies particularly during their activity phase. The attractiveness of the WG 10 formulation is increased by a mixture of z-9 tricosene and a new fly attractant (LEJ 179) developed by Bayer. The product remained attractive for flies over a period of several weeks and moribund and dead flies were observed under field conditions up to 6 weeks when applied as spray and 8 weeks when applied as paint-on. A high level of pyrethroid resistance in fly populations did not influence the good results with imidacloprid WG 10. The fast knock down within minutes and long term activity of the imidacloprid WG 10 against *Musca domestica* (L.) (Diptera/Muscidae) after application as spray or paint-on was confirmed with numerous trials in different livestock housings.

Imidacloprid WG 10 was also effective against other fly species such as the blood sucking *Stomoxys calcitrans* (Linnaeus) (Diptera/Muscidae).

Key Words *Musca domestica*, imidacloprid, sprayable baits

INTRODUCTION

Imidacloprid is an insecticide belonging to the chloronicotinyl class of compounds; it's use as a crop protection agent was first proposed in 1991 (Elbert et al., 1991; Leicht,1993). The active imidacloprid is also effective against a wide range of nuisance and public hygiene insect species like flies, cockroaches, fleas, crickets and termites (Londershausen, 1996; Pospischil et al., 2000; Pospischil, 2001; Kraemer and Mencke, 2001). The compound shows activity by ingestion and is particularly suitable for use in bait formulations.

A sugar based imidacloprid granule formulation (QuickBayt®1 Granular Fly Bait) has been identified as effective against flies, particularly those that are attracted to sweet substances like the larger house fly, *Musca domestica* (Linnaeus) (Diptera/Muscidae) (Pospischil and Junkersdorf, 2002; Pospischil, 2003). However, the use of water-based sprays against flies is more common worldwide, particularly in livestock housings. Another imidacloprid-based fly control product, imidacloprid WG 10, that could be selectively applied as a spray in areas where flies are active, was therefore developed.

The efficacy of this new formulation particularly against the larger house fly was confirmed in livestock housings in the area of Bitburg (Germany).

MATERIALS AND METHODS

Insecticides. Imidacloprid WG 10 consists of a water dispersible granule formulation based on sugar with 10.0 % (w/w) imidacloprid, which belongs to the chloronicotinyl class of compounds (CAS no.: 138261-41-3). The attractiveness of the bait is increased by the lures, z-9 tricosene (0.1%) and LEJ 179 (0.25%). The product contains Bitrex®3 (0.01%). It may help to prevent accidental ingestion by people. Imidacloprid WG 10 can be used as a spray or as a paint-on application.

Azamethiphos WP 10 (WP = wettable powder) was applied as a spray in trials in Germany and Italy as a comparison standard. The active ingredient azamethiphos (CAS no.: 35575-96-3) belongs to the chemical group of organophosphates and its sugar based wettable powder formulation has been used for a long time in fly control (Pospischil et al., 1996). Imidacloprid WG 10 was compared as paint-on with spinosad GR 1.0 (GR = granule). The active ingredient spinosad (CAS no.: 168316-95-8 (131929-60-7 + 131929-63-0)) belongs to the chemical group of macrolides. The larvicide triflumuron WP 25 (Baycidal®2 WP 25) was applied together with imidacloprid WG 10 in a fly control program. The active ingredient triflumuron (CAS no.: 64628-44-0) belongs to the benzoylphenylurea group of compounds. It inhibits chitin synthesis and interferes in the moulting process.

Sites. Hog farms with moderate to high fly problems in stables (more than 25 flies per animal) were selected in the area of Bitburg (Eifel, Germany) in 2003 and 2004. Fly infestation was determined in all animal houses directly before application. The farms in the trial program were free of animal diseases and had no adulticide or larvicide treatment during the last 4 weeks.

Spray Application. Imidacloprid WG 10 (250 g) was mixed with 2 liter of water per 100 m^2 stable ground surface. The suspension was applied by a backpack-sprayer. Only 25 to 50% of the stable surface up to 2.5 meters high was treated. Floors and ceilings were not sprayed. Animals, feed and drinking supplies or on any site, which can be reached by the livestock, were not treated. In all trial descriptions, the application rate was given in gram formulation per 100 m^2 of animal house floor area. Azamethiphos WP 10 was used as a comparison standard and was applied according to label recommendations, 500 g product/100 m^2 was mixed with 4 liter water.

