Establishment of infestivity model for *Sarcoptes scabiei* var *canis* in Nigerian dogs

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Abstract Experimental transmission patterns involved with the establishment of mange in dogs were studied to ascertain the effective means of infestation model for mange experiments in dogs. A total of eighteen (18) dogs were used out of which three (3) were naturally infested with *Sarcoptes scabiei* var *canis*. Five (5) healthy dogs were co-mingled with the three (3) donor dogs for direct contact transmission. Another five (5) mange free dogs were aggregated in a kennel recently vacated by mange infested dogs for environmental and formite transmission while the last five (5) healthy dogs had scrapings from a proximate area of mange lesion sites transferred into the pinnae of each dog for experimental and indirect contact transmission. Successful mite transmission with associated clinical features of pruritus, alopecia, erythema, papules and crusts was achieved with co-mingling of mange naïve and mange infested dogs. These clinical features also differed ($p < 0.05$) from dogs experimentally infested as this method of transmission was largely unsuccessful. Following the success of the direct contact model closely is the environmental and formite transmission model. Here, healthy dogs were housed in recently vacated mange infested kennels. The direct contact model only differed from the environmental model ($p < 0.05$) in the expression of erythema and papules in dogs. Although comingling infested and mange naïve dogs guarantees successful direct contact transmission, exposure of healthy dogs to infested

facility would also lead to infestation. This study showed that comingling remain an effective means of infestation model for mange experiments in dogs.

Keywords Transmission · Establishment · *Sarcoptes scabiei* var *canis* · Dogs

Introduction

It has been documented that scabies remains a scourge threatening both human and animal existence, hence its description as a disease of substantial veterinary and public health importance (Daszak et al. 2000). The poor state often complementing the infestation brings about production losses as well as death when left unattended to Walton and Currie (2007). Scabies has been described as a resource poor population disease and this has largely hampered frequent reporting of disease outbreaks (Heukelbach and Feldmeier 2009). This poor reporting of outbreaks remains contributory to the variations in the estimate of people infested with scabies worldwide (Chosidow 2006).

The parasite *Sarcoptes scabiei* remains responsible for scabies in humans as well as sarcoptic mange in various animals (Pence and Ueckermann 2002). It is a highly contagious skin disease, both male and female mites as well as their larvae and nymph wander on the skin surface of hosts (Pence and Ueckermann 2002). The roaming of these parasites on the skin of infested hosts has made transmission a lot easier as transmission can be direct or indirect (Arlian et al. 1988a, b).

A direct contact of an infested host with a non-infested host guarantees transmission as reports of mite's attraction to lipid compounds found on host's skin abound (Arlian 1989). However, direct contact between hosts has to be

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sustained for successful establishment of mite populations. This no doubt led to Walton and Currie's (2007) description of scabies as a sexually transmitted disease. Nevertheless, the spread of scabies has been noted in individuals without intimate encounters in health care facilities. These encounters are those of extensive scabies infections especially those marked with thick crust formations (Hsueh et al. 1992).

The ability of mites to survive for a while when dislodged off the host ensures the possibility for an indirect contact transmission (Arlian 1989). Most mite instars are displaced when hosts respond to the secretions of the mites via scratching. Worthy of note is the temperature dependence of all stages of these mites as a temperature of 21 °C and 40–80% RH favors survivability and infestivity of mites for about 24–36 h off the host (Arlian et al. 1984a). However, females and nymphs of *Sarcoptes scabiei* var *canis* has been proven to have the longest recorded survival time off the host of between 1 and 3 weeks at 10–15 °C and a Relative humidity of 97% (Arlian et al. 1984a). Mite's penetration and host seeking reduces at temperatures below 20 °C but rises at 35 °C (Ljunggren 2005). There have been accounts of some variants of scabies mites possessing the ability to detect odor and thermal stimuli which assists them to find a host again quickly (Arlian et al. 1984b). Continuous contact between non infested hosts and infested inanimate materials possibly assist the spread of the mites. Thomas et al. (1987) reported an outbreak of scabies in a hospital associated laundry where employees contacted scabies from contaminated items like linen and bedclothes.

