Animal Biotechnology

Satish Kumar

Animal Biotechnology Section was established in the Institute on May 22, 2002 with the aim to initiate and conduct the cutting edge research in the field of sheep genomics, reproductive biotechnology, disease resistance and molecular parasitology. The objectives of biotechnological research in the Institute are to characterize the native sheep breeds at molecular level with respect to the prolificacy and other reproduction traits and to identify the genes /markers linked to the economically important traits like parasitic resistance, meat production and meat quality, wool and milk production and diagnosis of the sheep diseases. Keeping in view of the above thrust, two main projects namely "Genome analysis of sheep breeds by molecular methods" and "Genetic improvement of resistance to *Haemonchus contortus* in sheep" were undertaken. The achievements made in the project genetic improvement of resistance to *H. contortus* in sheep were described as alternate method of worm control in earlier section of Animal Health.

Creation of the DNA repository bank of various sheep breeds

The DNA repository bank was created for Ganjam, Kendrapara, Deccani, Nellore, Nali, Magra, Chokla, Garole, Patanwadi, Marwari, Madgyal, Kheri, Malpura, Muzaffarnagri, Jaisalmeri, Sonadi, Garole x Malpura, GMM, MGM, GMM x Patanwadi, Patanwadi x GMM, Bharat Merino and Avikalin breeds/strains. A total of 2789 DNA samples were deposited in repository banks.

Molecular characterization of sheep breeds by RAPD markers

The adaptability of various sheep breeds in different zones represents variation in the gene pool and this variation is the basis for conservation of valuable germplasm and further genetic improvement of sheep breeds. The genetic diversity of sheep breeds is declining due to breed substitution/crossbreeding. For this purpose, a powerful technique is required to estimate the genetic variability within or between breeds/species. At CSWRI, the random amplified polymorphic DNA-PCR (RAPD-PCR) using 16 RAPD primers was employed to estimate the genetic variability and construct phylogenetic relationship among six sheep breeds (Malpura, Kheri, Chokla, Garole, Avikalin and Bharat Merino). The overall genetic distance was highest (D=0.1428) between Malpura and Garole, whereas, the lowest (D=0.0612) between Avikalin and Chokla.

Molecular characterization of broiler rabbit breeds by RAPD markers

RAPD-PCR technique was employed to assess the genetic variability and phylogenetic relationship among three broiler rabbit breeds (White Giant-WG, Soviet Chinchilla-SC and Grey Giant- GG). The band sharing frequencies (BSF) were computed within and between breeds. The overall BSF value within breed was highest in WG (0.846±0.02) and GG (0.846±0.01), while lowest in SC (0.818±0.02). However, between breeds, BSF value was found higher in SC-GG (0.805±0.01) followed by WG-SC (0.792±0.02) and WG-GG (0.790±0.02). The BSF value indicated low genetic variability within the breed as compared to between breeds. The Nei's genetic distance was found highest between WG-GG (D=0.1605) followed by WG-SC (D=0.1403) and SC-GG (D=0.1295). The phylogenetic relationship among breeds was analyzed and dendrogram revealed that SC and GG are closer, while WG and GG are distant to each other.

Standardization of the PCR protocol for sex identification in sheep

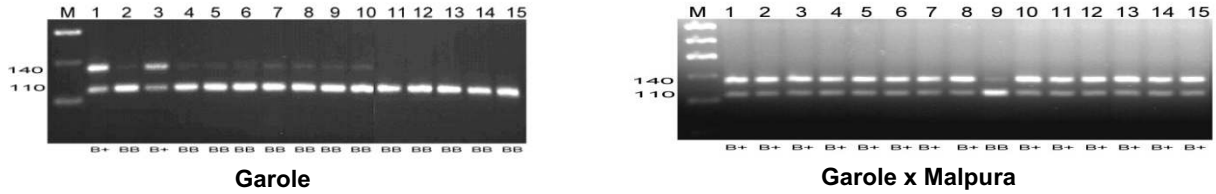
Primer based on ZFY gene was used successfully for differentiation of male and female DNA on PCR. The conditions for PCR were comprised of initial denaturation at 94^{0}C for 4 min followed by 40 cycles of denaturation at

94^{0}C for 1 min, annealing at 54^{0}C for 1 min, extension at 72^{0}C for 1.5 min and final extension at 72^{0}C for 5 min. The ZFY primers amplified the PCR product of 689 bp in DNA from male samples, while no amplification from the female DNA.

Identification of Booroola fecundity (*FecB)* and bone morphogenetic protein 15 (BMP-15) genes in Indian sheep breeds

It has been reported that high prolificacy in Indian Garole and Australian Booroola Merino sheep is due to a mutation (Q249R) in the bone morphogenetic protein receptor-1B (BMPR-1B), located in the region containing the *FecB* locus. Mutation in the BMPR-1B (*FecB* gene) increases the ovulation rate and litter size in sheep. Forced-RFLP-PCR using F12 (5'-GTCGCTATGGGGAAGTTTGGATG-3' and R-15 (5'-CAAGATGTTTTCATGCCTCATCAACACGGTC-3') primers was used for identification of the *FecB* mutation in prolific Garole, GM, GMM and MGM sheep. *FecB* gene was identified in Garole and Kendrapada sheep of India. For the first time, *FecB* gene mutation was discovered in Kendrapada sheep by Animal Biotechnology Section, CSWRI.

Identification of the FecB mutation in sheep breeds: The primer introduces the point mutation in PCR product amplified from the BMPR-1B receptor from carrier animals. The PCR products from non-carriers animals does not have *AvaII* restriction site. The 5µl PCR product was digested with *AvaII* enzyme at 37^{0}C for 2 hr and loaded in 3.0% agarose gel. After digestion with *AvaII*, the BB (homozygous carrier) individual showed a 110bp band, B+ (heterozygous carrier) showed 140 and 110bp bands and the ++ animals (non-carrier) revealed uncut 140bp band (Fig. 3).



Garole **Garole x Malpura**

Fig. 3. Forced RFLP-PCR of *FecB* gene. M: 50bp ladder, Lane 1-15: Female produced twin or more lambs

A total of 191 individuals of Garole sheep were screened for the *FecB* mutation and 95.3% were found to carry *FecB* gene (119- BB, 63- B+, 9- ++). In GM animals, out of 811 samples 72.7% were found to posses *FecB* gene (147- BB, 443- B+, 221- ++). The results confirmed that the *FecB* gene is segregating into different generations. The 140bp PCR product of BMPR-1B gene from Garole was sequenced which revealed some nucleotide deletions around the *FecB* mutation in the sequence. Approximately 57.3% lambs (408/712) of backcross (440 GMM and 272 MGM) inheriting the *FecB* gene. Out of 138 individuals of Kendrapara sheep, 88.4% were segregating the *FecB* gene (73- BB, 49- B+, 16- ++). Out of 83 animals of Ganjam, 5 were found heterozygous for the *FecB* gene. Malpura, Marwari, Deccani, Bharat Merino and Madgyal sheep which had at least one record of twin in one lambing were also tested and found non-carriers for the *FecB* mutation.

Effect of FecB gene on litter size in Garole and GM sheep: Single and two copy of the *FecB* gene increased 1.88 and 1.98 litter size in Garole ewes, respectively. In GM sheep, the single and two copy of the *FecB* gene increased 1.73 and 2.17 litter size, respectively. The overall mean litter size was recorded 1.95±0.08 and 1.58±0.04 in Garole and GM ewes, respectively.

Effect of FecB gene on body weight and average daily gain (ADG) in Garole and GM sheep: In Garole sheep, the non-significant effect of *FecB* was observed on body weight from birth to 12 month of age. The *FecB* genotypes significantly affected with the lamb's body weights from birth to 12 months of age of GM lambs. The body weight of non-carriers of GM lambs was higher than the carriers from birth to 12 months of age. The ADG of ++ lambs was comparatively higher than the BB and B+ lambs from birth to 12 months of age.

Effect of FecB genotypes on ewe's productivity efficiency (EPE) in GM sheep: The *FecB* genotypes significantly affected the EPE from birth to 12 months of ages. At birth, B+ and BB ewes had 23.75 % and 34.1% higher EPE as compared to ++ ewes, respectively. However at 6 months of age, B+ and BB ewes weaned 5.90 kg (35.4%) and 1.62 kg (9.7%) higher litter weight over ++ ewes, respectively. The EPE of B+ and BB ewes were increased by 7.86 kg (36.9%) and 2.32 kg (10.9%) as compared to ++ ewes at 12 months of age, respectively.

Effect of FecB gene on average daily milk yield (ADMY) and wool yield: The ADMY was found significantly higher (P<0.05) in $FecB^{++}$ ewes as compared to $FecB^{B+}$ and $FecB^{BB}$ ewes. The ADMY was significantly (P<0.01) higher in ewes those carry *FecB* gene with twin bearing lambs (CTL) as compared to *FecB* carrier single lamb bearing ewes (CSL). The 1st 6 monthly GFY was significantly lower in *FecB* carriers as compared to non-carriers in GM sheep.

Effect of FecB gene on semen production in GM ram and ovulation rate in Garole ewes: The *FecB* genotyping had a significant effect (P <0.05) on percent linearity and rapid motile sperms. Although sperm concentration was higher in BB and B+, compared to ++ genotypes, but the effect was non-significant. The age and *FecB* genotyping had significant effects (P <0.05) on straightness, average path velocity, straight-line velocity and percentage of medium or slow motile sperms. The results indicated that sperm concentration increased in BB and B+ as compared to ++ individuals. The ovulation rate was higher (~3.41) in homozygous Garole ewes.

Confirmation of Garole lambs produced from Awassi x Malpura recipient through embryo transfer: The Garole embryos were transferred into large size Awassi x Malpura recipient with the aim to produce heavy birth weight of Garole lambs from recipient. The forced RFLP-PCR technique was used to identify the *FecB* mutation in Garole and Awassi x Malpura crosses (Fig. 4). The technique confirmed that the lambs born from recipient ewes were genetically derived from the Garole not from the recipient.

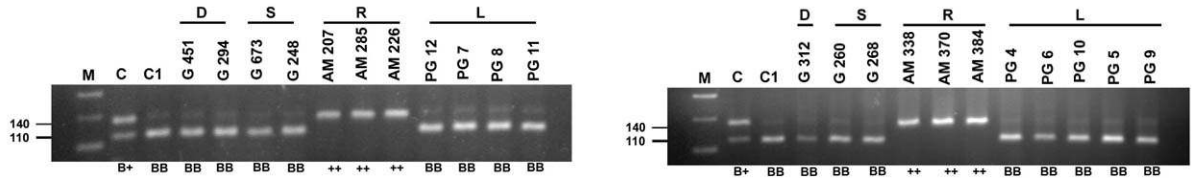


Fig. 4. Forced RFLP-PCR of *FecB* gene. M: 50 bp ladder, C, C1: heterozygous and homozygous control, respectively, G: Garole donors (D) and sires (S), AM: Awassi crossbred recipients (R), PG: Garole lambs produced through embryo transfer (L)

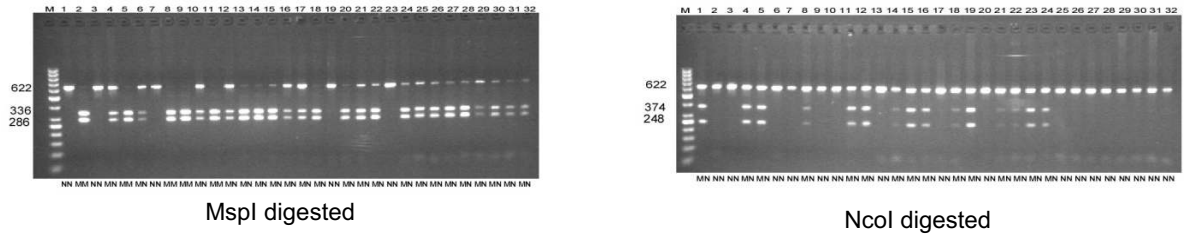
Introduction of FecB gene into Patanwadi sheep for production of three breed cross: A total of 42 GMM x Patanwadi progeny were screened for *FecB* gene and 29 and 13 were found B+ and ++, respectively. In Patanwadi x GMM progeny, out of 34, 19 were B+ and 15 were non-carrier (++) for the *FecB* gene.

Screening for BMP-15 mutation in Indian sheep breeds

The BMP-15 is expressed specifically in oocytes and maps to the sheep X-chromosome. The mutation in the BMP-15 gene (i.e. $FecX^{G}$, Galway mutation, Q239Ter) was associated with increased ovulation rate and sterility in Cambridge and Belclare sheep. The mutation in the BMP-15 gene was screened in Garole, Ganjam, Kendrapara, Deccani, Malpura, Marwari and Bharat Merino sheep. The primers B2-Hinf1F (5'-CACTGTCTTCTTGTTACTGTATTTCAATGAGAC-3') and B26 (5'- GATGCAATACTGCCTGCTTG-3') were used to detect the BMP-15 mutation. The primer pairs amplified the 141bp PCR product. The PCR amplification reaction conditions were consisted of initial denaturation at 95^{0}C for 5 min, denaturation at 95^{0}C for 45 sec, annealing at 63^{0}C for 45 sec, extension at 72^{0}C for 1 min for the 34 cycle and final extension at 72^{0}C for 10 min. PCR product digested with HinfI enzyme. All sheep breeds were found non-carriers ($FecX^{+}/FecX^{+}$) for the BMP-15 gene mutation.

Polymorphism in the meat production and meat quality associated genes in sheep breeds

Polymorphism in the calpastatin gene in sheep breeds: Calpastatin is the specific inhibitor of the calcium-dependent proteases mu calpain (CAPN1) and m-calpan (CAPN2) and plays a regulatory role in muscle growth and tenderization of meat following slaughter. The calpastatin gene was genotyped in Deccani, Nellore, Sonadi, Malpura, Nali, Ganjam, Chokla and Garole sheep by RFLP-PCR technique. The PCR primers Ovine 1C (forward): 5'-TGGGCCCAATGACGCCATCGATG-3' and Ovine 1D (reverse) 5'- GGTGGAGCAGCACTTCTGATCACC-3') were used. The primer pairs amplified the 622 bp PCR product. The 5µl PCR product was digested with *MspI* and *NcoI* enzymes in separate tubes at 37^{0}C for 2 hr. After *MspI* digestion, the M amplimer produced the 336 and 286 bp bands (MM, homozygous), 622, 336 and 286 bp (MN, heterozygous) and uncut 622 bp band (wild type). After the *NcoI* digestion, the N amplimer produced the 374 and 248 bp (MM, homozygous), 622, 374 and 248 bp (heterozygous) and uncut 622 bp (wild type) (Fig. 5).



MspI digested NcoI digested

Fig. 5. RFLP-PCR of calpastatin gene amplified from eight breeds of sheep. Lane 1-4: Deccani, 5-8: Nellore, 9-12: Malpura, 13-16: Chokla, 17-20: Nali, 21-24: Sonadi, 25-28: Ganjam, 29-32: Garole sheep. M: 50bp ladder

A total of 330 sheep samples were analyzed for identification of the polymorphism in the calpastatin gene. The overall frequency of the M and N alleles in the population was estimated as; 0.771 and 0.229, respectively. The Nellore breed of sheep had the highest frequency of the M allele (0.899) using both the enzymes. It is indicated that Nellore sheep has the highest polymorphism in the calpastatin gene, which may be correlated as more tenderness in the meat than the other breeds of sheep. The genetic distances (D) were calculated by POPGENE software using standard genetic distance equation. The genetic distance was found lowest between Nellore and Malpura (D=0.0001), whereas highest genetic distance (D=0.1658) between Nellore and Sonadi sheep. Dendrogram showed that the Nellore and Malpura sheep are closer in terms of meat tenderization, whereas Sonadi sheep falls in to separate group.

Polymorphism in the callipyge gene in sheep breeds: Avikalin, Bharat Merino, Nellore, Chokla and Malpura were studied for the polymorphism in the Callipyge gene (CLPG). To amplify CLPG with product size of 426 bp, CLPG-Forward 5'-TGAAAACGTGAACCCAGAAGC-3' and CLPG-Reverse 5-' GTCCTAAATAGGTCCTCTCG -3' primers were used. Touch-down PCR method was used to optimize the reactions (94^{0}C for 5 min, 35 cycles of 95^{0}C for 30 s, touchdown annealing from 65^{0}C to 52^{0}C for 30 s (1^{0}C per cycle), 72^{0}C for 45 s, and a final extension at 72 ^{0}C for 7 min). The PCR products of 426 bp were digested with *FaqI (BsmFI)*. The *Faq*I digested PCR fragments of 395 bp and 31 bp for mutant allele G and 278 bp, 117 bp and 31 bp for wild allele A. All the samples of sheep were found monomorphic for CLPG gene and only wild allele A was detected. Thus, the Callipyge phenotype was not present in the five studied sheep breeds. The PCR product of CLPG gene was sequenced and submitted to NCBI.

Polymorphism in the growth hormone (GH) gene in sheep breeds

The primer pairs used to detect the polymorphism in the GH gene in sheep breeds were GH1F and GH1R (A781G locus) and GH2F and GH2R (A1575G locus). A total of 645 animals of nine different sheep breeds belonging

to different agro ecological regions were genotyped at two different loci viz. A781G and A1575G of GH gene using PCR-RFLP techniques. The PCR amplicons were digested with *HaeIII* restriction endonuclease and obtained DNA fragments of 366 and 56 bp for AA genotype, 422, 366 and 56 bp for AB genotype and 88 and 28 bp for CC genotype (Table 1). Products of both the locus of growth hormone gene were sequenced for confirmation.

Table 1. Genotype and allele frequencies of GH gene across nine sheep breeds

Breed (n)	Genotype				Allele			
	Locus A781G		Locus A1575G					
	AA	AB	CC	CD	A	B	C	D
Nellore (40)	0.400	0.600	1	0	0.700	0.300	1	0
Patanwadi (40)	0.275	0.725	1	0	0.637	0.362	1	0
Sonadi (43)	0.023	0.976	1	0	0.511	0.488	1	0
Garrole (37)	0.162	0.837	1	0	0.581	0.418	1	0
BM (38)	0.078	0.921	1	0	0.539	0.460	1	0
Avikalin (154)	0.201	0.798	1	0	0.600	0.399	1	0
Chokla (42)	0.214	0.786	1	0	0.607	0.393	1	0
Magra (39)	0.051	0.949	1	0	0.526	0.474	1	0
Malpura (212)	0.061	0.093	0.97	0.03	0.530	0.469	0.98	0.02

Polymorphism in the wool associated genes in sheep breeds

There is a major concern to reduce the fiber diameter and to improve the quality of the wool fibres through biotechnology intervention. Most important aspect is that to identify the genes and DNA polymorphism affecting the wool production and quality. Keratin proteins are the major components of hair and wool. The keratin proteins are divided into two large groups: the keratin Intermediated filament proteins (KIF) and Keratin associated proteins (KAP). In wool fibre, these are associated in highly organised fashion, the keratin IF proteins forming 8-10 nm diameter filaments embedded in a matrix of KAPs. Malpura, Avikalin, Chokla, Sonadi, Nali, Nellore, Garole, Magra, Deccani, Kendrapada and Patanwadi sheep were studied for KRT (or KIF1.2) gene. Six breeds (Malpura, Avikalin, Chokla, Nellore, Kendrapada and Deccani) were studied for KAP gene. The DNA fragments were generated by the KRT 1.2 *MspI* RFLP polymorphisms were 159, 126 and 100 bp for MM genotype, 259 and 126 for NN genotype and 259, 159 and 100 bp for MN genotype. For KAP 1.3 *BsrI* RFLP polymorphisms these were 350 and 225 bp fragments for XX genotype, 309 and 225 bp for YY genotype and 350, 309 and 225 bp for XY genotype. The genotypic and allelic frequencies in the different sheep breeds were analyzed (Table 2).

Table 2. Genotypic and allelic frequencies at KRT 1.2 and KAP 1.3 locus in different sheep breeds

Breed (n)	KRT 1.2 locus						KAP 1.3 locus				
	Genotype			Allele		n	Genotype			Allele	
	MM	MN	NN	M	N		XX	XY	YY	X	Y
Avikalin (42)	0.62	0.38	0.00	0.81	0.19	40	0.35	0.50	0.15	0.60	0.40
Chokla (128)	0.51	0.44	0.05	0.73	0.27	114	0.25	0.50	0.25	0.50	0.50
Magra (40)	0.53	0.40	0.07	0.73	0.27						
Malpura (40)	0.63	0.37	0.00	0.81	0.19	40	0.25	0.45	0.30	0.48	0.52
Sonadi (32)	0.84	0.16	0.00	0.92	0.08						
Nali (34)	0.50	0.38	0.12	0.79	0.21						
Nellore (41)	0.63	0.32	0.05	0.79	0.21	19	0.37	0.58	0.05	0.66	0.34
Garole (41)	0.46	0.36	0.18	0.64	0.36						
Deccani (39)	0.82	0.18	0.00	0.91	0.09	37	0.43	0.49	0.08	0.68	0.32
Kendrapada (49)	0.65	0.33	0.02	0.82	0.18	14	0.29	0.57	0.14	0.57	0.43
Patanwadi (48)	0.69	0.25	0.06	0.82	0.18						

Identification of wool and wool fiber by species specific PCR method

The mitochondrial cytochrome b sequences of both species (sheep and goat) were amplified by PCR primers from conserved regions. A 172-326 bp fragment of species specific was amplified. The pashmina fibre PCR product was sequenced and submitted to Genebank database.

Polymorphism in the reproduction associated genes in sheep breeds

Polymorphism in the aromatase gene in sheep breeds: The aromatase cytochrome P_{450} enzyme is responsible for estrogen biosynthesis by conversion or aromatization of androgens into estrogens. Estrogens are imperative for reproductive development, fertility, bone growth and sexual behavior. The key enzyme in estrogen biosynthesis is cytochrome P_{450} aromatase (EC1.14.14.1), the protein product of CYP19 gene. The polymorphism in the CYP19 with different genotypes for this gene would be helpful in selection of animals with better production traits. The PCR primers (F: 5'-CCAGCTACTTTCTGGGAATT-3' and R: 5'-AATAAGGGTTTCCTCTCCACA-3') were used to amplify the CYP19 gene in sheep breeds.

Five breeds of sheep (Garole, Avikalin, Malpura, Magra and Chokla) were studied for polymorphism in the Cyp19 gene at C242T locus. The PCR product of Aromatase (Cyp19) gene was digested with the *Bsp1431* restriction enzyme. The PCR digested products revealed all three genotyping for the Cyp19 gene. Genotyping AB represents three fragments, of 140, 82 and 58bp, respectively, whereas genotyping BB represents only one fragments, of 140 bp. The genotyping AA represents 82 and 58 bp fragments. The genotyping AB was found dominant in the population of sheep breeds.

Polymorphism in the melatonin receptor gene (MTNR1A) gene in sheep breeds: Melatonin is monoamine that plays an important role in seasonal reproductive animals like sheep and goat. PCR-RFLP technique was used to determine the allelic frequency of the G612A and C606T (U14109) loci in the MTNR1A gene. An 824 bp fragment of the gene was amplified using the primers (F: 5-TGTGTTTGTGGTGAGCCTGG-3, R: 5-TGGAGAGGGTTTGCGTTTA-3). The PCR products on digestion with *RsaI* revealed four cleaved sites at position 56, 323,346, and 757 bp and produced five bands of 411, 267, 67, 56 and 23 bp sizes. The cleavage site at position 323 was polymorphic. The polymorphism was caused by the presence of a cytosine (C) at position 606 of the sequence (U14109) and produced two bands of 267 and 23bp, which identified as “R allele”. The substitution of cytosine-thymine C606T caused the absence of this cleavage site and produces a single 290 bp band, and known as “r allele”. The PCR products were digested with *MnlI* and digestion evidenced seven cleavage sites at position 221, 254, 324, 560, 582, 610, and 693 bp. Site at position 324 was polymorphic. The polymorphism was caused by the presence of a guanine (G) at position 612 of the sequence (U14109) and produced two bands of 236 and 67bp, which allowed identifying the allele “M”. The substitution of guanine-adenine G612A caused the absence of this cleavage site and produce a single 303 bp band, which known as “N allele”. The remaining cleavage sites produced six bands of 221,131, 83, 36, 28 bp. The PCR product of 824 bp of MNTRIA gene was sequenced and submitted to NCBI.

The locus C606T having polymorphic site for *RsaI* restriction enzyme. The DNA polymorphic fragments present were 267 and 23bp for RR genotype, 290, 267 and 23bp for Rr genotype and 290 bp for rr genotype. The locus G612A having polymorphic site for *MnlI* restriction enzyme. The DNA polymorphic fragments were 236 and 67bp for MM genotype, 303, 236 and 67bp for MN genotype and 303 bp for NN genotype. Allelic and genotyping frequencies of MNTR1A gene in locus C606T and G612A in different sheep breeds are presented in Table 3.

Table. 3. Genotype and allelic frequency of MTNR1A gene

Breed (n)	Locus C606T					Locus G612A				
	Genotype			Allele		Genotype			Allele	
	RR	Rr	rr	R	r	MM	MN	NN	M	N
Avikalin (46)	0.347	0.500	0.152	0.597	0.402	0.777	0.133	0.088	0.844	0.155
Garole (44)	0.727	0.204	0.068	0.829	0.170	0.545	0.386	0.068	0.738	0.261
Malpura (39)	0.435	0.512	0.051	0.692	0.307	0.692	0.179	0.128	0.782	0.217
Magra (43)	0.790	0.209	0.000	0.307	0.104	0.581	0.325	0.094	0.744	0.256

Polymorphism in the β- lactoglobulin gene in sheep breeds

Polymorphism in the β -lactoglobulin gene will help in identifying the animals with respect to the milk quality and production potential. The PCR product of β-lactoglobulin gene was cleaved with the *RsaI* restriction enzyme and the genotyping patterns were visualized in agarose gel. The PCR digested products revealed all three genotyping for the β-lactoglobulin polymorphism. Genotyping AB represents four fragments, of 103, 66, 37 and 17 bp, whereas genotyping BB presents only two fragments, of 103 and 17 bp. The genotyping AA presents 66, 37 and 17 bp fragments. The genotype and allele frequencies for β-lactoglobulin gene in Dumba, Patanwadi, Kendrapada and GM cross are given in the Table 4.

Table 4. Genotype and allelic frequency of β-lactoglobulin gene

Breeds (n)	Genotype Frequency			Allelic Frequency	
	AA	AB	BB	A	B
Patanwadi (44)	0.25	0.30	0.45	0.42	0.58
Kendrapada (45)	0.20	0.38	0.42	0.48	0.52
Dumba (43)	0.05	0.93	0.02	0.95	0.05
GM cross (41)	0.29	0.22	0.49	0.37	0.63

Future research priorities

Molecular characterization of the genes/markers associated with economical important traits in Indian sheep breeds (prolificacy, parasitic resistance, mutton and wool production, stress) through high throughput technology

In India, there are about 42 sheep breeds with vast genomic diversity mainly categorized on the basis of mutton type, carpet type and both. Some of the Indian sheep breeds have distinct characteristics like prolific type (e.g. Garole, Kendrapada and Bonpala), mutton type (Nellore, Deccani, Malpura and Mandya), fine wool (Bharat Merino and Gaddi synthetic), coarse and carpet wool (Chokla, Marwari and Malpura), lustrous type (Magra), foot rot resistant (Garole) and parasitic resistance line (created Malpura and Avikalin sheep). Except the prolific breeds, none of the Indian sheep breeds have been analyzed at genomic levels for identification of the genes/ markers responsible for economical important traits. The genes/mutations for economical important production traits have major interests for increasing overall productivity of sheep. If any genes/ mutations are identified; this could be used in sheep breeding programme.

Many new opportunities have been opened to the breeders like SNP tests for economically important traits that are either expensive or difficult to measure (for e.g. staple strength, feed efficiency) or animal to be slaughtered to gain the information (e.g. dressing percentage, lean meat yield, colour stability of meat etc.). SNP chips are now

available for several species for e.g. human, mouse, rat, chicken, dog, horse, cattle, sheep and pig. After the release of sheep genome map, Scientists from International Sheep Genomics Consortium (ISGC) have developed the Ovine 50K SNP chip (single nucleotide polymorphism) in collaboration with Illumina Inc. California, USA, in a series to use genome wide association studies in different sheep breeds. The "SNP chip" is a small glass plate that has 12 panels, with each panel able to test about 50,000 SNPs for one animal. Recently, Pfizer Animal Genetics, in collaboration with Ovita, have developed the Sheep 50k (S50K) panel marker test which builds a genetic profile early in an animal's life. It is the first SNP chip panel in the world to be commercialized for sheep. The test represents a DNA panel marker of more than 50,000 SNPs which have been identified in the ovine genome. From the 50,000 SNPs spaced evenly across the entire genome, the test can predict breeding values for economically important traits. Currently, new generation sequencing (NGS) technology has opened many avenues for generating whole genome sequencing data, transciptome sequence data, SNP discovery and differential regulation of the gene in livestock species.

A population of sheep with full pedigree and extensive performance records for traits such as eye muscle depth, carcass weight, fibre diameter and worm egg count etc. is tested to show which SNP variation occurs at each SNP locus for each animal. This is called a genome-wide SNP assay. Individual gene identification for a particular trait and then screening for other genes in any breed takes lot of time, while SNP chip could screen thousand of SNPs at a time. Thus, the major advantage of SNP testing is to shorten the generation interval to make faster genetic gain, testing for traits not able to be tested and the cost of SNP testing early in life against the costs of maintaining the extra animals. Similarly, NGS technology also have more advanced applications in analyzing the sequences, transcriptomes or splice variants of known and unknown genes. Keeping in view of the advantage of the SNP chip for identification, selection and faster genetic gain of the animals, we are interested to use this technology to screen the important Indian sheep breeds for economical traits for faster multiplication of the superior germplasm. A substantial work has been done on the investigation of the fecundity genes (*FecB*) in Indian sheep breeds and analyzed its effect on production traits at CSWRI, Avikanagar. The susceptible and resistant Malpura and Avikalin sheep have been created against the *H. contortus* parasite at this Institute. In addition to this, we have distinct mutton type and wool characteristics sheep breeds at the Institute or its regional centres. None of information is available on the analysis of putative genes /markers/SNPs linked to the traits of economical importance (i.e. parasitic resistance, meat and wool production etc.) in sheep breeds of India. It is therefore urgent need to analyze the available valuable Indigenous sheep breeds through SNP chip technology for identification of the economically important traits and further utilization in the breeding programme.

