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PREVALENCE OF VARROA IN UGANDA

E. Moiti*& A.M. Akol

Department of Biological Science, College of Natural Science, Makerere University, Kampala, Uganda.

* For correspondence Email: moitieriya@yahoo.com / moitieriya@gmail.com

Abstract: *Varroa* mite has been a concern and worry to the bee scientists and beekeepers since it was first discovered in 1904, and continues to be the most serious pest of honeybees. It causes clinical symptoms on the brood and adult bees. This study determined the occurrence and degree of infestation of *Varroa* mites in five selected agro-ecological zones in Uganda and also examined the influence of altitude and management attributes on the degree of *Varroa* infestation. Alcohol wash method was used to dislodge *Varroa* mites from the bees sampled from 300 hives across 150 beekeepers operating as individual and group beekeepers. A global positioning system was used to take the coordinates and altitude of the apiary sites surveyed. A questionnaire was used to get information on hive management attributes. *Varroa* load levels were statistically significant amongst the agro-ecological zones while levels of incidence were not. Differences in the *Varroa* load levels amongst the agro-ecological zones were statistically significant. Incidence and Varroa load (Varroasis) was not associated with altitude or hive management attributes. This study provides baseline information on *Varroa* prevalence and highlights the necessity for apiary management training among beekeepers as a component of *Varroa* management.

Key words: Severity, incidence, management attributes, infestation and agro-ecological zones.

INTRODUCTION

Parasites and diseases affecting honey bees are a global problem that threaten the apiculture industry. A number of pests such as *Varroa*, tracheal mites, hive beetles, wax moth and ants are key pests of honey bees (Wilkins *et al*. 2007; Dietemann *et al*. 2009; Kajobe *et al*. 2009). The most serious pest of honey bees in the world is the Varroa mite (Rosenkranz et al. 2010; Damos 2012; Dooremalen *et al*. 2013). The *Varroa* mite has been incriminated as one of the causes of bee colony losses and responsible for nearly complete eradication of feral honey bees in Europe, North America, South America, Middle East, Canada and Japan (Barlow 2006; Guzman-Novoa *et al*. 2010; Johnson 2010; Bobryni *et al*. 2011; Locke 2012).

Varroa mites spread through movement of infected bees to other colonies. Spread can also occur through close transfer where the mites move from one bee to another in the field and between bees within the hive (Barlow 2006). Robbing of the infected colonies, drifting of infected bees into other colonies and migrating swarms are other forms of spread (Calderone 1999; Bokaie *et al*. 2014). Heavy *Varroa* infestation causes reduction in weight and abdominal protein level in individual bees (Dooremalen *et al*. 2013). The *Varroa* mites pierce and suck haemolymph from the adult and developing brood bees. This continuous feeding weakens the bees and suppresses their immunity (Rosenkranz *et al*. 2010).

In Africa, *Varroa destructor* Anderson & Trueman was noticed in South Africa in Cape Town in 1997; and by 2002, *Varroa* had spread to the borders of Botswana, Mozambique, Swaziland and Zimbabwe (Allsopp 2006). Varroa and the spread of *Apis mellifera capensis*

Eschscholtz led to a rapid decline in the native honeybee populations for seven years in South Africa (Allsopp 2006). The introduction of Varroa mite in Algeria, Tunisia and Morocco caused dramatic loss of bees until chemical control methods were used to halt the losses and to stabilise the bee populations in the colonies (Dietmann *et al*. 2009). In 2013, the magnitude of infestation of *Apis mellifera adansonii* Latreille colonies with *Varroa* was 78.57% of the colonies sampled in Western Nigeria (Akinwande *et al*. 2013).

In 2009, it was reported that *Varroa destructor* had infiltrated East Africa and was present in 87% of the colonies sampled in central and western Kenya, Eastern Tanzania except in colonies sampled in mid- western Uganda (Frazier *et al*. 2010). *Varroa* is the most serious ecto-parasite of honeybees (Anderson &Trueman, 2000; Damos, 2012). Varroa mites are difficult to control because they easily develop resistance to varroacides (Thompson et al. 2003; Elzen *et al*. 2004). A high *Varroa* level causes a reduction in honey production in the bee colonies (Currie& Gatien 2006). *Varroa* is also known to impair the health of honeybees and eventually reduce colony strength and number of colonies in infested areas (Sean *et al*. 2003, Hendrikx *et al*. 2009).