Intellectually disadvantaged persons, incapacitated and elderly patients with low abilities to scratch the mites away as well as interpret their symptoms have become an additional vector involved in scabies infestations (Wolf and Krakowski 1987). Arlian (1989) observed little initial physical reaction of the host to mite's burrowing activity. As the mite increased its movement, increased keratinocyte damage causing skin shedding, local hemorrhaging and sensitization (due to Type 1 cutaneous hypersensitivity) were noticed.

Reports of dust containing live mites from infected people has added dust as a vector of transmission (Arlian et al. 1988a, b), as well as reports of density reliance since mange has been found more prevailing when coyote population densities are high in Texas (Pence and Windberg 1994). Sarcoptic mange has also been found most prevalent in drought or winter seasons (Skerratt and Beveridge 1998).

Scabies has largely been associated with socially disadvantaged communities as overcrowding favors spread of mites (Kate et al. 2010). In Nigeria, the abundance of remote communities predominated by hunters whose

occupation relies on dogs and the dearth of information on scabies should call for immediate attention. This information drought could have resulted from the neglect of scabies as an infectious disease as well as the limitation of parasite availability for research studies. Reports of scabies self-cure potential could be contributory to the neglect and availability of mites for research purposes.

The study aims at investigating the transmission patterns involved in establishing sarcopticosis in dogs as well as to propose a model that would favor mite abundance and infestation duration for research studies without the use of immunosuppressive therapies.

Materials and methods

Ethical approval

All international and national conducts and ethics guiding and justifying animal use and welfare was approved by The University of Ibadan's Animal Care, Use and Research Ethics Committee UI-ACUREC 17-0027. The scientific merits of the study was weighed as to justify animal use. An assessment of the impact on animal's well-being which includes animal handling, housing, feeding, monitoring and management was conducted. The fate of animals after 8 weeks (treatment) was also fully guaranteed. Approval was finally granted after certifying the protection of the rights, safety and integrity of vulnerable subjects.

Source of infestation

Three dogs owned by the principal investigator and showing varying degrees of alopecia with heavy crusts and severe pruritus were recruited for the study. The principal investigator fully and strongly consented to dog's participation. Dogs were housed in the fumigated research kennels of Federal College of Animal Health, Ibadan. With protective clothing and gloves, skin scrapings were taken from the lesion area of the dogs using glycerinized scalpel until capillary bleeding occurred (Elsheikha 2015) (Fig. 1).

Identification of mites

Morphological identification of mites was done in the Parasitology laboratory of The Federal College of Animal Health and Production Technology, Ibadan. 10% potassium hydroxide was added to the scrapings which was then heated near the boiling point and then examined with the help of dissecting (4×) and compound (10×) microscope. Final identification was done according to the keys and descriptions of Soulsby (1982) and Wall and Shearer (1997). After identifying microscopically that the mange

Fig. 1 aShowing the three donor animals, b impregnated female *Sarcptes scabiei* var *canis* isolated from the donor dogs (10% potassium hydroxide preparation, $\times 100$ magnification)

was exclusively caused by *S. scabiei* var *canis*, the three dogs became the donor animals as they were solely maintained as source of *S. scabiei* var *canis* for further transmission studies.

Source of experimental animals and acclimatization

Five (5) dogs were purchased randomly irrespective of sex from different dog farms and dog markets. All dogs were young (< 3 months old) and scabies naive. Health status of dogs was determined by eye inspection and body condition (absence of prominence of ribs, hipbones, Para lumbar fossa depression, and dehydration). Dogs were acclimatized for 2 weeks in which dogs were dewormed and fed with food and water ad libitum.