It has been well established that during the heat stress in livestock, a group of proteins i.e. heat shock protein (HSPs) are over expressed to commensurate the stress in the animals. It has been reported that thermotolerance and resistance to protein denaturation are induced by a family of proteins referred to as heat shock proteins (HSPs). Heat shock genes are activated when cells are exposed to stress stimuli and form heat shock proteins. Among HSPs, HSP70 is an essential molecular chaperone of primary importance to all mammalian cells. HSP70 gene family in bovines includes HSP70-1, HSP70-2, HSP70-3, and HSP70-4 gene. The other HSP90 also play an important role in heat stress animals during the environmental stress. Molecules of the HSP70 family may provide thermo protection by refolding damaged proteins and protecting r-RNA. During heat shock, cellular damage is caused by a variety of factors and a single thermo protectant is probably unable to protect cells from damaging effects. Thus, HSP 70.1 could prove a useful tool to indicate stress caused by suboptimal culture conditions. In India, none of information is available on the identification and characterization of the heat shock protein in sheep. We shall be able to provide the information on characterization of the HSP70 and HSP 90 and other heat shock related genes/ transcripts in Indian sheep breeds. This study will enable us to examine the expression of the HSP proteins among different sheep breeds existing in varying agro-climatic zones of the country or climatic stresses animals. This work will help us to identify the breed or animals linked to a heat stress/resistance to climatic conditions. Development of the molecular marker/DNA

test for heat stress/susceptible animals that could be utilized in breeding programme to make the heat resistant flock in the country. This study will provide valuable baseline information on SNP data/ markers/ mutations which is associated with growth, meat quality, parasitic resistance, wool quality, stress traits in different Indian sheep breeds. The data on differential expression of the genes or transcriptome associated with the production traits will be generated and utilized for understanding the mechanism/polymorphism of economical important traits.If any association is found than DNA test will be developed and will be utilized in the sheep breeding programme.

Production of superior germplasm for enhancing prolificacy, meat and disease resistance by cloning (SCNT), stem cell and transgenic technologies

The use of transgenic will lead to improvement in sheep productivity in terms of prolificacy, mutton, wool, and milk. Transgenic animals can be produced to increase disease resistance and improve the health of animals. For gene farming, human protein genes viz. blood clotting factor IX, α-antitrypsin and insulin can be targeted. Transgenic animals are used as an experimental model to perform phenotypic and for testing in biomedical research. Stem cell treatments have the potential to change the face of human diseases and can be utilized for enhancing the productivity potential of the superior animals. The ability of stem cells to self-renew and give rise to subsequent generations with variable degrees of differentiation capacities, offers significant potential for generation of tissues that can potentially replace diseased and damaged areas in the body, with minimal risk of rejection and side effects. Cloning of domesticated animals could be important in the future production of transgenic livestock.

Sheep blastocysts are produced *in vitro* through a combination of the techniques of *in vitro* maturation, *in vitro* fertilization and *in vitro* culture of oocytes obtained from sheep ovaries from slaughter house. Blastocysts are used for isolating the ICM (inner cell mass) and finally generating and establishment of the embryonic stem (ES) cells. ES cells are characterized by cell surface and transcription based markers. ES cells have varied applications like enabling studies on the conservation of endangered native breeds of sheep, production of the superior animals, the production of therapeutic agents and regenerative medicine and studies on fundamental events in embryonic development of sheep. The use of ES cells technology in farm animals may overcome current limitation on efficient gene transfer by providing an abundance of stem cells to be genetically manipulated by using conventional recombinant DNA techniques. Viable progeny following embryonic stem cell mediated nuclear transfer (hand made cloning) provides exciting new opportunities for basic research investigating early embryogenesis and for the propagation of valuable or endangered animals, and for the production of the cloned animals. Cloning can be used to generate genetically elite sheep by fusion of the embryonic stem cells with demi oocytes to produce cloned sheep for enhancing the sheep productivity by incorporating economically important traits (viz. fecundity, disease resistance and mutton production).

Booroola fecundity (*FecB*) gene causes the high fertility in Indian Garole and Kendrapada sheep. The BMPR-IB gene from carrier Garole sheep can be characterized and cloned in eukaryotic expression vectors. The suitable gene construct will be analyzed for its expression by the real time PCR and western blotting. The generated construct can be transfected/microinjected into an embryo or suitable techniques. The generated embryos will be analyzed for its integration and localization. Likewise, the genes responsible for muscle growth (e.g. callipyge or myostatin) and parasitic resistance gene (MHC or interferon gamma if identified) will be utilized for production of the transgenic animals. The transgenic embryos will be transferred into recipient for its viable progeny and will be tested for prolificacy and other traits of economic importance. Sheep productivity in terms of mutton, wool and milk production could also be attempted. Gene farming will be a potential application of developing a transgenic sheep for treatment of the human diseases.

Molecular diagnostics of major pathogens causing diseases in Indian sheep breeds by PCR/real time PCR and micro-array techniques

Rapid and early diagnosis of disease is prerequisite for successful prophylaxis and treatment as well as elimination of disease condition from herd in order to sustain production with good economic returns. Furthermore, there are certain chronic diseases which can be cured in its earlier stages. This also warrants early diagnosis of such diseases. There are some prevalent diseases occurring in sheep farms causing loss to sheep farming industry. These diseases are mainly caused by pathogenic bacteria, mycoplasma, chlamydia and viruses. Ante mortem diagnosis of these diseases is difficult, costly and time consuming by using conventional methods. Post-mortem diagnosis of certain complicated diseases like pneumonia in lambs and abortion in ewes are also difficult to detect by means of conventional diagnostic procedures. Recent advancement in molecular biology tools made a tremendous impact on effective disease diagnosis of several diseases of animals and human beings. Newer high throughput molecular tools have several benefits like specificity, sensitivity, rapidity, accuracy and capacity over conventional methodologies used for disease diagnosis and prevention.

Pathogens that invade a vertebrate host initially recognized by the host innate immune system through germ-line encoded pattern-recognition receptors (PPRs). The innate immunity is first line of host defence against pathogens. Pathogens adapt it by several strategies to evade the host immune system. Studies indicated that cooperation between immune cells is critical for the rapid elimination of pathogens from host system. Different pathogens including bacteria, parasites viruses and fungi cause immunosuppression and stress to the sheep production. This immunosuppressive effect of pathogens is counteracted by host implying several mechanisms. There is individual variations has been observed in counteracting these pathogen-induced stressed animals. Molecular analysis of these pathogens (bacterial and viral) causing disease in sheep needs to be investigated by PCR, real time PCR and microarrays.

Grassland and Forage Agronomy

S.C. Sharma and Roop Chand

Grassland and Forage Agronomy Section initiated research work on productivity and suitability of natural vegetation as fodder for sheep and goats. In initial years, cenchrus pastures were established with introduction of improved varieties, their testing for productivity, nutritive value and compatibility in forage production system was assessed. Cultivated fodder suitable to semi-arid areas like cowpea, cluster bean, lucerne, berseem, sorghum, pearl millet, oats, barley etc. were tested with number of different genotypes and explored for enhancing yield. Later on, in order to harvest quality fodder from pasture land, exotic and native perennial legumes (*Dolichos lablab,* Siratro, Atylosia*, Clitoria ternatea,* Stylosanthus spp*)* were introduced and evaluated in combinations with cenchrus in different ratios with varying fertility levels. Based on preliminary results, agronomical package were developed for raising cultivated fodder, cenchrus pasture production and thereafter, studies were conducted on carrying capacity and stocking rates of rangelands and improved pastures.

In 1990's, different land use systems were developed with emphasis on enhancing fodder production per unit area per unit time. In this line, two tier and three tier systems were studied with different fodder trees suitable to semiarid regions. Tree growth, their leaf fodder, green as well as dry fodder were assessed for production and compatibility to underneath associated grasses, legumes and cultivated crops along with their nutritive value. Later on, tree management aspects were taken with regards to lopping time, lopping interval, lopping intensities with varying age of tree. Research on growth enhancing measures followed after establishing management aspects. In the beginning of 21st century, alleopathic effects of fodder tree in agro-forestry and silvi-pastoral systems were studied. Besides plain land, attempts were made to establish pasture on undulated topography, efforts have been made to convert it into productive for fodder production. In this context, watershed approach was tried and pasture establishment / slivipastoral system were developed on sloppy land / rolling topography. In recent past, research has been concentrated on enhancing the income of farmer along with maximizing food, fodder and fuel production per unit area per unit time and reducing climatic risk to ascertain production under unpredictable climatic behavior. Different land use systems with proper geometrical set of fodder tree, fodder bush, grasses and cultivated fodder and food crops were integrated to harness the maximum benefits from natural resources. Further, to strengthen the economic condition of the farmer, fruit trees were incorporated in prevailing pasture and silvipastoral system as agro-horti-pasture system. In order to bring unproductive land into cultivation, research work on salt affected land and water was also initiated in last decade and forage cropping sequences were suggested with proper ameliorative measures on salty land.

Pasture establishment, management and renovation

The natural grassland consisted of 9 species of grasses/ sedges and 18 species of forbs. *Aristida adscensionis* was the predominant grass followed by *Perotis hordeiformis, Eragrostis ciliaris, Digitaris adscendens* etc. *Indigofera cardifolia, Tephrosia strigosa, Zornia diphylla, Borrevia hispida and Crotolaria burhia* were the forbs of major availability. The total yield of natural grassland was 10.41 q/ha (73% of grasses and 27% of forbs). *Aristida adscensions* contributed about 48% of the yield followed by *Perotis hordeiformis, Eraqrostis ciliaris, Indigofera cardifolia, Zornia diphylla* etc. Reseeding of pasture yielded about thrice as much as rangeland. Dry matter yield from cenchrus, cenchrus + clitoria and clitoria was 26.64, 28.66 and 31.04 q/ha, respectively. The ground cover under the vegetation in rangeland was found to be 5.76% (4.02% under grasses/sedges and 1.74% under forbs). *Aristida adescensionis* made the largest contribution in ground cover followed by *Cyprus* spp, *Crotolaria burhia* and *Eragrostis ciliaris*.

Among different methods of cenchrus establishment, line sown of pellet gave the highest yield, though it is costlier one. Out of various legumes (cluster bean, moth and cowpea) tried along with cenchrus; all gave more yields than cenchrus alone. Broad casting and inter-sowing of legume did not have any impact on total fodder production. The highest production of cenchrus was recorded on harvesting at 5 cm height from the ground level after 30 days of germination. Out of four varieties of cenchrus (IGFRI-3108, IGFRI-358, Pusa Giant and Pusa Yellow Anjan), the highest production and number of tillers were recorded in Pusa Yellow Anjan on the basis of two cuttings after establishment year. Application of 40 kg N/ha produced higher DM yield than 20 kg N/ha. A Split application of nitrogen either through soil or foliar were better than single application of nitrogen in terms of dry fodder production. Among the split application, full fodder application was better than rest of the methods. The DM was highest in *Panicum maximum* at pre-flowering, flowering and post flowering. At maturity, maximum dry matter was recorded in blue panic.

Twelve varieties of *Pennisetum pedicilatum* were evaluated and IGFRI-866 variety was found to be the most suitable for semi-arid conditions in terms of fodder production. The DM yield of rangeland was higher with foliar application of 20 or 40 kg N/ha. Foliar nitrogenous fertilizer application of rangeland showed good yield response however, undesirable and poor quality grass species responded more to the fertilization leading to change in botanical composition of rangeland towards undesirable species. The decrease in herbage yield was to the tune of 56.06% due to grazing as compared to production ground cover and of 31.84% due to grazing as compared to production grazing/browsing. The crown cover of top layer was 18.83 and 13.27% under production and grazing, respectively. Considerable changes in physical properties of soil (bulk density and filed capacity) were not observed due to grazing and production.

Survivability of cenchrus plant in horti-pastoral system reduced slightly in third year as compared to second year after planting. Four levels of sheep manure viz., 0, 5, 10 and 15 t/ha and three levels of nitrogen viz., 0, 30 and 60 kg/ha were evaluated. Increase in cenchrus yield with increase sheep manure doses up to 15 t/ha was observed. Addition of urea did not produce any extra beneficial effect. Sheep manure @ 10 t/ha replaces 60 kg N/ha. Soil organic matter and available K improved by manure application.

Five varieties of Napier hybrid were tested and variety BN 86061 yielded 238.49 q/ha green fodder followed by NB 21(53.56 q/ha). Pala yield was at the maximum in bush cleaning + N-25, P-40 and tiller cultivation. Application of 325 kg N and 25 kg P followed by tiller cultivation produced 50 % more dry fodder than untreated 6 year old cenchrus pasture. Three growth regulators viz., Zibbralic acid (ZA), Indole acetic acid (IAA) and Indole butyric acid (IBA) at 50, 100 and 150 ppm were tested for germination of cenchrus. Seed soaking for 16 hr with 150 ppm of ZA gave highest germination of *Cenchrus ciliaris*, however, at par germination of *Cenchrus ciliaris* was recorded with 8 hr seed soaking in IAA at 100 ppm. The highest shoot length of cenchrus seedling was with 100 ppm GA at pH 8.0 after 10 days of germination. Increased growth regulator concentration beyond 100 ppm and pH beyond 8.0 drastically reduced growth of seedling. The maximum germination of cenchrus seed was recorded with 10 ppm GA at pH 7.0. At higher pH beyond 8.0, sulphuric acid (70% soaking and then washing water) was better than growth regulator.

Mixed cropping and forage quality improvement

Among different legumes, *Dolichos lablab* produced maximum dry matter per plant followed by *Clitoria ternatea*, *Siratro* and *Atylosia searaboides*. Sewan grass (*Lasiurus sindicus*) did not perform well under semi-arid conditions. The dry forage yield of *Dolichos lablab* was maximum with application of suphur @ 40 kg/ha. The yields of cluster bean (cluster bean) were higher at the seed rate of 4-8 kg/ha with positive effect on nursing of cenchrus pasture

during establishment. Relatively higher production was obtained from cenchrus: dolichos in 1:1 proportion compared to 2:1, 3:1 and cenchrus alone in both grass. Maximum fodder was obtained from the plant population when harvested at late flowering stage and with the application of 15 kg P_2O_5/ha. Application of 20 kg N was found good enough for forage production from *Dolichos lablab*, however, maximum seed was collected at 45 kg N/ha. Phosphorus has no effect on forage production but 40 kg P_2O_5/ha had pronounced effect on seed production.

Mixture of cenchrus and *Dolichos lablab* (1:1) gave maximum yield of 12.48 q/ha after application of $NaNO_3$ (@ 20 kg/ha). The dry forage yield from dolichos was 17.02 q/ha after treatment with $Na_2B_4O_7$. The mixture of cenchrus and dolichos yielded maximum fodder under two cutting system while, *Clitoria ternatea* was second in fodder yield. The maximum dry fodder (76.11q/ha) and crude protein (9.46 q/ha) was obtained from the mixture of cenchrus and dolichos in the ratio of 50:50.

The highest dry fodder production (59.06 q/ha) was recorded with the mixture of cenchrus and dolichos. The yield of other forages were in the range of 28.82 to 45.24 q/ha where as lowest yield (28.82 q/ha) was recorded from *Cenchrus setigerus* alone. From mixture of cenchrus and clitoria, 45.24 q/ha dry fodder was obtained. Maximum production was observed when 60 kg N/ha in the form of sheep manure (9 t/ha) was applied in mixed pasture of cenchrus and dolichos in alternative strips. The inter cropping of cowpea and moth found to increase 5 and 2 times higher dry fodder yield of cenchrus. Application of wool dust (@ 200 kg/ha) does not affect the cenchrus production, however, production of *Dolichos lablab* was equally good at fertilizer treatment of 40 kg N + 60 kg P_2O_5/ha.

Maximum dry fodder (41.0 q/ha) from single cutting was obtained when the carpet legume was sown at spacing of 30 x 30 cm and harvested at late flowering or pod swelling stage (90 days after germination). Effect of dose of phosphorus application was not evident on dry fodder yield. The inoculation of rhyzobium (@ 15-20%) during sowing resulted in increased the nodule weight per plant. In low rainfall year (375 mm) the highest production was recorded from the mixture of pearl millet and carpet legume in the ratio of 1:2 and 30 cm raw spacing, where as in high rain fall year (1000 mm) the maximum fodder was obtained from the mixture of maize and carpet legume. In case of total crude protein the mixture of pearlmillet and dolichos in the ratio of 1:4 and 1:6 with 30 cm raw spacing were at par with pure dolichos, thus to obtain maximum benefit in terms of fodder production as well as crude protein, inter cropping the pearl millet in the main crop of dolichos in the ratio of 1:4 with 30 cm row spacing under rain fed condition of semi-arid region was advocated. Erect type and spreading type varieties of dolichos were at par in terms of fodder production per unit area and time.

Maximum yield was recorded when *Cenchrus ciliaris* was sown in lines + broad casting of dolichos seed followed by cultivator. Similar results were also observed over cenchrus + clitoria. The application of P_2O_5 increased yield over control, however levels of P_2O_5 (20, 40 and 60 kg/ha) were at par in dry fodder yield and grass legume ratio. Among the legumes the highest crude protein was recorded in Siratro at pre flowering stage. At the remaining stage crude protein was the highest in dolichos. At maturity the crude protein content was lowest in velvet bean. Among the grasses the highest crude protein content was found in *Cenchrus ciliaris* at all the stages of growth.

Sowing of clitoria at row spacing of 30 cm produced higher dry matter yield than other spacing. Harvesting of forage at 40 days interval produced maximum dry matter yield. Maximum grain yield was produced with pure pearl millet followed by pearl millet + clitoria and maximum dry fodder yield was obtained when pearl millet inter cropped with cenchrus. Spacing of 40 cm between two rows of pearl millet gave the highest grain yield and dry matter production. The maximum dry matter yield of maize was obtained when sown in association with berseem with full seed rate.

Tillage operation gave appreciable increase in germination of legumes. Stylosanthus gave maximum number of plants/m^2 followed by clitoria, dolichos and siratro. Pelleting of legume seeds increased the neem germination by

16% over no pelleting. Grain and fodder yield was almost similar on sowing of pearl millet under single and paired row pattern. The grain yield of pearl millet was not affected by legume introduction, however, dry fodder yield increased due to legume incorporation recorded maximum with cowpea followed by dolichos and cluster bean. Among different legumes, cowpea gave maximum fodder yield followed by cluster bean, dolichos, siratro and stylosanthus. Inter-seeding of legumes in paired cropping of cenchrus gave maximum fodder yield followed by inter-seeding in normal rows, alternate cropping and strip cropping. Among different legumes, cenchrus + dolichos gave the highest forage yield. Grass legumes mixed pasture gave the highest yield than grass alone. Among various shrubs, *Sesbania sesbane* found best growing with better establishment. Dhaincha increased organic matter of surface soil layer (0-15 cm) to the maximum while the *Leucaena leacocephala* increased organic matter of sub-surface soil layer (15-30 cm).

Introduction of cowpea in rainfed cereal gave maximum crude protein yield followed by dolichos and cluster bean. Paired cropping was superior to normal cropping. In semi-arid conditions, among legumes, Pusa bean produced higher dry matter followed by velvet bean and Atylosia. Among cenchrus spp., *Cenchrus ciliaris* 358 produced higher yield. The crude protein was highest in Atylosia followed *by Stylosanthus hamata* and *Desmodium infortum*. *Cenchrus ciliaris* and *Clitoria ternate* produced maximum DM during December.

Maximization of food and forage production through land use system under agroforestry

Khejri densities were tested for performance of pearl millet and maximum grain yield of pearl millet was recorded in association of 50 trees/ha, however, dry fodder yield (stover) was higher in control. Khejri, babool, ardu, neem, dicrostachys alone or in alternate rows and in mixed plantation exhibited that *dicrostachys* registered the highest survivability while ardu showed the lowest one. Khejri found to be slowest growing tree, however, neem showed the lowest crown spread at the age of three year. The soil status and cenchrus pasture was not affected by plantation of fodder tree up to three years of age. In established ber orchard, cenchrus, pearl millet, green gram, clitoria as pure stand and mixed were evaluated with various levels of N and P. Maximum fruit yield was with the application of 20 kg N and 20 kg P_2O_5/ha and under pearl millet + green gram crop combination.

Natural, single, double and multi-tier systems were studied for fodder production. Cenchrus yields from all the systems were higher over natural pasture. Growth of ardu was better in two-tier system. The production for 5 years in natural land, single tier (seeded pasture), two tier and three tier silvi-pasture was to the tune of 16.59, 19.20 and 23.74 q/ha, respectively. The three and two tier system provided 9.5 and 6.25 q/ha tree fodder. Five year study showed the leaf fodder and fuel wood yield were 3.01, 6.81, 0.92, 3.67 and 0.11, 2.80, 0.10, 0.28 kg/tree in ardu, neem, siris and babool, respectively. The average net income over four years was highest in ardu pasture system. Ardu, neem, siris and babool having cowpea, sesamum, pearl millet, cluster bean, black gram, green gram and moth as associated crops showed highest production of green leaves, dry leaves and fuel wood in association of ardu followed by siris and babool. Highest increment in plant height and collar diameter was observed at 50 plants/ha followed by 25 plants /ha density. Under the horti-pasture system dry fodder yields were compared in open space and in association of ber and aonla. The green and dry fodder yield of other rested crops were at par in aonla and ber association with open field conditions, though highest with aonla association, however, grain yield of all the crops were highest in open space. Dicrostachys, mulberry and zinja with ardu were studied for the performance along with cenchrus grass in the multi-tier system. Total biomass in ardu + zinja was at maximum followed by ardu + dicrostachys and ardu + mulberry. Zinza grow tallest and dicrostachys had maximum collar diameter. Ardu grew at maximum in combination with mulberry.

The highest green fodder yield (154.69 q/ha) was in multi-tier system (Ardu + pearl millet + cowpea) followed by two-tier, however in multi-tier, maximum dry fodder yield was with sole pearl millet followed by cenchrus +cowpea. Dry fodder production from cenchrus, cowpea and their combination increases progressively with increasing level of fertilizers in all land use systems. The highest dry fodder yield from crop and grasses and their combinations was in single- tier system followed by two and multi-tier system. Growth parameters and yield of cenchrus were comparatively higher in association of ardu tree in comparison to other fodder trees. Application of 60 kg N and 50 kg P registered highest cenchrus production in association of all fodder trees.

The maximum increased in grain and straw yield when application of chemical fertilizers as well as sheep manure at recommended doses was applied both in crops and aonla plant. Cropping pattern also has significant effect on dry fodder and seed production. Maximum yield of seed was obtained in cluster bean followed by groundnut and lowest seed yield was in cowpea. Applications of sheep manure @ 5 t/ha gave significant higher seed and straw yield as compared to control treatment. Green fodder production was the maximum under cluster bean-oat cropping sequence followed by cowpea-oat system. Sheep manure application significantly increased green and dry forage yield of oat at both cuts. Cluster bean varieties (RGC-936, HG-75 and local) were tested with fodder trees ardu, babool, siris and neem. The maximum grain and dry fodder yield of cluster bean HG-75 was obtained in association with ardu. HG-75 produced maximum total biomass in association of ardu tree, which was significantly higher to other cluster bean varieties in any agro-forestry system except RGC-936 in association with ardu. In a horti-agro system study, moth and cluster bean were taken in association of fruit trees (ber and aonla) and sown in different ratios. Total biological yield was significantly higher in open space than ber and aonla association. Application of 10 t sheep manure/ha recorded significantly higher yield over no use of sheep manure in agro-horti system. The maximum increase in grain, straw and biomass production was with fertilization to both crops and aonla. Among the cropping pattern, cowpea-oat gave maximum green fodder than rest of the system.

Application of Zn up to 20 kg/ha significantly increased the growth and yield attributes. The maximum seed yield (2.55 t/ha), stover yield (7.32 t/ha), crude protein content (27.15%), protein yield (168.10 kg/ha), gum content (26.95 %) and gum yield (179.96 kg/ha) were recorded with application of Zn 20 kg/ha. The quality traits viz., ADF (16.06%), NDF (52.03%), cellulose (17.51%) and lignin (0.34%) were also highest in cluster bean seed when Zn was applied @ 20 kg/ha. The higher yield attributes were recorded with RGC936 followed by RGC1017, BG3 and BG2 varieties.

Higher green and dry fodder was recorded in *Cenchrus setigerus* than *Cenchrus ciliaris*. Application of NPK fertilizers @ 40:40:20 kg/ha to grasses and 500g urea+750g SSP+750g MOP to ber plant was found statistically at with the treatment of sheep manure applied @ 10 t /ha in grasses and 20 kg sheep manure in ber plant. However, maximum dry fodder and yield production in grasses were obtained when the sheep manure applied @ 5 t/ha and 10 kg sheep manure in ber plant along with 50% doses of recommended inorganic fertilizers (20:20:10 kg/ha in grasses and 250 g urea+ 375g SSP+375g MOP in ber plant). Ber fruit yield was not influenced significantly due to grass species. Increase in application of sheep manure (0-15 t/ha) resulted in considerable increase in cenchrus and ground nut yield, under different tier systems. Cenchrus + groundnut in 1:1 ratio yielded the highest biomass (37.2 q/ha) in two-tier system. The three-tier system registered 8.49 and 24.33% higher biomass yield in comparison to two and single tier system. Dry fodder and biomass production of ground nut in strip cropping was significantly higher as compared to sole crop.

Average fodder, seed and biomass yield of various crops in three tier agro-forestry systems were significantly higher as compared to two tier and open field condition. Three year average revealed that three tier agro forestry system registered 3.68 and 16.74% higher seed yield, 4.73 and 12.2% higher dry fodder and 4.83 and 14.74% higher biomass in comparison to two and single tier system. Cenchrus grass production was also higher by 3% and 10.4% in three tier compared to two tier and open field. All the arable crops (pearl millet, ground nut and green gram) produced

almost similar dry fodder, seed yield and biomass yield when sown either sole crop or in combination with cenchrus as strip in the ratio of 3:2.

Allelopathic effects of tree leaves were studied for germination and subsequent growth of cluster bean and pearl millet. Significant reduction in growth parameters was observed in 12 hr soaking compared to 4 hr soaking and significantly higher plant height was observed in association of ardu, siris and open compared to neem and babool. Average growth attributes, dry fodder and biomass production of cowpea, cenchrus, cluster bean and pearl millet were recorded the highest in association of ardu which were observed at par with siris association and open field conditions and significantly higher to that neem and babool association. The total biomass yield was the highest with cereal crops viz. cenchrus and pearl millet compared to legume crops. Yield attributing characters dry fodder and seed yield of various arable crop viz. groundnut, moth, cenchrus, cluster bean were not significantly influenced either growth in open filed or in association with fruit trees as agro horti-pasture system.

Top feed resources, their establishment and management

Babool and ardu registered higher dry fodder than khejri at one lopping at the interval of 6 months. In case of babool difference in dry fodder production/tree/year was noticed between two lopping at 6 months. Four tree species *viz*. *Acacia nilotica, Leucaena leucocephalla, Bauhinia racemosa* and *Dichrostachys nutans* with two spacing (55 and 44 m) were evaluated. *Dichrostachys nutans* had maximum survivability (92.7%) where as *Leucaena leucocephalla* had minimal survivability (30.5%). In khejri, all yield attributes except length of clear bole have significant association with each other. The joint contribution of bole height at girth, length of clear bole, length of crown, diameter of crown was having 70.38% variability in fodder yield of khejri, however crown diameter alone explain 67.84% of variability and thus can be utilized for prediction of dry fodder yield in khejri. A prediction equation derived is

Dry fodder yield (kg) = - 12.77 + 4.88 (Crown diameter)

In case of ardu similar study suggests that yield attributes jointly contributed 73.99 % variability in leaf fodder yield which is highly significant. The number of active branches and diameter (at breast height) can be taken as criterion to predict the ardu leaf yield and the prediction equation is

Leaf yield (kg) = - 2.98+ 0.02 (Number of active branches) + 0.36 (Diameter of trees at breast height)

Khejri gave the highest production (12.04 kg) followed by ardu, zinja and kakeda. Cost of lopping was the lowest in case of khejri followed by ardu, zinza and kakeda. Twenty different fodder trees were evaluated for crude protein in four season *viz.* summer, winter, autumn and spring season. Crude protein content did not exhibit any appreciable variation in all the tree species. However, its content was higher during spring and rainy season. Dry matter yield continue to decline from February to May. Top feed yield from ardu during summer and winter season was 0.73 and 1.90 q/ha, respectively. Under Dicrostachys plantation, DM yield was 14.2 q/ha in February, 4.4 q/ha in May, 17.3 q/ha in rainy season and 13.1 q/ha in November.

Fodder trees (Babool, ardu, dicrostachys, neem, khejri) in alternate and mixed rows were evaluated in cenchrus pasture. The CP content ranged from 11.90% (khejri) to 15.18% in ardu. Alternate pattern of row gave higher CP content. The effect of intensity, interval and age of lopping on natural regeneration, growth, fodder yield and nutritive value in ardu, khejri, neem and dicrostachys showed that difference in dry fodder yield in young trees lopped twice a year were marginal where as it was higher in old trees. Older tree contained lower leaf moisture than younger trees. Ardu can be lopped fully twice a year in the month of December and May-June at any stages of its age. Fully-grown neem can be lopped fully once in a year during December-January. However, young tree of neem can be lopped fully twice a year during December-January and May-June. Reverse is true for Khejri. Young khejri plant can

be lopped fully only once in a year, however, old tree can be lopped up to 2/3rd twice a year in May-June and November -December. Comparative study on freshly planted and 5-6 year old ardu, neem, siris and babool fodder trees showed that the highest increment in crown diameter and plant height in neem, siris and babool was recorded with the application of 10 kg sheep manure + 220 g urea + 240 g DAP per tree.