Varroa presence in bee colonies in Uganda is highly significant given that honeybees are responsible for pollinating 75% of the agricultural crops and supplementing income through honey production (MAAIF 2012b). The annual economic value of pollinators in Uganda of which bees contribute the biggest number was estimated to be worth of US$ 0.49 billion for a total economic value of crop production of US$1.16 billion (Munyuli 2011). Apiculture is a viable economic activity and formerly contributed about 8% to the total national gross domestic product (UEPB 2006).

Uganda is endowed with a rich variety of honeybee species that include: *A.m. scutellata*, *A.m. adansonii* and *A. m. monticola* with a suitable flora for bee-keeping (FIT Uganda 2006). According to the national livestock census of 2008, over 750000 beehives existed then in the country, and of these 65% were colonized with an estimated honey production of 2600 MT per year (MAAIF 2012b). The sub sector serves both the local and the international market. Its major apiary products are honey, bees-wax and propolis (FIT Uganda 2006). Production of honey is done on a small scale by individual farmers or farmers organized in groups, largely making use of low cost technologies. Most farmers use traditional beehives and adoption of modern beehives such as the Kenya top bar (KTB) hive and Langstroth is still low (FIT Uganda 2006; Mujuni *et al*. 2012). The honeybee population and other pollinators in Uganda are facing increasing loss of habitat to crop agriculture, enterprises and destructive threats of wild fires, hunting and unregulated use of chemical pesticides (Kajobe *et al*. 2009; MAAIF 2012b). *Varroa* is another anticipated threat that could further affect the health and status of the honeybee population in Uganda.

We started a nationwide survey for *Varroa* in the selected five agro-ecological zones in the country. The aim of this wider study was to establish the extent of Varroa mite infestation in five selected agro-ecological zones of Uganda: the Lake Victoria crescent zone, Western medium high farmlands, Lake Albert crescent zone, Northern moist farmlands and the Elgon farmlands. Specific determination of incidence and severity, and influence of altitude and hive management attributes on Varroa infestation was also investigated.

MATERIALS AND METHODS

Study area

The survey was done in five major bee keeping agro-ecological zones of the fourteen agro-ecological zones that make up the geographical zones in Uganda (Fig. 1). The zones were characterised on the basis of the amount of rainfall received as the primary dependent factor for each zone. The other secondary factors were topography, temperature and vegetation which were considered to be uniform in each zone but differed between the zones. The Lake Victoria crescent extends 48-64 km from the lake shore. It experiences two relatively dry periods between December and March and the other between June and July. The peak rainfall periods are received in March to May and October to November. Average rainfall received varies from 1250-1500 mm per annum and has a minimum temperature of 12 °C. The mean altitude of this zone ranges from 1174-1235 m above sea level (Kamanyire 2000). The study districts in this zone were Luweero and Masaka. The second zone was Western medium high farmlands. This is a narrow zone along the western boundary of Uganda. The rift valley part of this zone is hot and dry with mean annual rainfall ranging from 875-1000 mm. In the higher altitude southern part (south-western high lands), the mean annual rainfall exceeds 1875 mm. The mean altitude of the zone ranges from 1428-2123 m above sea level (Kamanyire 2000; START 2009). The study districts were Kabarole and Kyenjojo.

The third zone was the Lake Albert crescent (western mid-altitude farmlands and the Semliki flats). The districts chosen for the study were Masindi and Hoima. This zone receives average rainfall between 1000 mm and 1270 mm annually and its minimum temperature is 10 °C. The mean altitude of this zone ranges from 621-1585 m above sea level (START 2009; NEMA 2009). The fourth zone was Northern moist farmlands. This zone is generally flat with isolated hills, wide wetlands and soils are moderate to poor. The average rainfall received ranges from 1197-1000 mm annually. The zone receives one rainy season of 6-7 months between April to late October. It has a minimum temperature of 15 °C and the mean altitude of the zone ranges from 1024-1075 m above sea level (START 2009; NEMA 2009). The study districts were Kitgum and Gulu. The fifth zone; the Elgon farmlands receives bimodal high rainfall greater than 1200 mm per year. The minimum temperature is 15 °C. The mean altitude is 1075 m above sea level (START 2009; NEMA 2009). Sironko and Mbale were the study districts.