Paint-on Application. Imidacloprid WG 10 was mixed with water in the ratio 1 to 0.8 (= 250 g product in 200 ml water for 100 m^2 ground space of stable). The mixture was stirred until a homogenous liquid was received. The paint was applied with a brush to areas where flies tend to congregate, e.g. pipes, beams, window sills, cubicle partitions, tethers, the outsides of feed troughs and walls up to 2 meters high. The size of the bait painted areas ranged from 5 x 20 cm to 5 x 40 cm. Ceilings and the top sections of walls were not treated as flies settle there only during the dormant phase and will not ingest any bait. Places, which could be reached by the livestock, were also not treated.

Larvicide Application. The larvicide triflumuron WP 25 was mixed in a ratio of 200g product in 10 liters of water per 100 m^2 manure surface. The suspension was applied to the breeding sites of fly maggots, such as slurry channels, dung channels, faecal remains near the pen walls, the edges of pens and bedding areas, slatted floors and feed remnants outside the troughs. Manure areas were treated 3 times at 2-week intervals.

Fly Assessment. The fly populations prior to treatment and at the evaluation times were assessed by counting living flies at specific intervals in the whole stable and calculated per animal. The assessment method depended strongly on the different stable conditions. For example, counting dead flies is only possible where enough surfaces are available, that expose the flies and do not hide them in straw or allow them to fall through slatted floors. Pre-treatment assessment of the fly population was done directly before application.

A visual assessment of the initial reduction of the fly population was carried out during the first hour after application by counting dead and affected flies near the treated areas. The initial efficacy was assessed 1 day after treatment. To assess the residual efficacy, adult fly assessment/monitoring counts were conducted once per week for the length of the study (at least 3 weeks up to 8 weeks or until fly population density had reached the level it was at before the trial).

RESULTS

Spray Application

Imidacloprid WG 10 was applied in 9 stables of 4 hog breeding and fattening farms versus azamethiphos WP 10 (Table 1). The farms provided good to moderate sanitary management. The imidacloprid WG 10 was sprayed with the application rate of 250 g in 2 liter water per 100 m^2 stable ground surface. Azamethiphos WP 10 was used in 4 stables of 2 farms according to label instructions with 500 g in 4 liter water per 100 m^2 stable ground surface. In the stables to be treated, the number of house flies (*Musca domestica*) per animal ranged from 38 to over 200 with a mean fly number per animal of 93.2 flies in the stables treated with imidacloprid WG 10 and 119 flies in the stables treated with azamethiphos WP 10.

Farm A consisted of 4 buildings each with different sanitary management, that were separated from each other. Building 1 had excellent sanitary management and relative low fly populations (38 flies per animal before treatment), with the exception of birthing pen 1. Both products (imidacloprid WG 10 in birthing pen 2 and azamethiphos WP 10 in the sows and boar stable 1) received 100% control from 1 DAT (day after treatment) to 6 WAT (week after treatment). The fly population declined in birthing pen 1, where the sows and piglets were kept on straw, from 100 flies per animal (pre-treatment) to 2 flies per animal at day one after treatment with imidacloprid WG 10. The fly population remained at this low level until 4 WAT. By 6 WAT, an increase of the fly population to 38 flies per animal was observed. The open piglet stable (building 2) was treated with imidacloprid WG 10. The fly population declined from more than 200 to 10 flies per animal within one day and remained at this level from 1 WAT to 6 WAT. The fly population was also reduced, in a separate stable with fattening pigs on straw (building 3), after treatment with imidacloprid WG 10 from more than 200 to 50 flies per animal at 1WAT. During the assessments from 2 WAT to 6 WAT, 10 to 38 flies per animal were found. Treatment with azamethiphos WP 10, in the sow barns 1 and 2 (building 4), resulted in a reduction of the fly population from more than 200 flies to 38 and 50 flies per animal at 1 DAT, respectively. In sow barn 1, 75 flies per animal were found during the assessments from week 1 to week 6 after treatment. The fly population was lower in the sow barn 2 with 25 to 75 flies during the assessment period.