In survey of ardu in 18 districts of Rajasthan, one new species of Ailanthus was identified which is different in morphological as well as inflorescence characteristics than *Ailanthus excels*. The specific epithet has been derived from the place Avikanagar as *A. avikanian*.

Package of practices for cultivated fodder

Cowpea variety Russian Giant and E4216 resulted in higher fodder yield compared to P7, 7/12 Red, No. 10, Jodhpur and K-147. Among 8 varieties of cluster bean, Malpura Giant and T-3 were superior in dry fodder production over test one. Further, Durgapura Safed and FOS-277 also observed better than T-87, T-16 and local one. Cowpea variety Russian Giant yielded the highest dry fodder when applied with 40 Kg N and 60 kg P/ha, while Malpura Giant variety of cluster bean yielded maximum with the application of 20 kg N and 6 kg P/ha. In case of moth bean (*Phaseolus aconifolius*), yield remained unaffected by N and P application. In sorghum cultivation spraying of 2-4 D @ 2 kg/ha was able to control weeds. Phyto-toxicity of 2-4 D on sorghum was observed beyond 2 kg/ha. The highest dry matter was obtained from Algerian variety of oat with the application of 100 kg N/ha but the dry matter production per day was the highest in case of Kant variety. Trace element were applied to lucerne crop in the form of $CaSO_4$, $MgSO_4$, $ZnSO_4$, $FeSO_4$, $Na_2B_4O_7$ and Sulphur @ 20 kg /ha except $Na_2B_4O_7$. Though, the highest green and dry matter production was registered with the application $FeSO_4$ but no significant variation in dry matter accumulation was noted amongst micronutrient.

Application of GA proved significantly better in terms of dry matter production of cowpea EC-4216 only up to 45 days of sowing. Application of GA did not give significant response in *Dolichos lab lab.* Out of 18 varieties of cowpea, C-25, FOS-1 and NP-3 were found to be superior over to other varieties in respect of fodder yield as well as resistant to aphid attack. Strip cropping of cenchrus and dolichos in the ratio of 50:50 across the slope followed by cenchrus furrow (60X20 cm) was found to be a suitable technique for the establishment of mixed pasture of cenchrus and dolichos on rolling topography (1-2% slope) with respect to fodder production.

The highest grain fodder was recorded in OS-8 variety of oat, however maximum dry matter yield was produced by Pusa oat-1. The highest crude protein yield (16.8 q/ha) was from VPO-121 followed by OS-8. Four varieties of oat (Kent, Fulghum, 2688 and 3921) taken @ 1 and 2 kg/ha with three N levels (0, 40, 80 kg N/ha) exhibited that the Kent variety gave the highest dry matter yield (69.9 q/ha). The dry matter yield of Japanese Sarsoon was the highest when crop was sown at the rate of 1 kg seed/ha.

Maximum green fodder yield of lucerne (36.00 q/ha) was recorded when fertilized with 120 kg P_2O_5 /ha. No effect of cutting management was assessed due to single nipping in all the treatments. In single cut entry, maximum seed yield from first cutting was obtained from OS-10 followed by PO-2 and OS-7, however, in two cut entries HDF-114 yielded highest seed yield. The seed yield from second cut was highest in UPO-1.

Application of 120 kg P_2O_5/ha produce significantly higher seed/ha. Two cuttings of lucerne was significantly better in seed production, number of seed/floret than others. Three cutting gave highest seed/1000 grains. Dry matter was highest in four cuttings. The seed yield and number of branches per plant was the maximum with 120 kg P_2O_5/ha, however dry matter yield, 1000 grain weight was higher in 40 kg P_2O_5/ha. Foliar application of phosphorus did not show any effect.

Cowpea followed by maize alone produced higher green fodder as well as dry fodder yield. The line sowing (45X15 cm^2) along with application of 60 kg N and 50 kg P was better for fodder production. Sorghum variety PG 3060 performed better than MP-Chari under similar conditions. The green fodder yield of Jumbo and MP-Chari of fodder sorghum was highest in 4 days irrigation interval followed by 6 days interval. Increasing levels of fertilization up to 120 kg N and 50 kg P progressively increased green fodder yield. Jumbo variety yielded higher green fodder yield than Hara Sona and MP-Chari. Among the varieties 'SSG-5001' produced the maximum green forage (556.9 q/ha) and dry matter yield (9107.5 q/ha). The green and dry fodder yield increased considerably with increasing level of N from 0 to 120 kg/ha. Remarkably higher green forage and dry matter yields, net return and benefit: cost ratio were obtained with the application of FYM @10t/ha as compared to no application of FYM.

Sorghum genotype SSG-887 gave higher green and dry fodder yield as compared to other genotypes (SSG-1000 and ASSG-117). The green and dry fodder yield was increased linearly with increase in additional dose of zinc up to 20 kg/ha. The green fodder, dry matter and seed yield of cenchrus and moth bean were increased remarkably with different intercropping system. However, these were the higher in two rows of cenchrus and one row moth bean. Amongst the cowpea varieties, EC-4216 was found significantly superior over 'RC19' and 'Kohinoor' varieties. Green and dry fodder yield of cowpea were recorded higher with increasing level of phosphorus up to 60 kg P_2O_5. Green and dry fodder was also increased significantly with the application of bio organic manure (sea weed extract @ 15 kg/ha). Among fodder cowpea varieties 'EC-4216' had highest yield potential when P (60 kg P_2O_5/ha) and bio organic manure (15 kg/ha) were applied combined.

Wasteland development and their conservation

Rangeland improvement was carried out through protection, sod seeding, scrubbing and fodder tree plantation, gully plugging and grassing the waterways. Sod-seeding with grass legume mixture gave satisfactory results in improving degraded natural land. Khus (*Vetiver* spp.) followed by panipulla (*Saccharum munja*) were effective with V-ditch contour bund in conserving higher moisture and reducing run off. The highest survivability was observed in panipulla under both conditions i.e. with and without V-ditch contour bund. Green and dry fodder yield of cenchrus was also highest with vegetative barrier panipulla along with V-ditch contour at upper as well as lower most contours.

Study on different moisture conservation measures at the time of planting of various trees revealed that use of pond mud, pond mud + sheep manure and polythene sheet resulted in significantly higher survival of trees up to 75 days of planting in comparison to control and only sheep manure. In burnt pasture at 30 and 60 days of sowing, V-ditch contour bunds significantly increased plant height and plant population, tillers/plant, spike length, seed yield, dry fodder yield and biological yield of cenchrus in comparison to without V-ditch contour bund. V-ditch contour bund increased the seed yield, dry fodder yield and biological yield over without V-ditch treatment by 16.05, 49.95 and 49.54%, respectively. Further, place of planting at lower side contour bunds reveals 15.57 and 16.70% higher dry fodder and biological yields over upper contour bunds, respectively. Further in third year of pasture establishment. The dry fodder and biomass production was higher by 11.75 and 11.67% respectively at below V-ditch in comparison to above V-ditch contour bund. In varying slope study, the highest dry fodder and biomass production of cenchrus was recorded up to 5% land slope progressive increase in land slope (5-20%) significantly reduced these parameters.

Among fodder trees babool registered highest survivability in comparison to ardu and neem when planted inside V-ditch contour bund. The highest dry fodder yield of cenchrus was recorded in line sowing treatment which was significantly higher to pelleting and broad casting sowing methods, but observed to be at par with pelleting and line

sowing treatment. Line sowing resulted in 7.34 and 24.07% higher dry fodder yield in comparison to pelleting and line sowing and pelleting and broad casting sowing methods.

The place of planting at upper, middle and lower contour could not registered significant variation in growth parameters of cenchrus and other grasses and their yield however, biomass yield was comparatively higher towards lower side of the slope *i.e.* lower contours with V-ditch contour bunds, among tree species babool, registered considerably higher survival as compared to ber and aonla. Maximum survival was observed when tree species were planted inside V-ditch followed by above V-ditch planting and outside V-ditch planting.

The collected soil and water samples in farmers field reveal that most of the soil and water sample were observed to saline and alkaline having high pH, low organic carbon and poor available nutrients. To ameliorate the salt affected soil, the application of gypsum and FYM improved the soil health and the crops green gram and mustard produced higher yield and biomass production in gypsum treated plots as compared to control. Application of gypsum in soil and saline irrigation water as well as green manuring (dhaincha and cluster bean) brought about significant improvement in soil properties *i.e.* reduction pH of soil and water, increased organic carbon and slight reduction in bulk density. The gypsum treatment of saline water produced higher growth and yield attributes of barley crop as compared to control.

Future needs / research strategies and approaches

- Interactive effects of tree components on ground flea (particularly range grasses) required to study in accordance to growth, water and nutrient utilization.
- Agro-techniques related to conservation of soil moisture needs tailoring for improving rangelands.
- Studies on germination regulative mechanisms of various grass-legume species and their eco-physiological characteristics
- Improvement in pastoral species for tolerance to saline/alkali condition though application of amelioration measures or genetic manipulation
- In order to generate stability through diversity, study on different biotic and abiotic factors for different edapho-ecological conditions is needed and a multidimensional and integrated approach involving computer application at various levels is the need of hour.
- Research may be intensifying on recycling of organic waste for adding organic carbon to enrich rangeland vegetation and quality produce.
- Soil ameliorative role of multi-purpose trees on rangelands and consequent change in vegetation needs study.
- Introduction and multiplication of fast growing tree, shrubs and under shrubs in ranges of pastures of degraded lands would serve in increasing the availability of protein rich fodder, in maintaining the fertility of the soil.
- Unlike for crops and cultivated lands, no national level data base exists on the productivity and extent of grazing lands. This area needs urgent attention.

The future area of research will be on intensification of alternate land use system to increase biomass production per unit area per unit time through agro-forestry systems, rehabilitation of sloppy barren, problematic wasteland (salt affected lands) through agronomical manipulation / watershed approach for sustainable forage production and their conservation, economic evaluation of recommended technologies for integrated farming and arable farming system, effect of different farming system on physical, chemical and biological properties soil and exploring the possibilities of sustainable and organic forage production system under semi-arid conditions.

Textile Manufacture and Textile Chemistry

D.B. Shakyawar and A.S.M. Raja

The Division of Textile Manufacture and Textile Chemistry was established Avikanagar since inception of the institute. The mandate of the Division is to carry out research on various aspects of wool and all other animal fibre evaluation, scouring, woolen spinning, worsted spinning, weaving, chemical finishing, mechanical finishing, product development etc. A full pledged wool processing plant was established at the Division under UNDP aid. The plant was operational in the year 1968 with the set of woolen spinning and wet processing machineries. The weaving machineries were operational since 1969-70. The worsted spinning machines and finishing ranges was installed in 1970-1971. The Division has complete set of machineries from scouring to finishing of woolen goods. A testing lab was also established to carry out all kind of testing related to wool and animal fibre.

Initial phase of research (1962-1985)

In early 70's main thrust was given to most efficient and economic utilization of Indian wools on the woolen, worsted and allied sectors. Investigations into the various processing stages like sorting, scouring, carding, spinning, weaving, dyeing and finishing were undertaken. Similarly, thrust was also given to evaluate the fibre characteristics of indigenous and cross bred wools of India. Initially the Magra, Nali and Chokla woolls were taken for study. During 1970, Division undertook a major consultancy work from Himachal Pradesh Khadi and Villagae Industries Board for scouring and carding of their wool for Khadi spinning. About 9 tonnes of wool was scoured and carded into sliver for further hand spinning. The sliver was then successfully spun into yarn by the KVIC, Himachal Pradesh. One of the major problems faced by the industry at that time was the removal of vegetable matters, burrs etc., from wool. Division took up this problem and optimized the carbonization process. During 1971, consultancy project was awarded by Animal Husbandry Department, Mysore state for processing their wool. Two major All India Coordinated Research Projects were undertaken on canary colouration and manufacturing trials. The Division took lead in manufacturing trial of graded wool projects. Some experiment were also conducted on wax recovery system, preparation of hospital/military blankets from Chokla and Nali breeds as per ISI 1681-1960 and removing highly medullated fibre in Indian fleeces. Various trials were made to prepare the carpets out of indigenous wool blends. During 1973, Angora hair from Himachal Pradesh was analyzed for quality parameters.

All India coordinated research project on manufacturing trials of graded wools (1971-1974)

The project attempted to explore the potentialities of different graded indigenous wools for the manufacture of various end-products. The Indian woolen industry were benefitted to a greater extent by utilizing the technical know-how available from the research trials carried out in respect of utilizing the indigenous raw wool thereby minimizing fine wools import and spending of foreign exchange. Various trials on the manufacturing performance of indigenous wools graded as per ISI specifications (2900-1970) on the basis of diameter, staple length, burr-content and colour were under taken. According to fibre diameter, the wools were classified into four categories as A (<34.4µ), B (34.4 to 37.0µ), C (37.1 to 40.0µ) and D (40.1µ and above). On the basis of staple length, two groups were recommended. Wools with staple length of 75 mm and above were designated by double letters AA, BB, CC and DD while wools with staple length below 75 mm were designated by single A, B, C and D depending upon the fibre diameter. While considering the vegetable matter, the following classification was used:

Burr content	Designation	Colour	Designation
Low (up to 3%	LB	White	-
Medium (3-5%)	MB	Tinged white	TW
Heavy (> 5%)	HB	Light yellow	LY
		Heavy yellow	HY
		Other colours	Coloured

The other important wool quality parameters like medullation percentage, scouring yield, vegetable matter and grease content also determined for various indigenous wool. After evaluating the fibre qualities, the wool were subjected to all the three spinning systems viz. woolen, semi-worsted and worsted spinning.

Processing of wool on woolen spinning system: Each wool lot was passed through dusting machine twice and each weighed lot was subjected to three/four bowl process for scouring. Water oil emulsion of 3-4% concentration (on the weight of wool) was sprinkled on each lot of wool during willowing. The wool was carded in the carding machine consisted of breaker, inter and finisher card. It was observed that the fibre length was decreased at finisher card in comparison to fibre length at willowing stage. This was attributed to the fact that a reasonable proportion of wool fibre particularly the medullated got broken during carding process when wool lumps were opened up. After carding, the condensed sliver of each roving was spun on woolen ring frame at 2000 rpm. The scouring yield of different wool was in the range of 47-74% depending on dust, dirt and other foreign matters. The spinnability of processed wool was found 7-12 Nm on woolen spinning system with carding and spinning loss of 18-30% and 2.8-5.4%, respectively.

Processing of wool on semi-worsted spinning system: Methods used in woolen spinning system for dusting, scouring and willowing were adopted for semi-worsted system. The carding of wool was carried out on worsted card. The carded sliver was given one/two passages at the auto leveler (Gill box). The material from auto leveler was run through super drafter. The numbers of passages given were adjusted according to the desired evenness and quality of the sliver. The material processed from the super drafter was further passed through the bobbiner. The roving obtained from bobbiner for each lot was spun on the worsted ring frame. The wools were spun between 13-18Nm.

Processing of wool on worsted spinning system: After carrying out scouring, willowing, carding and auto leveling in common with the lots processed for the semi-worsted system of yarn manufacture, a part of the material in respect of each lot was taken up for worsted system of manufacture. The material was run through Rectilinear Combing machine to remove short fibre. The sliver obtained from the comber was passed through auto-leveler. The leveled material was the passed through Super Drafter for 2-3 passages with the object of achieving desired average sliver weight per meter suitable for worsted spinning. The material was then run through bobbiner to prepare suitable roving for worsted ring frame. The roving was spun into yarn of suitable linear density (Nm). The carding, combing and spinning loss were 21-22%, 8-15% and 6-8% respectively. Combing noil was 8-13% and the spinnability of the wool was in the range of 21-28 Nm.

It was concluded that Rambouillet x Chokla (F1) crossbred wool had a great potentiality for its utilization for apparel purpose. It was found that the crossbred wool can be very suitably spun upto the optimum count of 11.49 Nm on woolen system, 16.34 Nm on semi-worsted system and 28.01 Nm on worsted system with reasonable limits of end breakages at the ring frame with optimum yarn strength. On the basis of the results, it was proposed that efforts should be concentrated to encourage the cross breeding programme in the country on large scale by infusing exotic fine wool blood with the indigenous qualities to produce sufficient quantity of fine wool for its utilization in apparels and other end products. Based on the results, it was proposed to do research in the fields of wool grading, wool quality evaluation, spinnability trials of Indian wool and fine wool produced through cross breeding programme.

Evaluation of Indian wools (1975-1984)

Both indigenous and crossbred wools were analyzed for different fibre properties. The results indicated that the fibre diameter of the native wool was improved as a fine wool with 20-25μ with below 5% medullation through cross breeding with exotic fine wool sheep (Table 1). However, the staple length of the cross bred wool was reduced.

Table 1. Fibre characteristics of Indigenous and crossbred wool

Breed	Fleece weight (kg)	Fibre diameter (μ)	Medullation (%)	Staple length (cm)
Northern Temperate Region				
Gaddi	0.7	29-35	5-10	8-10
Karnah	1.0-1.5	29.32	-	12.15
Kashmir Valley	1.0-1.5	27-33	6.00	5-8
Rampur Bushair	1.0-1.5	34-35	20-25	5-8
Poonchi	0.9-1.3	20.30	-	-
Northwestern Arid and Semi-arid Region				
Bikaneri	1.067	24-35	10-20	7-10
Nali	1.460	34-45	15-30	6-9
Patanwadi	1.056	28-36	20-50	6-8
Sonadi	0.409	50-60	50-80	4-5
Chokla	1.149	26-28	10-25	5-10
Malpura	0.524	40-50	60-80	5-8
Jaisalmeri	-	31-40	40-60	6-8
Marwari	-	35-40	40-60	6-9
Magra	0.760	33-40	35-45	6-9
Pugal	0.800	35.13	61.86	5.71
Muzaffarnagri	0.650	45.17	69.92	3.72
Avikalin	1.500	30-35	20-40	6-9
Southern Region				
Deccani	0.359	45-55	40-70	5-8
Ballary	0.300	50-60	40-60	-
Coimbatore	0.365	40-50	40-60	5-6
Nilgiri	0.615	25-27	5-10	5-7
Bharat Merino	2.000	18-22	<1	6-8
Eastern Region				
Chhotanagpuri	0.184	50-55	60-80	-
Shahabadi	0.240	45-50	60-80	-
Jalauni	0.455	40-50	60-80	-
Bonpala	0.200	45-50	60-80	-

Morphological studies of wool: Morphological studies of wools were undertaken to assess the cuticular scale patterns. The scales were found to have various shapes like regular, irregular, mosaic and wavelike. The size and number of scales per cm was found out (Table 2). Attempts were also made to study the frictional properties of various wools. The fibres were dragged against a thin wire in both directions. The experiment was carried out on Instron by moving the fibre at the rate of 2.0cm/min. From the values, Directional Frictional Index was determined (Table 3). The circularity factors of cross section of Indian and crossbred wools was measured using the formula C (circularity factor) = $4\pi A/P^2$ where A is the area of cross section and P is the perimeter of the cross section. It was observed that irrespective of the type of fibre (i.e.non-medullated and medullated), the circularity factor decreased with the increase in major axis. The circularity factor of medullated fibre was less than that of true fibre. The circularity factor varied from 0.88 to 0.93 in exotic breeds, from 0.84 to 0.93 in crossbred and from 0.79 to 0.83 in medullated fibre.

Table 2. Scale structure of native and crossbred wools

Wool	Scale size (μ)	No. of scales/cm
Rambouillet	14.34	697
Chokla (Pure)	20.18	498
Chokla (Hetero)	23.12	432
Chokla (Hairy)	22.19	450
Malpura (Pure)	15.37	650
Malpura (Hetero)	17.13	584
Malpura (Hairy)	27.48	364
R X C (3/4) Pure	15.72	630
R X C (3/4) Medullated	19.80	505

Table 3. Frictional properties of wool and rabbit hair

Wool	Frictional force (g)		Directional frictional
	Along the fibre	Against the scales	index
Rambouillet	2.171	2.366	0.077
R X C (3/4)	2.326	2.484	0.056
Chokla	1.918	1.990	0.073
Malpura	1.825	1.990	0.090
R X M (1/2)	2.346	2.603	0.028
Corriedale	2.221	2.350	0.055
Rabbit	2.227	2.429	0.076
Mohair	1.677	1.743	0.046

Stress-strain behaviour of wools: The stress-strain properties of the wools showed that in native wools (Chokla, Malpura, Sonadi, Nali etc) the difference in tenacity is negligible (11.17 to 12.82 g/tex) even though there were large difference in fineness (37 to 56μ). In all the cases heavy yellow wool showed lower tenacity as compared to light yellow wool. The difference in extensibility among wools was rather small. The elastic recovery studies indicated that all the wools under test are 100% recoverable immediately at 2.5% of their extension. The RxC wool behaved almost equivalent to Rambouillet from the elastic recovery point of view even at increased extensions. The results on bulk resiliency indicated that the fibre diameter and crimp/cm controls 13 and 19% variability for first and fifth cycle, respectively. The infusion of exotic blood in the native breeds has improved the quality of wool to the extent of corriedale, these crosses were having sufficient strength to produce the yarn economically and usefully. The curve parameters regress positively with fibre diameter in pure fibre and negatively in medullated fibre. This was attributed to the fact that pure fibre tend to be structurally stronger with increase in diameter whereas in medullated fibre. The increase in diameter results in increase in medulla resulting in poor elasticity.

Effect of temperature on stress-strain behaviour of wool: It was observed that in general, stress fell by 70% and extension increased by 50% on changing the temperature from 25-95°C. The rate of fall of stress with temperature was sigmoidal in nature. Up to 51°C, there was sharp fall; between 50-70°C, it was fairly constant and above 70°C, it again fell rapidly. For temperature above 60°C, the fibre showed slippage in post yield region (i.e. extension above 35%). This was attributed to increased mobility of the molecular chains.

Stress-strain behaviour of thioglycollate treated wool: Chokla white and canary coloured wool fibres were reduced with sodium thioglycollate in order to know the contribution from the structural components to stress-strain properties. As the treatment reduced the disulphide bonds, the main structural backbone of the fibre, the stress value decreased and extension increased due to treatment. The change was different in the white and canary coloured wool. The yield slope of the curve at 65% RH of yellow wool was lower than white wool indicating that canary colouration modified the matrix adjoining the microfibril which weakened the fibre.

Torsional rigidity of wool: The torsional rigidity values of native wools showed least resistance to twisting while the cross bred wools showed higher resistance to twisting. In all the fibre groups, torsional rigidity had a high correlation with fibre diameter and it was found to be proportional of 3.8 powers of diameter. The diameter variation along the fibre length was measured in order to ascertain fibre breakage during processing. Wool fibre (22 each) from Rambouillet, Chokla and their half bred sheep were studied for their diameter at 36 places over 3 cm long fibre. The fibres of latter two breeds were separated into pure and medullated and load-elongation curves of all the 110 fibre were obtained. Results showed that diameter depends on genetic group but not on the different properties of the fibre. It was also found that except breaking strain, all other values were higher in pure fibre compared to medullaed fibre. The main effect of medullation is to reduce the stress and increase the strain in a fibre.

Chemical processing of wool

Scouring: Malpura and Chokla wools had the highest and Rambouillet had the lowest percent scouring yield in both anionic and non-ionic treatments. The crossbreds (RxC and RxM) had the intermediate percent scouring yield. With non-ionic detergents the percent scouring yield was lesser as compared to an anionic detergents in all the native, exotic and crossbred wools. The scouring of wool without the addition of detergent and sodium carbonate was also attempted in order to minimize the damage to wool fibre by utilizing the suint present in the wools. This process was called suint scouring process. The process was projected as a best suitable for indigenous wool especially canary-coloured wools. The suint scouring process produced a fluffy soft feel and less yellow to scoured wool. However, further research revealed that the suint scouring process was slightly less efficient and time consuming than the detergent.

Carbonization: Attempts were also made to optimize the carbonization process of wool which contained more than 5% vegetable matters. It was found that 3.5-4.5% sulphuric acid with 10 min for acidification, drying for 20 min at 80°C and baking at 130°C were the suitable parameters for carbonization. It was also attempted to reduce the damage to wool during carbonization by the addition of different anionic and non-ionic surface active agents (detergents). In general, tenacity of the wool was higher with the addition of surface active agents and anionic sodium lauryl sulphate gave better results than non-inic detergent. Several experiments were conducted to find the chemical damage in wool using alkali and urea-bisulphite solubility tests. It was observed that alkali solubility test results did not give any clear picture regarding the damage in wool. It was also attempted to study the effect of oxidizing agent (hydrogen peroxide) and reducing agent (thioglycollic acid) on native and crossbred wools. The treated wools were characterized with X-ray diffraction photographs, thermo-gravimetric analysis etc. The results showed that the degree of orientation of keratin decreased after both the treatments. The thermal stability of the wool was reduced more with hydrogen peroxide that with thioglycollic acid.

Low temperature dyeing of wool: The processing of wool at higher temperatures leads to fibre damage especially during dyeing. Hence, it was attempted to develop a low temperature dyeing process using different mixtures of alcohol and water as a medium of dyeing instead of conventionally used water. The liberation of lanthionine was taken as a measure of damage to wool. The results indicated that the dye uptake percentage was greater with water-alcohol mixture in general compared to water. The light fastness of the water-alcohol mixture dyed canary coloured Chokla wool was very good compared to water dyed wool.

Mechanical processing of wool: The processing trials were carried out in semi worsted and worsted spinning system. There was non-significant difference in fibre diameter at various stages of processing. However, the fibre length influenced the processing performance of the wool. There was a decreasing trend in the fibre length at different stages of processing. This was attributed to the fact that long fibres (probably medullated ones) break during carding action. The behavior of Chokla and Corriedale wools during processing was extremely good. However, much difficulty was encountered while processing RxC crossbred and Rambouillet wools especially during auto leveling and combing. The possible reason for the processing difficulties was attributed their short fibre length. In the case of Chokla and Corriedale, the fibre length was 11.27 and 11.32 cm, respectively where as in the case of cross bred wools, the fibre length ranged from 5.63 to 8.7cm which clearly showed reasons for their poor performance. The second major problem faced during processing of RxC cross bred wools was generation of extremely higher percentage of noils to the tune of 40% which would make them unsuitable for commercial exploitation. In industry, the normal noils percentage was kept around 15-20% at the most during that time. Hence, it was proposed to change the shearing regime for the crossbreds so as to increase the fibre length. The yarn tenacity obtained for Chokla and Corriedale was 6.83 g/tex whereas the Rambouillet and its cross wools ranged from 4.82 to 5.70 g/tex which was significantly lower.

Apart from above wool lots, a variety wools like Nali, Corriedale X Bellary, Corriedale X Nellore, Malpura, Sonadi, Rambouillet X Malpura, Karakul, Dorset-Suffolk crosses with Malpura and Sonadi were processed on woolen system. Corriedale, Gaddi. Avikouillet, Mohair woools were processed on semi-worsted system; Nali, Nali x Merino, R x C+Mohair (75:25), R x C+Mohair (50:50) were processed on worsted system. It was observed that fibre length had most influencing effect in the cases of semi-worsted and worsted spinning systems. In general, it was observed that spinning to approximately 50 fibre per cross-section was normal on to the existing set of machinery on commercial basis. Spinning of wool finer than 50 fibres was not common and economically viable. The Mohair and its blended yarn have got better tenacity and elongation than pure wool. During 1977, new crossbred wool of Rambouillet and Merino with Chokla and Nali was available. The wool was with sufficient fibre length to process in semi-worsted and worsted systems. Using this wool a higher count of 30 Nm yarn was spun. The yarn was strong enough to withstand the processing strain in further processing sequences.

Blending of wool with other fibre

Blending of wool with polypropylene: During 1978-79, it was attempted to blend polypropylene (15 denier) with mixed cross bred wool in various proportion to prepare blanket /carpet yarn on woolen spinning system. The fibre diameter, medullation percentage and staple length of the cross bred wool were 25.6µ, 13.10% and 62.9 mm, respectively and the fibre length of polypropylene blends were 80, 100 and 120 mm in equal proportion. The blends could be spun into the yarn of 3-4 Nm count. The yarn tenacity and yarn elongation increased with the increase of polypropylene content. The wool-polypropylene blended fibre were also spun on semi-worsted system and worsted system to the yarn of around 20 Nm count for knitting purpose. The problem of poor dyeability of polypropylene in the blended yarn was also forecasted.

Blending of wool with polyester and viscose: In order to study the difference in yarn quality of two processing systems (worsted and cotton), blending trials of wool, polyester and viscose in two different propositions (W:P:V; 50:40:10 and 50:10:40) were undertaken and it was observed that the increase in the polyester percent in the blend improved the processing behaviour and finer counts with higher strength could be spun with higher strength as compared to viscose blend.

Blending of native wool with New Zealand wool: In 1979-80, to produce the carpet yarns with improved luster and abrasion resistance, New Zealand wool (34.2 µ diameter, 10% medullation, 90 mm fibre length, 14.7 g/tex tenacity and 38% breaking extension) was blended with Chokla/Nali (32 µ diameter, 49% medullation, 83 mm fibre length, 13.1 g/tex tenacity and 35% extension) and Malpura/Sonadi wool (53 µ diameter, 80% medullation, 73 mm fibre length, 8.4.1 g/tex tenacity and 32% extension) in the proportion of 10, 20, 30 and 40%. Carpet yarn of 4 Nm was

prepared on woolen spinning system keeping a TM of 70 from each wool and blends. The experiment reveals that yarn produced out of Malpura/Sonadi wools was much inferior in terms of tenacity and breaking extension. Its performance was improved with the addition of New Zealand wool. The performance of New Zealand wool blends with Chokla/Nali was also better that pure Chokla. Thus, it was inferred that New Zealand wool blending with Indian carpet wools would produce better yarns than the native wool yarns. The same wool blends were also attempted to spin in semi-worsted spinning system and a yarn of 4 Nm was produced. From the experiment it was concluded that increased percentage of New Zealand wool upto 30% in the blends resulted in the increase of yarn tenacity and elongation percentage. Increase of New Zealand wool above 30% proportion did not respond favoorably.

