6. Wool

Early evolution of wool in the present breeding area of the Awassi

The woolly fleece of the Awassi seems to be a very early achievement of sheep breeders in southwest Asia, being traceable to the urban revolution in Mesopotamia. In Sumer sheep breeding, wool spinning and weaving were organized by the temple authorities of the various cities. In the territory of Lagash, more than 15 000 people were employed in the wool industry. In the Baba (Baü, Ba'u) temple in Lagash, the several operations of textile manufacturing were allotted to three distinct groups of craftswomen, made up of 127 slave girls and 30 of their children. Forty female slaves cleaned and prepared the wool from the goddess's flocks, eighteen others did the spinning, and a third group the weaving. Sorting was done by the weavers. The wool was plucked from the sheep in a special compound outside the temple precincts. The average yield was 666 g — or 715 g according to another account — for each animal. Part of it was distributed as rations to members of the community and another part was exported. The best quality in Lagash, Drēhim and Ur came from 'fat-tailed sheep from the mountains'; black wool was of the lowest quality. The goddess also possessed breeding stock to ensure the production of good raw material. The flocks were tided over periods of drought with barley (Childe, 1942; Frankfort, 1951; Waetzoldt, 1972).

Nuzi documents of about 1500 BC mention Canaanite wool and discuss the wool of the sheep of ancient Palestine (Breasted, 1935). The histological examination of parchment samples from early scrolls from Palestine indicates that 2 000 years ago local wool was finer than that of the recent Awassi breed (Ryder, 1962). The sheep skin has two kinds of follicles: primaries and secondaries. Primary follicles are large and are basically arranged in groups of three known as trios. In wild and hairy domestic sheep, these produce the long, coarse, hairy fibres of the outer coat. The secondaries are smaller and more numerous than the primaries and in wild sheep they produce the fine woolly fibres of the undercoat. Being shorter than the hairs, they are obscured by them. The fundamental difference between the primary and secondary follicles that distinguishes them in the skin is the association of the primary follicle with a sweat gland and erector muscle, and the absence of these in the secondaries. Both types of follicle do, however, have sebaceous glands. In the evolution of woolled sheep, a gradual movement of the secondaries from between the primaries seems to have taken place, accompanied by a decrease in size of the primaries, their closing together, and a tendency to grow less hairy fibres. On this basis Ryder found that among 20 samples of parchment from the Dead Sea (Qumran) Scrolls (about 100 BC-AD 69) and five from the nearby site of Murabba'at (about AD 130-135), there were some that had nearly as large groups of fine fibres as are characteristic of recent Merino sheep, fibres as fine as in the Merino, and a surface scale pattern of the fibres also suggestive of the Merino.

While the evidence provided by the parchments demonstrates that a certain number of true fine-wooled sheep did exist in Palestine before the Christian era, more recent evidence from wool cloth from caves near the Dead Sea, dated about AD 130, shows that although the wool appeared fine to the naked eye, thus supporting the ancient records of fine wool, microscopic examination revealed a certain proportion (15-20 percent) of medium fibres within a majority of fine fibres, indicating a fleece type more primitive than the true fine-wooled (Ryder, personal communication, 1963).

The cloth referred to was part of the material from the 'Cave of Letters' near the Dead Sea, which

comprised six pieces of leather, one specimen of unspun wool, one of yarn, and two of cloth, that had belonged to Jewish rebels against Roman rule. The scale pattern of the surface cuticle of the wool fibres was clear, particularly in the medium fibres, in which an irregular-waved mosaic pattern could be discerned. Some of the medium fibres from the leather had an irregular mosaic pattern lacking a wave. Wool from the two pieces of cloth was non-medullated, but a few of the medium fibres from the unspun wool had a fragmental medulla. Some fibres from the yarn had an interrupted medulla, while others had an unbroken medulla for an appreciable length and could therefore be regarded as fine hairs. One of these fibres, 44 µ in diameter, had a medulla 12 µ wide, while a fibre from a parchment of the Dead Sea Scrolls was only 16 µ in diameter, yet had a medulla 12 µ wide and was apparently from a hairy sheep. The mean fibre diameter of the unspun wool from the Cave of the Letters was 24 µ, of the yarn 30 µ, and of the two pieces of cloth 24 µ and 25 µ, respectively. The fibre diameter of the unspun wool and the cloth ranged from 10 to 48 µ, and of the yarn sample up to 54 µ. The diameter frequency had a skewed distribution with the greatest number of fibres in the fine diameter range (see Fig. 6-1). This explains why the specimens appeared fine to the naked eye, whereas in fact most of them came from sheep of a medium-wooled type. Only one was from a fine-wooled sheep with a fibre diameter ranging from 16 to 24 µ, similar to the fibres from the Dead Sea Scrolls (10-28 µ) (Ryder, 1964).

In the patriarchal household of barbarism, sheep breeders probably did not pay particular attention to the colour of their flocks, which comprised white, tan, grey, black, and variegated animals. Laban's flocks, which were herded by Jacob with such profitable results to himself, included brown, variegated and speckled sheep. The unpigmented wool of the Awassi and other breeds of sheep is traceable to the purple-dyeing industry, first developed on a large scale on the coast of Phoenicia, which provided the impetus for the gradual elimination of coloured sheep from improved flocks, for none but a black dye can be used on wool that is black, tan or grey. As the extension of murex fishery started the Phoenicians on their maritime career, purple dyeing spread throughout the Mediterranean region, and with the dyeing industry, extended the demand for white wool (Epstein, 1955).

The pigmentation of the head of the Awassi is probably a result of artificial and natural selection. It is of value in subtropical regions characterized by intense solar radiation as it provides immunity to affections associated with the extreme photosensitivity of unpigmented and exposed areas of the head and ears. Pigmentation of the hoofs and lower part of the legs serves to strengthen them.

Awassi fleece

Yield. For the wool of improved Awassi sheep in Israel, Becker (1958) gives a clean scoured yield of only 40-50 percent, but the fleeces of 45 improved Awassi ewes of different ages, examined by Goot (1972), yielded 74.6 ±7.0 percent scoured wool.

In Lebanese Awassi flocks, the normal yield of scoured wool averages 50-60 percent. In a flock kept at the experimental farm of the American University of Beirut, the annual average yield in two successive years was 66.3 percent (McLeroy & Kurdian, 1958).

In 147 samples of wool of six months' growth from 9-, 15-, 21-, 27- and 33-month-old Awassi ewes of Syrian derivation in Egypt, shrinkage varied between 20.2 and 31.3 percent, with an average of 25.4 percent. The greasy fleece weight of sheep of all ages averaged 1.308 kg, and the clean scoured fleece weight 0.976 kg, that is, a yield of 74.6 percent. Age had no significant effect on yield (Ghoneim, Ashmawy & El-Mekkawi, 1967).

