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Research Article

Effect of Climate on the Epidemiology of Bovine Hypodermosis in Algeria

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Abstract

In order to explore the effect of climate on cattle warble fly infestation, a total of 1.635 animals from 4 departments of Northern Algeria were examined visually and by manual palpation for the presence of warbles. Cattle were examined from March to June 2014, coinciding with the peak of emergence of warbles, and both the prevalence and intensity of infestation were recorded. The departments included in this study were located in the two different climatic areas in Northern Algeria: humid (Bejaia and Tizi Ouzou) and semi-arid (Tissemssilt and Ain Defla). The overall prevalence was 28.75%; the intensity of infestation ranged from 1 to 98 warbles per animal (mean 18.93±11.05). The prevalence and intensity of infestation within the departments with semi-arid climate (38.23%; 21.57±11.98) was significantly higher than in those with humid climate (20.74%; 14.84±7.86). The CHAID algorithm showed the climate as the most influencing factor for warble fly prevalence, followed by the husbandry system and breed. Logistic regression and multivariate ANOVA indicate that in addition to climate, other intrinsic (age, sex, breed) and extrinsic factors (husbandry system, treatment) included in the study also were associated with both, prevalence and intensity of infestation. Our results indicate that in semiarid areas of Northern Algeria environmental conditions are more favorable for the development of free stages (pupae and adult flies) of *Hypoderma* spp life-cycle than in humid areas.

Keywords: *Bovine hypodermosis, Myiasis, Cattle, Climate, Algeria*

Cezayir'de Sığır Hipodermosis'in Epidemiyolojisine İklimin Etkisi

Özet

Sığırlarlarda warble sineği (büvelek) istilası üzerine iklimin etkisini ortaya koymak amacıyla, Kuzey Cezayir'in 4 bölgesinden toplam 1.635 hayvan görsel ve el palpasyonuyla büveleklerin varlığı yönünden muayene edildi. Sığırlar büveleklerin ortaya çıkışının zirve (pik) yaptığı Haziran-Mart 2014 arası incelenerek, hem prevalans hem de enfestasyon yoğunluğu kaydedildi. Bu çalışma kapsamındaki bölgeler, Kuzey Cezayir'de iki farklı iklim alanında yer aldı: nemli (Bejaia ve Tizi Ouzou) ve yarı-kurak (Tissemssilt ve Ain Defla). Tüm prevalans %28.75 idi; hayvan başına istila yoğunluğu ise 1 - 98 büvelek arasında değişti (ortalama 18.93±11.05). Yarı-kurak iklime sahip bölgelerdeki yaygınlık ve istila yoğunluğu (%38.23; 21.57±11.98) nemli iklime sahip olanlara göre anlamlı derecede daha yüksek bulundu (%20.74; 14.84±7.86). CHAID algoritması, büvelek sineği prevalansını etkileyen başlıca faktörün iklim olduğunu, diğerlerinin ise yetiştirme sistemi ve ırk olduğunu gösterdi. Lojistik regresyon ve çok değişkenli ANOVA, iklime ek olarak, diğer iç (yaş, cinsiyet, ırk) ve çalışma kapsamındaki dış faktörlerin (yetiştiricilik sistemi, tedavi) hem yaygınlık hem de istila yoğunluğu ile ilişkili olduğunu göstermektedir. Bizim sonuçlarımız; Kuzey Cezayir çevre koşulları altındaki yarı-kurak alanların, *Hypoderma* spp. yaşam döngüsünün serbest aşamalarının (pupa ve ergin sinek) gelişimi için nemli alanlara göre daha uygun olduğunu göstermektedir.

Anahtar sözcükler: *Bovin hipodermozis, Miyazis, Sığır, İklim, Cezayir*

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INTRODUCTION

Cattle hypodermosis is an obligatory myiasis caused by larvae of *Hypoderma bovis* and *Hypoderma lineatum* (Diptera, Oestridae), characterized by the presence of subcutaneous warbles in the dorsal and lumbar region of the animals. For the last 50 years, cattle hypodermosis has represented one of the most significant parasitic diseases in many countries of the northern hemisphere. Warble fly infestation (WFI) greatly impairs livestock production not only by inducing mechanical damage to internal organs (esophagus, spinal column, rumen, lungs) or skin but also by down-regulating the host immune system [1-4].