Development of hand knotted carpets: Over all comparison of the functional properties of Chokla, Nali, Jaisalmeri, Magra and RxM wool carpets in all constructions tested elucidated that though Jaisalmeri and Magra wool carpets possessed an ideal compression and recovery behavior but retained their ignition appearance for shorter period of their use due to higher rate of weight and thickness losses under abrasion and dynamic loading impacts, respectively. Chokla and RxM wool carpets demonstrated an excellent appearance retention potentialities at all stages of their use combined with moderate compression values. Nali wool carpets though possessed good recoveries after compression lacked appearance retention powers. Thus it was proposed that a blend of Jaisalmeri, Chokla, Magra and Nali wool can help to attain an optimum quality performance characteristic to the carpet; whereas RxM can itself be considered as ideal carpet wool. Research was also conducted to correlate the fibre properties with the carpet performance properties. For every wool, carpet was prepared with varied pile densities (25, 30 and 35 knots/inch) and pile height (1/2, 3/4 and 1 inch) using three ply yarn. An overall comparison of the functional properties of Chokla, Nali, Jaisalmeri, Magra and RxM wool carpets elucidated that though Magra and Jaisalmeri carpets possessed an ideal compression and recovery behaviour but retained their initial appearance for shorter period of their use due to higher rate of weight and thickness losses. Chokla and RxM wool carpets demonstrated excellent appearance retention combined with moderate compression values.

Abrasion resistance: The results indicated a decreasing trend in the loss of weight of the carpet samples with the increase in the height of the pile. Among the native wools, a minimum loss of 4.20% was noticed in Chokla wool carpet in 4000 cycles of abrasion and Jaisalmeri wool carpets showed highest percentage of weight loss. The abrasion loss values of Magra wool carpets were in between Chokla and Jaisalmeri with 7.4% loss. Magra wool carpets have a tendency of losing more weight in the initial stages of abrasion whereas Jaisalmeri wool showed more abrasion loss towards the end of the abrasion cycle. Weight loss and pile density relationship showed that abrasion loss percent decreased up to a pile density of 30 knots/sq.inch, whereas further increase in pile density increases the weight loss. The cross bred wool showed lower weight loss % like Chokla wool.

Compression and recovery properties: Compression and recovery had shown inverse relationship. Generally, recovery percentage decreased with the increase in pile height and increased with increased pile densities where as the residual compression and compression behavior revealed reverse trend to that of recovery in the same pile combinations.

Dynamic loading: The thickness losses increased with the increase in pile height and decreased with the increase in pile height. The Chokla wool exhibited minimum thickness loss whereas the Jaisalmeri wool exhibited higher thickness loss and Mara fell in between the two.

New Zealand wool in blends with Indian wool for hand knotted carpets: In order to evaluate the influence of New Zealand wool fibre on carpet performance, it was blended with indigenous Chokla/Nali and Malpura/Sonadi wool keeping the New Zealand wool proportion 0, 10, 20, 30 and 40%. 4Nm yarn was prepared out the blends and hand knotted carpet of 120 knots per square inch were prepared. The chemically finished carpet samples were evaluated in

terms of abrasion loss, resiliency and thickness retention on dynamic loading. The results indicated that blending of NZ wool reduced the abrasion loss. However, the indigenous wool samples were superior in respect of resiliency and thickness retention which are the most desirable properties of the carpets.

Wool - Jute blended carpet and blanket: It was found that on treatment with strong sodium hydroxide solution (6-20%) at room temperature, jute fibre get wool like appearance in respect of feel and crimp. This process was known as woolenization of Jute. The formation of crimp in alkali treated wool was attributed variation of molecular orientation within the single fibre caused by alkali treatment. However the process was resulted in 50-60% fall in strength but the elongation was also increased to same extent. The decrease in strength was attributed to rupture of the bond between lignin and hemi-cellulose.

Two types of jute, the Tossa (42 µ diameter) and White (46 µ diameter) were blended with two grades of wool viz B (35 µ diameter) and C (40 µ diameter). Jute fibres were cut into 75 mm staples to match length of wool fibre. The blended fibre (15:85, 30:70 and 50:50 proportions) were processed on woolen as well as on semi-worsted system of yarn manufacturing. Woolen yarns were spun to an average yarn count of 7.5 Nm to produce carpets and blankets. No trouble was encountered during processing at carding and spinning stages except with 50:50 blends. Similarly except for 50:50 blends, processing was trouble free on the semi-worsted system of yarn manufacturing and the yarns were spun for 6 and 12 Nm counts. It was observed that the jute blended wool yarns were lesser in strength than all wool yarns. Blends of Tossa jute and 'B' grade wool in the proportion of 30:70 was found suitable for carpet. The performance properties of the carpets showed that, except for resiliency, jute/wool blended carpets were inferior in all other properties as compared with all wool carpets. The jute/wool blended carpets showed higher abrasion loss and found not suitable for floor coverings. The jute/wool blended yarns were also used for producing blanket type fabric. The results showed that in certain cases fabrics produced out of 30:70 blends of jute and wool were found superior to all wool fabrics in breaking strength. The only drawback observed was poor elongation in jute/wool blended fabrics as compared to all wool fabrics thus restricting its utilization. It was proposed that the best utilization of jute/wool blended fabrics would be in curtain cloth, wall hanging, upholstery etc.

Effect of TPM and fibre in cross-section for spinning of wool: During 1982, spinnability trials were conducted on woolen system of spinning with Chokla, Nali and Avivastra wool to determine the optimum twist factor. It was observed significant increase in strength when TPM was changed from 110 to 135. Further increase in TPM did not increase the strength to any significant level. The elongation percent was found to be highest at 155 TPM and then started declining. In the case of worsted system the TPM was optimized at 600.The yarns spun on woolen system at 1.3 draft and 151.4 TPM were given steam treatment for 10 minutes in the tension state. It was revealed that the strength of the steam treated yarn was more than untreated yarn. For spinning a yarn of acceptable norms with yarn regularity, yarn strength etc., the required number of fibre per cross-section was optimized at 40-50 fibre on worsted system and 200 plus fibre per cross-section for Indian and cross bred wools. However, if the fibre characteristics were favourable, spinnability limit was achieved at 120 fibres per yarn.

Utilization of coarse wools: Wools from Coimbatore, Corriedale and their crossbreds (1/2, 5/8 and 3/4) were processed on woolen spinning system for preparation of blanket yarns. A yarn count of 4-5 NM was prepared and it was found that lea-breaking strength of halfbred Corriedale x Coimbatore was reasonably good breaking strength as compared to yarns of other lots. Further, Corriedale (25.4µ diameter, 60mm fibre length, 4% medullation) and Malpura/Sonadi wool (53.6µ diameter, 80 mm fibre length, 85% medullation) were taken as a representative fibre of fine wool and coarse wool, respectively were blended in different proportions and processed on woolen system with an aim to find out the influence of coarse fibre of the different end product qualities. A 4 Nm yarn was spun and carpets and blankets were manufactured. The study revealed that sliver strength gradually reduced with the increase in the coarse fibre content because of the lack of cohesion.

As expected the yarn tenacity and breaking extension was maximum in blends containing higher number of finer fibre per cross-section. Finally, it was observed that a blend of 50:50 provided satisfactory spinning and yarn performance. In fabric stage also, with the increase in the coarser fibre, the strength and elongation of the grey fabric in both warp and weft direction decreased. The processing loss increased with the increase of the proportion of medullated fibre. The felt made of above blends showed that thickness of the felt improved with the increase of medullated fibre. The abrasion loss of the carpet increased with the increase in the modulated fibre proportion. Study on the effect of medullation on yarn and fabric performances exhibited that the processing loss, breaking strength of yarn, the strength of fabrics, felts and abrasion loss of carpet increased with the increase in the modulated fibre proportion.

Utilization of noils for spinning woolen yarn: The noils even though finer in diameter could not be spun in woolen system. This was attributed to shorter fibre length. The 5% addition of proplon (3 denier, 70 mm length) had improved the spinnability and yarn strength. The proplon fibre acted as a binding fibre on the yarn surface and increased the spinnability and yarn strength. However, the yarn produced from noils was quite softer. It was also attempted to spin the cross bred wools such as Dorset and Suffolk crosses with Malpura and Sonadi with the addition of 20% noils which improved the spinnability. The wool lots were drafted from 1.004 to 1.602 and the best suitable draft on wool system was found from 1.196 to 1.310. The elongation decreased with increased drafts.

Development of serge fabric from medium fine indigenous and crossbred wools: The worsted yarn prepared from Chokla, RxC crosses and RxN crosses were used to prepare serge fabrics in accordance with IS 2319:1969. The performance results indicated that weight /square meter varied from 358 to 399 which is below the prescribed norm of 425 g/m^2. The overall flexural rigidity showed that Chokla wool had got highest flexural rigidity and RxC (3/4th) had least rigidity and the rest of the wool fabrics lie in between. Fibre fineness had positive effect on fabric flexural rigidity. The relaxation shrinkage of the fabrics was well within the norms. However, higher pilling tendency was observed in the fabrics prepared from finer wools and this reduced with the use of coarser wools. Chokla wool produced roughest fabric whereas practically no difference was noticed amongst the other fabrics.

Development of knit-wears from Indian wools and their blends: Several blends of specialty hair fibre were spun on woolen system keeping linear density as 125 tex. These yarns were subsequently used for hand knitted fabrics using two ply yarns. The wales and courses per decimeter and stitch length were kept as 50, 32 and 1.18 cm, respectively. Rabbit hair-silk blended knit goods appeared to be superior in respect of luster, appearance and feel. In order to study the effect of knit structure, plain, 1X1 Rib, 2X1 Rib, half cardigan and full cardigan structures were prepared with wool/mohair (50:50) two plied yarns with same constructional properties. It was observed that Rib fabrics were the most symmetric fabrics. Full cardigan was bulkier and extensible with very low dimensional stability. Plain knitted fabrics were softer in feel whereas 2X1 Rib fabrics had excellent thickness and widthwise elasticity, more than twice of the plain knits.

Processing of rabbit hair: The rabbit hairs blended with polyester, acrylic and silk in different proportions were processed on cotton system with the addition of 1% Nipotex F antistatic agent. The polyester and mulberry silk blends with rabbit hair resulted in stronger yarn. Rabbit hair-polyester blend in 50:50 proportions was processed on commercial cotton spinning machinery for spinning 50Nm yarn with 682.5 TPM. The spinning performance and yarn properties were quite satisfactory. Shawls were produced using the yarn. It was observed that fibre shedding reduced considerably due to polyester blending.

Effect of storage on quality of wool: Extensive research was carried out to study the effect of temperature, humidity and light on the quality of wool during storage. The results indicated existence of significant positive correlation

between relative humidity and wool weights. Decrease in temperature and rise in relative humidity resulted in gain of wool weights. Likewise an increase in temperature and fall in relative humidity resulted in loss in wool weights in different type of wool both in raw and scoured conditions. Variations in wool weights due to atmospheric fluctuations was observed to be more in raw wool as compared to the wools stored in scoured forms. No significant effect of storage under different temperatures and relative humidity conditions during various seasons was observed on wool fibre tenacity and bulk resiliency. The scoured lots of wool of different breed showed higher degree of damage during the different seasons of the year as compared to the lots in raw form under identical conditions of storage. The moth resistance properties of wool in greasy and scoured form were also studied by treating with 2% Dielmoth insecticide. The insecticide treated lots exhibited less damage compared to the untreated lots.

Second phase of research (1985-2005)

In the second phase, attempts were made to utilize the native wools, speciality hair fibre and wool felt. The different studies carried out in this phase are summarized below:

Development of light weight blankets: The indigenous wools (Chokla, Nali etc) were blended with polyester filament yarn (PFY) waste and blanket quality yarn was spun. The warp and weft wise breaking strength and abrasion resistance of the blanket was higher compared to all wool blanket with appreciable reduction in weight. The blanket weight of 324 g wt/m^2 was reduced to 266 by blending 60% PFY.

Spinning of Indian wools on DREF-2: Nali wool was processed on worsted card and the material was sent to Austria for its spinning on friction machinery. The yarn received (0.45, 1, 1.5, 2 and 3.5 Nm) was converted into carpet pile and fabric. The yarn produced was comparable to ring-spun woolen yarns for tenacity and breaking elongation. The carpet pile performance was good for the yarns spun without filament as core. The yarns having core were unable to maintain pile structure and the carpets lost its appeal. The fabrics produced were quite good with very high abrasion resistance making them suitable for furnishings.

Mohair processing: Mohair is a speciality hair fibre difficult to process for lack of cohesion due to its smoothness and absence of crimp in the fibre surface. Mohair was blended with Merino wool and acrylic fibre in varying proportion. Yarns of 20 Nm linear densities were spun by blending at gilling stage. The inclusion of wool and acrylic improved the cohesion and facilitate spinning of mohair. The blended yarns had tenacity in the range of 5.1 to 6.6. The uniformity of Merino blends was superior to cross bred sheep wool blend. The 50:50 blend of Mohair and wool had shown optimum qualities and further increase in Mohair proportion increased the yarn variation.

Camel hair processing: The average diameter of Camel hair fibre ranged between 27-38µ, fibre length from 51 to 67mm, crimp was totally absent, 0.5 to 0.7% grease and vegetable contamination was found to be in between 3 to 5%. Among the four coloured lots, the brown and deep brown coloured was selected for spinning trial. The coarse black coloured camel hair created processing problems. Camel hair lots along with two blended lots (60% Camel hair and 40% wool and 60% Camel hair and 40% polyester) were processed on wollen spinning system. It was observed that coarser camel hair got removed preferentially as fly/card droppings. The camel hair blended fabrics made by using all wool yarn as warp and all camel hair and camel hair/silk waste blended yarn in filling direction were softer after scouring and milling due to migration of camel hair to the surface. The natural colour of the fabrics was quite attractive and the fabrics could be used as over coating. However, cropping was necessary to remove the protruding coarser beard camel hairs.

Processing performance of Bharat Merino wool: Bharat Merino wool of SRRC, Mannavanur had longer staple lengths (6.7cm) with the average diameter of 23.0µ. However, wool of Mannavanur found to have higher contaminates (23%) of sand/dust etc. The scouring yield was approximately 44%. The combing loss of carded sliver was 30%. The wool

was spun into the yarn of 20 NM and converted into the fabric of 190g/m^2. The combing loss was reduced to 13% with the graded wool and a yarn of up to 35Nm was spun. The Avikanagar wool of 3.6cm was spun into 2.5 Nm yarn and blankets made out of the above yarn had desirable softness, fullness and warmth.

Processing performance of Avikalin wool: The Avikalin wool was converted into carpets and compared with the carpet made from Nali wool. The loss in thickness and abrasion loss were lower in carpets from Avikalin wool compared to from Nali wool. However, the resiliency and recovery properties were higher in Nali wool carpets. Further, Avikalin wool carpets showed lower abrasion loss compared to other indigenous wools. The abrasion loss increased and resiliency reduced with higher pile height. The resiliency and recovery from compression improved with higher pile density.

Carpet performance of New Zealand wool: Ten carpets prepared from a blend of non-medullated and modulated fibre during were subjected to visual appeal and handle test. The visual appearance of carpet made from about 80% medullated fibre gave the best carpet visual appeal and handle. This was attributed to limpy nature of fine wool carpet piles. However, considering the abrasion loss it was concluded that 50% medullated fibre content could produce best carpet. The other study indicated that New Zealand wool was more compressible and had less recovery compared to Bikaneri Chokla wool. Addition of Bikaneri Chokla helped in better performances. However abrasion loss was more in Bikaneri Chokla wool due to higher medullation.

Lustre wash of carpets: Carpets made out of Avikalin, Magra and Marwari wools were washed with alkali-hypochlorite. The chemical washing resulted in the removal of coarse medullated fibre with improvement in the fineness of pile. The fibre loss was more in Magra and Marwari compared to Avikalin carpet. The functional performance test indicated that Marwari carpet had better resiliency than Magra and Avikalin after washing due to the coarseness of the fibre. The thickness retention on dynamic loading was not improved by chemical washing. Due to washing, the resiliency was improved little bit whereas compressibility was reduced. There was no change in the recovery properties. Carpets made from Uttaradha, Shyamgarh, Magra and Gujarat wool were given moderate luster wash treatments to increase the visual appeal. The carpets made from Uttaradha and Shyamgarg were scored first place followed by Magra and Gujarat wool.

Survey and analysis of mandi wools of Rajasthan: During 1985-1991, extensive work was carried out to survey and analysis the wool mandies in Rajasthan. Rajasthan has 10n major wool marketing centres (Mandi). Three wool mandies namely Bikaner, Beawar and Kekri are internationally known. Four wool mandies Jaipur, Barmer, Jodhpur and Jaisalmer have the national status, whereas Churu, Pali and Sri Ganganagar are the regional wool marketing centres. The domestic and imported wools of every divergent quality are traded in these wool mandies. A comparison of quality characteristics of wool from different wool mandies indicated a large scale divergence in wool quality attributes. The March clip wool was white/tinged white in colour, July and November clips were pale yellow while, September clip wool was dark yellow in colour. The processing losses of autumn clip wools were higher than corresponding spring clip wools. Among the domestic wool, Uttradha (Bikaneri Chokla) followed by Magra, Marwari and Chokla were lustrous.

Fluorescence and reflectance: The fluorescence at 365 nm was in the order of Nali > Magra> Marwari wool. At 405 nm, there was no significant difference among wools, whereas at 436 nm, Nali scored lowest while others did not differ significantly. The reflectance of Magra and Marwari were similar and significantly higher than Nali wool. The fluorescence at 450 and 470 nm was higher in Beawar Chokla whereas, at 510 nm, the reflectance was more in New Zealand wool. It was inferred that New Zealand wool was more lustrous. Wool samples collected from the field showed that luster differed significantly with respect to locations, age of the animals, diameter, month of sampling and year of collection. It was observed that luster was increased after chemical treatments. The acid hypochlorite treatment improved the luster of the samples more than that of alkali hypochlorite treatment.

Indian wools and their blends with New Zealand wool: New Zealand wool (NZ) and its blends with Beawer Chokla (BC) 40:60, 50:50, 60:40 had diameter 31.04, 33.76, 35.90 and 37.50 µ and medullation 7.51, 19.90, 49.67 and 61.13%, respectively. The compressibility studies were carried out at 0.9 and 5.0 kg loads. The bulk of the blend increased with the increase in the proportion of indigenous wool.

Studies on natural dyeing of wool: Natural dyes are well known for their eco-friendly nature. Several natural dyes were identified for wool and dye was extracted. The wool materials were dyed with and without the use of metal salts (mordants) like chromium, copper, iron, alum, tin etc. Barks of acacia, eucalyptus, magenta root, henna leaves, tea waste, onion skin, wattle bark, wall nut fruit etc were used in dyeing the wools. The colour produced on wool was fast to washing.

Development of handloom woven carpet: The wool fineness varied from 28-41µ where as medullation varied from 21-47%. Generally, 100% wool was being utilized in Bikaner carpet weaving units. The two ply or three ply woolen yarns were used for carpet making. The pile height varied from 7.0-9.3 mm and pile density 24 to 29 /inch^2. The pile weight varied from 890-1300 g/m^2. The resiliency (43-55%) and compressibility (33-47%) of the carpets were good. The life of the carpet estimated to be 6 years for carpets with pile height 5-7mm and 12-14 years in carpets with pile height 11-13 cm.

Blending of wool and speciality hairs with synthetic and natural fibre: Gaddi synthetic wool was blended with non-shrinkable acrylic fibres, spun into 25 Nm yarn and converted to knitwear. Bharat Merino wool and polyester (30:70) were blended and five types of fabrics were made which had bulk varying from 2.06 to 3.4cm^3/g. Aerial density varied from 182-280 and thickness 0.47 to 0.62. Rabbit hair was blended with Bharat Merino wool in 20:80, 40:60 and 60:40 and spun into yarn of 12 NM with 377 twist per inch. The tenacity and elongation of the yarn increased with the increase in rabbit hair content. Rabbit hair and acrylic fibres (50:50, 60:40) were spun on dref-2 system. From the yarn properties it was concluded that rabbit hair could be blended with acrylic upto 40% for good quality yarn of 2/20Nm. The yarns were used to prepare shawl. The shawl was found bulky with higher thermal insulation. The shawl had low stiffness (610 mg-cm) inferring good handle.

Camel hair (27.21µ diameter and 59 mm fibre length) and polyester waste (80:20) were blended and spun into yarn using dref-2 system. Equine fibres were processed for different value added products. The horse and donkey fibre (diameter -40-160 µ) were blended with indigenous wool and processed on dref-2 system using acrylic as core yarn. The yarns were used to produce furnishing fabrics. Considering the colour, equine fibre were sorted into black fine, black coarse, brown and grey. The fineness of black and black coarse fibres were 42.1 and 52.5 µ, respectively whereas, for the brown and grey fibre were 46.5 and 56.5 µ, respectively. The tenacity varied from 8-9g/tex and elongation varied from 19-26%.The camel fibre scored lower tenacity and elongation than equine fibre. Donkey hairs were blended with wool in different proportions for producing certain cloth in a natural colour. Pure wool, Wool-acrylic blended blankets were manufactured to optimize the performance and to reduce the cost. Very coarse yarn of about 0.5Nm was spun by hand from goat hairs (70-80 µ fibre diameter) and utilized for making goat hair patti and durrey. The fineness of yak fibre varied from 36 to 46µ. Though the fibre was quite coarse, its bundle tenacity and elongation percent were adequate for utilization in blanket, carpet and felt preparation.

Shawls out of rabbit hair / Pashmina blends were got prepared from the yarn with the aim to observe the effect of blend level of rabbit hair and Pashmina fibre. Yarns were spun out of Ramie-Polyester blends in 20:80 and 40:60 and 50:50 proportions. The yarn performance was quite satisfactory.

Studies on blending of wool and Angora rabbit hair with cotton: A collaborative project with CIRCOT, Mumbai on short staple wool-cotton blends processing revealed that the short staple fine wool (Avivastra) could be blended with medium and fine cotton in different proportions and processed on cotton spinning system for 32 and 48 cotton counts. The wool-cotton blends were used to prepare different value added product. The blended products were dyed in a

single bath using different natural dyes like ratanjot, henna, haldi with good fastness properties. The blended products were dyed with reactive dyes in a single bath at different pH to obtain solid shades. Similarly, Angora wool was blended with cotton and polyester. The blendes were then processed in cotton spinning system.

Survey of felt Industries: Among hand made felt manufacturing units, the installed capacity was ranging from 50-100 kg/day. Production efficiency varies from 70 to 80%. The annual production per unit was ranging between 10000-15000 kg. It was estimated that total hand made felt produced in the country is about 0.6-1.0 m kg which consume 1.0-1.5 million kg of raw wool, synthetic waste and low quality cotton during 2003. Among the machine made felt manufacturing units, the installed capacity was varying from 150-200 kg/day. These units run on an average efficiency of 70-80% and total felt production per annum varied from 18000 to 40000k. Considering 40 of machine made felt units, the annual production of machine made felt is about 1.2 m kg which consumes about 1.5-2.0 m kg of raw wool and other synthetic fibre. Among wool fibre, medium-coarse Indian wool and fine merino waste (noils) are used. Virgin Merino is also used as source for quality products. Among Indian wool Chokla and Sekhawati wools are commonly used. Polyester, viscose, acrylic and cigarette filter in the form of waste also serve as raw material for this industry. The proportion of these fibres was restricted up to 20% in hand made felt and 30% in machine made felt. The hand made felt is generally used in handicraft and floor covering items. However, most of the units surveyed at Jaipur also manufacture felt for industrial application of lower density 0.31-0.35 g/cm^3. The felts used for Industrial applications include washers, channels, rings, strips, filters, bubs and baits padding, oil seal, gaskets etc. Various kinds of industrials woolen felt products are used in automobile, packing, defense, leather industry, railways, filter industry, glass industry etc.

Development of hand-made felts: The medium quality wool, coarse wool, camel hair and rabbit hair were used to prepare the felt. All the blends were dusted, opened and carded as per normal practice. The opened carded web of fibre was laid down manually in the form of bed keeping in view that almost equal density of fibre was laid per unit area. The bed was impregnated with an emulsion of desi soap in water by sprinkling the emulsion by hand and rolling the bed. The fibre bed was left for about 4 hr so as to allow all the fibre to absorb the desired moisture. After that, the bed was rigorously rubbed with the help of hand. Simultaneously mending of thin places was done by putting extra tuft of fibre and rubbing till a compact structure was achieved. Felt of 4'x6' size were prepared and washed to remove extra alkali present in the felt. The washed felts were dried, cut to size and ornamentation was done by stitching thin pieces of felt of different colours by hand. The felts were prepared keeping 5 mm thickness and 1 Kg/m^2 weight. However, thickness and weight had varied from 4.6 to 6.6 mm and 0.8-1.2 kg/m^2 in medium wool-camel blends and 3.0-4.6 mm and 0.46-0.8 kg/m^2 in Rabbit hair blends.

Objective evaluation of hand-knotted carpet: Best-fit equations for THV (Total Hand Value) obtained from regression analysis shows that THV mainly depends on thickness and pile density of carpets. The coefficient of regression was 0.715 and best-fit equation was THV (Predicted) = (-) 0.847+ 0.124 Thickness + 0.023 Pile density. The empirical equation is obtained for abrasion loss is Abrasion loss (%) = 1.64 + 0.035 Medullation (%). The regression coefficient is 0.60 significant at 99% confidence level. Similarly the empirical equation for TAV is Visual appearance at cut pile TAV = (-) 4.35 + 0.023 Pile density + 0.1 Compressibility. The regression coefficient is 0.75 significant at 99% confidence level.

Wool - Jute heterogeneously mixed carpet yarn: Jute obtained in the form of sliver is blended with Magra wool top on gill box. One passage of gill imparts heterogeneous blending of wool jute in the sliver. The slivers were fed into Dref-2 spinning system and yarn of 2 Nm was prepared. The ratio of wool: Jute in the yarn was maintained as 82:18. Yarn spinning particulars were consisted of yarn delivery rate- 80 m/min, drum speed -1200 rpm and feed rate -1.82 m/min. These yarns were dyed with metal complex dyes. The dye was absorbed by only wool component and Jute was left undyed. As a result, unique shade is obtained with variation in colour at irregular length interval. These yarns were converted into tufted carpet with special appearance and feel. The marketing intelligence revealed that carpet sample had good demand.

Current research (2005-2011)

A project on "Processing of different hair wool for value added products" under National Agricultural Technology Project (NATP) was carried out to study the animal fibre and to promote their utilization in diversified value added products. The salient findings are:

- The gross physical characteristics of fibre from different sheep breed determine the end-use suitability for making suitable end products.
- The study differentiates the premium on white yarns over pale yellow or medium yellow in terms of price indicating the lower impact of other characters.

Processing and product manufacturing from Camel hair: Camel hairs were procured and sorted according to fineness into fine, coarse and brownish black. Kid camel and adult camels were sorted separately. In kid hair fine, coarse and black were 59, 16 and 25%, respectively. Similarly, in adult camel hair the brown, coarse and black hair was 67, 11 and 22%, respectively. The adult camel hair brown was blended with Uttaradha (Magra wool) wool at 20 and 40% levels. Similarly, the camel hair was blended with VSF at similar levels. The fine kid camel hair was processed on miniature spinning system in blend with VSF at different blends levels and the yarns of approximately 30 Nm could be prepared which indicates that hosiery yarns can be prepared. The adult camel hair blended yarns with 20 and 40% with Uttaradha wool and VSF was processed on woolen system of yarn spinning. The same blends were hand spun also. The tenacity of machine spun yarns was found to be superior because of yarn regularity and uniform insertion of twist. All the yarns were converted into blankets fabric on handlooms keeping the warp of wool. The fabrics were subjected to the process of scouring, milling, raising, decatising and stentering. The blankets met the relevant B.I. standards thus indicating the potential of camel hair fibre utilization in blends with wool for blankets. The machine spun yarn prepared blankets did exhibit better performance and rank correlation studies established the same. The thermal insulation did not exhibit any significant variation.

The blended camel fibres were also converted into Hand-made felts and they were tested for abrasion loss at 1000 cycles against a standard abradant, compressibility and resiliency. The test results revealed a superiority of 20% blended products. The different blended yarns were also converted into handmade durries keeping cotton yarn as warp. It was revealed that the Durries prepared from pure wool were best followed by camel wool blends and machine spun yarns.

Hand knotted carpet samples were prepared from different types of wools, camel hair blends and also from handspun yarns. The pile height kept was 12 mm and after sample preparation these were clipped and neutral wash treatment was given. The test results indicated that abrasion loss on 1000 cycle is within limits. Compressibility, resiliency and recovery values were reasonably good. The visual appeal and handle values of carpet were good. Since the camel-wool blended carpets exhibited nearly equal performance as that of pure wool carpet, it was inferred that carpets of good performance characteristics can be prepared from camel hair in their own natural colour limitation

being dyeing of camel hair in pastel shades. This can also be overcome by keeping camel hair yarn as base material and designs introduced by pure wool dyed yarns.

Processing and product manufacturing from goat hair: The common goat hair is obtained from many domestic breeds (Marwari, Mehsana, Ghiluwadi, Zalawadi, Kutchi, Gaddi etc.). The average fibre diameter was 69±5 µ and the fibre length ranged between 42 to 76 mm. The tenacity was 8 to 12 g/tex with breaking extension of 25±3%. Goat fibre being very coarse, it was not possible to spin it on the conventional machinery. Therefore, all the coloured fibres were hand spun on a wheel Charkha into single yarns. Thereafter each of yarn was doubled also to minimize the variations in yarn irregularity. Each single yarn and doubled yarn was evaluated for performance characteristics. The results indicated high amount of variation in all the measured properties, which is obvious due to the hand spinning procedures. The variability was removed to a good extent in the doubled yarn. The yarn breaking elongation was also on to a lower range as compared to woolen and camel yarns. The fibre and yarns both being coarse were converted into hand made Durries and Hand made carpets keeping warp of cotton yarn. The doubled yarn druggets fulfilled the norms of IS 697 whereas the single yarn druggets were nearer to it. The independent rank evaluation studies of druggets indicated preference for Red and White coloured one as compared to Black and Bagari. Carpets were also prepared from Goat hair yarns in suitable quality with 12 mm pile height. The carpet performance was evaluated and the test results indicated lower variation in respect of performance characteristics amongst the different coloured carpets. However, the abrasion loss is relatively higher with slightly lower recovery values. The handle values reveal the repeat pattern as in case of druggets i.e. red followed by white. It is pertinent to mention here that the coloured carpet specimen reflected a highly glossy lustrous surface appearance.