At the Hofūf Agricultural Research Centre, Saudi Arabia, patch samples of wool of six months growth were taken from the right mid-side of 20 ewes and 15 nearly four-month-old lambs of an improved Awassi flock originally imported from Syria. After washing with a non-ionic detergent and drying in the controlled atmosphere of a wool laboratory in Bangor, Wales, the mean percentage yield of clean wool from the ewes was 77.9 and from the lambs 77.5, the shrinkage being attributed to the loss of some grease and a larger quantity of dust, for the sheep were kept in dusty yards (Pritchard, Pennell & Williams, 1975).

At the Ereğli Animal Breeding Research Station in central Anatolia, a flock of İvesi sheep had an average clean wool yield of 61.2 percent during two years of examination (Yalçin & Aktaş, 1969). Imeryüz, Müftüoğlu and Öznacar (1970) recorded a slightly higher mean yield of scoured wool of 12 months' growth in adult İvesi sheep in Turkey, namely 66.8 percent. In wool samples taken from the hip region, the clean fibre yield was 77.0 percent for rams, 71.7 percent for ewes, and 78.2 percent for yearlings.

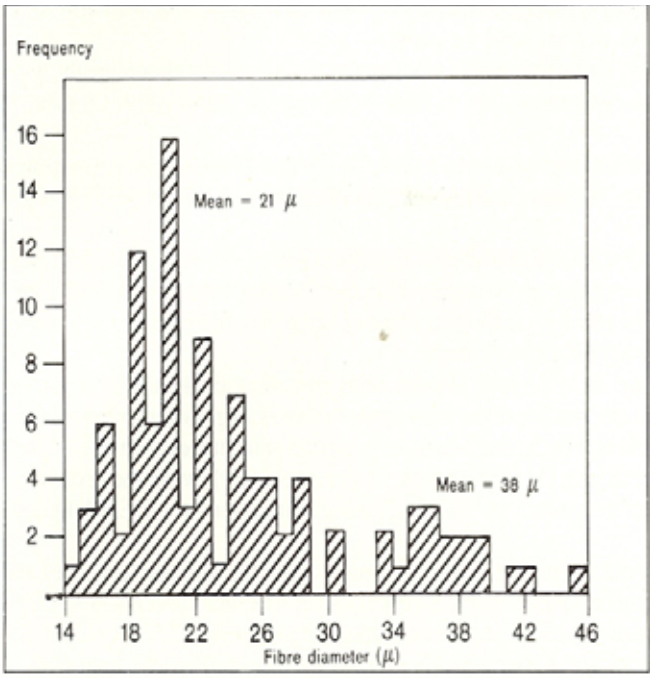

Figure 6-1. Distribution of fibre diameters in unspun wool from a cave near the Dead Sea, AD 130. (**Source:** Ryder, 1964)

In Iraqi Awassi ewes, stationed in Abu-Ghraib near Baghdad, the mean yield of wool of 12 months' growth from 18-, 24-, 36- and 48-month-old animals ranged from 84.0 to 85.6 percent, with an overall average of 84.85 percent. As in the case of the Syrian Awassi sheep in Egypt, the age of the ewes had no significant effect on the scoured wool yield. The low shrinkage is attributed by Sharafeldin (1965) to the comparatively small number of sudoriferous and sebaceous glands in the wool-follicle structure of the Awassi.

Fibre types. The Awassi is a long-wool sheep with an open, lofty and moderately lustrous fleece of carpet wool with distinct wide crimps (Nichols, 1932). The fleece consists of an outer coat, undercoat and kemp. It has the principal requisites of carpet wool, namely, coarseness and resilience, qualities that make carpet wool resistant to matting and wear. An ideal carpet wool should have a fibre diameter of 30 µ, a fibre length of 10 cm with a 20 percent variation in length and 4 percent by weight of kempy fibres. Awassi wool complies with these requirements as regards fibre thickness and length, but the fibre length variation and kemp contents are somewhat larger.

The scales on the surface of the fine fibres of the undercoat are arranged tile-like, not in rows. The stronger fibres of the fleece are lustrous and more or less uniform, save for their greater fineness toward the tips. The scales covering their surface are broader and relatively shorter than those of the fine fibres (Apler, quoted by Becker, 1958).

In fleeces of Syrian Awassi sheep, Erokhin (1973) recorded the percentages of fibre types by weight (Table 6-1). Table 6-2 gives the mean percentages of coarse, fine and kemp fibres for clean wool samples of six months' growth taken from 20 ewes and from 15 nearly four-month-old lambs of an Awassi flock of Syrian derivation at the Hofūf Agricultural Research Centre (Pritchard, Pennell & Williams, 1975).

Considerable variability existed between individuals. Kemp fibres, shed in the fleece, were present in most samples from the ewes and one sample consisted of 40 percent kemp. No recognizable kemp fibres were found in any of the samples taken from the lambs that were too young for the first

TABLE 6-1. **Percentage of fibre types in Awassi sheep in Syria**

Fibre type	Rams	Ewes
Heterotype	45.2	41.5
Undercoat	2.7	15.5
Kemp	52.1	43.0

TABLE 6-2. **Mean percentages of fibre types in wool samples from Awassi ewes and lambs in Saudi Arabia**

Fibre type	Ewes	Lambs
Coarse	47.3	54.1
Fine	43.2	45.9
Kemp	9.4	—

growth of kemp fibres to have already occurred, but variability between samples in the proportions of coarse and fine fibres was similar to that found in the ewes.

At the Ereğli Animal Breeding Research Station, wool of 12 months' growth taken from the hip region of İvesi sheep had the fibre-type ratios given in Table 6-3 (Imeryüz, Müftüoğlu & Öznacar, 1970).

In 264 samples of wool of six months' growth from 9-, 15-, 21-, 27- and 33-month-old Awassi ewes of Syrian origin in Egypt, Ghoneim, Ashmawy and El-Mekkawi (1967) recorded the mean fibre-type ratios (Table 6-4).

The total average ratio of undercoat, outer coat and kemp fibres was 69.7:24.4:5.9 by count, and 41.4:54.2:4.4 by weight, the estimate of the percentages of fibre type by count being considered to be more accurate than by weight. The relatively high percentage of kemp fibres by count as well as by weight clearly shows that the Awassi has a kempy fleece.

There is no appreciable difference in the ratio of outer coat, undercoat and kemp fibres among the different ages of the sheep, but the location of the wool on the body has a significant influence on the percentages by weight of the fibres. For the outer coat and kemp the percentages are higher in the hip than in the shoulder region at all ages (54.9:53.2 and 5.3:3.6, respectively), while the reverse obtains with regard to the fibres of the undercoat (39.8:43.2) (Ghoneim, Ashmawy & El-Mekkawi, 1967).