Farm B consisted of a house with several pig breeding units of high sanitary standard. Low fly problems occurred only in two sow/boar stables and in a barn, where piglets were kept on straw. The fly population declined in the sow stable on straw from 75 flies per animal to 7 flies per animal (= 90% reduction) one week after application with imidacloprid WG 10 but increased again after 2 weeks to 38 flies (49% reduction). After 4 weeks the population had increased to 75 flies per animal. Dead and affected flies were found at every assessment. The other two stables started with a lower fly population of about 38 flies per animal prior to treatment, the fly infestation declined to 2 and 7 flies per animal over the whole assessment period (= 81% to 94% reduction).

Farm C also had excellent sanitary conditions and low fly pressure. Two small birthing pens were treated which were managed as ‘all in/all out compartments’. Both tested products gave 100% control against *Musca domestica* until the animals were removed and the stables were cleaned between 3 WAT and 4 WAT. The application of Imidacloprid WG 10 gave 97-98% fly reduction until 6 WAT in the sow stable (Farm D).

Efficacy Against Flies With High Resistance Level Against Synthetic Pyrethroids

Stables that were treated with residual contact sprays based on synthetic pyrethroids but where this treatment failed, were re-treated with imidacloprid WG 10 (250 g/100 m^2) one week later. The application of imidacloprid WG 10 (250 g/100 m^2) resulted in a good initial efficacy with a mean reduction at 1 DAT = 92.3% (Figure 1). The mean % reduction in the fly populations remained at a level of 95% or more over the assessment period during the following 3 weeks.

Combination of Imidacloprid WG 10 With A Larvicide in a Fly Control Program

Five stables were treated with imidacloprid WG 10 in week 26 in 2003 in a farm with poor sanitary management at this farm and a high amount of breeding sources for *Musca domestica* that were not cleaned on a regular basis, fly control with only an adulticide was not successful (Table 2a). The main sources of fly pressure were the units with sows and boars where a lot of fly puparia were found on the floor during the assessments. A decline in fly numbers was only found at day 1 of assessment in the sow and boar units and in the young sows unit. A better and longer fly control was achieved in the sow stable after treatment, however, an increase in flies was also found in this stable at week 2 caused by invading flies from the neighbouring sow/boar stables. In the separated birthing pen 1, the fly infestation broke down from 150 flies per animal before application

Table 1. Fly infestation in the stables in stables with poor sanitary management and high fly populations (Farm Nattenheim)

(The results are expressed in flies per animal);

Date of treatment: Week 26 / 2003; Assessments: Week 26 / 2003 to Week 32 / 2003

Farm/stable	Pre-count	1 DAT	1 WAT	2 WAT	3 WAT	4 WAT	6 WAT
Imidacloprid WG 10 – application rate: 250 g/100 m² in 2 liter water (n= 9 stables in 4 farms)							
Farm A - Birthing pen 1	100	2	1	0	0	2	38
Farm A - Birthing pen 2	38	0	0	0	0	0	0
Farm A - piglets (open stable)	>200	10	7	10	10	18	7
Farm A - Fattening pigs separate	>200	n.d.	50	18	18	38	10
Farm B - sows	75	n.d.	7	38	38	75	50
Farm B - Sows/boars	38	n.d.	2	2	2	2	7
Farm B - piglets	38	n.d.	0	2	7	7	7
Farm C - Birthing pen 2	75	n.d.	0	0	0	empty	n.d.
Farm D - sows	75	n.d.	0	2	2	2	1
Mean fly numbers per animal	93.2	4	7.4	8.0	8.5	18.0	15
Range of fly numbers per animal	38->200	0-10	0-50	0-38	0-38	0-75	0-38
Mean % reduction		95.7	92.1	91.4	90.9	80.7	83.9
Azamethiphos WP 10 – application rate: 500 g/100 m² in 4 liter water (n = 4 stables in 2 farms)							
Farm A - Sows + boar 1	38	0	0	1	0	0	0
Farm A - Sow barn 1	>200	38	75	75	75	75	75
Farm A - Sow barn 2	>200	50	25	25	38	75	38
Farm C - Birthing pen 3	38	nd	0	0	0	empty	n.d.
Mean fly numbers per animal	119	29	25	25	28	50	38
Range of fly numbers per animal	38 - >200	0 - 50	0-75	1-75	0-75	0-75	0-75
Mean % reduction		75.6	79.0	79.0	76.5	58.0	68.1