Estimation of mites in lesion sites

Severe skin lesion sites pronounced by marked alopecia and encrustations were mapped to be scraped for presence of mites. Scraping from an approximate area of $3\text{ cm} \times 3\text{ cm}$ in size was performed at six mange lesion sites from each donor animal. Scraping of mange lesion sites was sufficiently deep enough till blood oozed out. Three $3\text{ cm} \times 3\text{ cm}$ field scrapings were then collected into the pinnae of each dog. Skin scrapings were held in place with a little amount of cotton wool. An adhesive tape was then used to firmly attach the cotton wool to the dog's pinnae. This lasted for 48 h to enable successful establishment of mites. Areas scraped were chosen as the effect of the mites trying to digest host's skin leads to intense itching and rubbing which later results to the loss of hair and skin thickening. Hence these are the most preferred site for investigation as mite activity supposedly abounds therein.

Natural infestation (direct contact transmission)

Five (5) other healthy young dogs with no history of scabies were purchased, screened and acclimatized as above. All dogs were then co-mingled together with the scabies infested dogs to allow for direct contact transmission.

Environmental infestation (formite transmission)

The last five (5) healthy young scabies free dogs were also purchased, screened and acclimatized for 2 weeks. The dogs were then aggregated together in the kennel recently vacated by scabies infested dogs for fomite transmission. All studies lasted for eight (8) weeks.

Statistical analysis

Data obtained were subjected to analysis of variance (ANOVA) and variant means were separated by the least significant difference (LSD) method, using SAS 2004 statistical package. Significant differences were accepted at $p < 0.05$ probability level. Mange lesion scores were also subjected to Wilcoxon signed sum rank test analysis.

Results

See Table 1.

From the six (6) examined lesion fields of donor 1 dog, a total of three (3) mites and five (5) eggs were encountered. A total of two (2) mites and three (3) eggs was come across after skin scraping examination from Donor 2 dog while the scrutiny of lesion sites from donor 3 dog revealed three (3) mites and 4 (four) eggs. Most of the studied lesion fields of all donor dogs either had a mite or an egg present thereby confirming Sarcpticosis (Table 2).

Table 1 Examined fields of skin scraping of donor dogs

	Donor 1		Donor 2		Donor 3	
	Mites	Eggs	Mites	Eggs	Mites	Eggs
Site A	0	2	1	0	0	3
Site B	1	0	1	0	0	1
Site C	0	0	0	1	1	0
Site D	1	3	0	2	2	0
Site E	1	0	0	0	0	0
Site F	0	0	0	0	0	0

Table 2 Chronological appearance of clinical features of dogs exposed to scabies

Days: post exposure	Pruritus			Alopecia			Erythema			Papules			Crusts		
	Exp	Nat	Env	Exp	Nat	Env	Exp	Nat	Env	Exp	Nat	Env	Exp	Nat	Env
0	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
7	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
14	0/5	3/5	2/5	0/5	1/5	1/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5
21	0/5	5/5	3/5	0/5	2/5	2/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5	0/5
28	0/5	5/5	3/5	0/5	5/5	3/5	0/5	3/5	0/5	0/5	2/5	0/5	0/5	1/5	1/5
35	0/5	5/5	3/5	0/5	5/5	3/5	0/5	3/5	0/5	0/5	2/5	1/5	0/5	2/5	2/5
42	0/5	5/5	5/5	0/5	5/5	3/5	0/5	2/5	1/5	0/5	1/5	1/5	0/5	3/5	2/5
49	0/5	5/5	5/5	0/5	5/5	3/5	0/5	2/5	1/5	0/5	3/5	0/5	0/5	5/5	2/5
56	0/5	5/5	5/5	0/5	5/5	3/5	0/5	3/5	0/5	0/5	2/5	0/5	0/5	5/5	3/5

Exp experimental infestation, Nat natural infestation, Env environmental infestation