The biology of *Hypoderma* is very influenced by weather conditions. Climate directly influences the development of the free stages of the parasite, pupae and adult flies, affecting the chronology of this myiasis and the intensity of infestation [5,6]. Adults are generally active from April to June in the case of *H. lineatum* and from mid-June to early September in the case of *H. bovis*, though precise periods of activity depend on seasonal and geographic differences in climate [7].

Algeria is the second largest country in Africa; it extends from the Mediterranean coastline to the Sahara desert. The slopes of Algeria's northern mountains and plateaus are used for grazing farming. Cattle are mainly limited to the north of the country with some enclaves elsewhere. Cow's milk and sheep's meat are the highest-earning agricultural products for domestic farmers.

Hypodermosis is an underestimated problem in Algeria. Algerian farmers are not aware of the economic losses caused by this parasitic disease and therefore, no specific control measures are undertaken against this myiasis. Moreover, the application of some anthelmintics having ectoparasitic action against *Hypoderma* spp. (i.e. ivermectin, moxidectin etc.) is widely used in some departments and scarcely employed in others. In Algeria, except the data provided by Benakhla *et al*.[8] and Benakhla *et al*.[9] during the 90s in the North East of the country, and more recently by Saidani *et al*.[10] in the North Central part, not any reliable data are available regarding the epidemiology of this infection. In order to cover this lack of information, the present clinical survey, including departments from humid and semi-arid areas of Algeria, was carried out.

The main objective of this study was to explore the effects of the climate, on the prevalence and intensity of infection of bovine hypodermosis in Algeria. In addition, our survey could provide some epidemiological data on bovine hypodermosis in the western part of northern Algeria giving that the previous studies on this topic have never covered this area.

MATERIAL and METHODS

Study Area

Northern Algeria is in the temperate zone with a mild Mediterranean climate. However, its broken topography provides sharp local contrasts in both prevailing temperatures and incidence of rainfall. This area is inhabited by more than ninety percent of Algeria´s population, because is the most fertile region in the country. The geographic distribution of cattle, very scarce in southern Algeria, follows almost the same pattern as human inhabitants The present study has been conducted in two bioclimatic areas of northern Algeria *(Table 1)*: in the humid area temperatures are mild and precipitations are around 1.000 mm annually; in contrast, in semi-arid areas differences between high and low temperatures are high and annual rainfall is scarce.

Fig. 1 shows the location of the four Departments included in this study. Two Departments were sampled in the humid area: Bejaia (n=419) and Tizi Ouzou (n=468) and another two in the semi-arid area: Ain Defla (n=325) and Tissemssilt (n=423).

Animals and Sampling

A total of 1.635 animals were randomly examined visually and by manual palpation for the presence of warbles, and both the prevalence and intensity of infestation were recorded.

All the animals were examined at monthly intervals from March to June 2014, which are the months of the year that correspond to the peak of emergence of warble flies in this region. To ovoid false results, neglecting the month effect, all the animals were examined at monthly intervals, and the peak value was taken into account (that of April)

In order to found out the relative distribution of the two species of *Hypoderma spp.*, naturally emerged larvae (n=152; 80 larvae from Tizi Ouzou and 72 from Ain Defla) were collected and preserved in ethanol 70% and subsequently identified by using the morphological keys

Table 1. *Mean weather conditions in two climatic areas of northern Algeria (2013)*
Table 1. *Kuzey Cezayir'in iki iklim bölgesindeki ortalama hava koşulları (2013)*

Climate	Temperature (°C)	Rainfall (mm)	Length of Dry Period (month)	Relative Humidity (%)
Humid	Min: 0-9; Max: 28-31	900-1.200	3-4	79.09
Semi-arid	Min: 2-4; Max: 33-38	300-600	5-6	62.25

