Comparison of Milk Yield and Reproductive Performance of Sheep Breeds in the West Bank, Palestine

مقارنة إنتاجية الحليب والكفاءة التناسلية لسلالات الأغنام في الضفة الغربية - فلسطين

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Abstract

The aim of this study was to compare milk production and reproductive traits of sheep breeds in the West Bank. The data included 1711 milk records on 1243 ewes and 3682 lambing records on 1837 ewes from the local Awassi breed, Assaf breed, Awassi x Assaf crosses, and two Improved Awassi strains, one of which is carrying the Booroola FecB gene. The data were collected between 2003 and 20١٠ from 21 farms covering five locations in southern West Bank (Dora, Hebron, Bethlehem, Jerusalem, and Ramallah) and three locations in northern West Bank (Nablus, Qalqiliya, and Jenin). The results showed significant differences ($P < 0.05$) in performance among and within breeds in different locations. Milk production was highest for Awassi x Assaf in Nablus and Jenin (least-squares means of 330.6 kg and 267.6 kg for total milk yield in 150 d of lactation, respectively) and Assaf in Jenin (268.1 kg), and was lowest for Awassi in Jerusalem (124.6 kg). The Improved Awassi strain carrying the FecB gene had the highest reproductive performance (mean litter size of 1.69 lambs and mean lambing interval of 304.3d), while the lowest performance was for Awassi (mean litter size of 1.12 to 1.21 lambs and mean lambing interval of 347.3 to 416.6 d). The means of litter size and lambing interval for the Improved Awassi strain not carrying the FecB gene were 1.28 lambs and 353.5d. Introgression of the FecB gene may be utilized to improve reproductive performance of sheep breeds in the West Bank, particularly Awassi.

Key words: milk yield, litter size, lambing interval, Awassi, Assaf, West Bank.

ملخص

هدفت الدراسة إلى مقارنة إنتاجية الحليب والكفاءة التناسلية لسلالات الأغنام في الضفة الغربية. واشتملت معطيات الدراسة على ١٧١١ سجل حليب من ١٢٤٣ نعجة و ٣٦٨٢ سجل ولادات من ١٨٣٧ نعجة تعود إلى سلالة العواسي المحلي، وسلالة العساف، والسلالة الهجينة (عواسي × عساف) بالإضافة إلى صنفين من أغنام العواسي المحسن أحدهما يحمل طفرة الخصوبة FecB لأغنام البورولا. وقد تم جمع المعطيات في الفترة ما بين ٢٠٠٣ و٢٠١٠ من ٢١ مزرعة توزعت على خمس مناطق في جنوب الضفة الغربية (دورا، الخليل، بيت لحم، القدس، رام الله) وثلاثة في شمال الضفة (نابلس، قلقيلية، جنين). وقد أظهرت النتائج وجود فروقات معنوية ($P < 0.05$) في الكفاءة الإنتاجية للحليب والكفاءة التناسلية ما بين السلالات وبين المناطق لنفس السلالة. وكانت أعلى إنتاجية حليب للأغنام الهجينية (عساف × عواسي) في نابلس وجنين (٣٣٠.٦ كغم و٢٦٧.٦ كغم في فترة حلابة ١٥٠ يوم، على التوالي) وأغنام العساف في جنين (٢٦٨.١ كغم) وأقل إنتاجية كانت لأغنام العواسي في القدس (١٢٤.٦ كغم). كماأظهرت النتائج أن صنف العواسي المحسن الذي يحمل جين الخصوبة كان الأفضل من حيث الكفاءة التناسلية (متوسط عدد التوائم كان ١.٦٩ ومتوسط الفترة بين ولدتين كان ٣٠٤.٣ يوما) بينماكانت أقل كفاءة تناسلية لسلالة العواسي غير المحسن (متوسط عدد التوائم تراوح بين ١.١٢ و١.٢١ ومتوسط الفترة بين ولدتين تراوح بين ٣٤٧.٣ و٤١٦.٦ يوما). أما صنف العواسي المحسن الذي لا يحمل جين الخصوبة فقد بلغ متوسط عدد التوائم ١.٢٨ ومتوسط الفترة بين ولدتين ٣٥٣.٥ يوما. وتدل هذه النتائج على أنه يمكن زيادة الكفاءة التناسلية للأغنام في الضفة الغربية من خلال إدخال جين الخصوبة إليها وبخاصة في أغنام العواسي.