Sampling design

Five agro-ecological zones (Fig.1) with varying altitudes were chosen. Two districts with substantial number of beekeepers were selected in each zone. Main beekeeping areas in the districts were sampled. Fifteen beekeepers were randomly selected in each district (30 beekeepers for the two districts in each zone). Two hives were randomly selected from the apiary of each beekeeper. A total of 60 hives were sampled in the representative districts of each zone. Beekeepers operating as individual or as a group beekeeping association were interviewed and their apiary sites sampled. A prior notice was given to the beekeeper and group beekeepers before samples were collected from their apiaries. Some apiaries which were very close or within the yard of the homestead were sampled at night. This was done to avoid bee attacks on unprotected people and their livestock.

Honeybee samples and mite collection

In each selected apiary, the two hives selected randomly were opened one at a time. The middle hive bee combs were removed and the bees on these combs were brushed into a labeled transparent jar of 500 ml using a bee brush. The jar was then immediately covered with a lid. 70% ethanol (Lab care grade) was added to completely cover the bees. The jar was shaken to fully soak the bees in the ethanol and then left to stand for five minutes. The bees remained in a tightly closed jar as the sampling continued at other sites during the day. After the sampling process for the day, the jars were arranged for the sorting of the mites from the bees. The jar was inclined at an angle and the bees were removed from ethanol using the uncapping fork into a 1000 ml transparent jar. The dislodged mites and ethanol were poured on a white cloth placed on top of another 1000 ml jar. The mites trapped on the white cloth were sorted and counted. The bees were then washed twice with water in a transparent jar to get the remaining dislodged mites in the sample. The bees were then carefully removed from the water using the uncapping fork. The floating mites in the water were poured on the white cloth suspended on top of the jar. The trapped mites on the cloth were sorted, counted and added to those got in the first wash. A sample of sealed drone brood was also removed from the sampled hives that had drone brood at the time of sample collection to check for the presence of the mites in the rest of the hive.

Data analysis

All data collected from the survey was entered into MS Excel work sheets. The number of mites got per hive was divided by the number of bees sampled in the hive to get the infestation per bee (severity).

$$\text{Severity (infestation per bee)} = \frac{\text{Number of Varroa mites}}{\text{Number of bees sampled}}$$

The severity per 100 bees (% severity) was then determined by multiplying the infestation per bee by 100. Mean % severity for the two hives sampled from each beekeeper was determined by the average of the percentage severity of the two hives. The number of hives infested and non-infested were recorded for each farmer, district and agro-ecological zone. Percentage incidence was calculated for each zone.

$$\text{Incidence} = \frac{\text{Number of hives infected in the zone}}{\text{Number of hives sampled in the zone}}$$

Descriptive statistics and Fisher's exact test were used to analyse incidence while Kruskal Wallis test was used to determine the level of Varroa load in the zones.

Altitude

The altitude and coordinates of the apiary sites were recorded using a GPS (global positioning system, Garmin Ltd, Kansas City, U.S.A.). The first zone was Lake Victoria crescent zone. The altitude of the apiary sites surveyed ranged from 1082 to 1313 m above sea level. Northern moist farmland sites ranged from 928 to1086 m while Elgon farmland sites ranged from 1110 to 1808 m above sea level. The Western mid-high farmland sites ranged from 1312 to1659 m and Albert crescent zone sites ranged from 1054 to 1214 m above sea level. The altitude of the survey sites was categorised as high (above 1400 m), medium (1201-1400 m) and low (below 1201 m). The altitude of the apiary sites surveyed in all the zones was accordingly grouped into the three categories of altitude above. The number of hives infested and non-infested were recorded and the mean severity in each category of altitude range was calculated by taking the mean of all the average severity in each category, using MS Excel software. Using the XLSTAT 2014.1.05 version, a logistic regression was used to examine the statistical relationship between altitude and varroasis.

Colony management attributes

A pre-tested questionnaire and observation of the hives were used to generate information on hive management practices and hive attributes that can be related to *Varroa* infestation. The management attributes were: hive quality, inspection, spacing between hives, hive location, treatment against pests and water provision in the apiary. Other information gathered was on: beekeepers state of and access to information on pests and diseases in bee-keeping, source of bees for stocking the hives, and records on pest attack on the hives. Interviews were conducted with each bee-keeper by a single enumerator, and during the face to face interaction, a separate questionnaire was filled. Discussions were done in English and the local language through an interpreter who at the same time worked as a research assistant, knew the place and the local language used. This was done either at the beekeepers' home or at the apiary site.