During XI plan a project on "Development of carpet pile, technical textiles and apparels utilizing indigenous wool blends" was undertaken and the salient achievements are:

Development of high quality blankets: High quality check blankets using different colour patterns were developed by optimising different wool mix. Indian wool of different fineness mixed in different proportion was spun into 4 Nm yarn on woolen spinning system. Fine cross bred wool: indigenous Chokla wool: Nylon in the proportion of 45:50:5 was found as a optimum blend for good quality blanket. The blanket of BIS specifications was woven on power loom. The chemical finishing treatments viz., milling, decatizing and raising were given to enhance softness and dimensional stability of blanket. The blanket possesses soft feel and excellent thermal insulation properties.

Quality carpet from Indian wool-nylon blends: Indian carpet wool in pure form gives excellent resiliency property to the carpet. However, it has higher abrasion loss during usage due to higher percentage of medullated fibre which adversely affects the life of carpet. To improve abrasion resistance and other functional properties of the hand knotted carpet, Nylon-6 (3 denier) was blended with Magra wool in different proportions. Yarn was spun on woolen spinning system with 3.5 Nm. The yarn was dyed into different colours using metal complex dyes. Anti-moth treatment was also applied simultaneously. The computer aided design (CAD) system was used to develop design on paper. The paper design was converted into intricate designed hand knotted carpet of 144 knots per inch with pile height of 10 mm. The carpet was chemically treated using standard technique. The blending of nylon up to 10% level improved the spinnability as well as yarn quality in terms of tensile strength and lustre. Carpet made from wool-nylon (90:10) gives very good appearance as well as abrasion resistance without adversely affecting resiliency property.

Development of handloom woven carpet: For enhancing productivity and profitability of carpet manufacturing, handloom weaving was introduced. It can produce plain carpet for wall to wall floor coverings. The technique was standardized using various constructional parameters such as pile height, density and ply of yarn. A mono-colour carpet of 1500 g/m^2 could be produced with pile height of 8-12 mm. The carpet costs cheaper and affordable for middle income group consumers. However, the life of such carpet is shorter than hand-knotted carpet.

Development of shawl from Bharat Merino wool and its blends: Bharat Merino wool, a fine cross bred wool graded for longer staple length and scoured into three bowl scouring machine to the extent of <0.5% residual grease content. The wool was processed on semi-worsted system and finer yarn of 56 Nm was spun. The quality shawl was manufactured conform BIS specification as well as other quality norms.

Angora rabbit hair: Bharat Merino wool blended shawl: Angora rabbit hair products are always in high demand due to their special attributes like high thermal insulation and superior softness with light weight and thickness. Blending of Angora wool with fine crossbred wool was carried out using modified cotton card at slow speed to avoid breakage. The blends were then processed into yarn using semi worsted system using gill box, roving frame and worsted ring frame. The blended yarns were then woven into shawl in 2/2 twill weave pattern on handloom. Shawls were developed from blends of Angora rabbit hair and Bharat Merino wool using proportion of Angora rabbit hair (70%): Bharat Merino wool (30%). Blended shawl possess excellent whiteness, soft feel and good thermal insulation property.

Improvisation in whiteness and softness of shawl: A process for improving whiteness and softness of Angora rabbit hair: Bharat Merino wool blended shawl was developed. In this process, bleaching using H_2O_2 followed by finishing with cationic softener was done in the same bath. The processed shawl shows 30% higher whiteness and 20% improved softness as compared to conventionally processed shawl.

Economically viable natural dyes: Economically viable natural dyes from different sources like silver oak, onion peel-off, saffron, cochineal, walnut, henna, seshame leaves and madder root for woolen yarn were identified. Natural dyes extracted from the above sources were extracted by conventional aqueous extraction method and applied to Pashmina shawl and other woolen products in presence of mordants such as aluminum sulphate, stannous chloride, and ferrous sulphate. A wide range of colours ranging from orange to grey, black, yellow and green was developed using the selected natural dyes. The fastness properties of the dyed samples were very good. Hence these dyes have potential for eco-friendly dyeing of wool shawl as well as carpet.

Non-woven felt for technical textiles: The processing techniques like fibre selection, scouring, mixing, carding, hardening, felting and other chemical finishing treatment were standardized for the development of apparel and technical felts. Inferior grade rabbit wool, which had little textile application for quality goods, was blended with short length crossbred sheep fine wool in various proportions. The blend optimization indicated that up to 40% inferior rabbit wool can be blended with wool for making superior quality lightweight and extra white felts; converted into value added products like Jackets and women ruffles. These products had enhanced product quality and consumer acceptance with better luster, durability and thermal insulation value. These felts are also found suitable for surgical application in medical textiles. Technical-felts were also developed using blends of spinning wool waste (50%) and coarse wool (50%) with thickness of >6 mm. The felts were dyed in attractive colours using natural and synthetic dyes and made

into Namda of three different dimensions viz. 6'x9', 5'x7' and 4'x6' with attractive embroidery works. These products had enhanced product quality and consumer acceptance.

Software for forecasting quality of carpet: Software named "Module for predicting performance characteristics of hand knotted carpet" was developed using database on performance of hand knotted carpets. Fibre characteristics such as average fibre diameter, hetero fibre and medullation and carpet construction parameters i.e. carpet thickness, pile height and pile density are used as input parameters to predict carpet performance in terms of Carpet Hand Value (CHV), abrasion loss, compressibility, resilience and recovery after dynamic loading. The software is capable to classify the carpet into five categories i.e. poor, average, good, very good and excellent. It can predict these properties within the range of error ± σ value.

NAIP on Pashmina fibre: Research efforts were carried out jointly by CSWRI, Avikanagar and SKUAST-K under National Agricultural Innovation Project entitled "A value chain on enhanced productivity and profitability of Pashmina fibre" with the thrust of utilization of Pashmina for its cost effective value addition and its suitability for blending with other natural fibre in order to produce varieties as well as products of high quality at reasonable cost. Technologies developed are summarized below:

Study on manual v/s machine dehairing: Pashmina was procured from All Changthangi Pashmina Growers Association, Leh Ladakh. Half of the Pashmina was dehaired manually in Kashmir valley while half was dehaired on machine. Fibre diameter and bundle strength showed non-significant difference whereas fibre length and co-efficient of friction showed significant difference between the treatments. Scanning electron microscopic images clearly showed surface damage in case of machine dehaired Pashmina fibre.

Modification of traditional charka: The traditional charka used for spinning pashmina fibre was modified to improve its efficiency. The improved charka proved efficient by 74% in terms of time and 80% in terms of remuneration as against traditional one. A patent has been filed for the improved charka as table top pedal operated charka.

Development of machine spun yarn using nylon as carrier fibre: Pashmina fibre is very difficult to spun in machine due to its very soft, short and slippery scales which create lapping and static charge during carding, sliver making and spinning processes. The nylon was blended with pashmina in the ratio of 50:50 and 60:40 proportions at gilling stage followed by spinning on ring frame. By this process, a yarn of 2/48 Nm was produced. A shawl type fabric was manufactured out of the produced yarn. The nylon portion of the fabric was removed by treating with hydrochloric acid. The produced fabric was compared with conventionally hand spun made pashmina shawl fabric and found that there was significant difference between the two fabrics in terms of softness, thermal conductivity. However, the machine spun yarn made fabric showed 60% lower extension and 50% higher abrasion loss. The SEM results showed that the machine spun yarn made fabric had minute deposit of dissolved nylon in few places compared to the hand spun yarn made fabric.

Use of PVA as carrier fibre: The pashmina fibre was spun in machine using poly vinyl alcohol fibre (PVA) instead of nylon as carrier fibre. PVA fibres are soluble in hot water. To remove the PVA from the fabric, the fabric is treated with hot boiling water instead of hydrochloric acid. The advantage of this technique is that pashmina fibre does not get damaged in hot water as was the case with HCl. This method of spinning is considered as eco-friendly as well as cost effective.

Development of size-box for improvement of weaving efficiency: Sectional warping machine has been introduced which improves efficiency of warping and maintain uniformity in tension and avoid entanglement of yarns on beam.

Under the process, size box has been introduced between creel and sectional warping machine. The section of warp was passed through between sizing and squeezing rollers. The sizing roller was immersed into size paste which was taken by sizing roller up on the top of roller. The section of warp yarn was touched the sizing roller at top and the yarn gets immerged with size paste. Excess amount of size paste got removed by squeezing roller mounted on the top of the sizing roller. In order to separate threads from each other, a reed has been fixed before sizing box. Conventional sizing was not suitable for woolen and worsted warp because of their stretchability and heat sensitivity. Cold sizing was found to be one of the alternatives to solve this problem. Poly-vinyl alcohol (3%) was found suitable sizing material for pashmina and pashmina blended yarns. Weavability of shawl was improved by 40% as compared to traditional weaving using the developed method.

Value addition of Pashmina: The shawl made of silk filament or silk blended yarn has better lustre and visual appearance as compared to pure Pashmina. Blending of rabbit hair also improved lustre of the shawl. Shawls made of Pashmina-Nylon blended yarn after dissolving Nylon by chemical treatment improves lustre significantly. The softness found to be decreased after blending of wool, rabbit hair or silk. Shawls made of machine spun PashminaNylon or PashminaPVA as well as Pashminasilk, wool blended yarns gave highest total hand value followed pure Pashmina shawl, Pashminawool as well as rabbit hairwool blended shawl. The relaxation shrinkage of the shawl made of pure Pashmina and blended yarn is within acceptability of ±2%. The formability of Pashmina shawl was lower in comparison to suiting fabrics. The extensibility of pure Pashmina shawl was ranging between 5-6% at 100 g load. Blending of wool/silk/rabbit hair enhances the extensibility. Extension in biaxial direction was higher in PVA/silk blended shawl as compared to pure Pashmina shawl. The bending rigidity significantly lowered in Nylon or PVA blended shawl as compared to pure Pashmina shawl. The shear rigidity did not show significant differences between pure Pashmina and blended shawl. The shawl made of silk filament was thinnest followed by pure Pashmina and blended shawl. The bending rigidity showed significant negative correlation with softness of the shawl. The thickness at 100 g load showed significant correlation at 95% confidence level with smoothness.

Development of natural dyes for Pashmina fabrics: The dyeing of pashmina fabric using natural dyes is definite value addition to the product. However, there are some problems associated with the use of natural dyes on Pashmina fabric. The major problems are non-availability of suitable dye in bulk, poor fastness properties. In order to solve these problems, a comprehensive natural dyeing process with the abundantly available natural materials was developed. The locally available materials like saffron flower petals, walnut husk, onion peel off, henna, pomegranate rind etc were used for dyeing. A wide variety of shades from yellow to blue, grey etc were produced on Pashmina fabric. The fastness properties of the developed shades were very good.

Dyeing with saffron petals extracts: The saffron flower petals were dried and ground into powder form. The natural dye was extracted from the powder by aqueous method using boiled water. The extracts were then applied on pashmina at pH 5.0 and 8.0. Aluminium sulphate, stannous chloride and ferrous sulphate were used as mordants. Saffron flower petals were able to dye the pashmina shawl satisfactorily with very good washing and light fastness properties. The dye uptake on Pashmina using saffron at acidic pH showed 60% higher dye uptake as compared to the dye uptake at alkaline pH. The developed shades at pH 5 exhibited bathochromic shift at alkaline pH due to the deprotonation of phenolic and carboxylic acid groups present in the dye extract.

Dyeing with onion peel off: Boiling water was used for extraction of natural dye. The extracts were then applied on pashmina fabric at at pH 5.0 and 8.0. Aluminium sulphate, stannous chloride and ferrous sulphate were used as

mordants for dyeing. The onion peel off extracts was able to dye the pashmina shawl satisfactorily. The fastnesses of the dyed materials is satisfactory and with acceptable standards.

Dyeing with walnut husk: The colorant from dried walnut husk (*Juglans regia*) was extracted by conventional aqueous extraction method. The extract was applied on woolen fabric with eco-friendly metallic mordants. They produced dark brown shades with very good to excellent fastness properties.

Dyeing with pomegranate rind: The rinds of pomegranate contain colour compounds such as 1-O-Isopentyl-3-O-octadec-2-enoyl glycerol, 1-O-Trans,cis,trans-9,11,13-octadecatrienoyl glycerol, Luteolin and Tricetin. These substances tested as dye on Pashmina wool with promising dyeing properties. The colours obtained on the Pashmina fabric using pomegranate dye extract are pale yellow, bright yellow, orange and dull green.

Dyeing with cochineal insect extract: Generally, the Pashmina shawl is dyed with very bright purple and scarlet colours. There is a lack of such colours in the plant based natural dyes. In order to address this problem, cochineal extract obtained from insect was attempted. Pashmina fabric could be dyed with a natural dye extracted from a cochineal insect into scarlet red colour and cochineal dye was exhausted between 80 and 95% at 50-60°C in 120-150 minutes. The K/S value is ranged from 0.526 to 0.816 with very good washing (4-5) and light fastness (6-7) at this standard condition. Coordination complex could be formed between functional groups of Pashmina wool polymer and metal cation/dye molecule and that complex might be entrapped in between polymer chains. It was concluded that this natural dye could be given solid shade on pre-mordanted Pashmina wool at 60°C in 120 minutes through a strong co-ordinate complex between dye-metal ion-fiber.

Dyeing with other sources: The process of dyeing Pashmina fabric using Henna, Silver oak, Indian Tulip leaves, Dhol Kanali root, Madder etc was optimized. Based on this, it is possible to dye the Pashmina fabric using natural dyes comprehensively with good washing and light fastness properties.

Economics of natural dyeing: Cost analysis of dyeing of pashmina shawl using natural sources shows that artisans get profit of Rs. 400.00 with an investment of Rs. 100.00 per shawl. The shawl gets premium price due to eco-friendly nature of product.

Development of natural dyes with anti-microbial and anti-moth properties: The natural dyes apart from colouring the textiles also provide anti-microbial and anti-moth properties. The saffron flower petal dyed Pashmina shawls showed antimicrobial efficacy against *S. aureus*. However, the saffron, onion dyed materials did not show anti-moth properties, where as henna, walnut, sesame dyed materials had shown anti-moth properties.

PCR based method for identification of Pashmina fibre: By DNA based analysis method it is possible to distinguish Pashmina from wool. However, when the different animal fibre are mixed and subjected to conventional processes like dyeing, finishing etc, there is the difficulty in extracting intact DNA. Hence, an attempt was made to extract intact DNA from the processed fibre. From the intact DNA from sheep, Pashmina and Angora wool, 12S ribosomal RNA gene fragment was amplified in PCR by speciesspecific primer and was confirmed by sequencing. This PCR-based technique was able to amplify genes from DNA isolated from chemical and dye treated animal fibre as well as readymade woolen garments like shawl. Simple duplex PCR was able to amplify and identify sheep wool from Pashmina ≥ 10% of total volume. The developed DNA based analytical method can be used as quality control tool to measure purity and authentication of prepared garments like pure Pashmina shawl.

Meat Science and Pelt Technology

A.K. Shinde and Y.P. Gadekar

Meat production and consumption has increased remarkably in recent years in the country. Meat is one of the important components of human diet. Demand for quality meat and meat products are increasing due to growing awareness about nutritional and sensory characteristics of such meat products. Changing socio-economic status has also contributed for the enhanced consumption of processed and convenience meat products. As the demand for ready to eat meat products is ever growing due to rapid urbanization and industrialization, a lot of efforts are needed to meet such increasing demands. Variety of meat based products meat balls/koftas, patties, nuggets, meat pickles and sausages are developed by the Institute from sheep meat and many of them are now available in the market. In the Meat Science and Pelt Technology Section research is mainly carried out on two aspects viz., carcass evaluation of different species (sheep, goat and rabbits) and development of value added convenience mutton products.

Carcass evaluation of sheep, goats and rabbits

A series of experiment has been conducted over the last 50 year to evaluate the carcass traits of sheep, goats and rabbits under different feeding protocols. Similarly the new strains developed from cross breeding of native sheep with exotic one were also evaluated in term of carcass yield and quality attributes.

Carcass traits of sheep and goats: Suffolk and Dorset sheep breeds were imported for crossbreeding with native sheep to develop mutton sheep for enhancing mutton production in the country. The carcass traits of crossbreds developed from cross breeding were evaluated. Among the halfbreds the Suffolk x Malpura yielded heaviest carcasses followed by Suffolk x Sonadi, Dorset x Malpura and Dorset x Sonadi in the descending order. Halfbreds were 4.49 to 32.25 % superior over the respective natives. Dressing percentage based on empty live weight of Dorset x Sonadi (F2) and Karakul x Sonadi was significantly higher than that of Suffolk crosses with Sonadi and Malpura. Halfbreds were superior to natives for pre-slaughter weight, hot carcass weight and loin eye area. On empty body weight basis halfbreds were superior to Malpura but not different from Sonadi lambs. Sensory attributes of meat from Malpura, Dorset x Sonadi and Dorset x Malpura revealed that overall scores were higher for meat obtained from Malpura lambs. Mutton synthetic, Malpura selected and Malpura control groups attained 25 kg body wt almost on similar days. At 30 kg slaughter weight, lean and bone portions decreased and fat increased compared to carcass at 25 kg slaughter weights. The growth performance of Bharat Merino lambs during 3-6 months was better under intensive feeding than grazing with supplementation. Further, the finisher lambs raised on both the feeding protocol provided carcass of acceptable quality. The dressing yield and cut ability of standard cuts were comparable in Awassi x Malpura half bred and Malpura lambs. Carcass and meat quality of Garole was similar to Malpura or their crossbreds. It was also evident that the overall meat quality was better in Garole compared to Malpura rams. Pre-slaughter weight was higher in Malpura hoggets as compared to Garole. However, the dressing percentage on live weight basis was higher in Malpura x Garole than Malpura and Garole. In Avikalin, Chokla synthetic, Malpura and Garole x Malpura (GM) of 3, 6, 9 and 12 months of age maintained under grazing with concentrate supplementation revealed that pre-slaughter weight was similar in Avikalin, Chokla synthetic and Malpura while it was considerably lower in GM.

For chevon production castration at the age of 30 days was found to be better compared to at 7 or 15 days. The dressing yield was higher in sheep than goats. But goat yielded leaner carcass which is desirable for the calorie

concern consumers. It was also revealed that meat from goat carcasses was tougher than mutton. In Sirohi kids khejri or pala leaves and concentrate mixture in 50:50 ratios did not affect any carcass quality attributes. Intensive feeding of kids on complete feed consisting of roughage (tree leaves) and concentrate improved hot carcass yield to 11.73 kg with dressing yield of 56.07% from 8.68 kg and 55.76% under prevailing grazing plus supplementation system. Sirohi kids on intensive or semi-intensive system provided quality carcass with higher meat yield. In different breeds of goats, slaughter studies at 7, 8, or 9 months of age indicated that after feeding them on *adlibitum* concentrates from 6 months of age an increase in slaughter weight and carcass weight was observed with increasing age at slaughter in all breeds except Kutchi and Marwari. Tenderness of meat decreased and intramuscular fat increased with increase in carcass weight of older lambs.

Carcass characteristics of new developed strain A (GMM X Patanwadi) were slaughtered to study their carcass traits. Average pre-slaughter weight, dressing on ELW, loin eye area, caul fat and kidney fat was 43.69 kg, 53.65 %, 16.49 cm^2, 0.28 kg and 0.14 kg, respectively. Average lean, fat and bone content in carcass were 56.87, 9.04 and 29.59 %, respectively. Meat: bone and lean: fat ratio was 1.94 and 7.06, respectively. Water holding capacity was 25.28% while cooking losses and drip losses were 15.37 and 6.76 %, respectively. Shear force value as measure of tenderness was 4.14 kg/cm^2. GMM X Patanwadi (A genotype) genotype is more suitable than Patanwadi X GMM (B genotype) for mutton production due to higher body weight and thereby more meat yield. However the dressing yield, lean and fat contents and other quality attributes of both the genotype remained similar.

Growth performance of finisher lambs was better under cafeteria system of feeding management than grazing with 1.5 or 2.5% of body weight of concentrate supplementation. Under cafeteria system of feeding management, the feed conversion efficiency improved while carcass fat content remained well within limit of 9%. *Ad-libitum* concentrate feeding in cafeteria system of feeding management provided carcass of desired quality thus rendering the production system suitable for commercial application. Carcass yield and dressing percentage were higher in lambs maintained under grazing with supplementation and intensive feeding than extensive range management. The carcass separable fat content was 8% under extensive range management while it was 12% and 16% in semi-intensive and intensive system of management, indicating that the carcass was of acceptable quality. About 15% fat and 2.2 mm back fat thickness are considered optimum for better keeping and eating quality. Intensively fed younger lambs deposited more fat in their carcasses at younger age.

Carcass characteristics and meat quality attributes of defaunated, refaunated and control finisher Malpura lambs was similar, however comparatively higher bone and fat contents of defaunated lambs indicated their higher gain was primarily in terms of undesirable tissue like bone and fat accretion. The dietary supplementation of sodium bicarbonate in high concentrate diets did not exert much influence on carcass and meat quality characteristics. However, the dressing yield improved and total separable carcass fat was reduced by supplementing buffer to high concentrate fed lambs. The lambs receiving higher energy under heat exposure had higher dressing yield and muscle growth and optimum carcass fat content, and that lambs fed adequate energy provided carcasses of desired characteristics even under heat exposure.

Replacing the maize with animal food grade damaged wheat at 25, 50, 75 and 100 per cent in the ration did not affect the carcass characteristics and saleable meat yields. Pre-slaughter weights, empty live weights, hot carcass weights and dressing yield on ELW of spent ewes fed concentrate mixture @ 2.5 % of BW containing urea and molasses were 33.84, 28.82 and 15.53 kg and 53.77% and not adversely affected by incorporating urea in concentrate mixture.

Carcass traits of Malpura weaner lambs (6 month old) maintained on complete feed containing microbial feed additives under intensive feeding were evaluated. The carcasses of lambs supplemented with *Saccharomyces*

cerevisiae and Lactobacilli were found better than the control. *Saccharomyces cerevisiae* supplementation alone has no beneficial effect on meat yield and quality. The supplementation of microbial probiotics *Saccharomyces cerevisiae* and Lactobacilli in the ration of lambs provided additional body weight of 3.32 kg, hot carcass weights of 3.16 kg. Dressing yield on ELW was improved from 56.24 to 59.30 %.

The finisher lambs maintained on grazing and *ad lib* concentrate mixture feeding and slaughtered at 6 months of age provided hot carcass weight of 14-15 kg with dressing yield of 50-51%. Average lean, fat (subcutaneous and intra muscular fat) and bone contents of different parts of the carcass viz., leg, loin, rack, neck and shank and shoulder and breast was 50-54%, 18-20% and 21-22%, respectively. The fat content of carcass was found to be on higher side than standard norms of 13-14%. Malpura lambs maintained under stall feeding and supplemented with different level of fat (G1:0.0, G2: 2.5, G3: 5.0 and G4: 7.5%) were slaughtered at 6 month of age. The carcasses of lambs supplemented with 5% fat were graded better than the control and 2.5% and 7.5% level of fat supplementation but there were no significant differences. Hence, it was concluded that there was no difference of fat supplementation in male lambs as far as carcass characteristic is concerned.

Supplementation of rumen protected fat at 4.0% level in cull ewe's diet increased pre-slaughter weights and carcass yield but did not improve meat quality. Spent adult sheep maintained on grazing resources were slaughtered at 15 month of age and their carcass traits were evaluated. Spent sheep on an average produced carcass weight of 8.86 kg with dressing yield of 50.25%. The carcass contained 57.94% lean, 11.20% fat (subcutaneous and intra muscular fat) and 33.36% bone. Spent sheep meat contained higher proportion of bone and less of fat and lean and poorly accepted by the consumers due to toughness of muscle fibre. Urea and molasses can be used in the feeds of spent sheep without any adverse effect on meat yield and quality. The rumen protected fat supplementation was tried in 3 month old Malpura lambs for increasing meat yield and quality. The supplementation of lambs with 2% or 4 % levels of rumen protected fat did not improve the carcass quality and composition. Supplementation of 4% rumen protected fat in lamb's diet improved pre-slaughter weight, lean yield but did not improve meat quality significantly. Carcass characteristics of sheep of variable Body Condition Score (BCS) were studied. The present study suggests that spent ewes of BCS 3.0 to 3.5 yielded quality carcasses with desirable lean and fat contents. Further, BCS system could be used for estimating carcass traits of sheep without slaughtering of animals. Spent sheep maintained on grazing and supplemented concentrate mixture at the rate of 2.5% of BW or *ad lib* were slaughtered at 45, 70 and 90 days of fattening. The study indicated that 90 days of feeding increased the carcass yield and desirable composition in term of lean, bone and fat contents over 45 or 70 days but its economic viability is to be assessed.

Carcass traits of broiler rabbits: Adult male rabbit provides 53.5% dressed meat yield and that of female 52.0%. Under semi arid topography, Soviet Chinchilla breed is found to be ideal meat producer than Grey Giant, White Giant and New Zealand White. However all genetic groups (Soviet Chinchilla, Grey Giant, White Giant and New Zealand White performed well and provide desirable meat production and quality traits. On the basis of muscle fibre diameter, it was suggested that production potential can be realized around 12 week of age or up to 2.0 kg body weight. Average daily gain significantly reduced with the advancement of age. The dressing yield was found optimum at 12 weeks of age. Further, lean content of the carcass increased while its bone content decreased with the advancement of age.

Value Addition of Meat

In meat processing wheat or chick pea flour (@3%) in meat product formulation resulted in better yield. Restructured roast from rabbit meat chunks, sausages from spent rabbit meat and mutton nuggets had very good consumer acceptability. For natural casings hydrogen peroxide (0.06%) or peracetic acid (0.1%) can be very effective deslimer for enhancing their keeping quality. The cost effective, highly acceptable mutton soup was developed. Technology for various value added mutton products was optimized and the products were evaluated for

physicochemical and sensory properties. Feeding of vitamin E, rumen protected fat and Khejri leaves to lambs resulted in improvement in lipid stability in mutton nuggets. enrobing of mutton nuggets increased flavor and overall acceptability.

Meat sausage: Sausages are ready- to- eat meat based foods. Sausages have evolved into a wide variety of flavors, textures, and shapes resulting from variations in ingredients and manufacturing processes. Sausage manufacture uses two methods for preparing the ingredients for sausage making complete homogenization as an emulsion prepared and coarse, medium or fine grinding is used to make non emulsion types. Sausages are meat product, which is prepared from minced and seasoned meat and formed into cylindrical shape by natural or synthetic casings. Though sausages originated in the western world, these products acquired universal popularity due to variety and convenience to the consumers. While artificial or synthetic casings are peeled off before the product is packed, small sized natural casings need not be removed. The product is generally unit packed for retail outlets.

Meat nuggets: Meat nuggets is one of the most popular products among the ground meat items and is generally used as a snack food or mixed with gravy. This product has a very good demand in urban India. Nuggets are partially or completely emulsion based product, contain less fat and are moulded manually or mechanically.

Mutton patties: Meat patty is one of the most popular ready to eat meat product and is generally used as filling for burger roll or sandwich. This product has a very good demand in metropolitan cities in India. Patties are partially or completely emulsion based product, and are moulded manually or mechanically.

Meat pickle: Meat pickles are shelf stable, traditional and ready to eat products. Pickling of perishable foods in vinegar or edible oil with added salt, spices and condiments provide ready to eat products with good shelf stability at ambient temperature. Low moisture and reduced pH are the two major factors contributing to shelf stability of pickles.

Mutton soup: efficient utilization of byproducts is important. After separation of meat from bones (i.e. deboning) the bone with leftover small quantity of meat can be used to extract juice for preparation of mutton soup. The deboned frames can be pressure cooked to obtain the broth. The broth so obtained is to be processed as per formulation. The cost effective, nutritious mutton soup can be made from byproducts like deboned frames.

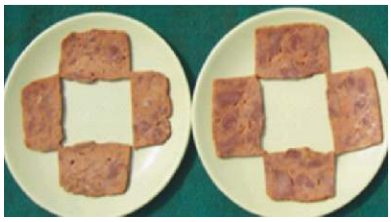
Enrobed eggs: Value added, convenience mutton product can be made using chicken eggs.

Meat loaf: It is ready to eat convenience meat product. This loaf can be used in preparation of sandwich. The mutton blocks are cut in to the slices of desired thickness by using meat slicer. These slices are then packaged and can be used for making meat sandwich.

Enrobed mutton nuggets: Variety of convenience meat based fast foods such as enrobed (coated) meat products have been popular both in developed countries and in our country by virtue of their versatility and superior sensory properties. Enrobing contributes multiple benefits like value addition, improvement of nutritive value and texture profiles as well as reduction of production cost. Application of edible coatings has been reported to extend shelf life and improve the quality of fresh frozen and fabricated foods. The mutton nuggets are coated with suitable ingredients and then deep fat fried. This gives attractive golden brown color and enhances palatability of the product

Mutton kofta: It is also known as meat ball. This is ready to eat convenience mutton product. The koftas can be eaten as such or can be added in gravy.

Restructured meat products: Restructuring is the technique in which meat is partially or completely disassembled and then reformed into the same or different. Reformed meat products are well-known and consist of meat pieces (usually minced meat or loose meat) which are bound together using a binder. In reformed meat products underutilized cuts and quality trimmings can be used. These restructured meats can be used for new product development, and upgrading and utilizing meat, of lesser economic value. A major benefit of restructured meat products is that they can be adapted to consumer needs for convenience, portion size, composition, and ease of preparation.