كلمات مفتاحية: إنتاج الحليب، عدد التوائم، الفترة بين ولدتين، عواسي، عساف، الضفة الغربية.

Introduction

Awassi is the main sheep breed in most of the Middle Eastern countries (Epstein 1985; Hailat 2005; Tabbaa et al., 2001; Zarkawi et al., 1999). It is adapted to arid and semi arid environments (Said et al., 1999). Milk production from Awassi ewes ranged from 73 to 150 kg and litter size ranged from 1.10 to 1.20 (Al-Samarai and Al-Anbari 2009; Dag et al., 2005; Galal et al., 2008; Iñiguez and Hilali 2009; Jawasreh and Khasawneh 2007; Kassem 1988). The performance of Awassi under extensive management conditions tended to be low: 40-60 kg of milk and 1.05-1.17 lambs per lambing (Abdallah 1996; Degen and Benjamin 2003; Epstein 1985).

Selection of Awassi for high milk production resulted in the formation of the Improved Awassi breed (Epstein 1985). The average milk yield of Improved Awassi ewes is 250-300 kg (Dag et al., 2005), but Gootwine and Pollott (2000) reported an average of about 500 kg from lactations averaging 214 days. Crossbreeding of Improved Awassi with East-Friesian lead to the development of the Assaf breed (Goot 1986). Under intensive management, Assaf ewes averaged 334 kg of milk over an average of 173 days of lactation (Pollott and Gootwine 2004). The prolificacy of Improved Awassi and Assaf ewes is relatively low to moderate: 1.28 and 1.60 lambs born/lambing, respectively (Gootwine and Pollott 2000; Pollott and Gootwine 2004). To improve prolificacy of Awassi breed, a new genotype (named Afec-Awassi) which carries the FecB mutation has been developed by crossbreeding with the Booroola Merino, averaging about two lambs per lambing (Gootwine et al., 2001; Gootwine et al., 2008).

In Palestine, sheep is the major small ruminant. In 2010, the total number of sheep in the West Bank was about 500 000 heads (Awassi, 54.5%; Assaf, 34% and Awassi x Assaf, 11%; PCBS 2011). In recent years, there has been an increasing interest of Palestinian farmers in keeping Assaf and Awassi x Assaf ewes: in 2010, these breeds represented about 45% of sheep in the West Bank (PCBS 2011) compared to about 32% in 2006 (PCBS 2007). Assaf and Awassi x Assaf breeds are more popular in northern areas of West Bank compared to southern areas as indicated by the 2010 agricultural census where they represented about 60% of sheep in northern areas compared to 33% in southern areas (PCBS 2011). Despite the importance of sheep in the West Bank, there is a lack of studies to evaluate their productivity. The objective of this study was to compare milk production and performance for some reproductive traits (litter size and lambing interval) among sheep breeds in different areas of the West Bank.

Materials and Methods

Data collection and processing

Data were collected from the farms participating in the Small Ruminant Middle East Regional Program in the West Bank. Under this program, several flocks with 50 or more ewes in different locations of the West Bank were selected as demonstration farms. The farms covered eight geographical locations: five locations in Southern West Bank (Bethlehem, Dora, Hebron, Jerusalem, and Ramallah) and three locations in Northern West Bank (Nablus, Qalqiliya, and Jenin). Sheep breeds in these farms were: Awassi, Assaf, Awassi x Assaf crosses, and two Improved Awassi strains, one of which is carrying the Booroola fecundity (FecB) gene (called Afec-Awassi). These Improved Awassi strains were imported from Israel and kept in the Beitqad experimental station in Jenin (Northern West Bank). The Booroola fecundity gene was introduced to the Afec-Awassi strain by crossing with the Booroola Merino (Gootwine et al., 2001). In this study, Awassi refers to the local (unimproved) Awassi sheep as opposed to the Improved Awassi of Israel. All records were validated and stored by technicians of the Ministry of Agriculture of the Palestinian Authority using the "Ewe and Me" software (Gootwine et al., 1994).