Direct observation of the beehives was done before and during sampling to ensure that right information was got on the chosen hive attributes. Photographs of adult *Varroa* mites, preserved *Varroa* nymphs and adult mites were shown to the farmers to confirm whether they knew the pest or not. Evidence of records on the honey production and pest attacks was requested from the beekeeper, as a way to prove that records were available. The survey questionnaire were coded and entered into the MS Excel computer software. The field data were then cleaned for factual errors. Data on source of bees for hive colonization, awareness of *Varroa*, source of support information and records on pest attacks were summarized using descriptive statistics procedures. A regression analysis was carried out using STATA version 10 to examine the relationship between varroasis and hive attributes. A logistic regression analysis using XLSTAT, 2014.1.05 version was used to determine the relationship between varroasis and management status.

RESULTS

Incidence and severity of Varroa

The survey showed that *Varroa* mites are widespread in all the five agro-ecological zones of Uganda. All of the hives (100%) sampled in the Northern moist farmlands and Western medium highland farmlands were infected with *Varroa*. Fifty eight hives (97%) out of the 60 hives sampled in Elgon farmlands and Albert crescent zone were also infected with *Varroa*. In the Lake Victoria crescent zone, 56 hives (93%) of the hives sampled had *Varroa*. All the 30 hives (100%) from each of the districts of Kitgum, Gulu, Mbale, Kabarole, Kyenjojo and Masindi were infected with Varroa mites, while 28 hives (93%) from each of the districts of Masaka, Luweero, Sironko and Hoima were infected with *Varroa*. Overall, 292 hives (97%) of the 300 hives surveyed in the five agro-ecological zones were infected with *Varroa.* The mean infestation (Table 1) per bee and per 100 bees in the agro-ecological zones was highest in the Elgon farmlands (0.0458 and 4.58) respectively and lowest in Western mid high farmlands (0.01761 and 1.761). Incidence was not statistically different among the agro-ecological zones while severity was. Elgon farmlands infestation level was different from the Western medium high farmlands.

Influence of altitude

The results of this survey showed that *Varroa* infestation was not significantly affected by altitude. Infestation was not significantly associated with altitude (P = 0.637), (Tables 3 & 4). The mean *Varroa* load (Table 2) for the high, medium and low altitude areas were 2.21, 2.90 and 2.82 mites per 100 bees respectively.

3.3 Influence of colony management attributes

The results of this study on the management attributes show that *Varroa* infestation rate is not influenced by hive attributes. The regression analysis that was carried out to examine the relationship between varroasis and hive attributes found that the relationship was not statistically significant; hive location (P = 0.1742), hive spacing (P = 1), hive quality (P = 0.2222), hive inspection (P = 0.2717, Pest treatment (P = 0.3119) and water provision (P = 0.8231) (Table 5). A logistic regression analysis of the relationship between varroasis and management status (poor and good) was not statistically significant (P = 0.359) (Table 6 and 7). Both poor and well managed hives were equally infected.

DISCUSSION

Incidence and Varroa load levels

This study set out with the aim of establishing the extent of *Varroa* mite infestation in five agro-ecological zones. It was predicted that *Varroa* infestation did not exceed 10% of the colonies sampled based on the ealier study by Frazier *et al*. (2010) which found that all the 14 colonies that were sampled in western Uganda were *Varroa* free. The findings of this study showed that *Varroa* is widely spread in all the five agro-ecological zones, including the areas surveyed by Frazier *et al*. (2010). Over 90% of the colonies sampled in all the agro-ecological zones were infected with *Varroa*. This incidence is higher than for colonies of *Apis mellifera adansonii* in south western Nigeria which was found to be 78.57% of the 14 apiaries sampled (Akinwandwe *et al*. 2013). The overall situation nevertheless is lower than Kenya where (Frazier *et al*. 2010) found 100% incidence levels of *Varroa* in 38 colonies sampled in Central and Eastern Kenya. The specific picture in Uganda is not good anyway, being that in the Northern moist farmlands and the Western medium high farmlands of Uganda the infestation was also 100%.