Broiler Rabbit Production

Rajiv Gulyani

Interest in rearing rabbit for meat and fur production has been generated in our country during the last two decades. Rabbit occupies a place, which is midway between ruminants and mono gastric animals. Like ruminants it can utilize greens and can perform satisfactorily on rations containing as little as 20% of grains. Its ability to convert forages into meat efficiently is of special significance for our country as there is abundant vegetation available. It is an ideal meat animal for a developing and populous country like India. The rabbit competes less with man for food than poultry and can, therefore, play an important role in hilly, tropical rain forests and legume, roughage and horticulture rich areas where there is comparatively less poultry penetration. It can also serve as an alternative to poultry in times of bird flu threat because of its white meat like poultry. Rabbits can be raised successfully in a backyard rearing system for the family and a small surplus for sale or as a large-scale commercial enterprise to supply large meat markets. It is estimated that a family raising a few does on locally available grain, forage and kitchen waste can obtain meat every week for domestic consumption or sale. Hence, small-scale backyard rabbit rearing can be a useful enterprise to improve the health and socio-economic condition of the tribals, rural and urban poor in our country. Similarly, large-scale commercial rabbit production has a great scope and can attract a substantial investment from entrepreneurs. Rabbit has a number of other attributes like small body size, short generation interval, high reproduction rate, rapid growth rate and early maturity. Its high quality meat is high in protein and low in fat, cholesterol and sodium, which is a boon for heart and hypertension patients desirous of eating meat. Its skin, which is soft and luxurious fur, can fulfill the demand for rabbit skins, which are either met through import or through illegal hunting of wild animals. An important by product obtained from broiler rabbits is the skin with soft luxurious fur. At present most of the demand for fur pelts for making fur garments is met out of illegal trade in pelts of wild animals and through import. Therefore, there is a good scope for obtaining good quality pelts at cheaper rates from broiler rabbits reared under farm conditions. Our country also has a large and thriving domestic fur industry mainly centered in Jammu and Kashmir. About 5 million fur skins are estimated to be imported every year, mainly from France, of which more than half are rabbit skins as they are cheaper alternatives to high priced furs and are affordable to the majority. Farm reared rabbits, particularly in high altitudes, can thus fulfill this domestic demand for rabbit skins and also relieve pressure on illegal hunting of animals and save valuable foreign exchange. Moreover, the fur produced in temperate regions is of superior quality as it is thick and has higher hair density and insulation capability. As the rabbit was introduced late in our country there are very few large rabbitries and most of the rabbitries fall under medium or small-scale category.

Advantages of rabbit production

The domestic rabbit by virtue of its special features, possessed by none other domestic livestock species, merits due consideration to be exploited as an important livestock species.

- The body size is small and requires comparatively lesser amount of feed which has little direct competition with human food. Further, it can be housed in small, inexpensive and easily constructed sheds/ houses.
- There are no religious inhibitions for the consumption of rabbit meat among non- vegetarian population.
- The gestation period of rabbit is short (one month) and it can be rebred within 24 hrs of kindling. This super-imposed with its high prolificacy (average litter size 6-8) provides an opportunity for fast multiplication.
- The animal is fast growing and approximately 2 kg live weight can be achieved within 12 to 15 weeks of age if managed properly.
- Rabbits can be reared on grain free diets comprising of forages, by-products etc.

- The rabbit meat is low in fat, cholesterol and sodium as compared to other meats like mutton, chevon, beef and pork and as such a boon for patients with heart ailment and hypertension.
- The skin of rabbit is a valuable by-product used to manufacture fur garments, toys, decoration pieces etc. It is soft and luxurious and commands a good price.

Rabbit meat production and consumption on large scale has been fully developed in European countries like France, U.K., Germany, Hungary, Italy, Spain and is showing an increasing trend in U.S.A., U.S.S.R., China, South American Countries like Brazil, Mexico, Columbia, Venezuela and African countries like Egypt, Algeria, Ghana and Morocco. In India rabbit meat production is still in initial stages. Despite good results shown by broiler rabbits in adaptation, productive and reproductive traits, it is yet to make a good impact on the farmers of North India but in Southern and Eastern states it is getting popularized and adopted.

Role of CSWRI in propagation of rabbit in the country

Taking in to consideration, the scope and potential of rabbit rearing in India, CSWRI introduced commercial rabbits in the public sector for the first time in the country by importing 60 New Zealand White (NZW) rabbits from UK in 1978. In 1979 another lot of 25 males and 100 females each of Soviet Chinchilla (SC), Grey Giant (GG) and White Giant (WG) were received under Indo-USSR protocol for agricultural development as free gift. These rabbits were initially reared at NTRS Garsa and later introduced at Avikanagar in 1983 to evaluate their adaptability and performance in semi-arid climate. The objective was to widen the scope of broiler rabbit rearing in most parts of the country as semi-arid type climate covers almost 60% of the geographical area of the country. The successful adaptation and performance of broiler rabbits at Avikanagar has opened a new avenue in livestock rearing for commercial purpose in our country. Majority of rabbit germplasm available in the country can be traced back to the original rabbit germplasm of CSWRI.

Broiler rabbit performance

Rabbits are highly susceptible to heat stress as they have few functional sweat glands and have a difficult heat output situation when environmental temperatures are high. In the semi-arid region, the rabbits show lower body weights from April to August and improvement in body weights as environment becomes favourable. Studies on thermoregulatory responses of SC and WG rabbits in the semi-arid environment have demonstrated that the period from October to March is favourable for rabbits while the April to July period is stressful. As compared to WG, SC is more tolerant to hot environmental conditions because of its ability to achieve higher respiration rates i.e., higher evaporative cooling.

The survivability of rabbits varies among different age groups. The survival rate in kits (0-6 weeks) ranged from 70.83 (NZW) to 83.17% (SC). During winter kits generally die of hypothermia and in summer due to hyperthermia. In weaner (7-12 weeks) and grower (13-24 weeks) the survivability varied from 82.89 (SC) to 95.85% (NZW) and from 93.70 (GG) to 97.38% (SC), respectively. In adult, it ranged from 82.44% in WG to 88.25% in GG.

The growth of the young during the suckling period, especially during the first three weeks, greatly affects their later performance. Apart from milk yield, the liter size and doe's nursing ability also influence the pre-weaning growth. The average birth weight ranged from 46.08 (BB) to 54.57 g (SC). The body weights at 6 weeks of age ranged from 708.1 (BB) to 764.4 g (WG). The 12-week weight ranged from 1554.60 to 1580.6 g showing no marked breed difference. The body weight at 12 weeks is of crucial significance as the broiler rabbit is usually marketed and slaughtered at this age. The growth is fastest during 7-12 weeks period. Under experimental *ad libitum* complete diet feeding system, average weight of 2.0 to 2.3 kg at 12 weeks has been achieved at this Institute. Now efforts are being

made to achieve 2.0 kg body weight at 12 weeks by increasing the milk yield of does and improving the feed accessibility to the weaner rabbits under routine management. The litter size at birth (LSB) ranged from 6.46 to 7.26 while the litter size at weaning (LSW) ranged from 4.92 to 6.17 in different breeds. High LSB and LSW were recorded in GG and WG breeds. Similarly, high litter weights at birth (LWB) and weaning (LWW) were recorded in GG and WG breeds. The average LWB and LWW ranged from 325.34 to 390.82 g and 3023.80 to 3488.22 g, respectively.

Rabbits are induced ovulator and can be bred within 24 hrs of parturition. The average number of kindling/doe/year and average number of offspring/doe/year achieved in the semi-intensive production system are 3.5 and 23.9, respectively while under intensive system it was marginally higher (4.0 litter/doe/year. Fertility is adversely affected in the semi-arid region as the semen quality of bucks deteriorates during summer and this condition continues up to the first half of the rainy season. Studies on reproductive efficiency of broiler rabbits revealed that the overall conception rate was 50.25% and number of services/conception was 1.98. Highest conception rate (53.33%) was recorded in SC, followed by WG (48.80%) and BB (46.80%).

Milk production by a rabbit doe is an important indicator of growth and health of young rabbits in their first month of life and is intimately related to the body weight achieved at the slaughter age of 12 weeks of age. Milk yield and nursing ability of does increases with parity order. The total milk yield of SC does was higher (4370.90 g) as compared to WG (4326.43 g) and BB (4179 g) in a 35 days lactation period. There is, however, a sudden decline in milk production in all the three breeds studied if lactation is continued beyond 28 days. Therefore, in order to take more number of kindlings per doe per year, it is recommended to go for early weaning at 28 days as by this time the young start consuming some solid feed as well as roughage and the role of milk in their diet declines.

About 70% of rabbit carcass is composed of edible meat as compared to 50% in chicken. Rabbit meat is also comparable to chicken in terms of low fat content (3.8%) and high protein (20.7%). Moreover the digestibility of rabbit meat is as high as 98.9%. Rabbit meat is in fact appreciated for its low content of total fat and cholesterol and high proportion of polyunsaturated fatty acids (PUFA) and phospholipids, which make rabbit meat a healthy meat for humans.

Broiler rabbit in hot climate

The performance over the years at Avikanagar has shown that broiler rabbits can be reared successfully in the hot semi-arid regions of our country which constitute roughly 65% of the total geographical area of our country and where temperatures reach 45-47°C during peak summer. Since Broiler rabbits are mostly reared indoors, these become most suitable for livestock production under prevailing and future global warming conditions. With a few modifications in their shelter management, they can tide over the difficult summer phase, which may extend beyond the two to three months period at present, but at an increased cost of production. Rabbits are highly susceptible to heat stress as they have few functional sweat glands and have a difficult heat output situation when the environmental temperature is high.

In a study undertaken at Avikanagar on the effect of season and breed on the thermoregulatory responses of broiler rabbits in hot semi-arid environment, we observed that winter and spring seasons are relatively comfortable than summer for broiler rabbits on the basis of their respiration rate (RR), which could go up to 450-500 breaths/min during hot summer temperatures of 35-45°C. It was also observed that SC rabbits could maintain relatively lower rectal temperature as compared to WG during peak of thermal stress by increasing the respiratory evaporative cooling through increase in RR, and that this breed characteristic in SC could be of help to tolerate high environmental temperature, which was manifested in lower mortality (15%) as compared to WG (40%). The severity of heat stress experienced by rabbit depends on a number of factors. The key ones include the actual temperature and humidity

inside the shed, housing type, the length of heat stress period, water availability, the degree of night cooling, ventilation and air flow, the size and age of animal, breed (native, exotic or crossbred), and density of fur and the level of production. Housing systems for rabbit should minimize the negative effects of natural environment on the animals.

Climate change and stress, in all likelihood, are going to impact seriously on animal productivity over the next decade and beyond. Production losses due to impaired physiology is quiet distinct. Thus there is an urgent need to understand these complex issues so that we can device suitable managemental practices to reduce the adverse effects of climate change. Proper shelter management has been known to mitigate climate related stress to a great extent. This assumes particular significance in rabbits as these animals are generally housed indoors where the micro-climate can be controlled. When productivity of other livestock becomes impaired, rabbits can play a crucial role in filling this gap. Day length plays a crucial role in rabbits and is responsible for the seasonality in reproduction observed in rabbits. This seasonality in reproduction can be overcome by providing artificial light to breeding does during short day length periods. At the same time, more emphasis can be given on selecting rabbit genotype which is more adapted to high ambient temperature and has better feed efficiency under stress. High ambient temperatures can cause infertility in breeding rabbits, bucks being more sensitive than does. Therefore, it is always advisable to provide a cooling system in the rabbitry during the hot periods to prevent male rabbits from becoming sterile resulting in lower conception rates in females. The does also exhibit poor receptivity, lower litter size, early embryonic deaths and decreased fetal growth if exposed to heat stress. Kits and weaners are particularly sensitive to hot and humid conditions, which causes rapid spread of coccidiosis and thereby heavy mortality due to enteritis. To overcome this problem, prophylaxis is employed against coccidiosis or breeding schedule planned in a manner so as to avoid kindling and weaning during the hot-humid months and instead intensive rabbit breeding and production is practiced during the remaining good part of the year to maintain the overall production. However, if the exposure is over long periods, the rabbits get acclimatized to constant stress situations, also termed as adaptation, to withstand the onslaught of adverse climate. Such adaptive changes are of advantage in terms of disease resistance and ability to withstand climatic stress but disadvantageous in terms of production performance. In general, growth rates of rabbits range from 10-20 g/day in the tropical regions compared to temperate countries where growth performance typically is between 35-40 g/day.

Augmenting reproduction in rabbits

Fertility and good body condition are closely related. One of the first body functions to suffer from poor feeding is the reproductive system. The ration should be properly balanced and proper amount of feed given to keep the rabbits in desired breeding condition. Rabbits that are abnormally fat or thin have impaired fertility, or they may become sterile. The ration, therefore, should be adjusted and breeding delayed until they are in proper physical condition. For those that are too fat, restrict pelleted diet and increase good quality greens/hay. For those that are too thin pelleted ration and greens should be fed in increased amounts. The does should, therefore, be checked regularly for their body condition by weighing them at regular intervals and through physical check-up. By passing the hand over the back of a rabbit one can determine the level of fatness. If the vertebras on the back are not felt easily on the palm, the doe is termed fatty and if the vertebras are felt easily and prick the palm, the doe is in poor body condition. In the commercial rabbit breeds the ideal body weight of a good reproductive doe is between 3.0 to 3.5 kg in the semi-arid region. Overly fat does are more likely to abort their fetuses. Molting or the development of new coat may tax the animal's vitality, which may lead to delayed conception in rabbits.

Higher percentages of fertile mating occur during autumn and spring in the semi-arid region. This is probably due to the adequate availability of good quality green fodder at these times. In contrast, a decrease in conception in the winter is usually observed in rabbits. This may be caused by inadequate feeding. In unheated rabbitries, the rabbits use more of their daily ration to produce heat to keep warm. Therefore, less energy is available for the

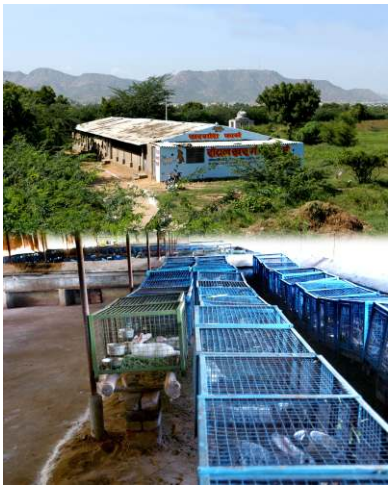
reproduction processes. To meet this increased body heat demand, it is recommended that the daily feed allotment to does should be increased by about 25% during winter. Studies on reproductive efficiency of broiler rabbits in the semi-arid region revealed that the overall conception rate was 50.25% and number of services/conception was 1.98.

Level of nutrition is also very essential for bucks and does to reach sexual maturity in time. After weaning, the food supply has a considerable influence on the rate of growth. Rabbits may be permanently stunted if their nutrition is poor, which may affect their overall productivity as adults. In such rabbits usually their sexual organs are stunted. In the breeds available at the Institute, the age of sexual maturity is 6 to 7 months in does and 7 to 8 months in bucks, but a minimum body weight of $\geq$ 2.5 kg is essential for the initiation of reproduction activity in these breeds. A breeding male should be fed approximately 10 to 15% above maintenance ration to keep it vigorous and in good health.

A doe usually consumes less than normal for 2 to 3 days before kindling (parturition), and this is normal as the developing fetuses exert pressure on the stomach to decrease appetite. She should be given small amounts of greens each day to tempt her appetite and to have a beneficial effect on the digestive system as when lactation begins, their feed intake will increase markedly. It is desirable to gradually increase the amount of feed offered to the doe for the first week following kindling until full feed intake is reached. Over feeding of the doe in lactation is not good as excessive milk production by an overfed doe may cause 5 to 6 day old kits to die of milk enterotoxaemia. Diseases account for only a small percentage of the mortality that occurs in the first week following kindling. Most of the losses during this time are due to improper feeding and management methods. Some losses may also be due to the doe failing to produce milk, which may be because the ration she received during gestation period was inadequate in quantity and quality.

Location, housing and equipment

Housing plays a vital role in broiler rabbit production in the semi-arid region. Housing and equipment depends on the location of the rabbit unit, the climate and the size of the enterprise. The main emphasis should be on a design, which is convenient and saves labour. The ideal temperature and relative humidity levels for rearing rabbits are 15-20ºC and 55-65%, respectively. Though the meat type rabbits are more adaptable to heat stress and can tolerate temperatures as high as 40°C, for maintaining productivity the temperature should be lowered to at least 30°C inside the shed during summer by sprinkling water on the “tatties” at hourly interval during peak hours and by thatching the roof. In general, the rabbitry should be well ventilated with provision of protection against strong winds and preferably surrounded by shady trees in the semi-arid region.



Rabbits can be housed either in hutch system or shed system. A hutch is a small self-contained unit containing cage and nest box and its own roof. It is used mostly for housing rabbit does in a backyard system. For housing single rabbits, rows of such hutches (minus nest boxes) can be constructed and fixed on the ground in the open under shady trees, like in orchards between rows of trees. This is a cheap system of housing which can be constructed easily using inexpensive locally available material such as wood, twigs, bamboo, elephant grass, etc. For a modern commercial rabbitry, the shed system with all-wire hanging system in a single tier is most suitable. In this system the cages are suspended from the ceiling, which is supported by an angular or tubular structure. The floor is kept “kutcha” to keep humidity and ammonia levels under control. The shed is surrounded by a three feet wall and the space above is covered with wire mesh to provide proper ventilation and protection. Cages can also be arranged inside the shed in a flat-deck two or three tier system. In tier system, the cages are placed on wooden or metal stands one above the other or in a step system. The latter is more convenient but the former though saves space, is more cumbersome to manage.

The rabbit cage is commonly made from galvanized wire mesh of 12-14 gauge. For the sides and roof the recommended mesh size is 1"x 2" and for floor it is 1"x ½". The dimensions of a cage depend upon the type of animal to be housed. A cage of 24" length x 24" width x 18" height is sufficient to house a single adult rabbit. Younger animals can be housed in groups of 2 to 3 in a single cage to overcome shortage of housing. For a kindling doe, a maternity cage of 36" x 24" x 18" dimensions is required which has an inbuilt nest box. A breeding buck should also be provided with a cage of 36" x 24" x18" dimensions to avoid space constraint during mating. Each cage is provided with a feeder and a waterer. These can either be an aluminum, steel or earthen bowl tied to the wire mesh or a J or L shaped feeder fixed at the front with arrangement to pour feed from outside and to eat from inside.

Broiler rabbit management

Feeding: Rabbits are fed concentrate feed in the form of a pellet of size 3-4 mm thick and 10-15 mm long along with roughages. Fodders most commonly fed to rabbits include lucerne, cowpea, berseem, oats, grasses, etc., and tree leaves like ardu, mulberry, robinia, etc., in fresh as well as hay form upto 60-70% of the rabbit diet and reduce the cost of feeding. Rabbits are usually fed fodder in the morning and pelleted concentrate diet in the evening in a fixed timetable. An ideal rabbit diet is a complete pellet diet containing concentrate + roughage. The pellets are offered at @ 50g/day to weaner, 80g/day to grower, 100g/day to adult and 150g/day to pregnant/lactating does.

Watering: The frequency of watering depends upon the season. During winter watering twice a day is sufficient but during summer it may be necessary to provide water 4-5 times a day. In other parts of the year 2-3 times a day is sufficient. However, water should always be available to kindling and lactating does.

Breeding: The age at first service is 6-7 months when the doe usually attains a body weight of 2.5-2.7 kg. Mating is preferably done early in the morning or evening i.e., during cooler periods of a day. For mating the doe is always taken to the buck's cage and never *vice versa*. Since there is no cyclicity in rabbits, the doe can be taken to the buck anytime. If the doe is in heat (receptive) she will readily lift her rump and assume the lordosis posture to allow mating. On successful mating the buck will fall to one side and may also produce a typical cry. Since the whole process is over quickly, the mating process can be repeated after 5-10 minutes. After 10-12 days of mating, the does are diagnosed for pregnancy by palpation of the abdominal area between the hind legs. The embryos are of the size of marbles and distinguishable from the fecal pellets. These can be felt by rolling them between the forefinger and thumb. If the doe is found non-pregnant, it should be mated again immediately.

Kindling: The gestation period in rabbit is 30-32 days. The pregnant doe is shifted to the maternity cage on day 28 of gestation and provided with bedding / nesting material like jute wool, wood shavings or dried dub grass in the nest box for nest making. The doe herself makes the nest by mixing the grass with the hair plucked from her chest. The doe should not be disturbed at the time of kindling. As each kit is delivered, she licks it clean and nurses it. The whole process is usually over in 30 minutes. Majority of the kindlings take place during the night or early morning on day 31. The nest box should be inspected daily for dead or weak kits and to make sure that the nest is dry. The doe usually nurses her kits once a day for 3-5 minutes only and so is given access to the nest box once a day. This allows the kits to sleep long and there is no danger of contamination of nest or accidental crushing of kits by the doe. During the lactation period the doe is fed adequately and provided water round the clock.

Fostering: Generally a doe can take care of 6-8 kits. All the kits in excess of 8 should foster to a doe that has a small litter. Fostering can only be done among does, which have kindled within 2-3 days of each other.

Weaning: Since the young ones start consuming some solid feed (apart from milk) after 21 days of age, they can be weaned or separated from the doe between 4-6 weeks of age. Early weaning leads to better survival and more number of litter/doe/ year. Care should be taken to adjust the feeder, waterer and hay rack to the height of the weaner for proper accessibility.

Sanitation: Good sanitation is a pre-requisite for controlling disease in the rabbitry. The cages should be cleaned daily. Manure and hair should be removed from cages, floor and stand regularly and not allowed to accumulate. The best way of disinfecting cages is by burning them with the help of a flame gun or blowlamp. The cages should be routinely disinfected and the shed floor sprinkled with lime 1-2 times a month. The "kutcha" floor mud should be replaced every 6 months.

Diseases: Diseases and death are an integral part of any livestock operation**.** The same is true in rabbit rearing. Mortality usually averages between 20-25% of all animals born in the semi-arid region. This high rate of mortality in other livestock enterprises would be very discouraging but is tolerable in rabbits because of its short generation interval and faster production. Since most diseases occur due to management mistakes, it is possible to keep rabbit diseases at a minimum. Ventilation, sanitation and observation are three of the most important factors involved in disease control. Less respiratory problems are encountered in well-ventilated rabbitries. The two most important specific rabbit diseases are pasteurellosis and enteritis. Pasteurellosis is caused by the organism *Pasteurella multocida* and this term covers a multitude of clinical conditions like snuffles, pneumonia, abscesses, weepy eyes, orchitis, metritis and wryneck. The first signs of *P. multocida* infection are snuffles or cold. Strict isolation / culling and treatment with antibiotics will control the problem. Ventilation is very important as both ammonia levels and humidity are involved in the transmission and development of snuffles. If snuffles is allowed to untreated the number of cases increase and rabbits start dying of pneumonia. Pneumonia is one of the leading causes of death in rabbits. Another major cause of death in weaner/grower rabbits in the semi-arid region is the complex of diseases called enteritis (enterotoxaemia, mucoid enteritis, coccidiosis and Tyzzer's disease). Other common diseases encountered in rabbits are mastitis, syphilis, sore hocks, malocclusion, pregnancy toxemia, ringworm, myxomatosis, mange and ear canker.

Angora Rabbit Production

J.B. Phogat and S.R. Sharma

Animal fibre had always been preferred by mankind to cover and protect from external environments both in raw and processed form. With the emergence of new innovations / technologies, the animal fibers use had attained newer heights in global scenario and elitist of the fashion garments are based on such fibers. In addition, a significant GDP of many countries is governed by the animal fibers primary by sheep wool (fine type). Additional four fibers - Mohair, Angora, Cashmere and Alpaca are also used. In India, use of Angora fibre in manufacturing of apparels, knitwear products, woolens and other textile products is significant and its demand is increasing with the time. Hairs or wool obtained from the Angora rabbits are known as Angora, which is considered as one of the noble fiber and is preferred over Cashmere, Mohair, Wool and Alpaca due to its fineness, warmth, fluffiness, odorless, lightness and anti-static property to repel the dirt. In addition, Angora being about 8 times warmer than sheep wool and for this reason, it is used either in pure or blended form for making the garments, throughout the world. Since, blending of angora is preferred with other fibers to make yarn and other products; it is required in very little quantity.

Historically, rabbit domestication can be traced to the late Middle ages and dates back around 1000 to 800 BC. Around 116-27 BC, the rabbits were thought to be kept in enclosures called *Laporaria* (stone walled pens) for rearing and domestication of rabbits was attributed to catholic monks. With passage of time several types of rabbit were evolved and during the 16th century, several breeds of rabbits were known. Rabbits were classified as early as 1606 by Olivier de Serres, into three types, *viz*. wild, semi-wild or warren (raised inside walls or ditches) and domesticated (hutch-bred) rabbit. Angora rabbit is considered to be originated in Ankara, Turkey and spread from there to Europe and other parts of the world.

The Angora rabbit industry came into existence in Europe during 17th and 18th centuries and the use of Angora in garments was appeared in 1870. The modern Angora industry based on intensive rearing combined with selection was started in 1930's. Later, Americans developed several breeds through selective breeding of rabbits imported from Europe. At present, there are about 45 recognized breeds of rabbits in the world with total estimated population of about 709 million rabbits. Four major Angora rabbit breeds recognized by the American Rabbit Breeders Association (ARBA) are English (British), French, Giant and Satin, of which French and German are two major commercial Angora breeds. Angora rabbits are reared throughout the world, both for meat and fibers because of some of the husbandry advantages associated with these over other domesticated livestock. The advantages are:

- Angora rabbit rearing can be practically done under any set up like rural, peri-urban and urban.
- The value of raw Angora wool per unit of weight is 40 to 50 times higher to that of equivalent greasy wool of sheep.
- One kg Angora could be produced by 30% less digestible energy as compared to 1 kg sheep wool.
- Angora rabbits are herbivore and do not compete with human for food.
- Space requirement of Angora rabbits is less as compared to other livestock.
- These animals are excellent converter of plant proteins of a little value into high-value animal protein in the form of meat and wool.
- About 50 Angora rabbits could be reared on kitchen waste.
- About 100 Angora rabbits can be managed easily by a household without affecting daily routine.
- Angora rabbits with concurrent pregnancy and lactation with short generation interval can multiply very fast. A single female can produce as many as 30-40 offsprings in a year.

- Angora is considered premium product; as these are directly influenced by the fashion industry. Moreover, it can be blended easily with natural and synthetic fibres to produce quality products, which had demand in most of the developed countries.
- Angora has been found to possess medicinal properties and its garments are recommended for arthritis because of its electrostatic properties.
- Angora rabbit meat is categorised as white meat, which is rich in poly unsaturated fatty acids and low in cholesterol. Meat is usually advised to persons having cardiac problem and hypertension.
- Rabbit manure is very rich in nitrogen contents and could replace inorganic urea on per unit basis in agricultural and horticultural crops. It can be used for organic farming, thereby, indirectly yielding higher returns for agricultural and horticultural crops or products.
- Rabbit faeces can be used for vermi-composting for additional income from sale of compost. Moreover, dried rabbit faeces can be added up to 10% in the ration of rabbits without affecting production and thereby, reducing the feed cost.
- Angora rabbit rearing can sustain multifarious activities in the area and can generate employment for youth, woman and skilled artisans, thereby, improving the social status.
- An Angora rabbit unit comprising of about 100 adults rabbits can generates an additional income of about Rs.3000-4000 per month.
- More so, in many developing countries, with shrinking land holdings due to continuous increase in population, reduced grazing areas and changing climatic conditions; the traditional livestock rearing has become difficult and uneconomical and there is shifting towards smaller sized animals like rabbits for steady and sustainable income, and nutritional security against protein hunger.

In India, rabbit rearing of indigenous stock as a pet had been a fancy since ages. The rabbit as a commercial livestock was introduced into the country by private sector long back but was kept in isolation. The Angora (British Angora) rabbit farming was started during 1962 by Mr. Butter Worth at Dharamshala in Himachal Pradesh (the then Punjab). Thereafter, some individuals and agencies made efforts to spread Angora farming in Kullu, Mandi and Kangra districts of Himachal Pradesh and Nilgiri hills of Tamil Nadu. Around 1979, Indian Council of Agricultural Research (ICAR) established the Division of Fur Animal Breeding (DFAB) at Garsa, Kullu (Himachal Pradesh) under the Central Sheep and Wool Research Institute (CSWRI) to initiate the scientific/ research work on British Angora (BA) and Russian Angora (RA) imported from UK and USSR, respectively under Indian sub-temperate conditions.

Initially, the research efforts were initiated to understand and evolve suitable strains adaptable to local conditions and develop packages of practice for small and large-scale production. After initial success in its endeavors, the North Temperate Regional Station (NTRS), Garsa introduced German Angora (GA) in the year 1986, 1992 (purchased locally) and 1997 (imported from Germany) and is continuously improving the Angora rabbit germplasm by scientific breeding and management. The improvement in GA, BA and RA stocks (breeding and general flock) at NTRS Garsa has been consistent and continuous with passage of time. Moreover, the crossbreds as well as purebred GA have better adaptability, less reproductive problems, better mothering ability, higher wool yield and better wool quality under natural rearing conditions in India. The improvement in the germplasm could be judged from the wool production performance and fibre characteristics detailed in Table 1 -5.