Milk data

Milk data were collected between 2004 and 2010. The first test date was on the first week after parturition. At least three milkings were made during the lactation period. Ewes were hand-milked twice daily (in the morning and the evening) and the total daily milk was recorded. A total of 1711 lactation records were obtained on 1243 ewes in 20 farms dispersed over 8 geographic locations of the West Bank.

Traits of milk yield included total milk yield from lambing to last test date (TMY), total milk yield from lambing to 120 days of lactation (TMY120), and total milk yield from lambing to 150 days of lactation

(TMY150). TMY was calculated using the Fleischmann method (Ruiz et al., 2000):

$$TMY= y_1t_1+ \sum((y_i + y_{i+1})/2)(t_{i+1} – t_i))$$

Where y_1 is the daily milk yield at first milk recording; t_1 is the interval (in days) between lambing and first recording; y_i is the daily milk yield of the i^{th} milk recording, and (t_{i+1} - t_i) is the time interval (in days) between record i and record ($i+1$), ($i=2,\ldots\ldots\ldots k$).

The traits TMY120 and TMY150 were calculated in the same way up to the appropriate number of days of lactation (up to 120 days for TMY120, and up to 150 days for TMY150). Ewes not completing 120 days of lactation were excluded from the calculation of TMY120. Similarly, ewes not completing 150 days of lactation were excluded from the calculation of TMY150.

Reproductive data

A total of 3682 lambing records on 1837 ewes were collected from 21 farms between 2003 and 2010. Reproductive traits included litter size (LS: number of lambs born per ewe lambing) and lambing interval (LI: number of days between two consecutive lambings). Due to missing data, the number of records available on LI was reduced to 29 for Afec-Awassi and 203 for the other Improved Awassi strain, 200 for Awassi, 428 for Assaf, and 731 records for Awassi x Assaf.

Data Analysis

Single-trait (univariate) analyses were performed using the following fixed-effects model (in matrix notation):

$$\mathbf{Y = Xb + e},$$

Where **Y** is a vector of observations on ewes for the given trait, **b** is a vector of fixed effects, **e** is a vector of residuals containing all effects unexplained by the model, and **X** is a design (incidence) matrix relating fixed effects to observations. The fixed effects fitted in the model for milk traits were: location-breed, parity, year-season of lambing where each year was divided into two seasons of six months each, method of induction of estrus (natural or hormone treatment), litter size, number of milking tests, and lactation period (number of days from lambing to last test date). Both number of milking tests and lactation period were fitted as covariates. For reproductive traits, the fixed effects were location-breed, parity, year-season, and method of induction of estrus (in addition to LS for the analysis of lambing interval). Multiple comparisons of least-squares means of milk and reproductive traits by parity and location-breed were performed using Tukey-Kramer adjustment of P values. The analyses were carried out using the GLM procedure of SAS/STAT software, V9.0 for Windows (SAS Institute Inc., Cary, NC, USA).

Results

Milk traits

Averages (unadjusted) of lactation period and milk traits by breed are in Table 1. Averages of total milk yield were 120.2 kg for Afec-Awassi, 142.3 kg for the other Improved Awassi strain, 92.9 kg for Awassi, 159.4 kg for Assaf, and 147.8 kg for Awassi x Assaf ewes based on average lactation periods of 110.8, 131.1, 86.6, 115.4, and 100.7 d, respectively. Averages of milk yield over 120 days of lactation ranged from 115.3 kg for unimproved Awassi to about 168 kg for Assaf and Awassi x Assaf. Average total milk yield over 150 days of lactation ranged from 135.7 for Awassi to 197 kg for Assaf and Awassi x Assaf.

Results of the influence (P values) of the fixed-effect factors on milk traits are in Table 2. The results showed that location-breed, parity, year-season of lambing, and lactation period had highly significant effects on all milk traits ($P < 0.001$), while the effect of litter size was not significant ($P > 0.05$) for any of the traits. Number of milking tests was not significant ($P > 0.05$) for TMY and TMY120 but was significant ($P = 0.02$) for TMY150. The lowest milk yield was in the first parity and increased in later parities (Table 3).