The onset of pruritus in dogs naturally and environmentally exposed to *S. scabiei* was quite early as dogs began to itch 14 days post exposure. The itching which signified mite attachment gradually progressed till the end of the study. The after effect of the process of trying to dislodge attached mites was hair loss which was mildly evident at the same time the itching started. Alopecia became apparent by the 28th day post exposure for dogs naturally and environmentally infested and this continued till the end of the study. Not all dogs were erythemic while study advanced as only one (1) fomite infested dog showed skin erythema 6 weeks post exposure. Dogs co-mingled showed marked signs of erythema as at the 28th day of housing together. Number of naturally infested dogs with papule formation varied from the 28th day post exposure. Only one (1) fomite infested dog had papules while the infestation lasted. Encrustation began in naturally infested dogs 3 weeks post exposure while it took 4 weeks to start in dogs environmentally exposed. Number of dogs with crust formation gradually progressed till end of study. The failure of mites to attach during the experimental transmission pattern led to the absence of all the above clinical features in dogs exposed (Fig. 2) (Table 3).

The total number of dogs exposed to *S. scabiei* naturally and environmentally did not differ significantly in their manifestation of pruritus and alopecia. In the appearance of erythema and papules during the course of infestation, there was a significant difference between numbers of dogs naturally and environmentally exposed. A slight variance also was observed in the numbers of natural and environmentally exposed dogs with crust formations (Table 4).

Mange lesion spread was scored (Rehbein et al. 2003). For the first 2 weeks post exposure, there was no significant difference in the spread of lesion in dogs experimentally, naturally and environmentally exposed to scabies. From the 21st day of mange contact, lesion spread in dogs both naturally and environmentally exposed differed significantly from dogs experimentally exposed to scabies. This trend continued till the end of the study as a result of the failure of the transmission model. Following natural infestation where dogs were housed together, active lesion of less than the palm of the hand (mild) was seen in just two (2) dogs by the 21st day of study. Active lesions progressed to more than the palm of the hand (moderate) before lesions then extended to more than half of the body (severe). Thus, lesion spread in dogs naturally exposed to

Fig. 2 aA naturally infested dog showing marked crust formations at day 56, b A naturally infested dog showing lesions of skin erythema and crust formations, c A naturally infested dog showing papule formations

Table 3 Mean ($\pm$ SEM) of dogs with varying levels of clinical features

Clinical features	Exp.	Nat.	Env.	SEM ($\pm$)
Pruritus	0.00 ^b	3.67 ^a	2.89 ^a	0.44
Alopecia	0.00 ^b	3.11 ^a	2.00 ^a	0.38
Erythema	0.00 ^b	1.44 ^a	0.22 ^b	0.20
Papules	0.00 ^b	1.11 ^a	0.22 ^b	0.16
Crust formation	0.00 ^b	1.89 ^a	1.11 ^{ab}	0.29

Exp experimental infestation, *Nat* natural infestation, *Env* environmental infestation

^{a,b}Means of different superscripts along the same row are significantly different ($p < 0.05$)

Table 4 Mange spread and lesion scores in infested dogs

Study days	Exp.	Nat.	Exp.	Env.	Nat.	Env.
0	-(5)	-(5)n	-(5)	-(5)n	-(5)	-(5)n
7	-(5)	-(5)n	-(5)	-(5)n	-(5)	-(5)n
14	-(5)	+1-(4)n	-(5)	+1-(4)n	+(1)-(4)	+(1)-(4)n
21	-(5)	+2-(3)s	-(5)	+2-(3)s	+(2)-(3)	+(2)-(3)n
28	-(5)	++(4)+(1)s	-(5)	+(3)-(2)s	+(5)	+(3)-(2)s
35	-(5)	++(4)+(1)s	-(5)	+(3)-(2)s	+(5)	+(3)-(2)s
42	-(5)	++(5)s	-(5)	++(3)-(2)s	++(5)	++(3)-(2)s
49	-(5)	++(5)s	-(5)	++(3)-(2)s	++(5)	++(3)-(2)s
56	-(5)	+++ (3) ++ (2)s	-(5)	++(3)-(2)s	+++ (3) ++ (2)	++(3)-(2)s

Exp experimental infestation, *Nat* natural infestation, *Env* environmental infestation