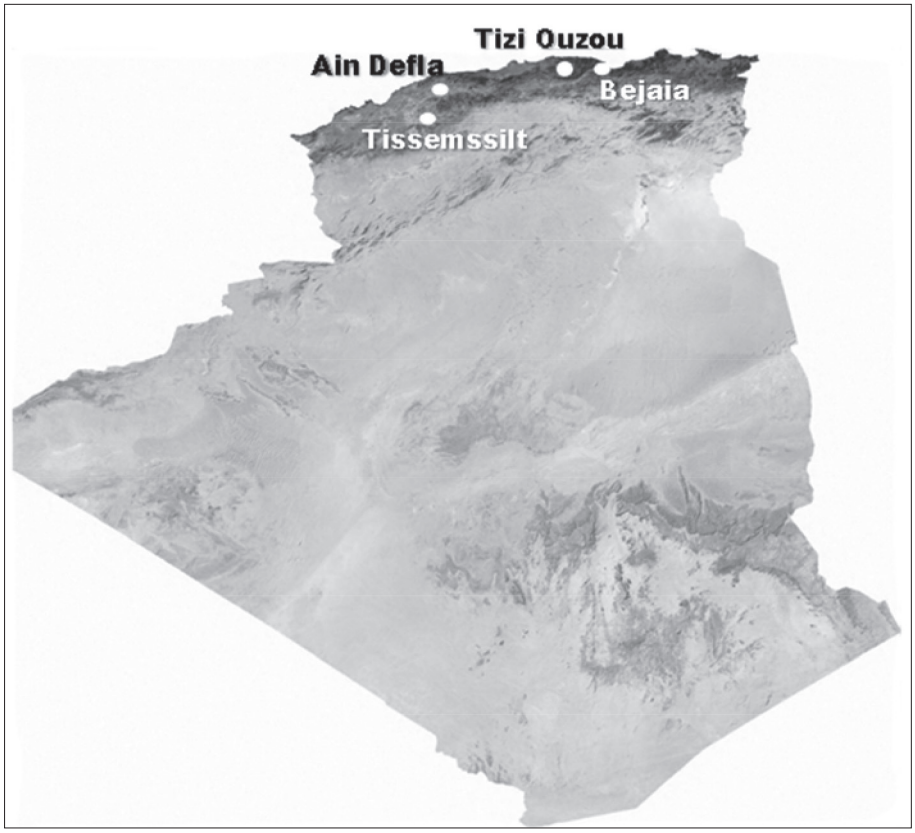

Fig 1. Geographic map of Algeria showing the location of the Departments included in this study

Fig 1. Cezayir'in bu çalışmaya dahil edilen Bölgelerin yerini gösteren coğrafi haritası

as described by James [11] and Zumpt [12].

Variables were grouped and categorized for statistical analysis as follows:

Age groups: 1 (≤ 12 months-old), 2 (13-36), 3 (>36),

Climatic area: 1 (Humid area), 2 (Semi-arid area),

Department: 1 (Bejaia), 2 (Tizi Ouzou) in humid area; 3 (Ain Defla), 4 (Tissemssilt) in semi-arid area,

Breed: 0 (Local breed), 1 (Frisian), 2 (Montbéliard), 3 (Flechvieh), 4 (Crossbreed),

Husbandry system: 1 (Intensive), 2 (Semi-extensive), 3 (Extensive),

Sex: 1 (Male), 2 (Female),

Treatment: 0 (Without treatment), 1 (Treated).

Statistical Analysis

In order to detect the influence of climate and other intrinsic (age, sex, breed) and extrinsic factors (husbandry system, treatment) in the prevalence of WFI, a Logistic Regression algorithm was applied. The dependent variable was the presence of warbles in each animal. Factors indicated previously were introduced in a backward conditional method and removed from the model one by one (on the basis of the highest p-value) until the best model was built. Next, all pairwise interactions that were biologically plausible were evaluated. Odds ratio were computed by raising e to the power of the logistic coefficient over the first category of each factor, not over the last.

Chi-squared automatic interaction detector (exhaustive CHAID) has been performed to stratify risk factors in order of importance. CHAID algorithm identified factors that divide cattle in subgroups with different positive/negative ratio [13]. CHAID is a tool to identify major factors using as criteria the significance of a Chi-squared test and successively splitting data in increasingly homogeneous nodes in relation to dependent variable (warble presence) until the classification tree is fully grown.