Least-squares means (adjusted means) of milk traits by location-breed are presented in Table 4. Over all location-breed levels, the highest milk production was for Awassi x Assaf crosses in Nablus and Jenin and Assaf in Jenin. The lowest yield was for Awassi in Jerusalem, Assaf in Qalqiliya, and the Improved Awassi strains in Jenin.

Comparisons of the same breed in different locations showed that Awassi produced more milk in Hebron than in Jerusalem, and Assaf produced more milk in Jenin than in the other locations (Qalqiliya and Hebron). Awassi x Assaf cross produced more milk in the northern locations of the West Bank (Jenin and Nablus) than in the southern locations (Jerusalem, Bethlehem, Hebron, and Dora). Milk production of Awassi x Assaf did not differ ($P > 0.05$) among the southern locations neither among the northern locations.

Comparisons of different breeds in the same location showed that Awassi in Hebron did not differ from Assaf but outperformed Awassi x Assaf cross. However, Awassi x Assaf was better than Awassi in Jerusalem. There was no difference in milk production between Assaf and Awassi x Assaf in Jenin. No significant differences ($P > 0.05$) were found in milk yield between the Improved Awassi strain carrying the FecB gene (Afec-Awassi) and the strain not carrying the gene in the Betqad experimental station in Jenin.

Reproductive traits

Averages of reproductive traits by breed are in Table 5. Awassi and Improved Awassi strains had higher average LI than Assaf and Awassi x Assaf. The influence of the fixed-effect factors on reproductive traits are in Table 6. Location-breed, parity, and year-season of lambing had significant effects ($P < 0.05$), method of induction of estrus did not have a significant influence on LI ($P = 0.58$), however it had a trend on LS ($P = 0.06$). Litter size had a trend on LI ($P = 0.08$). Litter size increased by parity but lambing interval decreased after the first parity (Table 3).

Least-squares means of reproductive traits by location-breed are in Table 7. The Afec-Awassi line in the Betqad experimental station of Jenin had the highest mean of LS (1.69 lambs per ewe lambing), followed by Awassi x Assaf in Jerusalem (1.40 lambs per ewe lambing) and Assaf breed in Ramallah, Hebron, and Qalqiliya (1.39, 1.37, and 1.36

lambs per ewe lambing, respectively). In Jerusalem, Awassi X Assaf ewes produced more lambs per lambing than Awassi ewes (1.40 vs. 1.12). In Jenin, no differences were found among Improved Awassi (not carrying FecB mutation), Assaf, and Awasi x Assaf in LS (1.28, 1.24 and 1.17 lambs born per ewe lambing, respectively). In Hebron, Assaf ewes had higher mean LS than Awassi x Assaf ewes (1.37 vs. 1.18 lambs per ewe lambing), but neither of the two breeds differed from Awassi (1.21 lambs per ewe lambing).

Significant differences among levels of location-breed were found in LI (Table 7). In general, Awassi flocks had the highest LI and Assaf and Awassi x Assaf flocks had the lowest LI. Awassi in Hebron had the highest mean LI (416.6 d) and significantly differed ($P < 0.05$) from Awassi in Jerusalem (347.3 d) and the Improved Awassi strains of Beitqad governmental station in Jenin (304.3 d for Afec-Awassi and 353.5 d for the other improved strain). On the other hand, Assaf and Awassi X Assaf crossbred ewes in Jenin had less LI (278.5 and 289.8 d, respectively) than Improved and Afec Awassi. In Hebron, Awassi ewes had higher LI than Assaf ($P < 0.05$), but neither breed differed ($P > 0.05$) from crossbred ewes (416.6 d for Awassi, 341.0 d for Assaf, and 375.7 d for crossbred ewes).

Discussion

The low to moderate estimates of milk production found in this study for unimproved Awassi sheep are in agreement with the estimates for the breed in neighboring countries (Al-Samarai and Al-Anbari, 2009; Dag et al., 2005, Jawasreh and Khasawneh, 2007, Iñiguez and Hilali, 2009). These production levels for the breed may reflect the lack of genetic improvement (i.e., selection) programs, and/or low management levels (i.e., feeding, housing, health management, etc). The Israeli experience with Improved Awassi proved that it is possible to use selection to improve milk yield of Awassi sheep exploiting the high genetic variation within the breed. However, the estimates of milk yield found herein for Improved Awassi were much lower than the reported estimates in Israel (Epstein, l985; Gootwine and Pollott, 2000, Pollott and Gootwine, 2001).