In an examination of 7 500 wool samples of 12 months' growth from the forequarters, sides and hindquarters of Awassi sheep in three different parts of Israel, Lewin, Horowitz and Zacks (1957) found that the average percentage of non-elastic, hard and brittle kemp fibres was 11.72 by weight, a figure very close to the mean percentage of coarse hair (11.4 percent) recorded in 800 samples of Israeli Awassi wool of ten months' growth by Apler (see following section). The wool from flocks in the south of Israel (Negev) contained the smallest percentage of kemp, namely 6.3 percent, the samples from the two other parts of the country being 13.3 and 12.3 percent, respectively. In all instances the wool from the forequarters included a smaller percentage of kemp fibres than that from the sides and rump (Lewin, Horowitz & Zacks, 1957).

Goot (1972) recorded the following percentages of hairiness (permanent medullated hair and kemp) in 260 fleeces of dry yearlings and 25 fleeces of lactating yearlings, and 134 fleeces of dry ewes and 1 082 fleeces of ewes in milk from improved Awassi flocks in Israel (Table 6-5). The data indicate that the amount of hairiness in the carpet wool fleeces of Awassi yearling and adult ewes is not palpably influenced by lactation.

Nor was the incidence of cotted fleeces in improved Awassi sheep in Israel affected by lactation. As the cotting of wool, that is, the matting or entangling of fibres broken at the base with the contiguous fibres, is influenced by nutrition, Goot (1972) suggests that the high plane of nutrition prevalent in Awassi dairy flocks in Israel prevents an increase in the percentage of cots in lactating ewes (Table 6-6).

TABLE 6-3. **Fibre types in İvesi fleeces in Turkey (%)**

Fibre type	Rams	Ewes	Yearlings
True wool fibre	75.8	78.2	80.8
Heterotype	8.1	11.8	8.1
Medullated	8.4	3.9	6.0
Kemp	7.7	6.1	5.1

TABLE 6-4. **Fibre-type ratios in wool of Awassi ewes at different ages (%)**

Age of ewes (months)	Fibre-type ratio by weight			Fibre-type ratio by count		
	Outer coat	Undercoat	Kemp	Outer coat	Undercoat	Kemp
9	53.8	41.3	4.9	25.4	65.1	9.5
15	53.8	42.0	4.2	24.9	71.6	3.5
21	53.0	42.5	4.5	23.6	72.8	3.6
27	55.9	40.1	4.0	25.4	67.7	6.9
33	54.6	41.0	4.4	22.7	71.3	6.0

TABLE 6-5. **Hairiness in fleeces of dry and lactating yearling and adult Awassi ewes (%)**

Hairiness	Yearlings		Adult ewes	
	Dry	Lactating	Dry	Lactating
Traces	5	8	2	2
Below 10	26	24	28	21
10-25	27	20	21	26
25-50	23	32	23	23
50-75	9	12	12	13
Above 75	10	4	14	15

TABLE 6-6. **Cots in shorn fleeces of dry and lactating yearling and adult Awassi ewes in Israel (%)**

	Yearlings		Adult ewes	
	Dry	Lactating	Dry	Lactating
Number of fleeces:	276	26	134	1 220
Free of cots	23.9	15.4	20.0	28.6
Slightly cotted	19.6	38.4	18.5	16.0
Cotted	19.2	11.5	11.1	10.2
Heavily cotted	31.5	30.8	35.6	31.4
Completely matted	5.8	3.9	14.8	13.8

Staple and fibre lengths. In fleeces of 12 months' growth from 729 Awassi ewes of various ages in Israel, Goot (1972) recorded a mean staple length of 13.75 ±3.76 cm.

At the experimental farm of the American University of Beirut, a flock of Awassi ewes derived from the stock of nomadic shepherds from the Syrian desert had fleeces of 12 months' growth with an average staple length of 10.05 cm in two consecutive years (McLeroy & Kurdian, 1958).

In Turkey the staple length of İvesi fleeces varies between 12 and 15 cm (Yalçin, 1979). At the Ereğli Animal Breeding Research Station, wool samples taken from the hip region of İvesi sheep in three consecutive years just before the annual shearing had the following average staple lengths: rams, 15.9 cm; ewes, 14.5 cm; yearlings, 15.1 cm (Imeryüz, Müftüoğlu & Öznacar, 1970). In fleeces of 12 months' growth from 225 Turkish İvesi sheep of varying coat types belonging to three village flocks, Sidal (1973) measured an average staple length of 16.4 cm. Staple length was found to decline with increasing age of the sheep.

In Iraq, the fleeces of 12 months' growth from 26 one-year-old Awassi rams, improved for superior wool production, had an average staple length of 9.82 cm, and those of seven two-year-old and older improved rams 9.68 cm, while the fleeces of 12 unimproved two-year-old and older rams had a staple length of 11.14 cm (Kaminkova, Al-Azzawi & Rahman, 1967). At Abu-Ghraib, the mean staple length of the fleeces of 12 months' growth from 268 Awassi ewes was 16.47 cm, with a variation of less than 0.2 cm for the different age groups (18, 24, 36, and 48 months). The mean fibre length ranged from 16.94 to 17.68 cm, with an overall average of 17.37 cm. The small difference between fibre lengths and corresponding staple lengths is attributed to weak crimp development in the wool. A significant positive correlation was found between fibre length and greasy fleece weight, and a highly significant negative correlation between fibre length and yield, probably owing to the larger amount of impurities in the long outer coat of the sheep. The age of the ewes had no significant effect on the staple or fibre lengths. This may be due to the fact that the first samples were taken at the age of 18 months, while most age differences in wool characteristics are observed between the first and subsequent years. The lack of an age effect on staple and fibre lengths may be taken as an indication that the follicle structure of Awassi wool reaches its full development at an early age and does not change afterwards (Sharafeldin, 1965).

The average fibre length of 7 500 samples of Awassi wool of 12 months' growth taken from the forequarters, sides and hindquarters of 2 500 fleeces from three different regions of Israel measured 12.57 ±0.71 cm (Lewin, Horowitz & Zacks, 1957). The shortest wool — 10.97 ±0.71 cm — came from the forequarters, and the longest — 13.54 ±0.71 cm — from the side samples, the difference being statistically significant. The fairly uniform length of the fibres in animals from different flocks and different parts of the country is attributed to the fact that shearing is completed in the whole of Israel within two weeks (see Fig. 6-2). The fibre length of Awassi wool of approximately ten months' growth from 800 sheep of different flocks in Israel ranged from 8 to 23 cm (Apler in Becker, 1958). Table 6-7 gives the fibre lengths recorded by Erokhin (1973) for fleeces of 12 months' growth from Syrian Awassi sheep.