n.d. = not determined

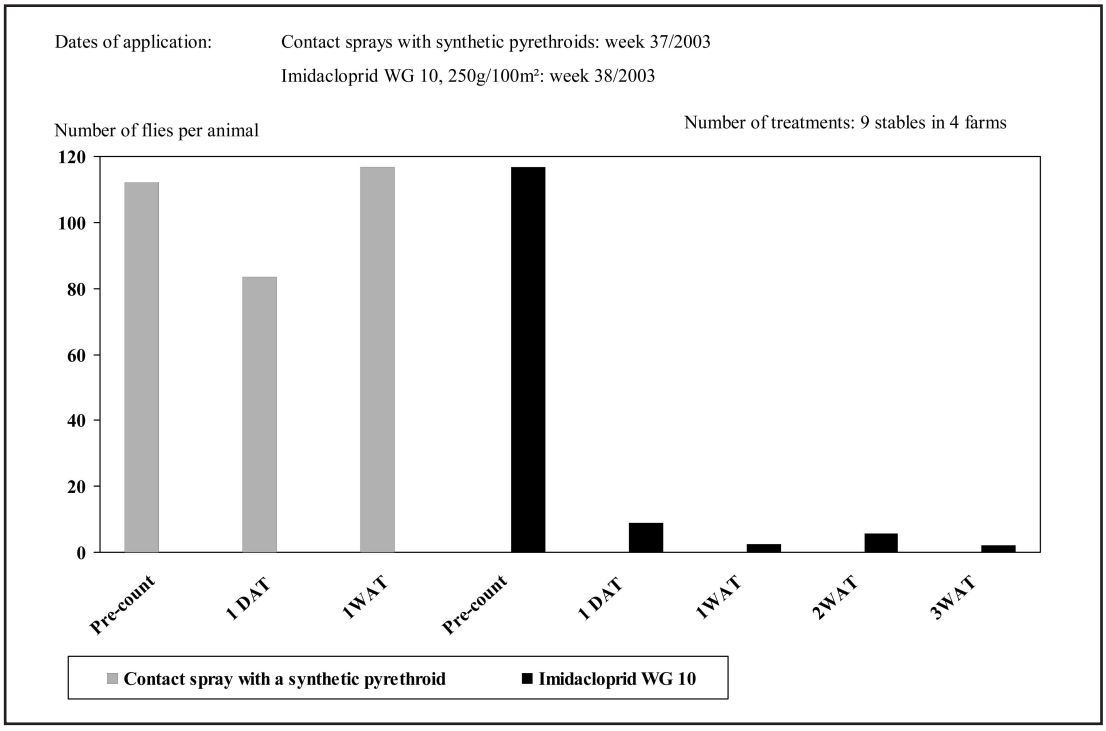

Figure 1. Efficacy of imidacloprid WG 10 after re-treatment in pig stables, where the treatment with water-based synthetic pyrethroid sprays failed

to 10 flies at day 1 after treatment. 50 flies were again found at the assessment on week 2. However, the fly pressure did not reach the level that it was before treatment during the 6-week assessment period.

A treatment with the lower application rate of 100 g Imidacloprid WG 10 per 100 m^2 was carried out in a small isolated sow stable. Only a small decline in the fly population from more than 200 to 75 flies per animal at 1 DAT was observed. These stables were treated again during week 35 using a fly control program with imidacloprid WG 10 as an adulticide and triflumuron WP 25 as a larvicide. The application rates were 250 g/100 m^2 stable ground surface for the adulticide, imidacloprid WG 10 and 200 g/100 m^2 manure surface for the larvicide triflumuron WP 25. The imidacloprid WG 10 was applied only at the beginning of the trial. Triflumuron WP 25 was sprayed 3 times on the manure with a gap of 2 weeks between each treatment.

With the combination of imidacloprid WG 10 and triflumuron WP 25, a fly reduction of 37.2% was achieved in stables with high fly pressure and poor sanitary management at 1 WAT (Table 2b). From week 3 to week 6, a fly reduction between 87.4 and 96.3% was achieved. The decline of the fly population in week 1 and 2 after treatment in most of the treated stables was caused mainly by the baits. The effect of the larvicidal treatment with triflumuron was visible from week 3 onwards when the fly populations remained at a low level at week 5 and 6 of the assessments.