The *Varroa* load (mites per bee) was statistically significant amongst the agro-ecological zones (Table I). The highest *Varroa* load was recorded in the Elgon farm lands while the lowest was in the Western medium high farmlands. The infestation levels in this study reached the threshold level of 0.07 to 0.12 mites per bee recommended for control at colony level in some areas though they are slightly lower than levels reported from other countries (Delaplane and Hood 1999; Strang and Sheppard 2001).

The difference in the occurrence of *Varroa* in Western Uganda between Frazier *et al*. (2010) and this study could be that the infestation level was very low and the mites were in initial stages of establishing in the hives. Therefore, most of the *Varroa* could have been in the reproductive phase than in the phoretic phase where they could be found on adult bees. *Varroa* in a reproductive phase is enclosed in the brood cell and can only be detected by opening the brood cells. Also the absence of mites in 2010 survey could also be linked to a small sample area that was considered. Only one district, Hoima was sampled, other areas in the country that could have had *Varroa* like the Elgon region neighbouring Kenya were not surveyed.

The difference in the degree of infestation in the agro-ecological zones being high in the Elgon farmlands and low in the western medium high farmlands (Table 1) could be due to the time lag between *Varroa* introduction in the two zones. *Varroa* probably, has undergone a number of reproductive cycles in the Elgon zone than in the Western medium high farmlands leading to a high load in the hives. Many crop pests in Uganda have been attributed to introductions from neighbouring countries either through cross border trade, human movements and flying vectors (MAAIF 2014). *Varroa* in Uganda could have entered by the same route through Kenya because the infestation rates observed in the Elgon farmlands neighbouring Kenya were much higher than those encountered in other areas. The Varroa of Sub-Saharan Africa were introduced into Cape Town, South Africa around 1997 by ship-borne swarms, or were on containers (Davey 2010). The mites began moving northwards reaching Zambia in 2007, and possibly continuing on to reach East Africa. According to Frazier *et al*. (2010), the mites in Kenya were identical to the South Korean haplotype of *Varroa destructor* that was the same haplotype found in South Africa (Allsopp 2006) and which was moving northwards.

The findings of this survey have important implications for the bee sector in Uganda. Colonies that may be heavily infested with *Varroa* may require treatment, this will increase the costs involved in beekeeping and the risk of chemical residues in honey. The presence of this pest in the colonies can be a crucial factor that may lead to decrease in the number of beekeepers and honeybee colonies in Uganda consequently causing a great impact on pollination of agricultural crops.

Threshold recommendation levels for control of *Varroa* vary by region depending on the brood rearing season, risk of mite migration, cold or hot environment and management history of the colonies (Moretto *et al*. 1991; Delaplane and Hood 1999; Strange and Sheppard 2001). Some studies have shown that Africanized bees seem to be tolerant to *Varroa* mites (Aumeier *et al*. 2002). Even then, there is still a threat to bee health given the presence of many pests such as the beetles, ants and the wax moth that are causing great brood damage to the bee colonies in Uganda (Kajobe *et al*. 2009; Kugonza *et al*. 2009).

It is also important to bear in mind that there are certain differences in tolerance mechanisms towards *Varroa* mites between the various sub species of *Apis mellifera* from various climatic regions (Rosenkranz *et al*. 2010; Stanimirovic *et al*. 2011). The degree of infestation is affected by the bee subspecies, brood rearing patterns, presence of drone brood, mite holotype and climate (Moretto *et al*. 1991; Vetharaniam and Barlow 2006; Damos 2012). As already observed above, the infestation rates observed in some areas like the Elgon farmlands zone were much higher at colony level than those encountered in other areas. Even though these levels seem not to completely destroy the colonies as they do in other areas of the world; these infestations are high enough to retard the colony growth and compromise their productivity. Furthermore, *Apis mellifera* does not have efficient grooming behavior like the original host, *Apis cerana* (Rath 1999; Wantuch and Tarpy 2009). All these factors in combination may lead to reduced bee health life span and hive productivity. On the other hand, the effects of *Varroa* in Uganda may take time to become very serious, being that even in South Africa, after nearly a dozen years of introduction, both feral and managed bee colonies of both *A.m. scutellata* and *A.m. capensis* were showing tolerance (Frazier *et al*. 2010) due to increased hygienic behavior and absence of chemical controls (Allsopp 2006).

The results of this study provide an insight on the incidence and the *Varroa* infestation levels in the five agro-ecological zones in Uganda. Contrary to what was predicted, *Varroa* is widely distributed. Other researches to follow may focus on: determination of the species and the holotype of *Varroa* parasitizing on the bees in Uganda and how *Varroa* infestations have impacted on bee health and hive productivity.