In a study of 405 wool samples of six months' growth, taken from the shoulder and hip regions of 9-, 15-, 21-, 27- and 33-month-old Awassi ewes of Syrian derivation born in Egypt, the average fibre length for the different ages ranged from 70.1 to 101.3 mm, with a total average of 85.2 mm. The longest fibres, averaging 122.2 mm in length, were from the outer coat. Those of the undercoat measured 77.6 mm in average length, while the kemp fibres were shortest, namely 29.2 mm.

The average fibre length increased from the age of nine to 15 months, and from 21 to 27 months,

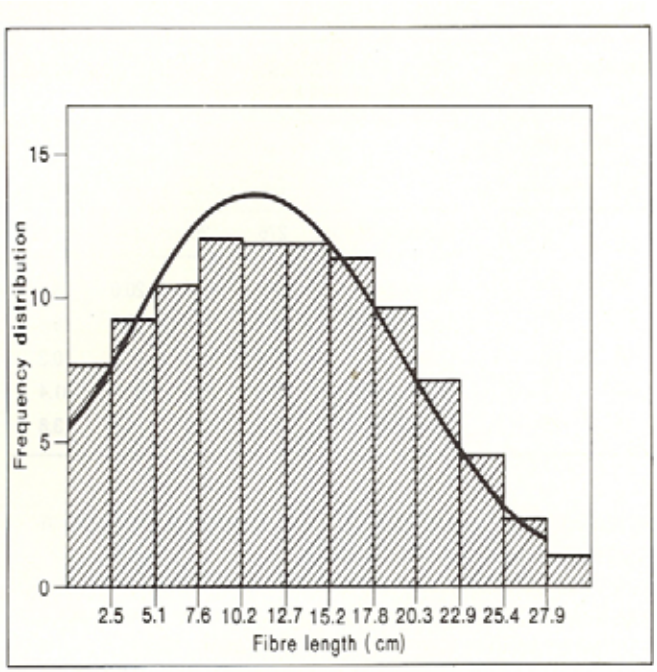

Figure 6-2. Frequency distribution histogram of fibre lengths. (**Source:** Lewin, Horowitz & Zacks, 1957)

TABLE 6-7. **Fibre lengths in Awassi fleeces in Syria (cm)**

Fibre type	Rams	Ewes
Heterotype	16.4	13.2
Undercoat	11.3	9.6
Kemp	20.6	15.8

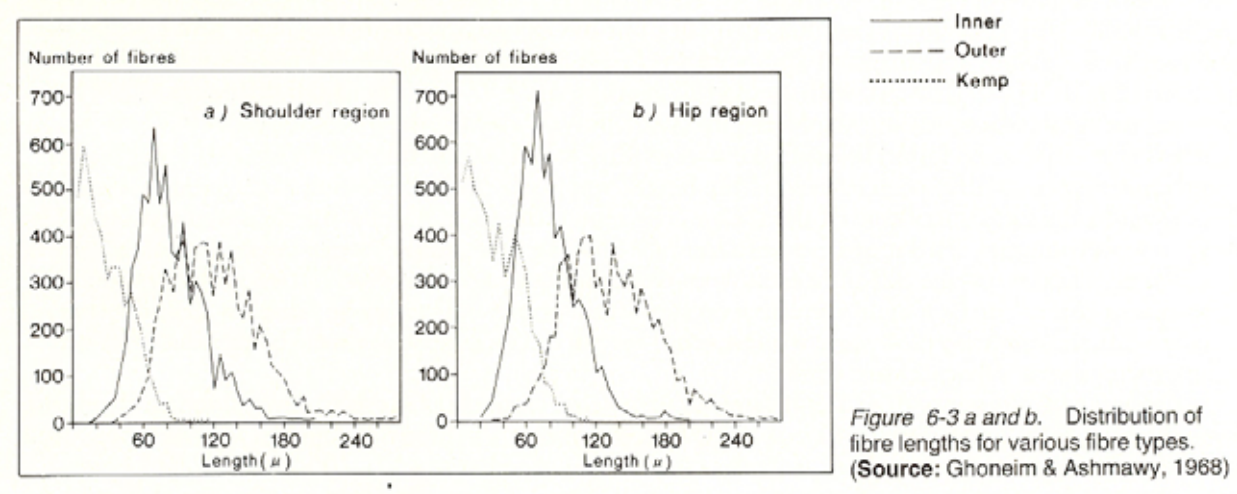

Figure 6-3 a and b. Distribution of fibre lengths for various fibre types. (**Source:** Ghoneim & Ashmawy, 1968)

and decreased from 15 to 21 and 27 to 33 months. This is attributed to the different seasons in which the sheep were shorn. The wool samples taken at the ages of 9, 21 and 33 months were shorn in October of different years, while those taken from 15- and 27-month-old animals were shorn in April. Wool grown in summer was generally shorter than that grown in winter. The hip region produced longer wool than the shoulder region (Fig. 6-3) (Ghoneim and Ashmawy, 1968).

Different types of fibre in wool samples taken from the mid-side of 20 ewes and 15 lambs of an Awassi flock of Syrian origin at the Hofūf Agricultural Research Centre had the mean lengths given in Table 6-8 (Pritchard, Pennell & Williams, 1975).

Fineness. The average fibre diameter of wool of 12 months' growth from forequarters, sides and hindquarters, collected in southern Israel (Negev) and two other areas, was 36.1 μ, equal to a 44s count (Lewin, Horowitz & Zacks, 1957). In all three regions of the country the side wool was finer

TABLE 6-8. **Mean fibre length of different fibre types in wool samples from Awassi ewes and lambs in Saudi Arabia (cm)**

Fibre type	Ewes (6 months' growth)	Lambs (15 weeks' growth)
Coarse	12.0	6.8
Fine	8.6	4.2
Kemp	5.3	—

than that from either the shoulder or rump. Wool fibres from forequarters averaged approximately 37.0 μ, from the sides 34.3 μ, and the hindquarters 37.0 μ. in diameter. Table 6-9 gives the average distribution of fibres according to fineness in the wool from the three parts of the body (see also Fig. 6-4).

In 800 samples of Awassi wool of approximately ten months' growth taken from different flocks in Israel, Apler recorded the data in Table 6-10 on fibre fineness (Becker, 1958).