Paint-on application

Imidacloprid WG 10 can also be mixed with water in a ratio of 1:0.8 (product:water) and be applied as a paint-on with an application rate of 250 g/100 m^2 stable ground surface. This type of application was assessed in 13 stables in 6 farms in the area of Bitburg and compared to spinosad GR 1.0, which is mixed with water at an application rate of 1:2.5 and applied with 200 g per 100 m^2 according to label instructions (Table 3). Fly populations ranged from 18 to more than 200 flies per animal before application with imidacloprid WG 10 and strongly declined in the first hour after treatment because of the fast knockdown action of the active ingredient. One day after treatment a 93% reduction in the fly population prior to treatment was found. The mean fly reduction after paint-on application of imidacloprid WG 10 was between 83% and 94% for the whole assessment period of 8 weeks.

Table 2a. Fly infestation in the stables in stables with poor sanitary management and high fly populations (Farm Nattenheim)

(The results are expressed in flies per animal);

Date of treatment: Week 26/ 2003; Assessments: Week 26/ 2003 to Week 32/ 2003

Farm/stable	Pre-count	1 DAT	1 WAT	2 WAT	3 WAT	4 WAT	6 WAT
Sows 1*	50	18	18	75	75	38	38
Sows/boars*	>200	38	>200	>200	100	>200	>200
young sows*	75	18	200	empty	75	75	25
Birthing pen 1*	150	10	18	50	50	75	25
Sows 2**	>200	75	>200	>200	>200	100	>200
Mean fly numbers per animal	135.5	31.8	127.2	131.3	100.0	97.6	97.6
Range of fly numbers per animal	50->200	10-75	18->200	50->200	50->200	38->200	25->200
Mean % reduction		76.5	5.8	2.7	25.9	27.7	27.7

*Treatment: Imidacloprid WG 10 (250g/100m²); **Treatment: Imidacloprid WG 10 (100g/100m²)

The knock-down effect of spinosad was low due to its slow mode of action and dead or affected flies were not found one hour after application. However, the fly population declined from 109 flies per animal before treatment to 5 flies within one day. A good control was found in all treated stables. After one week one stable (with poor sanitary management) showed poor control with 75 flies per animal. At week two, low fly populations were found in all stables. Fly populations increased again in week 3 and 4 and at week 5, half of the stables which were treated with spinosad had a fly level of 50 or more flies. At week 6 and week 8, fly reduction of 62% and 63% was achieved respectively.

DISCUSSION

Imidacloprid WG 10 is a new sugar based bait formulation against flies, which was particularly developed for application as a spray. However, its use as a paint-on is also possible. The efficacy of the bait was assessed in livestock housings, where flies tend to be a problem. In livestock housings, about one third of the surfaces in a stable are treated with imidacloprid WG 10, because this sprayable fly bait is only applied to surfaces where flies congregate during their active phase. This is in contrast to water-based residual contact insecticides which have to be sprayed on all available surfaces.

The amount of spray mixture, which can be sprayed on a surface without risk of dropping down, depends on the surface texture. On smooth and non-absorbent surfaces, 25-30 ml of a water based spray solution can be sprayed per square meter. On rough and absorbent surfaces, more than 50 ml needs to be applied without the risk of dropping down. According to these criteria, a 10% concentration of the active ingredient in the formulation was chosen to provide enough residual efficacy even on smooth surfaces with a low application rate per square meter.

Table 2b. Re- treatment of the farm Nattenheim with a fly control program (adulticide = imidacloprid WG 10 / larvicide = triflumuron WP 25)
Fly infestation in the stables in stables with poor sanitary management and high fly populations

(The results are expressed in flies per animal);

Date of treatment: Week 35/ 2003; Assessments: Week 35/ 2003 to Week 41/ 2003

Farm/stable	Pre-count Day 0	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT
Sows 1	75	25	2	2	2	2	2
Sows/boars	75	38	18	3	3	2	2
young sows	38	25	18	3	18	2	2
Birthing pen 1	150	50	38	10	7	2	7
Sows 2	>200	>200	50	50	75	18	7
Mean fly numbers per animal	107.6	67.6	25.2	13.6	21	5.2	4
Range of fly numbers per animal	38->200	25->200	2-50	2-50	2-75	2-18	2-7
Mean % reduction		37.2	76.6	87.4	80.5	95.2	96.3

Treatment at day 0: Imidacloprid WG 10 (250g/100m²) and triflumuron WP 25 (200g/100m²);

Re-treatment with triflumuron WP 25: 2WAT and 4WAT

The attractiveness of sugar for the larger house fly is well established; fly-attracting liquids based on sugar and water plus an inorganic poison were already used before the modern insecticides appeared (Keiding, 1986). Besides sugar, two special house fly attractants are included to intensify the fast knock down efficacy of this bait formulation. The addition of LEJ 179 increases the attractiveness of treated surfaces significantly. Z-9 tricosene is a proven fly attractant for the larger house fly *Musca domestica* and its use in fly baits is quite common (Chapman et al., 1998).