Also, the estimates for Assaf ewes were lower than those reported for Israeli and Spanish Assaf (Guti´errez et al., 2007 and Pollott and Gootwine, 2004). High producing breeds require high management levels to express their full genetic potential which may not be the case for most flocks in the West Bank. As expected, no significant differences ($P > 0.05$) were found in milk yield between the Afec-Awassi strain and the other improved Awassi strain because they only differ in carrying the Booroola fecundity gene.

The estimates of litter size for Awassi in the present study (overall average of 1.1 lambs born per ewe lambing and adjusted means of 1.12 in Jerusalem to 1.21 in Hebron) are consistent with the estimates of 1.05 to 1.20 lambs born per lambing reported by others (Abdallah, 1996, Galal et al., 2008, Hamadeh et al., 1998; Kassem, 1988). The average litter size in Improved Awassi was 1.25 lambs per ewe lambing which is close to the estimate of 1.28 found by Gootwine and Pollott (2000). In our study, Assaf produced an average of 1.35 lambs per ewe lambing which is lower than estimates of about 1.60 in Israel for ewes not carrying the Booroola FecB gene (Gootwine et al., 2001; Pollot and Gootwine, 2004).

Our study showed that the introgression of the FecB gene (in Afec-Awassi) resulted in significant improvement in litter size (+0.41 lambs per ewe lambing). Despite this improvement, the average litter size found for Afec-Awassi in our study (1.66 lambs per ewe lambing) is lower than that found in Israel (2.0 lambs born per ewe lambing; Gootwine et al., 2001; Gootwine et al., 2008). In Israel, introgression of the Booroola mutation into Assaf (Afec-Assaf) also resulted in significant improvement of litter size (Gootwine et al., 2001, Gootwine et al., 2008). The discrepancy between the estimates in our study and the estimates in Israel for Afec-Awassi may be due to differences in management levels. It is also possible that only a small proportion of the ewes in the Afec-Awassi line in our study are homozygous for the FecB allele. Further investigation is needed to determine the proportions of the three genotypes (*BB, B+, ++*) in the Afec-Awassi flock of this study. The results for Afec-Awassi and Afec-Assaf in Israel and the results of our study indicate that introgression of the mutation into sheep breeds of the

West Bank have high potential for improvement of prolificacy of these breeds which should be economically appealing given the large increase in lamb prices in recent years.

The estimates of lambing interval found herein for improved Awassi (338 d for Afec-Awassi and 355.4 d for the other strain) and Assaf (294.4 d) are close the estimates of 330 d for Improved Awassi and 272 d for Assaf in Israel (Gootwine and Pollot, 2000; Pollot and Gootwine, 2004). In this study, significant differences in lambing interval were found among location-breed levels and among locations for the same breed. Therefore, measuring reproductive performance as the number of lambs born per year could be a better basis for comparison of breeds for reproductive performance because it takes into account the differences in lambing interval. The mean number of lambs born per ewe lambing per year was calculated based on the adjusted means of litter size and lambing interval for each location-breed (Table 7). The results clearly show that Afec-Awassi ewes had the highest reproductive performance while unimproved Awassi, the Improved Awassi ewes not carrying the Booroola mutation, and Awassi x Assaf crossbred ewes in Hebron had the lowest reproductive performance.

In our study, milk production of Assaf and Awassi x Assaf was higher in Nablus and Jenin (northern West Bank) than in the southern locations which may in part explain why these breeds are more common in northern areas than in southern areas. Some farmers prefer crossbred sheep over Assaf and this is likely due to better adaptability to the local conditions (as they contain higher proportion of Awassi) than Assaf sheep which were originally developed in Israel (where management and feeding conditions are better than in the West Bank).

Conclusions

Awassi x Assaf ewes were very competitive in milk production and reproductive performance with Assaf ewes which justifies the increased interest of Palestinian farmers in keeping Awassi x Assaf crosses. The results of this study indicate that Assaf and Awassi x Assaf sheep could be recommended for raising in the northern areas of the West Bank.