TABLE 6-9. **Frequency distribution of fibre fineness in Awassi wool in Israel (%)**

Fineness of fibres (μ)	Below 30	30-40	40-50	Above 50
Forequarters	33.4	31.7	15.8	19.1
Sides	42.3	29.7	11.5	16.5
Hindquarters	32.5	32.4	13.9	21.2

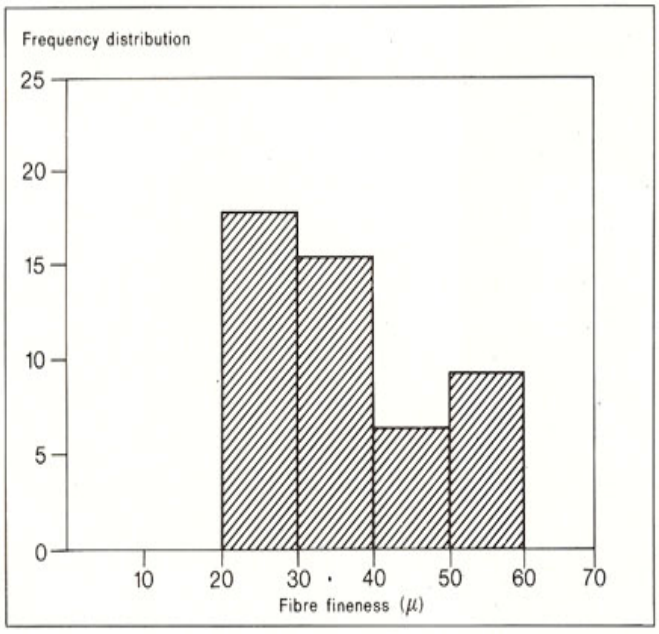

Figure 6-4. Frequency distribution histogram of fibre fineness in Awassi wool. (**Source:** Lewin, Horowitz & Zacks, 1957)

TABLE 6-10. **Mean percentages of fibres of different fineness in Awassi wool**

Diameter (μ)	Fibre length (cm)	Count	Uniformity	%
31	8-10	B II (58/60s)	good	13.3
54	13	D I (50/52s)	good	35.8
62	19	E (44/46s)	medium	37.0
90	20	F (40s)	medium	2.5
120	23	F (32/36s)	poor	11.4

Samples of Awassi wool of 12 months' growth taken from the mid-side of an adult stud ram and adult ewe of a highly improved dairy flock in Israel, and wool samples from a 4½-month-old male and a five-month-old female lamb of the same flock were examined by Ryder (personal communication, 1979), who noted that these were typical of a hairy carpet-type fleece (Table 6-11). The wool of the ram was particularly coarse, while that of the male lamb contained some unusually coarse kemp fibres (Fig. 6-5). Becker (1958) claims that Awassi wool of brown colour is generally finer than white wool.

In fellahin and especially in bedouin flocks of Awassi sheep, the wool fibres are uneven in thickness. The period of malnutrition during the year finds expression in the growth of finer sections of the fibres (Kamal, 1981). In fleeces of Syrian Awassi sheep, Erokhin (1973) recorded the average diameters of the different fibre types (Table 6-12).

TABLE 6-11. **Diameter range, mode, mean and coefficient of variation (CV) of wool samples from an improved Awassi dairy flock in Israel**

Sample	Diameter range (μ)	Mode	Mean	CV (%)
Ram	28-132	40	56.5 ±25.1	56.5
Ewe	16-56,88,98	30	35.2 ±15.9	45.3
Male lamb	22-56, 140, 146, 150(2), 164,184	26	43.9 ±31.4	71.4
Female lamb	16-68, 76, 104, 110	28	35.3 ±12.0	33.8

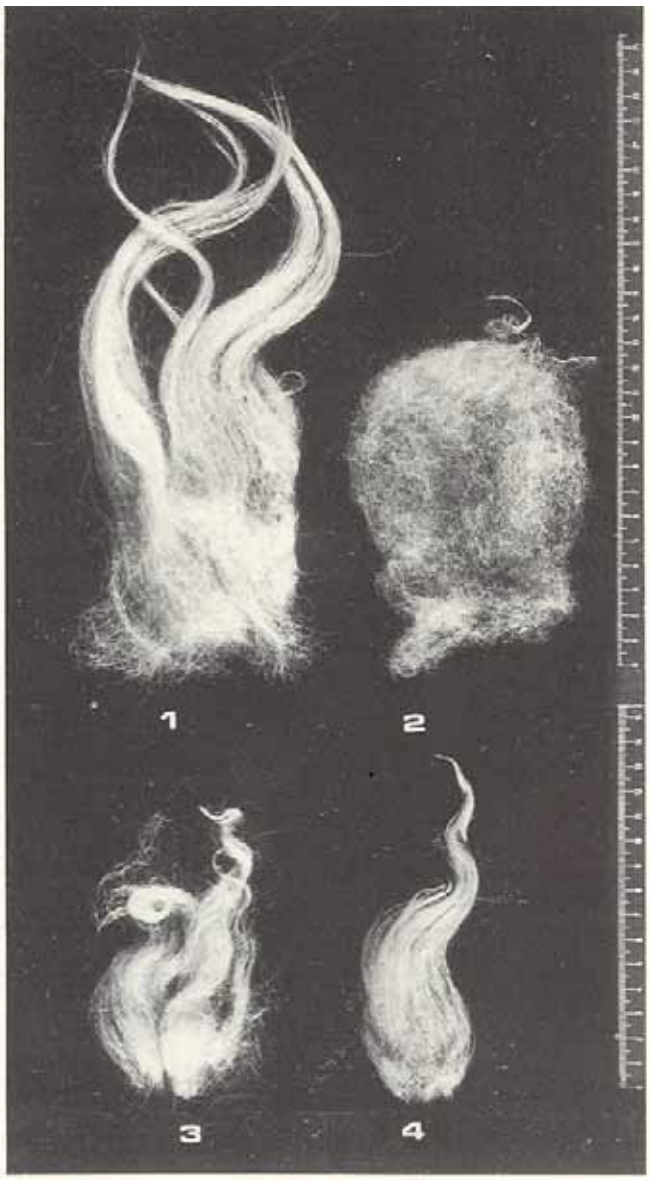

Figure 6-5. Awassi wool samples:
1. adult ram, 12 months' growth;
2. adult ewe, 12 months' growth;
3. male lamb, 4 1/2 months old;
4. female lamb, 5 months old

TABLE 6-12. **Fibre diameters in Awassi fleeces in Syria (μ)**		
Fibre type	Rams	Ewes
Heterotype	33.7	31.9
Undercoat	26.4	24.0
Kemp	56.9	49.0

At the Ereğli Animal Breeding Research Station, wool of 12 months' growth taken from the hip region of İvesi sheep had the fibre diameters given in Table 6-13 (Imeryüz, Müftüoğlu & Öznacar, 1970).

In wool samples from 26 one-year-old Awassi rams, improved with a view to superior wool production in Iraq, the average fibre diameter was 22.73 μ, and in seven two-year-old and older rams, 27.27 μ; the wool from 12 unimproved two-year-old and older Awassi rams had an average fibre diameter of 32.02 μ. (Kaminkova, Al-Azzawi & Rahman, 1967).

In 268 Awassi ewes in Abu-Ghraib in Iraq, the average fibre diameter of the wool of 12 months' growth was 33.3 μ, with a range from 32.8 to 34.0 μ between the age groups of 18, 24, 36 and 48 months. The age of the ewes had no significant effect on fibre diameter (Sharafeldin, 1965).