Influence of altitude

The purpose of this study was to examine the influence of altitude on the rate of *Varroa* infestation. It was predicted that there was no significant relationship between varroasis and altitude. This study found out that *Varroa* infestations were widely distributed with almost equal mean severity amongst the high, medium and low altitude areas. Contrary to the expectations, this study did not find a significant relationship between the levels of infestation in high, medium and low altitudes. This finding partially agree with Bokaie *et al*. (2014) findings which showed that elevation of apiculture centre from the sea level did not have significant influence on varroasis prevalence in the Northern Golestan province of Iran. All apiary centres above 800 metre altitude were equally infected. However, the finding in this study differ from the finding of a study done in Kenya by Muli *et al*. (2014) which showed that levels of *Varroa* were positively correlated with altitude of the apiary sites which ranged from 0 – 2500 metres above sea level.

The possible explanation for the insignificant relationship between the levels of *Varroa* with altitude could be due to the narrow altitude range which was encountered in this study. Also inside the beehive the conditions remain relatively constant irrespective of the change in altitude. Therefore, *Varroa* population build up can increase without being interrupted by the altitudinal difference of the geographical zones.

The contrary results between our study and Muli *et al*. (2014) may be caused by the difference in time lag of introduction of *Varroa* in these areas; and possibly other climatic factors such as humidity and temperature as suggested by Moretto *et al*. (1991). This could have influenced the number of the reproducing mites at different altitudes. Another possible cause of this discrepancy is that *Varroa* infestations change according to the drone brood season (Damos 2012). In this study most of the bee colonies surveyed did not have the drone brood. *Varroa* mites show high fecundity in the drone than in the worker brood. This may have contributed to similarity in the levels of infestations in apiaries located at different altitudes. These findings, taken together with previous study by Muli et al. (2014) and Bokaie *et al*. (2014), suggest that there other environmental factors that act together with altitude to influence varroasis. Future studies can focus on the effect of other climatic factors such as: humidity, cold and hot weather conditions that could be influencing *Varroa* infestations other than altitude.

Influence of colony management attributes

The aim of this part of the wider study was to examine the influence of hive attributes on the rate of *Varroa* infestation. It was predicted that well managed hives are less affected by *Varroa* mites than poorly managed hives. The results of this study did not show statistically significant relationship between varroasis with hive attributes and management status (Table 5, 6 & 7). Both good and poorly managed hives were infected, with a small difference in the level of severity. Therefore, the hypothesis of the study was not supported by these results. Elsewhere, in the Golestan Province of Iran, Bokaie *et al*. (2014) found a significant relationship between varroasis with hive location and water provision. This could be because Golestan being in desert, any slight improvement in the environment of the bees is likely to have a highly significant effect on colony and hive performance. Virtually all the sites sampled in Uganda probably had comparatively better climatic conditions compared to those in Golestan Province. *Varroa* infestation levels may also depend on the beekeepers awareness of the methods to control and prevent its multiplication in their bee colonies. In the current study, 149 beekeepers (99.3%) were not aware of the possible presence of *Varroa* in their bee hives, 97.3% could not identify it and only 8% had ever heard about *Varroa*. The lack of awareness of the presence of *Varroa* together with absence of preventive and control measures done could have contributed to the severity levels of *Varroa* to be nearly the same in both good and poorly managed hives. Although a relatively high proportion of beekeepers (41.33%) did inspect their hives for pests (Table 5). The inspection was done to check for the common pests previously known to them and not *Varroa*. Since there was no control of *Varroa* in both the good and poorly managed hives, the Varroa mites thrived and produced almost equally in all hives, whether well or poorly managed.

The effect of hive attributes may be significant in apiaries where the beekeepers are aware and hive management practices are improved in such a way as to reduce the *Varroa* load in the hives. Spacing of hives and placing them at a height above the ground are important attributes in preventing horizontal transmission and buildup of *Varroa* in the hives respectively (Jacobson 2010; Bokaie *et al*. 2014). A revisit of the relationship between these attributes on the rate of *Varroa* infestation may be necessary in a situation where there is awareness and control of the pest is done. These findings also suggest that there is need to reinforce the beekeepers knowledge and skills in good beekeeping husbandry information for better control of pests in their hives. They need to be equipped with skills of how to monitor and diagnose Varroa in their apiaries.