However, more research is needed to further clarify breed differences in southern areas. Introgression of the Booroola FecB gene into Awassi resulted in significant improvement of prolificacy and therefore can be utilized as a tool to improve reproductive performance of sheep breeds in Palestine.

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Table (1): Unadjusted means and standard deviations (SD) of lactation length and milk traits by breed.

Breed or strain	No of records	Trait [1]		
		TMY (kg)	TMY120 (kg)	TMY150 (kg)
Afec-Awassi [2]	40	120.2 (63.1)	130.7 (36.5)	169.0 (43.7)
Improved Awassi	224	142.3 (54.7)	139.6 (44.8)	161.3 (47.5)
Awassi (unimproved)	331	92.9 (44.0)	115.3 (50.4)	135.7 (46.0)
Assaf	288	159.4 (68.3)	167.9 (56.5)	197.0 (61.3)
Awassi x Assaf	828	147.8 (76.5)	167.7 (66.6)	196.7 (77.1)

[1] **TMY**= total milk yield; **TMY120**= total milk yield to 120 days of lactation; **TMY150**= total milk yield to 150 days of lactation.

[2] Afec-Awassi = Improved Awassi strain carrying the Booroola FecB gene

Table (2): Significance (P values) of the fixed-effect factors on milk traits.

Fixed Effect	Milk Traits [1]		
	TMY	TMY120	TMY150
Location-breed	< 0.001	< 0.001	< 0.001
Parity	< 0.001	< 0.001	< 0.001
Year-season	< 0.001	< 0.001	< 0.001
Induction of Estrus	0.59	0.94	0.82
Litter size	0.98	0.90	0.92
Number of milking tests	0.46	0.13	0.02
Lactation period	< 0.001	< 0.001	< 0.001

[1] **TMY**= total milk yield; **TMY120**= total milk yield to 120 days of lactation; **TMY150**= total milk yield to 150 days of lactation.

Table (3): Least-squares means of milk and reproductive traits by parity.

Parity	Milk traits [1]			Reproductive traits	
	TMY	TMY120	TMY150	Litter size	Lambing interval
1	131.3 [c, 2]	147.2 [c]	174.2 [c]	1.23 [b]	---------
2	151.8 [b]	167.7 [b]	195.0 [b]	1.26 [ab]	330.4 [a]
3	158.7 [b]	177.8 [ab]	208.0 [a]	1.29 [ab]	315.0 [b]
4	160.6 [ab]	178.6 [ab]	208.9 [a]	1.29 [ab]	315.2 [b]
5	169.8 [a]	188.8 [a]	219.7 [a]	1.33 [a]	312.5 [b]
6	163.3 [ab]	186.9 [a]	218.7 [a]	1.28 [ab]	309.2 [b]

[1] **TMY**= total milk yield; **TMY120**= total milk yield to 120 days of lactation; **TMY150**= total milk yield to 150 days of lactation.

[2] Means in the same column with similar letters are not significantly different (P > 0.05) using Tukey-Kramer adjustment for multiple comparisons.

Table (4): Least-squares means of milk traits (kg) by location-breed.

Location	Breed	No. of ewes	No. of records	Trait [2]		
				TMY	TMY120	TMY150
Jenin	Afec-Awassi [1]	24	40	128.0 [cde, 3]	146.1 [de]	184.7 [cde]
	Improved Awassi	138	224	120.6 [de]	144.1 [e]	169.5 [e]
	Assaf	25	75	216.2 [a]	236.4 [b]	268.1 [b]
	Awassi x Assaf	78	113	224.7 [a]	236.2 [b]	267.6 [b]
Nablus	Awassi x Assaf	61	70	224.8 [a]	278.4 [a]	330.6 [a]
Qalqilia	Assaf	85	107	128.4 [cde]	148.2b [de]	177.1 [de]
Ramallah	Assaf	73	100	143.8 [bc]	163.1 [cd]	190.9 [cde]
Jerusalem	Awassi	181	255	107.4 [e]	110.8 [f]	124.6 [f]
	Awassi x Assaf	47	47	154.3 [bc]	164.2 [cd]	191.5 [cde]