In wool samples of six months' growth, taken from the shoulder and hip regions of Awassi ewes of Syrian derivation born in Egypt, Ghoneim and Ashmawy (1968) found that kemp had the thickest fibres, ranging from 51.4 to 75.8 μ in diameter. These were followed by the fibres of the outer coat with a range from 46.5 to 54.5 μ, while those of the undercoat, measuring 23.9-29.8 μ in diameter, were the finest. The total average fibre diameter of the samples from 9-, 15-, 21-, 27- and 33-month-old ewes varied between 32.3 and 38.2 μ. With advancing age, the fibre diameter increased. In ewes of all ages, the wool grown on the hip region was coarser than that of the shoulder (Fig. 6-6).

Different types of fibre — coarse, fine and kemp—in wool samples from the mid-side of Awassi ewes and lambs of a flock of Syrian origin stationed at the Hofūf Agricultural Research Centre had the diameters given in Table 6-14 (Pritchard, Pennell & Williams, 1975).

TABLE 6-13. **Fibre diameter and distribution of fibre fineness in Turkish İvesi sheep (μ)**		
	Average fibre diameter	Distribution of fibre fineness
Rams	36.0	10-160
Ewes	35.0	10-180
Yearlings	33.8	10-130

TABLE 6-14. **Mean diameter of different fibre types in wool samples from Awassi ewes and lambs in Saudi Arabia (μ)**		
Fibre type	Ewes (6 months' growth)	Lamb (15 weeks' growth)
Coarse	47.2	53.1
Fine	23.5	21.0
Kemp	83.9	—

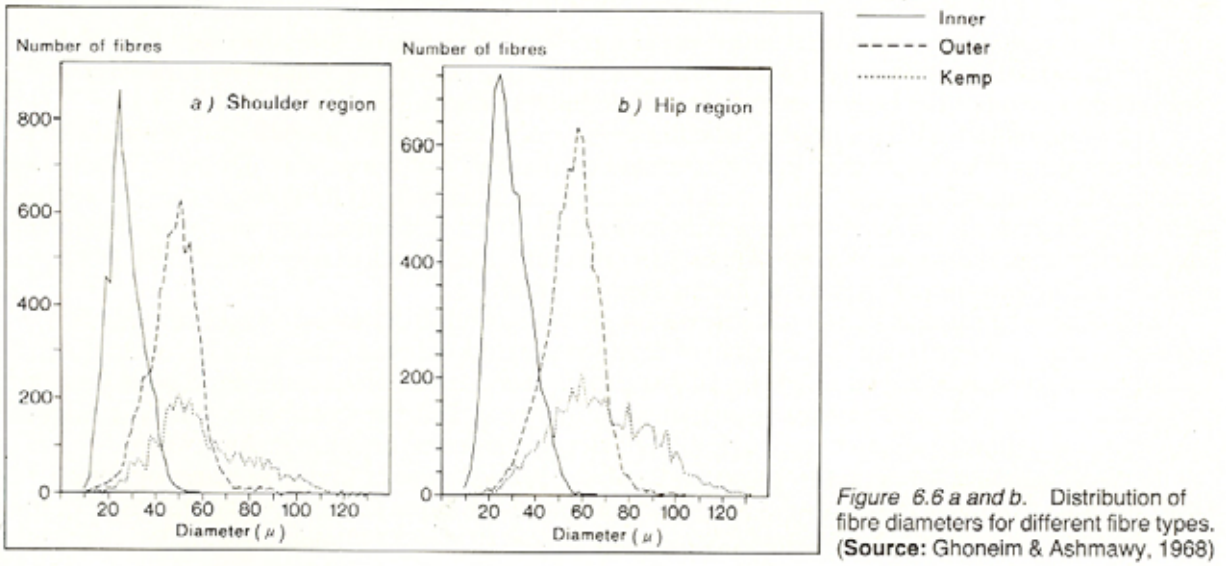

Figure 6.6 a and b. Distribution of fibre diameters for different fibre types. (**Source:** Ghoneim & Ashmawy, 1968)

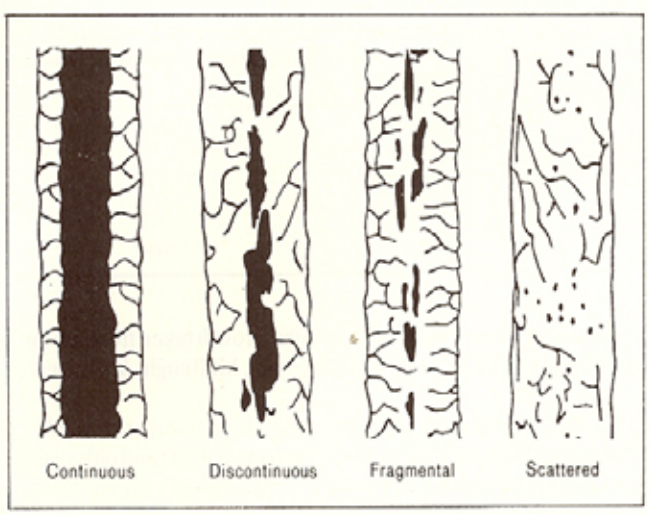

Figure 6-7. Different types of medullae in the outer coat fibres of the Awassi. (**Source:** Ghoneim, Ashmawy & Al-Mekkawi, 1968)

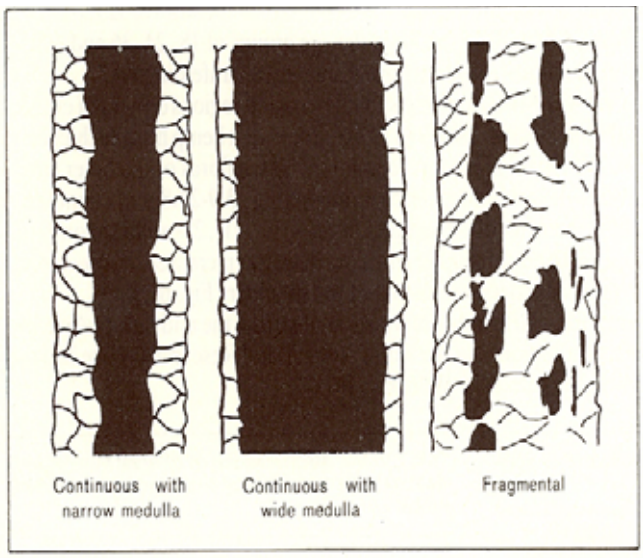

Figure 6-8. Different types of medullae in the kemp fibres of the Awassi. (**Source:** Ghoneim, Ashmawy & Al-Mekkawi, 1968)

The lambs were similar to the ewes in the mean diameters of the coarse and fine fibres, although the coarse fibres in the lambs' wool had a slightly higher mean value than that of the ewes. The fine fibre diameters were comparable to Merino wools. The diameters of the kemp in the wool samples from the Awassi ewes were similar to those typical of the kemp fibres of sheep.