A multifactorial ANOVA over positive animals was used for the examination of the intensity of infestation; the dependent variable -number of nodules counted in animals- had been previously transformed (squared root of nodules plus 0.5) to normalized the variable. Tukey HSD post hoc test was used to detect the differences between pairs.

Statistical analyses were done using R statistical package v. 3.2.0 [14]. CHAID algorithm was performed with Answer Tree 3.1 (SPSS Inc., Chicago, IL USA) [10].

RESULTS

In the present study, the overall prevalence was 28.7%. Notable variations in prevalence were observed

Table 2. *Prevalence by Hypoderma in cattle from northern Algeria*
Table 2. *Kuzey Cezayir'deki sığırlarda hypoderma prevalansı*

Factor	Levels	Examined Animals	Non Infested Animals	Infested Animals	Prevalence
Climate	Humid	887	703	184	20.74%
	Semi-arid	748	462	286	38.23%
Age	<13 months	493	346	147	29.82%
	13-36 months	790	552	238	30.12%
	>36 months	352	267	85	24.14%
Sex	Male	309	236	73	23.62%
	Female	1326	929	397	29.94%
System	Intensive	129	117	12	9.30%
	Semi-extensive	611	464	147	24.06%
	Extensive	895	584	311	34.75%
Breed	Holstein	52	40	12	23.08%
	Montbéliard	222	165	57	25.68%
	Fleckvieh	25	5	20	80.00%
	Crossbreed	572	378	194	33.91%
	Local breed	764	577	187	24.48%
Medication	Medicated	769	619	150	19.50%
	Non-medicated	866	546	320	36.95%

Table 3. *Logistic regression results*
Table 3. *Lojistik regresyon sonuçları*

Factors	Estimate	S.E.	Z value	P	OR*	Lower 95% CI for OR	Upper 95% CI for OR
Climate	1.5112	0.1594	9.481	<0.001	4.53	3.32	6.19
Local breed							
Freisian breed	2.1550	0.4524	4.763	<0.001	8.63	3.55	20.94
Montbéliard breed	3.4894	0.3251	10.732	<0.001	32.77	17.32	61.97
Flechvieh breed	4.8749	0.5690	8.567	<0.001	130.96	42.93	399.49
Croosbreed	1.3806	0.1675	8.240	<0.001	3.98	2.86	5.52
< 13 months							
13-36 months	-0.1107	0.1397	-0.793	0.428	0.89	0.68	1.17
> 36 months	-0.4271	0.1751	-2.439	0.015	0.65	0.46	0.91
Sex	0.6358	0.2269	2.803	0.005	1.89	1.21	2.95
Intensive system							
Semi-extensive system	1.8659	0.3754	4.971	<0.001	6.46	3.10	13.49
Extensive system	4.6646	0.5684	8.207	<0.001	106.13	34.84	323.314
Treatment	0.8670	0.4013	2.161	0.031	2.38	1.08	5.22

** Odds ratio were computed by raising e to the logistic estimation over the first category of each factor*

between the climatic areas *(Table 2)*; the prevalence within the departments with a semi-arid climate was significantly higher than in those with humid climate. Logistic regression *(Table 3)* indicated that in addition to climate, the other intrinsic (age, sex, breed) and extrinsic factors (husbandry system, treatment) included in the study were associated with warble prevalence *(Table 4)*. According to this test, cattle in semi-arid areas have 4.53 times more risk to acquire this myiasis than cattle in humid areas. When considering other factors, Flechvieh cattle have the highest prevalence and local breed the lowest, young animals (≤12 months) are more frequently infested than old animals. The likelihood of being positive is 106.13 times higher in animals kept in an extensive husbandry system than in an intensive system.