Table 1. Wool yield (g) in German Angora breeding stock

Clip\Year	2001	2002	2003	2004	2005
1st	164.3±4.7(54)	152.8±2.9(97)	170.4±4.3(67)	199.2±3.1(87)	212.4±2.1(99)
2nd	150.7±5.6(49)	157.5±4.6(96)	153.9±4.7(62)	194.8±4.2(84)	189.8±2.1(91)
3rd	147.7±4.2(46)	159.5±4.6(92)	161.4±4.9(59)	169.2±3.9(79)	184.3±3.5(84)
4th	150.9±3.5(47)	165.3±4.0(91)	185.0±5.0(56)	172.3±3.7(73)	184.5±2.4(71)
5th	143.5±5.2(10)	177.9±6.8(31)	205.0±5.2(51)	193.4±4.5(65)	207±1.8(130)
Annual	**757.1±5.3**	**813.0±4.3**	**875.7±7.5**	**928.9± 6.2**	**956.7±4.8**

Table 2. Wool production (g) in general flock of German Angora

Clip\Year	2001	2002	2003	2004	2005
1st	122.9±3.8 (208)	110.5±2.9 (433)	157.7±1.9 (304)	165.3±2.0 (369)	175.5±1.6 (274)
2nd	145.2±2.4 (168)	142.3±3.7 (379)	163.6±2.5 (178)	173.2±2.1 (294)	177.1±1.5 (236)
3rd	163.3±2.4 (160)	157.4±4.8 (274)	152.2±2.5 (140)	153.2±1.9 (229)	169.9±1.6 (219)
4th	139.6±3.1 (153)	138.8±4.5 (261)	151.8±3.1 (120)	153.0±2.2 (167)	155.5±1.6 (197)
5th	133.7±2.6 (125)	146.7±4.4 (216)	178.7±3.6 (96)	172.5±2.6 (136)	164.0±2.0 (104)
Annual	**704.7±5.8**	**695.7±7.8**	**804.0±2.6**	**817.6±4.5**	**842.1±4.1**

Table 3. Wool production (g) in adult BA rabbits

Clip \Year	2001	2002	2003	2004	2005
1st	92.5±8.1 (16)	107.3±2.4 (40)	135.6±6.7 (31)	155.6±4.7 (39)	144.9±4.4 (28)
2nd	108.3±11.7 (15)	108.3±3.9 (38)	114.7±5.9 (29)	135.0±5.6 (38)	129.4±5.8 (26)
3rd	99.7±11.9 (15)	110.8±4.1 (37)	124.8±4.5 (29)	98.3±4.8 (32)	127.3±6.0 (23)
4th	92.1±5.2 (14)	107.2±3.0 (37)	151.6±4.9 (25)	106.9±6.0 (22)	128.0±5.9 (11)
Annual	**392.6**	**433.6**	**526.7**	**495**	**529.57**

Table 4. Wool production (g) in RA rabbits

Clip \Year	2001	2002	2003	2004	2005
1st	112.7±6.2 (36)	99.5±3.7 (29)	116.9±6.1 (23)	137.7±4.5 (32)	147.5±3.9 (23)
2nd	116.9±5.0 (35)	119.3±5.8 (28)	107.6±4.7 (21)	121.4±4.7 (28)	136.1±3.7 (23)
3rd	102.8±4.9 (32)	103.6±5.4 (28)	121.8±4.8 (20)	95.7±4.6 (13)	136.2±5.4 (22)
4th	94.1±3.2 (31)	117.6±5.3 (28)	129.4±5.1 (17)	99.7±9.3 (6)	136.7±2.0 (3)
Annual	**426.5**	**440.0**	**475.7**	**454.5**	**556.39**

Table 5. Fibre characteristics of wool from different breeds of Angora rabbits

Genotype	Fibre fineness µm		Fibre length mm		Medullation %
	80's	Present	80's	Present	
GA	13.48	12.55	41.3	54.9	2.62
BA	11.80	13.20	45.5	61.5	3.12
RA	11.77	12.75	48.9	56.9	2.88
GxB	11.56	12.73	42.2	60.3	2.89
GxR	12.45	12.59	52.5	62.1	2.60
GxRxB	11.64	12.68	55.7	61.9	2.70

Hilly regions of the country (between 4000 and 6000 ft. above mean sea level) with colder climate have been found to be suitable for Angora rabbit production under natural and conventional system of rearing. The Angora rabbit can be reared successfully in areas having temperature range between 5 to 30^{0}C and relative humidity levels of 60-70% under conventional housing system. However, between 15-25^{0}C of ambient temperature the Angora feels much comfortable and produces more wool. On the other hand, at around 30^{0}C temperature, the feed consumption reduces as much as by 30% and the wool yield starts decreasing significantly. Further, quality of fibers is influenced by the environmental conditions like temperature, humidity, rainfall, etc., to a larger extent. Unfortunately, these natural climatic changes cannot be avoided and producers or farmers only have to modify the rearing systems and introduce new innovations to mitigate the influence of climate change.

Nationally, the North temperate Regional Station, Garsa has now been recognized as germplasm centre for pedigree Angora rabbits and making superior germplasm available to farmers, Universities, NGOs, different developmental agencies and private entrepreneurs in the states of Himachal Pradesh, Jammu and Kashmir, Uttarakhand, Rajasthan, Sikkim, Meghalaya and West Bengal (Darjeeling hills). In addition, training program on Angora rabbit farming are conducted regularly for farmers, NGOs, private entrepreneurs, etc. and technical knowhow is provided to the stake holders. An appreciable number of rabbitries had been established in the states mentioned above, which are producing the Angora to meet the local demand of the handlooms, khadi institutions, wool cooperatives and textile industries. With the initiatives and aid support from UNDP through the Central Wool Development Board (CWDB), the Angora rabbit farming, aimed at generating the employment and foreign exchange earning potential, have been extended to the hilly areas of Uttarakhand, Darjeeling and Sikkim. On account of such integrated efforts, these states also making steady progress in Angora farming and local germplasm centers are also being set up for providing rabbit germplasm in these states.

In India, the fluctuating angora wool prices have steadily acted as impediment in adoption of Angora rabbit farming. The situation has become more drastic not only in India but in rest of world as well, consequent to WTO agreement, as coarser Angora from china is available at cheaper rates leading to slump in the global markets. Over the years, fluctuation of Angora market price in India ranged from Rs 300 -1200 per kg and never stabilized. Due to yearly variability in Angora prices, the producers are getting discouraged and confused. Since, the cost of all inputs has been increasing steadily, the Angora producers at present are hardly meeting out the expenses from the sale of Angora. Moreover, there is no relief or intervention from state or central government to Angora producers. Because of all these circumstances, Angora producers are feeling helpless.

To get the Indian Angora rabbit farming revitalized, make it profitable enterprise and to protect the producer's interests, there is a strong need to redraw the strategies against price fluctuations, marketing, climatic changes, etc., so that Angora rabbit farming could be undertaken on large scale. Few of the steps in this direction could be:

- Angora is a premium produce with huge export potential. Hence, private entrepreneur should be encouraged for farming under controlled environment rather than restricting its propagation in the hilly areas only. Moreover, in National context, goals must be set for export of angora yarn and its products than raw fiber.
- Introduction of contractual system of Angora rabbit farming with concept of Angora based farming (which includes all components from production to utilization) than Angora farming to make angora more demands oriented and profitable.
- Availability of assured market through linkages between the Angora producer and processor (wool processing industry, handlooms, etc.), and remunerative prices for Angora through market intervention scheme in the form of minimum support price (MSP) and regulation of Angora import under OGL system by the government.
- Development of organized and strong marketing facilities for Angora and its product, regulated by independent national agency.

Transfer of Technology

Rajiv Gulyani and L.R. Meena

At CSWRI, Avikanagar, the Division of Extension and ORP (Operational Research Project), was later named as Division of Transfer of Technology and Social Sciences in 1975 with the objectives to transfer the technologies of sheep and rabbit production as well as fibre technology to farmers, rural artisans and wool industries. The work on TOT in sheep was initiated through three sub-centres at Arain (Ajmer), Lamba Harisingh and Malpura (Tonk) by covering about a total of 20 villages. Later the Arain centre was shifted to Diggi (Tonk) in 1982. Initially the division dealt with operational research project (ORP) on sheep and wool development with emphasis on cross breeding of local Malpura sheep with Russian Marino and half bred rams. The programme was supported by health coverage, feed resource development, nutrition, technical literacy and marketing of wool and animals. Later on this programme was strengthened with Lab to Land Programme in 1979 and thereafter through Transfer of Technology Programme in 1989 onward. At present the institute has its centres in Malpura, Chavandiya, Beepur and Sanwariya and covers more than 50,000 sheep in Tonk, Ajmer and Jaipur districts of Rajasthan under Sheep and Wool Improvement Scheme sponsored by Central Wool Development Board.

Experiences in sheep extension

Operational Research Project (ORP): The ORP on sheep and wool development programme was initiated in 1975 by adopting 20 villages. The major findings exhibited that the flock size varied from 10 to 150 sheep. On an average the flock comprised of 48 ewes, 21 lambs and one ram at the time of survey. Bigger flocks had 1-3 rams but smaller flocks normally did not have ram. The body weight of ewes varied from 20 to 25 kg and rams weighed up to 45 kg. The lambs continued to suckle for 5 to 6 months. There were very few migrating flocks in the area. However, 22% flocks do migrate to smaller distance (up to 20 km) during the lean period (April to June). Ponds were the usual source for watering the flocks; however they were totally dependent on wells in summers. The sheep were watered 2-3 times in a day in summer and once in rest of the seasons.

Sheep were grazed around watering points about 11-12 hrs in lean periods and about 8 hrs during rainy season. The lambs were grazed along with adult sheep. About 18% sheep farmers fed pala and 19.5% fed methi to their sheep during summer season. The quantity of green fodder did not exceed 350 g/ewe/day. During lean period, some breeders fed cluster bean stover, barley and wheat straw etc. About 50% sheep breeders offer supplementary feeding to rams during breeding season and lean period. Rams were always kept with the flock. No concentrate mixture or green fodder was given to flush ewes. Usually no good shelter was provided to flock. Only 22.5% breeders had small kachcha houses and 37.5% had small thatched roofs to save their sheep from rainy and cold weathers. The covered area was hardly 9 square feet per sheep. Though, the sheep came into heat round the year but the major breeding season was after rains in monsoon when about 42% sheep came into heat. About 35% sheep came into heat in February to April. The sheep were covered with natural service with native rams only. Artificial insemination was not practiced in the area. No treatment was given to naval cords of the lambs' after birth. The average birth weight of the lambs was 1.93 kg. The average marketing age of the lambs was around 10 month. No concentrate mixture was given to lambs raised for marketing. Most of the breeders sold the lambs to middleman on head basis.

Most of the breeders washed their sheep before shearing but they did not use to dip after shearing. Shearing was done by khatik only, no shearing machine was practiced. Shearing was done twice a year except in few cases a third shearing was also done in June before monsoon. An average flock of 48 sheep yielded 38.25 kg wool with an average of about 800 g/sheep/yr. Skirting of wool was unknown to the farmers. Most of the breeders sold the wool to

middle man, while the wool was still on sheep, on the basis of per animal. The breeders did not practice docking and castration in sheep. Teaser rams were not kept in the flocks. The prevalent diseases were enterotoxaemia, worm infection, ecthyma, naval ulceration, piroplasmosis and FMD etc. The mortality rate in sheep was found to be 18.78% before the ORP was started in 1975. Enterotoxaemia was reported after grazing of sheep in *Rabi* harvested fields and its occurrence continued up to September. Bottle jaw was seen round the year, however, it was more prevalent in February-March and July to September. Foot infection and Piroplasmosis were prevalent in rainy season while FMD occurred in winter season. Vaccination against enterotoxaemia and Sheep Pox was not much known amongst the breeders. The findings formed the basis for application of improved technologies in the field in the future.

Institute Village Linkage Programme (IVLP): This programme paved a new path for economic upliftment of resource poor farmers through participatory approach. Through participatory approach, shepherds problems were identified and prioritized as per their need and available resources. Shepherds along with scientist's team in participatory mode developed technical modules that highlighted their problems. Interventions were designed to test the technology for solving the constraints which may restrict the increase of benefit from sheep rearing. Shepherd practice and Institute developed practices were tested under shepherd management and resources situation and replicated according to convenience. In such a way shepherd and Institute participatory approach enabled us to solve the constraints being faced by the sheep owners. Non-adoption of improved technologies developed at various research Institutes is one of the important reasons for low productivity of sheep. Inappropriateness of technologies resulting from non-consideration of farmers' real life situations is recognized as main reason for non-adoption. After going through the results, it was felt that such model of sheep production should be replicated in every village for increased prosperity in rural areas.

Impact of transferable technologies

Supply of superior sheep germplasm in field for flock improvement: The improved germplasm (Bharat Merino, Avikalin and selected Malpura sheep) are regularly distributed to interested farmers for breeding purposes. The survey in the villages (around CSWRI) indicated that there are mainly three types of sheep, native (Malpura), crossbreds (half breds) and mixed type (quarter breds and natives). The crossbreds weighed more at 3 and 6 month of age than the other two types. The wool yield was 25% higher in crossbreds than natives. The wool quality in terms of diameter and medullation was better in the crossbreds. However, due to lack of grading and organized marketing the crossbred wool does not fetch better price. Only well to do farmers come forward to rear crossbred sheep. It was observed that farmers prefer Marwari and Kheri type of sheep as they are sturdy and well adapted for migration. Avikalin ram which need special care during lean period (April-June) has shown considerable improvement over its native contemporary Malpura breed with regard to GFY (greasy fleece yield) and wool quality. Avikalin can be used as an improver breed for cross breeding the coarse wool breeds to increase carpet wool production. The results obtained from Bharat Merino revealed that the genotype is promising to substitute the import of fine wool sheep as an improver breed. The comparison of growth performance of genetically improved Malpura rams distributed to the farmers' and their base line appraisal showed that the performance of progeny of genetically improved rams was better than base line under local feeding system. These results clearly establish the superiority of genetically improved rams over local bred under local conditions. In last 10 years (2001-2010) Institute has supplied 469 superior ram to farmers on book value. Besides rams, Sirohi bucks and broiler rabbits were also supplied to farmers.

Application of improved health technology in farmer flocks: Sheep health services were provided to the breeders at their doors. The sheep were regularly treated for different ailments, strategic drenching during monsoon and vaccinated against enterotoxaemia and sheep pox through annual flock health calendar. Prior to adoption of health

calendar for mortality in farmers flocks was around 22-25% in 1976. The planned health inputs resulted in reduction of mortality to around 12-13% in 1984-85 and around 5.0% since last 2 decades. Economic consideration revealed that a farmer maintaining a flock of 100 sheep can save around Rs 7000 per annum just by preventing the animals against diseases to avoid mortality.

Artificial insemination in the field flocks: The CSWRI has developed protocols for artificial insemination and estrus induction and synchronization in sheep. This can provide speedier multiplication of elite germplasm of sheep as well as produce more useful animals from indigenous surrogate ewes. With more facilities in terms of infrastructure the semen of better quality animals can be preserved and supplied to the field flocks so that the semen of better quality animals can be used for betterment. In this regard technologies have been tested in field conditions. The field studies on artificial insemination have showed about 55.49% successes in farmer's flocks. Given the relatively low input and significant return, artificial insemination of sheep is beneficial for maximum utilization of elite rams. The effective use of AI in sheep flocks will allow spreading the genetic influence over more progeny. AI in combination of estrus induction and synchronization is gaining popularity in recent times due to better awareness among sheep farmers of its benefits in terms of additional lambs and more income every year.

Improved feeding practices for sheep farmers: The Institute has developed technologies for utilization of various feed resources, agricultural waste and industrial by-products in sheep feeds and established feeding technologies to improve the growth rate in lambs after weaning. In field condition the surplus lambs are marketed at 20 to 25 kg body weight achieved at 9 to 12 months of age. Whereas, under intensive feeding on 50:50 concentrate and roughages based ration, 25 kg finishing weight could be achieved at the age of 125 days. A farmer raising 100 lambs unit for mutton production required to invest Rs 9200/- as non-recurring and Rs 66000/- as recurring expenditure and could receive a total of Rs 71250/- from live animal sale to contractor or Rs 82500/- if slaughtered. Thus a net profit of Rs 5250 - 16500/- in 90 to 100 days of feeding could be obtained. In addition to routine grazing, the concentrate supplementation @ 1% of the body weight improved the body weight of lambs which was successfully demonstrated at different production stages. Supplementation to sheep during later part of pregnancy resulted in 31.54% increase in birth weight of lambs over the control which gave Rs 493.00 as net return with 3.95 benefit: cost ratio.

Complete feed block using roughage and concentrate: Most of the quality roughage have low bulk density, which create problem during storage and transportation. These problems are overcome by converting them into complete feed blocks (CFB). The CFB consisted of roughage and concentrate in 70:30 ratios with 5 % of molasses for easy binding. The cost of feed block including cost of preparation was Rs 6.00/kg. The blocks have many advantages like ease in transport, palatable in nature, lower in space requirement for storage and lower losses during transport.

Technology for fat lamb production: Production of fat lamb is a promising commercial mutton production programme that can prove as a boon for meat industry. Malpura weaner lambs (2 months age) are capable of achieving 25 kg body weight at about 5 months of age under intensive feeding on composite ration of the ratio of 60% concentrate and 40% roughage. The major advantage of this technology is that sheep owners need to rear the animals only for about 5 months. Further, farmers will get the handsome profit after 5 months and this profit would be at par or even more than when the lambs are reared for 12 months under extensive grazing system. By considering all the inputs required for raising the lambs to attain finishing weight of 25 kg it is estimated that net profit of about Rs 370.00 per lamb on slaughter basis and Rs 100.00 on live animal sale basis can be obtained.

Urea-molasses-mineral enrichment of poor quality dry roughage: Low quality of nutrients restricts the utilization of dry and non-conventional roughage by ruminants. The treatment of 100 kg dries roughage (straw+ stover/grasses) with

urea (1kg), mineral mixture (1kg) and molasses (10kg) resulted in better utilization of poor quality roughages by adult ruminants.

Mineral mixture for improving production, reproduction and health in sheep: It consisted of di-calcium phosphate (73.90%), calcium carbonate (6.50%), zinc sulphate (0.10%), copper sulphate (0.10%) and sodium chloride (19.4%). At the dose rate of 40-50g day in cattle/buffaloes and 25-30g/day in sheep and goats results in enhanced milk yield and weight gain, reduced diseases incidences, and improved wool yield and quality

Feed and fodder resource development: Feed and fodder resource development programmes are being undertaken to encourage the sheep breeders to adopt newly evolved feed and fodder technologies keeping in mind the rejuvenation of degraded pasture lands though supply of good quality grass and legume seeds along with tree species to provide leafy fodder to animals. From 1994 to 2010, a total of 21548 tree saplings have been provided to sheep farmers. A total of 1387 field demonstrations were conducted on improved genotypes of fodder species along with supply of chemical and organic fertilizers, soil amendment in the form of green manures, crops seed and gypsum. The stocking rate on common property resource was 1.87 cattle, 0.69 buffalo, 2.06 sheep and 1.10 goats per acre. Protein content in pasture biomass in these pastures is very low (3-4%) in comparison to improved pastures (7-8%). To encourage agro-forestry systems, 50,000 tree saplings were supplied to sheep farmers for plantation on agriculture land and common pasture land. Reseeding pasture with cenchrus and clitoria gave 5-6 times more yield than the grazing lands in the villages. By introducing silvi-pastoral system 6-10 q/ha of dry fodder was harvested. Farmers in TOT area realized that with the protection of grazing lands and development of silvi-pasture, much more fodder could be produced than what was usually available from common grazing lands. However, gram panchayat had operational difficulties to continue them as protected pasture lands. The farmers who had planted fodder cum fuel trees were also able to get additional fodder from these trees. The pasture development programme in the State is being undertaken in association with government and non-government organizations and as a result of these demonstrations there is an increasing demand of fodder seeds in the area. The demonstrations motivated the sheep breeders to undertake improved methods of cultivation as well. Several management and biological techniques viz. closure sowing, introduction of improved grasses and legumes, fertilization and cutting techniques have been standardized for enhancing biomass production and quality of these grasslands.

Wool quality evaluation and utilization: The wool quality from sheep of ORP area was evaluated to demonstrate the improvement due to crossbreeding programmes in their flocks. Village artisans were trained regularly on the utilization of wool in the cottage sector. In recent years, women in particular were trained to spin Bharat Merino wool on hand charkhas and production of sweaters and pullovers. It was realized that though technologies were developed for wool utilization (as such or in blends with other fibres), but these could not be much utilized by the weavers, artisans and even by the industrialist mainly these do not match according to their requirement. Regarding value addition of the raw wool, awareness on sheep preparation for shearing, practical skill in selection of shearing tools, equipments, shearing site and preparation of clip and marketing of wool has been developed among the sheep farmers. In general 20-25% farmers sold their wool on weight basis against the sheep head basis (80-75%). Sale of wool on weight basis thereby enhanced the income by Rs 5-6/kg wool as compared to sheep head basis. Lack of proper grading of wool before marketing coupled with the highly unorganized nature of the farmers expose them to the exploitation by the buyers.

Handloom woven blankets technology for rural artisans: The blending was carried out with fine wools of around 20 and staple length below 50mm having insignificant heterotypic fibre component. The crossbred sheep wools of this low fibre length can not be utilized for apparel manufacturing. The blended yarns prepared in the ratio of 70:30 and 50:50 of native and crossbred sheep wools were spun on woolen system and approximately 2.5±0.5 Nm yarns were prepared. After dyeing the yarns, the blankets of stripe and check designs were prepared on handlooms and a standard weight of approximately 2.5kg. The cost of blanket was around Rs 450.00 per piece.

Technology for wool and camel hair blended products: Since Rajasthan and adjoining states have a sizeable population of camels, nearly one million kg of camel hair becomes available. In order to promote their utilization and to derive economic value, grey camel hair was blended with wool in different proportions after grading it according to colour and fineness. The results indicated that 30% blend of camel with native wools yields best results. The yarns were spun on woolen system. Similarly, the carpet samples also performed equally well. Camel hair is generally available @ Rs 15/kg as against Rs 60/kg for wool. Thus, the camel hair blankets are cheaper by Rs 50 or so per piece. Similarly handloom woven carpets may be cheaper by Rs 100 to 125 per square meter.

Hand made felts production technology: Inferior grade rabbit wool, which had little textile application for good quality goods, was blended with short length fine crossbred sheep wool in various proportions. The blend optimization studies revealed that up to 40% inferior rabbit wool can be blended with wool for making superior quality low weight extra white hand made felts. These felts can be converted into value added products like jackets, women ruffles etc. Little embroidery work further enhances the value addition. Studies revealed that such products would have greater demand providing employment in the rural/cottage sector.

Survey of sheep breeders: The socio-economic survey conducted on sheep breeders in TOT areas indicated that out of the total adopted sheep breeders 28.4 and 7.0% belonged to Schedule caste and Schedule tribe communities. Sheep farming and agriculture were the main occupations of 45.8 and 53.5% farmers, respectively, while 55.6 and 24.8% have sheep husbandry and agriculture as subsidiary occupations respectively. Further 52.1 and 47.9% were joint and nuclear sheep breeder families, respectively. The average land holding of the sheep breeders was 4.02 ha out of which 22.83% land was irrigated. Survey conducted in 1991-92 revealed that 5.67% sheep were crossbred with average flock size of 64. The body weights at different growth stages were higher in crossbreds than local breeds. The greasy fleece production of cross breeds was also higher than native breeds. The fibre diameter of native and quarter bred sheep wool was 41 and 26 µ with medullation of 70 and 30%, respectively indicating the improvement due to crossbreeding. Crossbred in the adopted area had wool of 32 µ and mixed flocks wool had of 36 µ. Overall morbidity in adopted villages ranged from 43.8- 64.9% while mortality in adopted villages varied from 2.44 to 8.65%. At present the emphasis is on rearing of native breed of sheep. A survey in Bikaner district of Rajasthan exhibited that Magra sheep was reared mostly with flock size ranging from 20-600. The wool yield ranged from 615-640 g per sheep with staple length 44.02-83.50 mm. The sheep breeders were aware of the modern health technology practices like vaccination.

Cost and returns from sheep, goat and bovine farming: The survey conducted in Tonk district of Rajasthan in 1990 indicated that Malpura and Kheri breeds of sheep are prominent breeds. Sirohi is predominant goat breed while bovines are non-descript. The per head annual gross cost and net return of sheep, goat and bovine rearing is Rs 71, 57 and 422 and Rs 44, 67 and 298, respectively. This resulted in the benefit: cost ratio of 1.62, 2.18 and 1.71 for sheep, goat and bovine, respectively indicating that goat rearing is more economically viable than sheep and bovine rearing. The component wise income from small ruminants shows the maximum return through sale of live animals followed by milk, wool and manure.

Technical literacy and extension education: The efforts were made to motivate the farmers by making extension approaches and using different media. Some of the salient ones were publication of pamphlets, prassar patra, organizing and participating in exhibitions, fairs, kisan gosthies, talks and news coverage on radio and television are being taken up regularly. Besides Institute activities, news was regularly published in newspapers particularly in Hindi. Farmers and women trainings are also being organized regularly to develop the skill among the farmers in adopting newer technologies. The impact of Institute in terms of gain in knowledge, attitude and socio-economic status of adopted farmers was found significant as compared to non-adopted

farmers. Socio personal traits *viz*. education and socio-economic status has a positive and significant relationship with knowledge level of respondents about improved sheep production technology. Majority of adopted respondents (98%) had medium to high knowledge level while in case of non-adopted respondents majority of respondents (86%) had low and medium knowledge level. This showed that CSWRI had a significant influence on the knowledge level of sheep breeders.

The survey conducted to study the benefits derived out of the technology passed on to sheep farmers revealed that the gross income increased by an annual rate of 8% from Rs 8800 in 1981 to Rs 26100 in 1989. Highest benefit: cost ratio was observed to be 2.38 in case of small farmer category with a livestock configuration of 66 sheep, 24 goats and 4 bovine and with land holding size of 1-2 ha. This combination of livestock configuration and land holding size along with free grazing area has generated maximum net returns of Rs 13400 per sheep breeder in 1990 in the semi-arid areas. Different queries received from the farmers on problems faced by them regarding sheep production were regularly answered and whenever required scientific and technical personnel visited such farmers flocks to alleviate their problems.

Attitude of sheep farmers towards technologies: It was observed that majority of the sheep farmers (80%) had a favourable attitude towards transferred technologies. Further, it was noticed that about 20% of the sheep farmers showed neutral attitude towards supplied technologies but none of the sheep farmer had showed unfavourable attitude towards supplied technologies. The data of surveyed flocks showed that improved rams for flock improvement obtained higher score (117.45) followed by the supplied seed of T-9 variety of lucerne (113.57). Farmers' showed less interest regarding infertility management (69.10) and AI practices in sheep. Practices like infertility management and AI in sheep received comparatively low score indicating thereby greater need for improvement in these two practices.

Arid Region Campus, Bikaner

R.C. Jakhmola and H.K. Narula

The Arid Region Campus (ARC) of Central Sheep and Wool Research Institute was established in July 1974, as Division of Carpet Wool and Karakul Pelt Production near Beechwal village at Bikaner. The campus is located at 28.3ºN latitude and 73.5 ºE longitude at 236 meters above mean sea level in the heart of Thar Desert. The average annual rainfall is low (250 mm) and erratic. The temperature varies between sub zero (-2°C) during winter to 49°C during summer. The centre has 636 hectares of land. The area is undulating having ranges of sand dunes covering about 25% of the land surface. The pasture is dominated by sewan (*Lasiurus sindicus)* and dhaman (*Cenchrus cilliaris*) grasses with khejri (*Prosopis cineraria*) trees and bushes (*Zyzypphus* sp., *Calligonum polygonoides*). An area of about 50 ha is under irrigated legume crop cultivation and horti-crop systems.

During early phase, ARC had been involved in developing technologies related to pelt production from Karakul and its crosses with three different native breeds (Malpura, Sonadi and Marwari). Also, activities of carpet wool production were strengthened. Later, in addition to Animal Genetics and Breeding, Animal Nutrition, Animal Health and Grassland and Forage Agronomy and Textile-processing components were strengthened at the ARC. However, at present the scientific activities are limited to Animal Nutrition and Animal Breeding. Magra and Marwari are the two major breeds of sheep that are being maintained and improved by selective breeding at this centre. One patent entitled “Fermentation vessel for conducting gas production studies (*in vitro*)” has been filed (no. 6642/RQ-DEL/2010 on 6.9.2010).

Karakul and pelt production

The karakul sheep is famous for production of quality lamb pelt. The animal is fat tailed, produce coarse carpet wool and adapted to wide range of climatic conditions. The pelt colour of Karakul is generally black with some colour variation. The pelt can be classified in to four categories, Jacket (characterized by presence of semi-circular piped curls of medium size), Caucassian (characterized by presence of semi-circular curls of walnut type with little overgrown hairs), Ribbed (presence of narrow feathery and small pipes arranged parallel to the ribs on the body of lamb) and Flat (lacks curliness, some time broad feathery curls). The pelt is lustrous and is good in look and feel.

A flock consisting of 200 ewes and 50 rams was imported from then USSR during 1975 and kept at Arid Region Campus of CSWRI, at Bikaner. In order to study the performance of this breed under cold arid conditions, a flock of 50 ewes and 10 rams was transferred to Jammu and Kashmir state during 1976, where they were stationed at Kumbhathan near Kargil in Ladakh district. Five rams were also transferred to Avikanagar for cross breeding programme on pilot scale. During initial two years up to 1978 only pure breeding was done, thereafter cross breeding was under taken. The breed could adapt well at the campus with a survivability of 82-89%. The average birth weight ranged between 3.2 to 4.0 kg (pooled average 3.6 kg) during different years. The average 6 and 12 month weight of lambs during different years ranged between 15.7 to 22.5 kg (pooled average 25.6 kg) and 22.2 to 28.8 kg (pooled average 25.6 kg), respectively. The adult weight of imported animals ranged 35.6 to 40.9 kg during different years, while during same year's farm bred Karakul had average adult weight that ranged between 26.4 to 35.7 kg. The annual greasy fleece yield was 1.76 kg. The reproductive performance was also satisfactory with 80% annual lambing on tupped basis.