Medullation. Awassi fleece is highly medullated. The difference in the percentage of medullated fibres between the outer and undercoats is very large. Scattered, fragmental, discontinuous and continuous types of medullae occur in the outer coat and kemp (Ghoneim, Ashmawy & Al-Mekkawi, 1968). Kemp contains the highest percentage of medullated fibres. (See Figs 6-7 and 6-8.)

The examination of a large number of samples of wool of ten months' growth from Awassi sheep in different parts of Israel showed that the fine and moderately fine fibres were not medullated. The stronger fibres had either a very thin medullary canal or a discontinuous medulla, present in some sections of the fibre and absent in others. The coarse wool fibres, permanent hair and kemp had fully developed medullae from root to tip. Table 6-15 gives the percentages of non-medulalted, heterotype and medullated fibres (Apler, quoted by Becker, 1958).

In a sample of wool of 12 months' growth taken from an adult Awassi stud ram of a highly improved dairy flock in Israel, 23 percent of the fibres were medullated. The same percentage of medullated fibres was found in wool from a 4½-month-old male lamb of the same flock. Nine percent of the fibres of the wool of 12 months' growth from an adult ewe and 5 percent of the fibres in a sample from a five-month-old ewe lamb were medullated (Ryder, personal communication, 1979).

In wool samples of six months' growth taken from Awassi ewes of Syrian ancestry in Egypt, Ghoneim and Ashmawy (1968) found 88.0-95.5 percent of the kemp fibres to be medullated. In the outer coat the percentage of medullated fibres ranged from 61.8 to 71.0, and in the undercoat from

TABLE 6-15. **Medullation of Awassi wool in Israel**

Fineness of fibres	Medullation	%
Fine	Non-medullated	13.3
Moderately fine	Non-medullated or heterotype	35.8
Strong	Heterotype	37.0
Very strong	Medullated	2.5
Hair and kemp	Medullated	11.4

TABLE 6-16. **Medullation in wool from improved and unimproved Awassi rams in Iraq**

Type of rams	Age (years)	Number	Discontinuous medulla (%)	Continuous medulla (%)
Improved	1	26	2.60	0.22
	2 and older	7	4.19	0.79
Unimproved	2 and older	12	4.63	7.12

11.6 to 14.1. The total average percentage of medullated fibres in all samples was 54.8. The age of the ewes had no significant influence on the medullation percentage; there was only a slight decrease of the latter from 57.2 in wool from nine-month-old lambs to 52.7 in 33-month-old ewes. However, a significantly higher medullation percentage was found in ewes of all ages in the wool samples from the hip than from the shoulder region.

In Iraq, Kaminkova, Al-Azzawi and Rahman (1967) compared the percentages of fibres with continuous and discontinuous medullae between Awassi rams improved for superior wool production and unimproved rams. The results of their study show that wool from the improved type contains a considerably smaller percentage of medullated fibres than that from the unimproved Awassi (Table 6-16).

Crimp. In wool of 12 months' growth from different age groups (18, 24, 36 and 48 months) of Awassi ewes in Iraq, the mean number of crimps for every 2 cm ranged from 3.8 to 4.4, with an overall average of 4.18. There was a significant positive correlation between crimps and fibre diameter, but the age of the ewes had no significant effect on crimp number (Sharafeldin, 1965). In Awassi fleeces of ten months' growth in Israel, the fine, non-medullated fibres had four to six crimps over a length of 1 cm (Apler, quoted by Becker, 1958).

In wool samples of six months' growth taken from 9-, 15-, 21-, 27- and 33-month-old Awassi ewes of Syrian derivation in Egypt, the average number of crimps over a length of 2 cm varied between 4.61 and 5.05 for the ages studied. The wool of the undercoat had more crimps than that of the outer coat, namely 6.10 on average versus 2.11. With the advancing age of the sheep, the number of crimps was found to decrease. Wool from the shoulder region was more crimpy than that from the hip region (Ghoneim & Ashmawy, 1968). (See Fig. 6-9.)

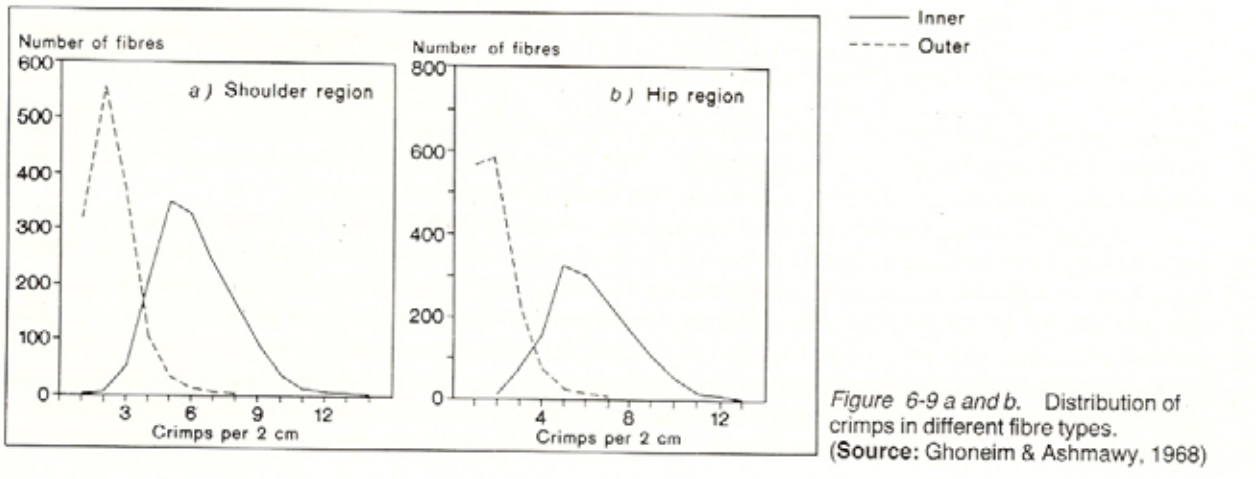

Figure 6-9 a and b. Distribution of crimps in different fibre types. (**Source:** Ghoneim & Ashmawy, 1968)

Tensile strength and elasticity. At the Ereğli Animal Breeding Research Station, wool fibres of 12 months' growth taken from the hip region of İvesi sheep had the absolute tensile strength and elasticity given in Table 6-17 (Imeryüz, Müftüoğlu & Öznacar, 1970).