Table 4. *Intensity of infection by Hypoderma spp and statistical result with multifactorial ANOVA*
Table 4. *Hypoderma spp enfeksiyonu yoğunluğu ve çok faktörlü ANOVA ile istatistiksel sonucu*

Factors	Mean±SD	F	P Value	Factors	Mean±SD	F	P Value
Climate		62.582	< 0.001	Sex		0.080	0.778
Humid	14.84±7.86			Male	16.03±9.76		
Semi-arid	21.57±11.98			Female	19.18±11.13		
Breed		2.417	0.048	Husbandry system		37.152	< 0.001
Local	20.65±12.96			Intensive	4.67±2.9		
Freisian	19.58±7.72*			Semi-extensive	14.38±6.55		
Montbéliard	13.75±6.68			Extensive	21.64±11.8		
Flechvieh	11.6±6.56*						
Croosbreed	19.52±9.88						
Age		16.074	< 0.001	Treatment		24.164	< 0.001
< 13 months	21.67±12.02			No treatment	21.64±11.8		
13-36 months	18.5±10.74			Treatment	13.16±6.6		
> 36 months	15.41±8.9						

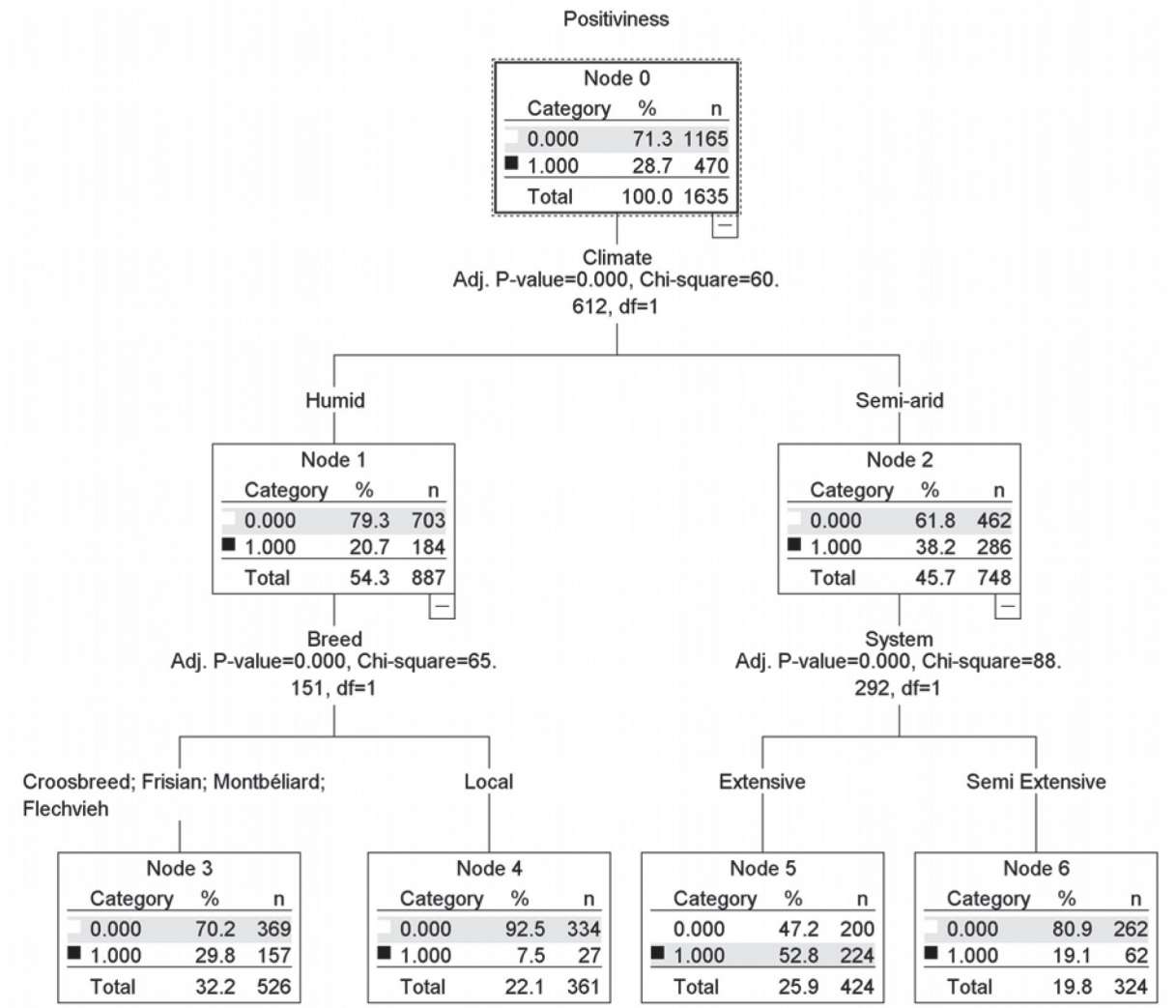

Fig 2. Classification tree produced by the CHAID algorithm when considering different factors
Fig 2. CHAID algoritmasıyla farklı faktörler dikkate alınarak üretilen sınıflandırma ağacı