- Healthy Skin

+ Active lesion, extent less than the palm of the hand

++ Active lesion, extent more than the palm of the hand

+++ Active lesion, extent more than half of the body of animal

n Not significant at $\alpha = 0.05$

s Significant $p < 0.05$

Table 5 Mean ($\pm$ SEM) of bi-weekly weight gain (kg) of dogs infested with *Sarcoptes scabiei* var *canis*

Study duration (week)	Exp.	Nat.	Env.
0	9.00 $\pm$ 0.31 ^c	12.00 $\pm$ 0.83 ^b	10.20 $\pm$ 1.06 ^a
2	9.30 $\pm$ 0.30 ^c	12.26 $\pm$ 0.79 ^{ab}	10.68 $\pm$ 1.13 ^a
4	10.20 $\pm$ 0.37 ^b	13.20 $\pm$ 0.58 ^{ab}	11.18 $\pm$ 1.01 ^a
6	10.80 $\pm$ 0.25 ^b	13.72 $\pm$ 0.38 ^{ab}	12.04 $\pm$ 0.88 ^a
8	12.88 $\pm$ 0.15 ^a	14.20 $\pm$ 0.37 ^a	12.66 $\pm$ 0.90 ^a

Exp experimental infestation, Nat natural infestation, Env environmental infestation

^{a,b}Means of different superscripts along the same column are significantly different ($p < 0.05$)

scabies significantly varied from dogs environmentally exposed to scabies (Table 5).

Dogs experimentally exposed to scabies had significant weight gain at the 4th and 8th week of exposure. Meanwhile, weight gain was only pointedly obvious by the end of the study in dogs naturally exposed to scabies. There remained no significant increase in weight in dogs environmentally exposed to *S. scabiei*.

Discussion

This study evaluates the establishment of mite infestation for experimental purpose in dogs. Three important methods of establishment of infestation were examined. Scraped sites were chosen based on the obvious alopecic and pruritic pictures. Sites were scraped with expectations to find both mites and eggs but either mites or eggs were seen after examination. Some other examined skin scrapes did not reveal mites nor eggs. This suggests that examination of skin scrapings does not guarantee finding mites or eggs. Absence of mites in the scrapings may be as a result of the characteristic burrowing potential of *sarcoptes* mites. Female mites burrow into the *stratum corneum* after mating to lay fertilized eggs, after which developing instars crawl out to seek and explore the skin of infested dog (Heilesen 1946). Lesion fields negative for mites may also be attributable to the fact that most of these first instars burrow out to build moulting pockets where they complete development (Arlian and Vyszenski-Moher 1988).

Since negative fields were encountered in all three-donor dogs, finding corroborates Morris and Dunstan (1996) that $> 50\%$ of skin scraping can be negative in dogs. Negative skin scraping remains the bane towards successful diagnosis of scabies in animals. This resultant possible misdiagnosis would always expose dogs to toxic medications since scabies mimics some other dermatologic or allergic conditions. Emerging parasite and drug resistance can as well be linked to false medications consequent

upon the flawed scabies diagnosis arising from a negative skin scrape.

Attempts to communicate *S. scabiei* var *canis* from scabies infested dogs to scabies naïve dogs experimentally were totally unsuccessful. No dog showed lesion characteristic of sarcoptosis. This transmission failure could have resulted from the low mite burdens associated with the infective materials from skin scrapings. The few mites that may well be transferred to the ear pinnae of the dogs may have been injured in the process of scraping too. These injuries sustained would without doubt hinder establishment of the mites. The eggs most likely transferred also failed to hatch. This is in agreement with Orion et al. (2006) that less than 10% of eggs laid survive to reach adulthood under the most favorable conditions. The disadvantaged hatching potential of the mite eggs may have also resulted from the harsh conditions encountered during the transfer into the ear pinnae.