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Table 1. Mean Varroa infestation in apiaries of the five agro-ecological zones in Uganda

Agro-ecological zones	Level of infestation: Average No. of mites per bee	Level of infestation: Average No. of mites per 100 bees	Rank sum
Elgon farmlands	0.04584	4.584	3414[a]
Northern moist farmlands	0.03044	3.044	2683[b]
Lake Victoria crescent zone	0.02159	2.159	1853[c]
Albert crescent zone	0.02039	2.039	1848[d]
Western mid high farmlands	0.01761	1.761	1527[a]

Zones with same superscript differed significantly, x^2 = 42.08, df = 4, *P* = 0.0001

Table 2. Incidence and mean Varroa load in high, medium and low altitude areas in the agro-ecological zones

Altitude (m) above sea level	Number and percentage of hives negative for Varroa	Number and percentage of hives positive for Varroa	Mean Varroa load per bee	Mean Varroa load per 100 bees
High (> 1400)	2 (3.23%)	60 (96.77%)	0.02215	2.215
Medium (≥ 1201≤ 1400)	2 (2.86%)	68 (97.14%)	0.02904	2.904
Low (≤ 1200)	4 (2.38%)	164 (97.62%)	0.02825	2.825
Mean	3 (2.82%)	97 (97.18%)	0.02648	2.648

Table 3. Logistic regression model parameters for altitude

Source	value	Standard error	Wald chi square	P>chi2	Wald lower bound (95%)	Wald upper bound (95%)
intercept	3.259	0.585	30.985	< 0.0001	2.112	4.407
altitude (M)						
900 - 1200	0.000	0.000				
1201 - 1400	-0.155	0.881	0.031	0.860	-1.881	1.571
1401 - 1800	-0.289	0.882	0.108	0.743	-2.018	1.439

Intercept is significant but variables are not significant (*P* = 0.860 and 0.743)

Table 4 Test of the null hypothesis Ho : Y = 0.973

Statistic	df	Chi square	P > Chi^2
- 2 log (likelihood)	3	1.6988	0.637
Score	3	1.7369	0.629
Wald	3	1.6349	0.652

Test of Chi-square on log ratio is greater than 0.0001. Information brought by the variables within altitude categories not significant (*P* = 0.637)

Table 5 Relationship between hive management attributes and varroasis

Hive management variable	Level	% mean No. of hives	Rank sum	Chi^2, df and probability
Location	Poor (on ground/high over 3 m)	7.33	643.00	1.847, df=1,
(n=150)	Good (2-3 m above ground)	92.67	10683.00	0.1742
Spacing	Poor (very close <1 m or in contact)	49.33	5970.50	2.078, df= 1,
(n=150)	Good (2-3 m spaced)	50.67	5354.50	0.1494
Quality	Poor (warped with holes + open cracks)	52.00	6213.50	1.490, df=1,
(n=150)	Good (no extra holes and open cracks)	48.00	5111.50	0.2222
Inspection	Poor (irregular/after two weeks/not done)	58.67	6932.00	1.208, df=1,
(n=150)	Good (done weekly)	41.33	4393.00	0.2717
Treatment	Poor (not treated)	50.67	6007.00	1.023, df=1,
(n=150)	Good (Treated)	49.33	5318.00	0.3119
Water Provision	Poor (no water provision)	27.33	3042.50	0.050, df=1,
n=150	Good (water available)	72.67	8282.50	0.8231

Table 6. Logistic model parameters for management status

Source	Value	Standard error	Wald chi square	P>chi2	Wald lower bound(95%)	Wald upper bound(95%)
intercept	3.384	0.719	22.157	< 0.0001	1.975	4.794
good	0	0				
poor	1.093	1.236	0.782	0.377	-1.33	3.51

Intercept is significant but variables not significant (P = 0.377)

Table 7 Test of the null hypothesis HO: Y= 0.98

Statistics	df	Chi square	Pr > chi^2
-2log (likelihood)	1	0.841135	0.359
Score	1	0.857639	0.354
Wald	1	0.781602	0.377

Chi square test on log ratio is greater than 0.0001. Information brought by variables (good and poor management) was not significant (*P* = 0.359)

Fig.1. Districts assessed for Varroa infestation in Uganda