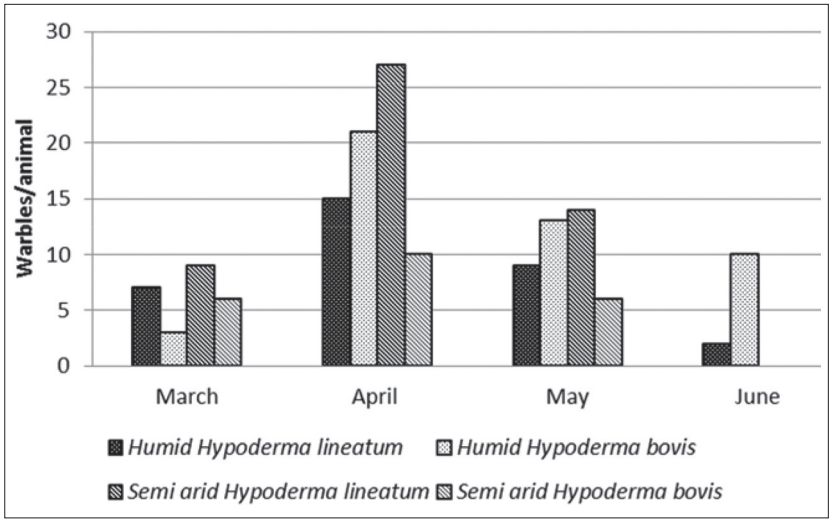

Fig 3. Monthly evolution of *H. bovis* and *H. lineatum* in two climatic areas in northern Algeria

Fig 3. Kuzey Cezayir'de iki iklim bölgesindeki H. bovis ve H. Lineatum'un aylık evrimi

The CHAID algorithm showed the climate as the most influencing factor for warble fly prevalence, followed by the husbandry system and breed *(Fig. 2)*.

The intensity of infestation ranged from 1 to 98 warbles per animal (mean 18.9±11.05). As occurred with the prevalence, the lowest intensity was registered in the humid area *(Table 3)*. In addition to climatic area, multifactorial ANOVA also showed significant differences in the intensity of infection when considering the breed and age of the animals; with local breed and young animals showing the highest rates. Management factors like husbandry system and treatment also have a significant influence in the number of warbles/animal.

Out of the 152 identified larvae, 83 (54.5%) were found to belong to *Hypoderma lineatum* and 69 (45.5%) to *H. bovis*. Under the humid climate, 47 out of 80 (58.7%) of larvae were *H. bovis* and the remaining part of *H. lineatum*. However, in the area from semi arid climate, 50 out of 72 (69.4%) belonged to *H. lineatum* species *(Fig. 3)*.

DISCUSSION

The overall prevalence of hypodermosis detected in northern Algeria can be considered as moderate (28.7%); this percentage was higher than the 18.1% observed by Saidani *et al.*[10] in cattle farms from North Central Algeria and the 3.7% found in an abattoir. However, this prevalence resulted very low as compared to the 76% recorded by Benakhla *et al.*[9] in the eastern part of the country.