Co-mingling of scabies infested and scabies free dogs to allow for natural infestation gave excellent results as three (3) out of five (5) dogs showed evidence of infestation by 14 days. The proof of invasion seen was the constant pruritus especially at the areas with less hairs (pinnae). Gradual hair loss followed the itching and as the itching and alopecia progressed, crusts began to form in response to the activity of the mite digesting the skin. The housing of scabies infested and non-infested dogs can well be described as successful since it agrees with Walton and Currie's (2007) description of scabies as a sexually transmitted disease. Hence, prolonged and sustained contact with infested animals favors spread of mites. Furthermore, the attraction of mites to skin lipid compounds together with the possibility of male and female mite meetings on the skin remains contributory to the severity of dermatologic lesions observed in this group. These lesions are as a result of impregnation as female mites begin to burrow her way through to oviposition. Other hypersensitive responses (erythema and papule formations) seen may also be results of the burrowing journey of the female mites (Sajad et al. 2017).

The successful formite infestation observed during the study period (December–January) which is characterized by low temperatures and relative humidity largely supports the submission of Arlian and Morgan (2017) that conducive relative humidity and temperatures were favorable for the survival of both male and female dislodged mites for up to about a week. The mites also validated their host seeking attitude whereby they detect stimuli source from the host while close to the host (Arlian et al. 1988a, b). All five (5) dogs presented evident pruritus by the 42nd day of housing. The last two (2) infested dogs most perhaps got infested via body contact with the three (3) formite infested dogs. It can thus be said that the environmental model of mite transmission is somewhat successful but largely limited by the number of the dislodged mites that were available.

Weeks and Kaufman (2015) observed that severity of mange lesions depends on type of mite and animal's health. The severity of lesions as well as the advancement of its spread could also be related to establishment of the female mites in burrows created. Eggs laid could have hatched to the developing instars. When these instars begin to crawl out to complete their development, they increase the itching of the host as they induce skin irritations (Weeks and Kaufman 2015). All dogs experimentally exposed to *S. scabiei* var *canis* mites remained lesion free all through study weeks.

The weight outcome of all dogs exposed to scabies naturally, experimentally and environmentally was good as the invasion and attachment of mites to the skin of dogs did not interfere with the dog's appetite for food. This is in contrast to Week and Kaufman's (2015) observation that mange infested animals may suffer from weight loss. There was no loss in weight of all the dogs exposed to the different transmission models. Although it could be said that dogs would have gained more weight without scabies. This submission is arising from the result of the weight of dogs experimentally exposed to scabies. These dogs possibly gained significant weight as they did not expend so much energy itching and trying to rub away attached mites. It can therefore be established that *S. scabiei* delays weight gain as animals tend to battle great discomforts even while feeding.

In conclusion, co-mingling of scabies infested dogs and scabies free dogs remains the best form of scabies transmission as the mites involved had no external interference with their growth, reproduction, development and feeding. Mites by means of their host seeking attribute had unrestricted access to explore hosts skin and cause lesions. Our submission therefore is that co-mingling remains the preferred model for mite abundance without the use of immunosuppressive therapies.

Author contributions Study was conceived, designed and supervised by N.A. Sadiq. Infestation, data gathering and analysis was done by O.C. Nwufoh (the principal investigator and a post graduate student of The Department of Veterinary Parasitology, University of Ibadan). Study was co-supervised by B.O Emikpe and manuscript was edited by B.O. Emikpe. All authors proof read and approved the final copy of manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interests.