…continue table (4)

Location	Breed	No. of ewes	No. of records	Trait [2]		
				TMY	TMY120	TMY150
Betlehem	Awassi x Assaf	95	170	138.1 ^{c}	157.8^{cde}	184.0^{cde}
Hebron	Assaf	36	36	160.5 ^{bc}	178.6 ^{cd}	208.6^{cd}
	Awassi	56	76	161.6 ^{b}	180.0 ^{c}	211.4^{c}
	Awassi x Assaf	67	67	137.5 ^{c}	149.1^{de}	175.1^{de}
Dora	Awassi x Assaf	277	361	136.8 ^{c}	150.7^{de}	173.7^{e}

[1] Afec-Awassi = Improved Awassi strain carrying the Booroola FecB gene

[2] **TMY**= total milk yield; **TMY120**= total milk yield to 120 days of lactation; **TMY150** = total milk yield to 150 days of lactation.

[3] Means in the same column with similar letters are not significantly different (P > 0.05) using Tukey-Kramer adjustment for multiple comparisons.

Table (5): Unadjusted means and standard deviations (SD) of reproductive traits by breed.

Breed or strain	Litter size		Lambing interval	
	No. of Records	Average (SD) [1]	No of Records	Average (SD)
Afec-Awassi [2]	56	1.66 (0.75)	29	338.0 (59.3)
Improved Awassi	431	1.25 (0.53)	203	355.4 (75.2)
Awassi (unimproved)	560	1.15 (0.38)	200	373.3 (67.0)
Assaf	874	1.35 (0.51)	428	294.4 (73.0)
Awassi x Assaf	1761	1.19 (0.40)	731	303.4 (79.1)

[1] SD = Standard deviation

[2] Afec-Awassi = Improved Awassi strain carrying the Booroola FecB gene.

Table (6): Significance (P values) of the fixed-effect factors on prolificacy and lambing interval.

Fixed Effect	**Trait**	
	Litter size	**Lambing interval**
Location-breed	< 0.001	< 0.001
Parity	0.027	0.002
Year-season of lambing	0.002	< 0.001
Induction of estrus	0.063	0.58
Litter size	-------	0.08

Table (7): Least-squares means of litter size (LS), lambing interval (LI), and number of lambs born per ewe lambing per year (NLBY) by location-breed.

Location	**Breed**	**No. of ewes**	**No. of records**	**Trait**		
				LS	**LI**	**NLBY** [3]
Jenin	Afec-Awassi [1]	26	56	1.69 [a, 2]	304.3 [cde]	2.03
	Improved Awassi	153	431	1.28 [bc]	353.5 [b]	1.32
	Assaf	33	76	1.24 [bcd]	278.5 [efg]	1.63
	Awassi x Assaf	102	242	1.17 [cd]	289.8 [def]	1.47
Nablus	Awassi x Assaf	189	291	1.13 [d]	246.8 [g]	1.67
Qalqiliya	Assaf	172	463	1.36 [b]	292.2 [def]	1.70
Ramallah	Assaf	119	252	1.39 [b]	304.8 [de]	1.66
Jerusalem	Awassi	272	448	1.12 [d]	347.3 [bc]	1.18
	Awassi x Assaf	56	56	1.40 [b]	------	-----
Betlehem	Awassi x Assaf	145	336	1.21 [cd]	266.3 [fg]	1.66

… Continue table (7)

Location	**Breed**	**No. of ewes**	**No. of records**	**Trait**		
				LS	**LI**	**NLBY** [3]
Hebron	Awassi	60	112	1.21 [bcd]	416.6[a]	1.06
	Assaf	45	83	1.37 [b]	341.0[bcd]	1.47
	Awassi x Assaf	139	255	1.18 [cd]	375.7[ab]	1.15
Dora	Awassi x Assaf	326	581	1.19 [cd]	297.2[de]	1.46

[1] Afec-Awassi = Improved Awassi strain carrying the Booroola FecB gene

[2] Means in the same column with similar letters are not significantly different (P > 0.05) using Tukey-Kramer adjustment for multiple comparisons.

[3] Estimated as follows: 365 x (least squares mean of litter size / least squares mean of lambing interval)