When considering the department of origin of cattle the lowest prevalence was registered in Bejaia (16.21%), followed by Ain Defla (19.08), Tizi Ouzou (24.79%) and finally, the highest percentage was recorded in Tissemssilt (52.96%). Similarly, as occurred in our survey, Panadero *et al.*[5] found that Coastal areas, characterized by relatively high temperatures and by an important summer rainfall, had the lowest percentages of grub presence, whereas in the interior areas the infestation percentages were higher. The wide variations on prevalence and intensity of infection between humid and semiarid departments could be mainly explained by differences on rainfall and temperature values, as flies generally are not active on dark, cloudy days, at wind velocities above 8m/s, or during periods of rain or snow [15]. However, other factors affecting the prevalence and intensity of infection might include, breed, husbandry system and the use of insecticides [16-19]. Indeed, Chi-squared automatic interaction detector (exhaustive CHAID) revealed the climate as the most important factor followed by the management system and breed. The husbandry system is known to exert a major effect on both prevalence and intensity of bovine hypodermosis since the free grazing system is the most favorable for the occurrence of this myiasis, under which flies have more chances to contact the animal. This fact agrees with several previous studies [5,10,16-19]. Surprisingly, in this study local breeds mainly kept under extensive and semi-extensive husbandry systems showed the lowest prevalence but the highest parasite burdens. Moreover, multifactorial ANOVA and logistic regression also identified the use of drugs (avermectins) as a factor influencing, the intensity and prevalence of infection.

Both the prevalence and the intensity of bovine hypodermosis differ significantly from one area to another. It is usual to notice a wide variation in the prevalence of WFI among different parts of the world and even within the same country [16]. This variability might be due to the differences in the climatic factors that affect the developmental stages of the larvae [5,20]. Consequently, the lower prevalence and intensity recorded in the area from humid climate can be explained by the high relative humidity and rainfall, which are harmful to the free stages of warble flies according to Tarry [20]. Ahmed *et al.*[18] found that the high level of infestation were due to the climatic conditions, location, treatment procedures, topography of the area and extensive grazing. Despite

the moderate prevalence found in this study especially in Bejaia and Tizi Ouzou departments, the burden of infestation is generally heavy (up to 98 larvae), which indicate that the implementation of a control program for hypodermosis in Algeria is very indispensable.

In our survey, *H. bovis* and *H. lineatum* were found infesting cattle, although there was a slight predominance of *H. lineatum* (54.5%). This statement agrees with previous findings in the same country [10,21]. The identification of the species of *Hypoderma* implicated in a given area is of vital importance for several reasons. Firstly because *H. bovis* is currently believed to affect only cattle living in the Northern countries, and secondly because the impact of *H. bovis* on animal welfare and health is more important than *H. lineatum* due to the fact that if treatments are not carried out promptly, when first stage larvae are still in the peri-rachidian channel, paralysis of the hind quarters may occur. This finding is of relevance for the correct use of drugs against hypodermosis [22]. Thirdly, *Hypoderma bovis* is more harmful and frighten the host several times during laying because its eggs are glued singly on the flank or lower abdomen while *Hypoderma lineatum* lays in groups of 5 to 15 eggs onto the hair of the forelegs, breast or underside of the body [1], thus it causes less fear. It is thus obvious that the severity of gadding is different according to the *Hypoderma* species.

As regard to the distribution of the two species, our results were in accordance with what was found by Benakhla *et al*.[9], where the 2 species of genus *Hypoderma* were present in cattle in Algeria *(H. bovis* and *H. lineatum)* with a predominance of *H. lineatum* (63%) in the semi-arid area and a majority of *H. bovis* (75%) in humid area. Warbles appeared and disappeared earlier in the semi-arid area. Indeed, in the present study no larva was found in the semi arid area since the end of May. During March, *Hypoderma lineatum* was predominant in both climatic areas, which is in favor of the early emergence of this species [8,9]. The peak of emergence was reached during April regardless to the species, similarly as recorded for the 1635 animals clinically examined. On May, *H. lineatum was* slightly more frequent. Finally, on June the larvae collected exclusively from humid climatic with of a majority of *Hypoderma bovis (Fig. 3)*. This finding is once more in agreement to previous studies on this topic, where the warbles disappear one month later in humid area [8].

As conclusion, climatic area was identified as a significant factor affecting the percentage of positive animals and the intensity of parasitation by *Hypoderma* sp. Our results indicate that in semiarid areas of Northern Algeria environmental conditions are more favorable for the development of free stages (pupae and adult flies) of *Hypoderma* spp life-cycle than humid areas. However, the climate does not exert its effect alone, others intrinsic and extrinsic factors such as grazing pattern, breed and medication were also involved on the epidemiology of warble fly infestation.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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