A total of 270 tests of wool from the forequarters, sides and hindquarters of Awassi sheep in three regions of Israel were carried out by Lewin, Horowitz and Zacks (1957) to determine fibre strength. The average tensile strength for all samples was 1.24 ±0.01 g/denier (d). There were three significantly different groups of fibres according to strength: the Negev (southern Israel) wool from all three parts of the body, the rump wool from sheep in another area of the country, and the forequarter and side wool from yet another region, which gave 1.29 ±0.01 g/d. The hindquarter wool from the third region gave 1.24 ±0.02 g/d, and the side wool from the second one 1.18 ±0.02 g/d. The authors emphasize the high strength of the Negev wools compared with the tensile strength of the wool samples from the two other parts of the country. In all samples tested, a positive correlation of 0.876 was found between fibre strength and thickness. This is illustrated by the fact that wool from the sides of the body is superior in fineness to that of the fore- and hindquarters, though 'rather weaker'. Fig. 6-10 summarizes fibre strength distribution in the range of samples investigated, the areas of the rectangle in the histogram being proportional to the observed frequency (percent) over intervals.

TABLE 6-17. **Tensile strength and elasticity in İvesi wool**

	Tensile strength (g)	Elasticity (%)
Rams	19.9	32.0
Ewes	17.5	31.7
Yearlings	28.2	32.3

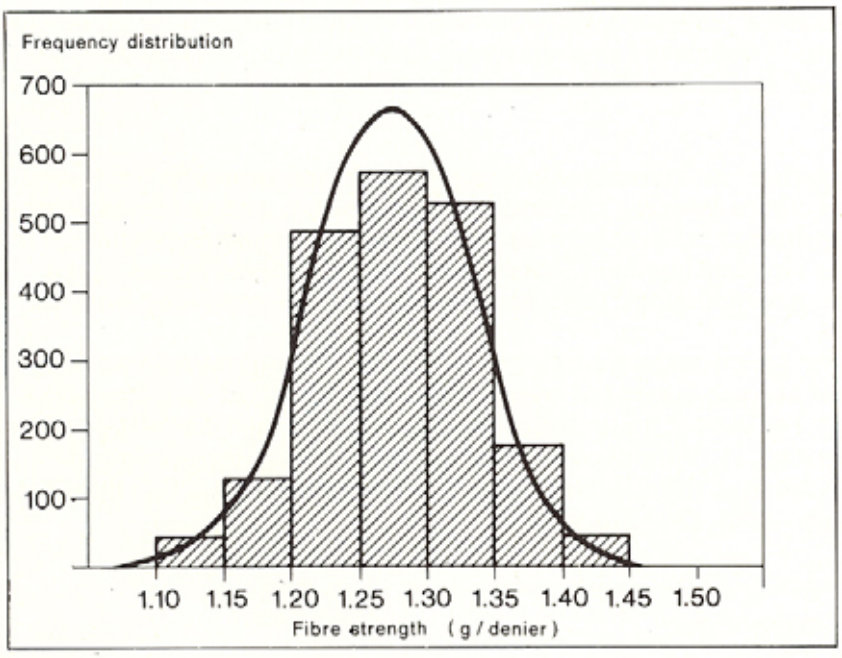

Figure 6-10. Frequency distribution histogram of fibre strength. (**Source:** Lewin, Horowitz & Zacks, 1967)

Yolk. Unscoured Awassi fleeces have a very low yolk content, a condition largely responsible for fibre and yarn harshness and poor spinning quality. The quantity of wool fat secreted by the sebaceous glands varies with season, level of nutrition, and individuality of the animals.

In Iraq, Eliya *et al.* (1969) recorded the quantity of grease in the fleeces of four non-lambing and six lambing three- to four-year-old Awassi ewes at monthly intervals for a year (Table 6-18). While there was no difference in average body weight between lambing and non-lambing ewes at lambing time in October and November, the difference in weight between the two groups in February, toward the end of winter, was very large (see p. 11). The differences in wool grease between individual and between lambing and non-lambing ewes, either by unit surface area of the skin (mg/cm^2) or expressed as a percentage of the weight of the wool taken after washing in cold tap water followed by thorough drying, were statistically highly significant. This is attributed to the low level of nutrition and the large

TABLE 6-18. **Variation of wool grease in lambing and non-lambing ewes (% and mg/cm^2)**

	February	September	Annual average
Wool grease (as % of dried wool)			
Non-lambing ewes	1.11	0.14	0.51
Lambing ewes	0.92	0.06	0.38
Average	0.99	0.09	0.43
Wool grease (mg/cm^2 skin surface area)			
Non-lambing ewes	0.216	0.013	0.071
Lambing ewes	0.117	0.007	0.042
Average	0.156	0.010	0:054

difference in condition after the winter season between the ewes that had lambed in autumn and those that had not lambed. Also significant were the monthly differences in the percentage and quantity of wool grease. These were highest from January to March and lowest from August to October.

Goot (1972) found that lactation had no effect on the incidence of canary or yolk stains in Awassi wool, although in dry yearlings a tendency to a higher percentage (71 percent) of slightly yellow fleeces was observed than in lactating yearling ewes (58 percent) (Table 6-19).

TABLE 6-19. **Percentage of canary stains in shorn fleeces of dry and lactating, yearling and adult Awassi ewes**

	Yearlings		Adult ewes	
	Dry	Lactating	Dry	Lactating
Number of fleeces:	276	26	134	1 200
Canary stains	47.9	34.6	45.2	44.4
Slightly yellow	22.8	23.1	20.0	17.9
Yellow	21.0	30.8	21.5	21.9
Deep yellow	8.3	11.5	13.3	15.8

TABLE 6-20. **Wool colour in Awassi sheep (%)**

White	30.45 ±0.66
Medium	66.43 ±0.68
Dark	3.12 ±0.25

Colour. Awassi wool, delivered to a central collecting station in Israel over a period of several years, consisted of 90 percent white to yellowish-white wool, 7 percent light to dark beige, and 3 percent grey, red or black wool (Becker, 1958).

The average colour distribution of 7 500 samples of Awassi wool from three different regions of Israel, determined by visual inspection, is given in Table 6-20 (Lewin, Horowitz & Zacks, 1957).

Wool from the sides of the sheep was generally superior in colour to that from the fore- and hindquarters. Negev wool contained a higher percentage of white and a lower percentage of pigmented fibres than that from the two other regions. Together with the side wool from one of the other regions of the country, it comprised 41.0 ±1.14 percent white fibres. The side wool from another area contained 33.7 ± 2.05 percent white fibres, while the wool from the hindquarters of the two regions north of the Negev contained only 23.0 ± 0.92 percent of these. The greatest percentage of dark fibres was found in the hindquarter wool from one of the two latter areas, namely 5.5 ±0.45 percent.

In Iraq, Asker and El-Khalisi (1966) counted 5.5 percent coloured ewes among several thousand sheep of commercial Awassi flocks. Previously, Williamson (1949) had claimed that 20 percent of the Awassi wool in Iraq was coloured.