References

- Arlian LG (1989) Biology, host relations and epidemiology of *Sarcoptes scabiei*. *Ann Rev Entomol* 34(139–161):1989
- Arlian LG, Morgan MS (2017) A review of *Sarcoptes scabiei*: past, present and future. *Parasit Vectors* 10:297
- Arlian LG, Vyszynski-Moher DL (1988) Life cycle of *Sarcoptes scabiei* var. *canis*. *J Para* 74(3):427–430
- Arlian LG, Runyan RA, Achar S, Estes SA (1984a) Survival and infectivity of *Sarcoptes scabiei* var. *canis* and var. *hominis*. *J Am Acad Dermatol* 11:210–215
- Arlian LG, Runyan RA, Achar S, Estes SA (1984b) Host seeking behavior of *Sarcoptes scabiei*. *J Am Acad Dermatol* 11:594–598
- Arlian LG, Estes SA, Vyszynski-Moher DL (1988a) Prevalence of *Sarcoptes scabiei* in the homes and nursing homes of scabietic patients. *J Am Acad Dermatol* 19(5, Pt1):806–811
- Arlian LG, Runyan RA, Vyszynski-Moher DL (1988b) Water balance and nutrient procurement of *Sarcoptes scabiei* var. *canis* (Acari: Sarcoptidae). *J Med Entomol* 25(1):64–68
- Chosidow O (2006) Scabies. *N Engl J Med* 354:1718–1727
- Daszak P, Cunningham AA, Hyatt AD (2000) Emerging infectious diseases of wildlife: global threats to biodiversity and human health. *Science* 287:443–449
- Elsheikha H (2015) Biology, diagnosis and management of Sarcoptic mange. *Vet Nurse* 6(5):3
- Heilesen B (1946) Studies on *Acarus scabiei* and scabies. *Acta Dermatol Venerol* 26:1–370
- Heukelbach J, Feldmeier H (2009) Scabies. *Lancet* 367:1767–1774
- Hsueh PR, Lin BH, Hwang CC, Hsieh BL, Liu JC, Lin M (1992) Nosocomial outbreak of scabies. *J For Med Assoc* 91:228–232
- Kate M, Mei-Fong H, Andrew K, Charlene W, Cielo P, Kemp DJ, McCarthy JS, Katja F (2010) A tractable experimental model for study of human and animal scabies. *J Negl Trop Dis, PLOS*
- Ljunggren EL (2005) Molecular analysis of *Sarcoptes scabiei*. Doctoral thesis. ISSN 1652-6880, ISBN 91-576-7046-3
- Morris DO, Dunstan RW (1996) A histomorphological study of Sarcoptic acariasis in the dog: 19 cases. *J Am Anim Hosp Assoc* 32(2):119–124
- Orion E, Marcos B, Davidovici B, Wolf R (2006) Itch and scratch: Scabies and pediculosis. *Clin Dermatol* 24:168–175
- Pence DB, Ueckermann E (2002) Sarcoptic mange in wildlife. *Rev Sci Tech* 21:385–398
- Pence DB, Windberg LA (1994) Impact of a Sarcoptic mange epizootic on a coyote population. *J Wildl Manage* 58:624–633
- Rehbein S, Visser M, Winter R, Trommer B, Matthes HF, Maciel AE, Marley SE (2003) Productivity effects of bovine mange and control with ivermectin. *Vet Parasitol* 114:267–284
- Sajad AB, Kate ME, Xiason L, Walton SF (2017) Host immune responses to the itch mite, *Sarcoptes scabiei* in humans. *Parasit Vectors* 10:385

- SAS (2004) SAS/STAT. User's guide (release 8.03) SAS Institute, Cary North Carolina, USA
- Skerratt LF, Beveridge I (1998) Human scabies of wombat origin. *Aust Vet J* 77:607
- Soulsby EJ (1982) *Helminths, Arthropods and Protozoa of domesticated animals*, 7th edn. Baillieri Tindal, London
- Thomas MC, Giedinghagen DH, Hoff GL (1987) Brief report: an outbreak of scabies among employees in a hospital-associated commercial laundry. *Infect Control* 8:427–429
- Wall R, Shearer D (1997) *Veterinary entomology*, 1st edn. Chapman and Hall, London
- Walton SF, Currie BJ (2007) Problems in diagnosing scabies, a global disease in human and animal populations. *Clin Microbiol Rev* 20:268–279
- Weeks ENI, Kaufman PE (2015) Mange in companion animals. *ENY-289* <http://edis.ifas.ufl.edu/>. Accessed Sept 2015
- Wolf R, Krakowski A (1987) Atypical crusted scabies. *J Am Acad Dermatol* 17:434–436