Imidacloprid WG 10 was applied as a spray in German pig stables in 2003/2004. A fast knock down after several minutes was observed in the field trials. Flies started to show typical symptoms of intoxication during and directly after spraying. The flies turned around, stretched their legs but coordination of the legs and wings was not possible any more. The product remained attractive for flies over a period of several weeks and affected or recently dead flies were observed under field conditions up to 6 weeks after application as spray. The long lasting efficacy of imidacloprid WG 10 in closed stables at swine facilities, which was found in German farms, was also confirmed in Italy (Fioretti, 2004) and South Africa (Nel and Loots, 2004). However, long lasting results were even found in pig stables, which were partly open and only covered with curtains in North Carolina (USA) (Stringham and Watson, 2004) and Brazil (Bendeck, 2004). Imidacloprid WG 10 performed better at an application rate of 250 g/100 m^2 stable ground surface compared to azamethiphos WP 10, which was applied at a higher dose of 500 g/100 m^2.

Table 3. Efficacy of imidacloprid WG 10 after application as paint- on versus spinosad GR 1.0 in closed hog houses in Germany

(The results are expressed in flies per animal);

Date of treatment: Week 29/ 2004; Assessments: Week 29/ 2004 to Week 37/ 2004

Tested product	Number of flies per animal – mean fly counts from n stables/range of fly numbers									
	Day 0	1 DAT	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT	8 WAT	n
Imidacloprid WG 10	73	9	10	10	7	5	8	11	9	13 stables
250 g / 100m²	18->200	0-7	0-50	0-38	0-25	0-18	0-38	0-50	0-38	6 farms
Mean % reduction	-	94	87	89	91	92	86	83	86	
Spinosad GR 1.0	109	5	17	12	19	24	50	39	37	7 stables
	38->200	0-18	2-75	2-25	2-50	2-50	2-150	2-75	7-75	4 farms
Mean % reduction	-	93	80	89	85	80	48	62	63	

n = no of stables/farms

Efficacy of imidacloprid WG 10 during application was also found against stable flies (*Stomoxys calcitrans*) garbage flies (*Hydrotaea* spp.) and vinegar flies (*Drosophila* spp.). The good initial and residual efficacy of imidacloprid WG 10 was also achieved in farms, where full surface treatments with synthetic pyrethroid sprays failed against *Musca domestica* (Figure 1).

The results, that were obtained under poor hygiene conditions and high fly populations with an adulticide alone (Table 3a) indicate that the sanitary management of livestock housing is an important factor which strongly influences the success of fly control with adulticides alone. However, the combination of the adulticide imidacloprid WG 10 with the larvicide triflumuron WP 25 in a fly control program has shown an excellent residual efficacy even in stables with poor sanitary management, where adulticides alone have no prospect of a successful fly control.

The use of sprayable baits as a paint-on application for house fly control is also quite common in many countries. A fast initial effect and 8 weeks residual efficacy were reached after application of imidacloprid WG 10 even in stables with poor sanitary management. The comparative product, spinosad GR 1.0 had a slower onset of efficacy and a shorter residual effect (Table 3).

According to these results, imidacloprid WG 10 has proven to have a high potential for the control of house flies, even those which are hard to control with synthetic pyrethroids. The good effect of imidacloprid WG 10 was underlined by the fact that some of the farmers had already used fly control products (sprays and baits) earlier in the season with poor success. The fast knock down and long lasting efficacy of imidacloprid WG 10 was noticed and emphasized by all farmers, even by those with poor interest in sanitary management. Imidacloprid WG 10 can be used as an important tool for fly control not only in livestock housings due to its superior advantages even against resistant flies, but also in other areas like professional pest control and public health.

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[1]QuickBayt® = Trademark of Bayer CropScience AG, Monheim, Germany, and brand name of Bayer Environmental Science. [2]Baycidal® = Trademark of Bayer AG, Leverkusen, Germany. [3]Bitrex® = Trademark of Macfarlan-Smith Limited

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