The Indian Karakul sheep were developed from pooled group of 3/4th of Karakul crosses with Malpura, Marwari or Sonadi. The performance of Indian karakul was compared with that of Karakul. The pelts obtained were lighter and there was possibility of obtaining different colour lines other than black from the base of Indian Karakul. Out of 850 lambs evaluated 50% had Jacket type, 7.6% had Ribbed type, 35% had Caucassian and 3.9% had Flat type pelt. After crossbreeding of Karakul with native breeds, the proportion of Jacket and Caucassian type pelt decreased. The pooled average of half-bred in respect of Jacket, Caucassian, Ribbed and Flat was 28.6%, 33.0%, 11.1% and 22.9%. respectively. With the 3/4th Karakul inheritance pelt quality of cross-bred improved and had 50% Jacket, 27% Caucassian, 10.9% Ribbed and 9.3% Flat type pelt.

Selection and improvement in Marwari sheep

Marwari is one of important carpet wool producing sheep breed of North Western arid and semi- arid region of India. The breed is hardy and well adapted to harsh and erratic climatic conditions of hot arid region. This breed is considered to be largest in number and distributed widely in Rajasthan and some parts of Gujarat. The animals of Marwari breed are distributed in Jodhpur, Jalore, Nagaur, Pali, Barmer districts of Rajasthan and border area of Gujarat. The Marwari project became the part of Network Project of Sheep Improvement from August 1993. Since then Marwari breed is being improved for carpet wool production through selection. The main objective of the project is to increase the body weight and greasy fleece yield (GFY). An elite flock of Marwari was established with more than 400 breed able ewes. The rams are selected on the basis of selection index incorporating 6 month body weight and first 6 monthly GFY. The body weight at 6 month of age improved by 41.94% (from 15.9 to 22.6 kg) over the period after start of Network Project. The improvement (46.00%) in body weight at 12 month of age was also recorded as it improved from 20.8 to 30.4 kg. The adult annual GFY was improved from 1209 g to 1484 g (22.8%) since inception of Network Project. Due to improvement in the body weights and proper management of flock the survivability of animals improved a lot over the years. In general the survivability in all age groups was recorded to be above 96% which is very much desirable for better remuneration to the farmers. The lamb survivability was more than 97% in flock. The improvement in tupping and lambing percentage on available and bred basis was recorded over the years. The tupping was improved from 72.6% in 1992 to 99.5% in 2010-11 and the lambing from 71.0% in 1992 to 91.1% in 2010-11. The twinning in Marwari breed of sheep is not common feature as evidenced and reported in literature. The twinning rate in Marwari was enhanced up to 22% in comparison to 2-3% in early years and it was significantly higher than previous year.The twinning rate ranged from 11% to 22% during the period from 2005 to 2010. The twining percentage was increased significantly due to better feeding and management practices. The available male lambs born in spring season were ranked on the basis of selection index constructed from 6 months body weight and first 6 monthly GFY. The top ranked rams were selected and used in breeding to bring genetic improvement in the animals. The selection index was revised at regular interval and new selection index was used for selection of rams. There is positive genetic and phenotypic trend in body weights at different stages and GFY. The positive phenotypic trends indicated about general improvement of flock whereas positive genetic trends indicated genetic improvement of the flock over the years. The superior breeding rams produced in the project were supplied to the government / farmers / NGO / other developmental agencies for the genetic improvement of the animals in the farmers flock. A total of 981 superior breeding rams and 206 hogget males were supplied since inception of Network Project.

Improvement of Magra sheep

Magra is an important carpet wool breed of Rajasthan and is found in its purest form in Bikaner and adjoining areas of Nagaur, Churu and Jhunjhunu districts. The sheep produces extremely white and lustrous fleece. The wool

therefore produced by Magra is most suitable for carpet production and is in great demand due to its lustre. The Magra sheep is being improved through selection under research project since 1996-97. An elite flock of Marwari has been established with more than 400 breed able ewes. The project was further strengthened by having external funded project from Central Wool Development Board, Ministry of Textile, on strengthening of ram rearing centre of Magra sheep at ARC to produce more number of superior breeding rams to fulfill the need of the farmers for genetic improvement of their animals. The rams are being selected on the basis of selection index incorporating 6 month body weight and first 6 monthly GFY. Every year nearly 100 superior breeding rams are being supplied to farmers/government agencies for genetic improvement in the animals in field. The overall performance of different economical traits of Magra sheep is given in Table 1.

Table 1. Performance of Magra at Arid Region Campus, Bikaner

Traits	Average
Birth weight (kg)	3.00
3 month weight (kg)	16.00
6 month weight (kg)	25.00
9 month weight (kg)	29.00
12 month weight (kg)	31.00
First 6 monthly GFY (g)	950
Second 6 monthly GFY (g)	1050
Annual GFY (g)	2200
Annual tupping (%)	> 97.00
Annual lambing (%)	90-95
Annual twinning (%)	3.50
Overall annual survivability (%)	98.00
Fibre diameter (μ)	32.00
Staple length (cm)	5.15
Medullation (%)	40-45

Characterization of Pugal sheep

Pugal is a medium carpet wool producing sheep breed of Rajasthan. The animals of this breed are found in Bikaner district only. Raika, Muslim, Rajput, Jat and Meghwal are the main communities maintaining this breed. Pugal sheep animals are known as "*Rataanaa*" in the field. The animals of this breed are generally found mixed with Magra, Nali and Jaisalmeri sheep in the flocks and percentage of pure Pugal breed animals in farmers flock ranges from 5-70%. The population of Pugal sheep is declining very fast because of farmers' choice to use Magra breed rams in their flocks reason being Magra breed is superior in wool production and wool quality which fetch more price as compared to Pugal breed .A National Agricultural Technology Project (NATP) entitled "Characterization and Conservation of Pugal Sheep" was initiated at CSWRI, ARC, Bikaner in May, 2000. The major achievements of the project were identification of Pugal sheep breeding tract, generation of scientific information on managemental practices, breed characters and body measurements, production traits, reproduction traits, wool quality and carcass traits, development of breed descriptors of Pugal sheep and conservation of breed in the form of autosomes.

Feed and fodder evaluation

Sewan (*Lasiurus sindicus*) and Dhaman (*Cenchrus cilliaris*) are the major pasture grasses available during rainy season; Sewan and Dhaman hay contained 5.2 and 5.0% DCP and 41.7 and 50.2% TDN, respectively. On sole feeding both the hays need to be supplemented with protein and energy supplements to support maintenance requirements of sheep. Higher supplementation would be required with *Lasiurus sindicus* compared to *Cenchrus cilliaris* hay. Even with stocking rate of 2.5 animals/ ha under hot arid condition it is desirable to provide rest to the grazing area after two years of continuous grazing else it would deplete vegetation and virtually cause desertification. Ewes could be maintained throughout the year on rangeland pasture of arid zone on sole grazing when not bred. For better lamb production ewes should be supplemented during advance pregnancy and lactation due to increase in nutrient requirements.

Plant population and DM availability from pasture improved with advent of monsoon up to October but decreased later and was least during June. CP content also increased up to 9.0% during August and September (during monsoon) due to new sprouts but decreases later on to 4.7% during winter reflecting need to provide concentrate supplement.

Sorghum sudanensis (Sorghum sudan) grass is a multi-cut forage crop which can be advocated in the arid region for summer season. The forage in hay form contains 7.0% DCP and 54.8% TDN and on sole feeding, the hay is adequate to support maintenance during scarcity periods. *Vigina aconitifolia* (Moth) chara - an agro by-product is available after harvest and can be used up to 25% in the diet for pre-weaning growth. Groundnut fodder can be used in the ration up to 70% for post-weaning growth. Supplementation of Cow pea hay should also be accompanied with an energy source for its proper utilization. *Prosopis cineraria* leaves (Khejri) can be incorporated in the dietary of sheep up to 25% for post-weaning growth. *Zizyphus nummularia* (Pala) is found in the habitat of arid region, the leaves can be harvested and fed to sheep up to 60% in the diet for post-weaning growth. Mature *Albizzia lebbeck* (Sirus) pods are potential forest resource with medium protein and energy and could be incorporated up to 40% in concentrate supplements. *Prosopis juliflora* (Vilayati babul) pods could be used in the diet of sheep up to 10%. *Colophospermum mopen* (Mopane), used as wind breaker and soil binder in arid region, green leaves could be fed along with sewan hay for maintenance of body weight during drought periods.

Barley could be replaced by jowar grain as a cheaper energy resource for concentrate supplement in the arid region. Groundnut cake can be replaced by cottonseed cake which is a cheaper protein supplement for use in lamb ration. Guar korma is a cheaper locally available by product of guar gum industry; it can be used as a protein supplement in the ration of adult sheep along with an energy source. Urea: starch ratio of 1.5:13 was found adequate and safe for maintenance of adult sheep, the mixture could be fed as concentrate supplement for maintenance along with low quality roughage, proper mixing of urea should be ensured.

Nutrition and rumen metabolism

The arid plants contain plant secondary metabolites. The concentration of condensed tannins and total phenols in Phog (*Calligonum polygonoides*), Bawali (*Acacia jacqumontii*), Khejri (*Prosopis cineraria*), Beri (*Zizyphus nummularia*) ranged between 4-6% in leaves and 6-23% in twigs. Inclusion of Jal (*Salvodora persica*), and Gundi (*Cardia gharaf*) at 10% in roughage based complete feed, decreased methane production (ml/kg DM) by 28%. A 34% decrease in methane production (ml/kg DDM) was also possible by increasing protein and energy content of roughage based complete feed. At 5% level of inclusion in high roughage diet, saponin rich plant parts - Lucerne

(*Medicago sativa*) roots, Reetha (*Sapindus rarak*) pulp and Shikakai (*Acacia concina*) pods decreased rumen protozoa by 45-75%. The herbal mixture developed in our laboratory at 1.0% level in complete feed decreased protozoa count by 19%.

Principal component present in Ajowin (*Trachyspermum ammi*), Dill (*Anethum sowa*), Cumin (*Cuminum cyminum*) and Fennel (*Foeniculum vulgare*) were thymol (72.28%), 2-cyclohexen-1-one 2-methyl-5-(1-methylethenyl)-(CAS) 2-methyl-5-isopropenyl-2-cyclohexenone (56.03%), Cumaldehyde / cuminal (39.15%) and P-Allylanisole (63.44%), respectively. The methane production (ml/g DOM) decreased with increasing levels of Cumin, Fennel, Ajowin and Dill, but at 10% inclusion levels rumen fermentation characters improved.

Garlic (*Allium sativum*) powder inclusion at 3% level in complete feed increased digestibility of dry matter (DM) by 7.5%, crude protein (CP) by 11% and ligno-cellulose (ADF) by 28%, as a result sheep gained 17% higher body weight. There was 14.6% improvement in daily gain of Marwari kids by inclusion of Bhringraj (*Eclipta alba*) in complete feed. Inclusion of mixture of Aswaganda (*Withania somnifera*) either with Jaiwanti (*Leptadenia* sp.) in Marwari goat diet or Reetha (*Sapindus mukorossi*) fruit pulp to Rathi cattle feed increased DM intake by 15%, DM digestibility by 11-15% and ADF digestibility by 10-11%.

Grassland and fodder production

The varieties CAZRI-M 305 of *Lasiurus sindicus* and CAZRI-75 of *Cenchrus ciliaris* were found promising and produced higher dry matter yields over other varieties. Half yearly grass cutting schedule was found better than annual cutting schedule. *L. sindicus* produced higher dry matter yield than cenchrus. In case of soil ameliorants combined application of sheep manure and gypsum @ 10t/ha in mine degraded soils was found best followed by sheep manure alone @ 10 t/ha. Sorghum Sudan grass (*Sorghum sudanensis*) and Cow pea (*Vigna unguiculata*) intercropping produced higher and economical green fodder and dry matter yields as compared to sole Sorghum Sudan grass and Cow pea. Application of 40+40 kg N/ha (at sowing + after each cut) recorded greater and economic fodder production than lower levels.

Post emergence application of metsulfuron methyl @ 0.008 kg/ha effectively controlled the broad leaved weeds in oats (*Avena sativa*) and recorded highest B: C ratio. However, weed free treatment produced maximum fodder yields. Application of 2, 4-D showed phyto-toxic effects in oats crop. Pre-plant incorporation of fluchloralin @ 0.75 kg/ha effectively controlled the weeds in lucerne (*Medicago sativa*) and recorded maximum B: C ratio. However, maximum green fodder and dry matter yields were provided by weed free treatments. In case of lucerne, chemical weed control in recommended in the conditions of human labour shortage. A pre-emergence application of pendimethalin showed its phyto-toxic effect and badly affected seedlings emergence and growth. Among rejuvenation techniques of old sewan pasture, stubbles burning (light burning) treatment produced maximum dry matter yields. In case of fertility schedules, 50% each organic and inorganic source of application produced higher dry matter yields than other treatments.

Pelt and wool technology

Technologies were developed to preserve the original characters of a pelt and to produce these with good feel, high lustre, softness, suppleness and strength. A curing method for preserving the freshly slaughtered lamb pelts for a few months without any serious damage was perfected at ARC. An alum-chrome tanning process useful for small scale cottage industry for tanning sheep skins and lamb pelt has been developed. The conventional methods of dyeing the pelts/fur with skin are to dye the fur/pelt and leather separately or both are dyed in same shade. A method has been developed to dye the two parts in two different shades simultaneously by taking advantage of difference in nature of protein of the two.

The alkaline solution (0.1% Na_2CO_3) was found to be most efficient medium for colour extraction as it yielded maximum colouring matter for all materials (Turmeric-rhizomes, Henna-leaves, Jatropha-root, Ratanjot-root, Pomegranate-peels, Babool-bark). Duration of 60 minute was found to be optimum for extraction of colorant from all the materials. Pomegranate peels yielded maximum colouring matter for all mediums and durations (120 minute) which was maximum for alkaline medium (83.37%).

To obtain an even, bright and fast shade from the colour extracts of different vegetable materials on woolen yarn the concentration, duration and temperature of mordenting process were optimized. The optimum quantities of five different mordents viz. Alum (10%), Copper Sulphate (5%), Tin Chloride (3%), Potassium dichromate (2%) and Hararh (10%) were used for pre-mordenting of woolen yarn dyed with colour extract from Heena leaves, Pomegranate peels, Turmeric rhizomes, Babool bark and Jaropha roots, respectively. The light fastness test of dyed samples revealed that mordenting prior to dyeing improved the fastness to light the obtained fastness to light is fairly good to good (3, 3-4 and 4) on scale of 1-8. The results of washing fastness test were observed very good fastness to wash (grade 4) for both mordented and unmordented yarn samples on scale of 1-5. Thus the fastness standards prescribed for woolen carpet yarn can be easily attained by these natural dyes in addition to protection of environment and pollution control.

The results of quality attributes of wool *vis a vis* visual grades indicate that visual grading of wool samples was very close to the quality appraisal of attributes; this could be used as a tool for grading of wool in the industry. Prolonged storage causes deterioration/ loss in fibre strength which results in higher weight loss.

Animal Health

The epidemiological studies were performed on Marwari, Indian Karakul, Nali, Avikalin, Avivastra and Magra breeds in arid region. Initially the mortality at ARC was high (~ 10%) which reduced gradually to 1-2% after applying scientific health technologies. Sheep pox was eradicated from the farm after introducing tissue culture vaccine after 1988. Johne's disease has also been under control after adopting suitable steps like isolation. There has been no incidence of enterotoxaemia and Blue tongue among the institute flocks. After the epidemiological studies of several years a systematic annual health calendar was developed for this arid region of Rajasthan.

Transfer of Technology

The transfer of health technologies were applied among the field flocks. Prophylactic programme like vaccination against Sheep pox, enterotoxaemia and PPR were applied and suitable anthelmintics were used periodically. Application of health technology and awareness in the field brought down the mortality in sheep flocks from 10-15% during early phases to 3.3%.

North Temperate Regional Station, Garsa

J.B. Phogat and S.R. Sharma

This station (presently called as North Temperate Regional Station of Central Sheep and Wool Research Institute) at Garsa, Kullu valley of Himachal Pradesh was started in 1963 with the mutual collaboration of Ministry of Food and Agriculture, Government of India and erstwhile Punjab Government (subsequently Himachal Pradesh) as a sheep breeding farm. The main objective of the station was to evolve a fine wool sheep producing 2.5 kg greasy fleece per annum with an adult body weight of 30 kg by crossing local Gaddi ewes with exotic Rambouillet / Soviet Merino rams and to carry out research on different aspects of fodder productions, farming system and to study health problems of sheep in temperate Himalayan region. Later on, the station was transferred to the Indian Council of Agricultural Research (ICAR) and functioned as the Regional Station of Central Sheep and Wool Research Institute (CSWRI) for North Temperate Region of the country. In April 1976, this station was upgraded as a full-fledged division and renamed as Division of Fur Animal Breeding. During 1978, studies were extended to rabbit breeding for wool and meat purpose.

This station is located at global position of latitude 31.58°N and longitude as 77.20°E with average annual rainfall of about 840mm. In Himalayan Kullu valley it is connected by Delhi-Manali highway (NH-21) lying 14 Km from Bhuntar on Bhuntar-Garsa road. This station has a typical temperate climate with maximum temperature between 30-34°C to lowest temperature in winter going down to -2 to 4°C with occasional snow fall. The farm area comprises of a flat irrigated valley land of 29 hectares and 861 acres of steep hill grazing land on lease from Government of Himachal Pradesh that provide natural grazing to sheep. This station is located at 1400-2100 meters above mean sea level on the right bank of Garsa stream from Bhosa area ridge to Hurla bridge ridge.

The pioneer research and development started at NTRS, Garsa with the import of Russian Angora from erstwhile USSR in the year 1979. Subsequently, this station introduced locally purchased German Angora in 1986 and then in 1992. Later on, a fresh lot of improved German Angora was imported during the year 1997 at this station. At the same time, four breeds of broiler rabbit viz. Soviet Chinchilla, Grey Giant, White Giant and New Zealand White were introduced in 1979 at Garsa and later Black Brown was obtained by crossing Soviet Chinchilla and Grey Giant. The initial attempts were made through breeding of imported Angora on scientific principles, popularized them among the farmers and finally transferred the derived technology to the farmers of hill region in the country. At present the station is having superior germplasm of German Angora, British Angora and Russian Angora for research, development and propagation in the region. The selection criteria in Angora rabbit is wool yield at 2nd and 3rd clip and litter size at weaning, while in broiler rabbit the body weight at 12 weeks and litter size at weaning.

To achieve the targets of sheep improvement programme, the local Gaddi ewes were crossed with Rambouillet and Soviet Merino rams. In this attempt several grades of crosses were produced and evaluated. The 50 and 75% crossbreds produced 26.0 and 40.8% higher wool yield than the indigenous Gaddi sheep, respectively. The improvement in adult body weight was 23.2 and 47.7% respectively. The wool quality improved to fine apparel type in the crossbreds from the carpet quality wool of Gaddi. The 75% exotic inheritance was designated as Gaddi Synthetic strain. Gaddi synthetic strain was further improved by selective breeding, multiplied and propagated among the farmers for improving the wool quality of native sheep. Subsequently, Bharat Merino (BM) developed at CSWRI was also introduced at NTRS Garsa during year 2002 to test its performance under temperate conditions. The selection

criteria include body weight and wool production at six months of age and along with reproductive performance. In addition, efforts were also made to improve pastures.

Angora/broiler rabbit

Basic and applied research in all disciplines relating to Angora /broiler rabbit production was carried out. Genetic stabilization of wool and meat breeds of rabbits was made. The housing system with locally available material for better management of rabbits/broilers under field conditions was developed. Locally available feeds, fodders, top feed and agro by-products for wool/meat production in the rabbits were evaluated. Epidemiological for rabbit/broiler diseases was studied and disease data base was developed to reduce morbidity and mortality in rabbits. Fibre and pelt technology was developed, updated and standardized. Training on rabbit and sheep farming to the farmers was imparted and superior germplasm was supplied to the farmers. Utilization and processing of wool and rabbit fur for garment preparation and development was standarised. The age of weaning with the aim to achieve the maximum body weight at 84 days of age was standarised. The eco-friendly technology for processing of rabbit pelt/fur/skin for value added garment preparation was developed.

Sheep

Fine wool Gaddi Synthetic sheep to produce greasy fleece yield of 2.0 kg with a fibre diameter around 20µ, medullation less than 5% and staple length of 6cm in annual clip was developed. The performance (growth, reproduction and production) of Bharat Merino sheep under temperate conditions was evaluated. Body weights and fine wool production was improved through selection and inter-se breeding of Gaddi Synthetic and Bharat Merino sheep. The growth, reproduction and production performance under migration to highland alpine pasture was recorded and compared with non-migratory flock. The training was imparted and elite rams to farmers was provided for improvement of local breeds and socio-economic conditions of farmers.

Salient Research Achievements

Through scientific interventions along with selection and breeding plans, a German Angora strain with adaptability to the Indian cold conditions has been developed. It has a potential to produce 850-950 g of wool per annum and average litter size of 6 kits per kindling. Attempts have been made to decrease the age at first mating and to improve the prolificacy of Angora rabbits through nutritional, hormonal and therapeutic interventions. Effect of level of protein contents in concentrate diet of adult and young rabbits on growth, wool yield, wool quality and digestibility was evaluated and found that 14% CP in adults and 16.1% CP in young weaners/growing rabbits gave best results. Influence of different seasonal fodders such as kudzuvine, oat, biul leaves, tall fescue, rye grass white clover, mulberry leaves, robinia leaves, willow forage, kachnar and hay from locally available grasses and also the feeding of different levels of concentrates on Angora rabbit wool production were evaluated. Research results suggested that Soviet Chinchilla (SC), Grey Giant (GG), White Giant (WG) and New Zealand White (NW) are adaptable to Himalayan conditions. By adopting scientific procedure, strains of broiler rabbits were improved which can produce 5-6 kits per quarter beyond six months of age and attain 1.8 kg weight at 84 days of age. Weaning at 28 days of age gives better pre- and post-weaning performance in Soviet chinchilla. Concentrate feeding of kits from 21 days of age increased pre and post weaning broiler traits. Pre-weaning kit mortality is affected by litter size at birth, season of birth and mothering ability of females. Mothering ability was found to be highest in Soviet Chinchilla among all broiler breeds. Weight at slaughter had a highly significant phenotypic correlation with carcass weight, pelt weight and dressing percentage.

Influence of season, parity, age and weight of doe on reproductive efficiency of rabbits was evaluated and concluded that all these factors affect the same. The spring season appeared to be most favorable season for efficient reproduction in rabbits. Technology for fur processing and its utilization was developed for making valuable garments such as caps, bags, muffler, cushions, gloves and jackets. Eco-friendly technology involving chemical treatment of rabbit skin through various steps such as soaking, scouring, pickling, tanning, tallowing and dyeing was developed to prepare value added garments, which are in much demand at tourist places of temperate region. Complete package of practices of rabbit and broiler feeding were developed by incorporating different local available feed and fodder sources including non-conventional and agro-industrial by-products to make rabbit feeding economical with feed conversion ratio between 3 and 4.With objective of economizing the ration for rabbits several proteins, mineral, additives and roughages were tried and their effect on growth and wool production were evaluated.

Bharat Merino strain was introduced at the NTRS, Garsa and growth, reproduction and production performance was assessed and improved in the temperate region by adopting scientific measures. Gaddi Synthetic strain developed at the station was further improved and popularized and propagated among farmers for improving the wool quality of native sheep. Gaddi Synthetic, Bharat Merino and their inter-crosses were developed through scientific selection and inter-se breeding which have the capabilities to produce 1.0kg of fine wool (around 20 µ diameter) and 28 kg of body weight at 6 months of age. Research over the years revealed that autumn is the best tupping season and spring is the best lambing season for sheep reproduction in the temperate region, which brings best results in terms of growth and production of newborns and adults. Study on sheep migration to highland alpine pasture during summer was conducted where growth and production performance of young ones and adults were found to be highly appreciable with least cost input as compare to non-migratory flock. In addition, migratory routes were defined and acclimatization at lower hills before high altitude migration resulted in better performance without any health problem. In sheep, creep ration containing 11.2% CP were found to be optimum for economic raising of lambs during pre-weaning stage. Provision of *ad libitum* concentrate and forage during 3-6 months of age under intensive rearing programme resulted in appreciable growth performance as compared to lambs reared under routine semi-intensive system.

Disease data base regarding sheep and rabbit disease was developed and to reduce the mortality and morbidity in these species appropriate therapeutic measures were adopted under temperate conditions. However, in migratory flock some problem due to natural calamities like untimely snow, heavy rains, hailstorms, etc. could lead to mortality. Hairball in Angora rabbit could be a major problem under poor management conditions. The problem of hairball gets accentuated in absence of proper fibrous diet or fodders. Diseases of respiratory system and alimentary system are predominantly observed clinically in rabbits. Death in rabbits is mainly due to pneumonia, rhinitis along with pulmonary abscesses, enteritis, hepatitis, etc. Aflatoxicosis outbreaks are not uncommon in rabbits and could results in heavy mortality.

Enterotoxaemia in rabbits with explosive deaths could occur with feed or diets containing high concentration of soluble carbohydrate or molasses. Kits born during spring season had better survivability.

Elite rams and angora rabbits were provided to the farmers in hill region through participatory approach and performance of these animals was evaluated at farmer's doorsteps and compared with the farm flock. Farmers from the different villages involved in rabbit or sheep rearing were surveyed and data on their socio-economic status, prevalent sheep and rabbit rearing practices and existing knowledge in this regard was collected and analyzed. Rabbit units were set up in rural area and free feed, cages and technological know-how was provided for improvement of their farms and to motivate them to take up rabbit farming as an economic enterprise. Package of practices for rabbit and sheep rearing in hill region was prepared and distributed to the farmers.

Future priority areas of research

Angora: The temperate environment of north India is well suited for Angora rearing, so performance (growth, production, reproduction and health) of Angora rabbits should be assessed at different altitudes and different environmental conditions of hilly regions of India. Apart from improving locally available German Angora by selective breeding, introduction of high quality German Angora by importation (to avoiding inbreeding) for boosting up the Angora improvement by mission mode. Efforts should be made to use of multi traits selection index with development of divergent lines in German Angora for exploiting hybrid vigor in terms of growth, wool yield, staple length, fibre diameter and guard hair.The superior germplasm from the organized farms such as NTRS should be supplied to regional centers (maintained by Government / private organizations / progressive farmers) for onward propagation / transmission to farmers flocks and it should be replaced more frequently. The selection of superior males from farmer's flocks and after testing their performance under uniform conditions, the superior males should be disseminated among farmers to avoid problem of inbreeding being faced by individual farmers. This should be done under strict surveillance and guidance of qualified specialists. Molecular genetic markers associated with growth and production performance, wool quality and higher prolificacy should be identified and which can be used for marker assisted selection. Research on low cost and economical feeding system preferably involving locally available feed and fodder resources (as protein and energy source) should be conducted to make this profession economically viable at farmers level. The impact of these feeding systems should also be assessed during different seasons on different physiological stages such as growth, gestation and lactation. Research should be conducted for increasing prolificacy and mothering ability in females by hormonal or therapeutic interventions since mortality is more in prolific females due to poor mothering ability. To have more lifetime profit from Angoras, age at first mating should be reduced by exploiting nutritional, genetic and management inputs without compromising growth and production performance of the progeny. In rabbits, usually 30-40% ova either remain unfertilized or suffer from early embryonic mortality before implantation, so future research in this direction should be diverted to overcome such losses and to harvest best kit crop. Impact of day length and light should be assessed on growth, production and reproduction of Angoras and best suited environment/management provisions should be pointed and made available depending upon different physiological stages and conditions to harvest the best performance. The German Angoras are usually not prone to viral or other contagious/deadly diseases but through more refined diagnostic, preventive and therapeutic research morbidity and mortality can be further reduced in kits, grower and adults. Different routine dietary causative agents of diarrhea, enteritis and bloat need identification. Apart from growth and production, nutritional research on fibre quality and quantity should also be concentrated.

Sheep: Research should be conducted to have increased prolificacy or multiple births through introduction of *FecB* gene / superovulation / embryo transfer programme and subsequent adaptability studies in temperate region should be assessed. Further research is required to reach at optimum and economic feeding managemental system during different physiological stages to maximize production and reproduction in the temperate region. Molecular and nuclear breeding programme should be adopted to achieve faster multiplication of desired genotypes. Adoption of 'reproductive assisted techniques' (RAT) and throughout the year breeding programme should be initiated to accelerate the lambing system and to harvest maximum life time productivity. Disease and parasitic resistant sheep strains needs to be developed.

During last five decades, a significant research on sheep and rabbit rearing programmes has been conducted at the station, which has proved handy for the scientists, stakeholders and farmers to enrich their knowledge in the existing scenario of this field and for future improvement of this enterprise. However, still there is lot of scope for research in the areas of management, health, reproduction, physiological aspects and nutrition are existing which can throw a fresh light while taking this profession to newer heights and can go a long way in improving socio-economic status of the landless and marginal poor farmers of this hilly region.

Southern Regional Research Centre, Mannavanur

A.S. Rajendran

Southern Regional Research Centre (SRRC), Mannavanur is a research unit under Central Sheep and Wool Research Institute, Avikanagar. It is 35 km ahead of Kodaikanal (Tamil Nadu), in the Poombaarai-Berijam-Kodaikanal circuitous route. The centre was started on 16.11.1965 over an area of 1346.88 acres, comprising of 545.38 acres revenue land and 801.50 acres of forest land. This centre is situated at an elevation of 2030 meters above mean sea level and located at 10° -11° N latitude and 77°-78°E longitude. The average annual rainfall is 1055mm, well spread throughout the year. The mean monthly ambient temperature from April to June is 25°C. Maximum temperature ranges from 26°C to 30°C and the minimum temperature ranges from -3°C to 5°C. Relative humidity varies from 15 to 90%. The available grass species in the farm is mostly *Kikuyu* (*Pennisetum clandestinum*) and spear grass (*Heteropogan contortus*). The other species available are *Setaria* (*Setaria splandida*), *Irrithrina, Desmodium, Phalaris tuberose,* cocks toot (*Dactalis glomarata*), *Congosignal, Lolium perene,* white clover, *Eschemum indicum,* Paragrass, Themada (*Themada tripogan*), love grass (*Eragrostis currula*), Napier (Pusa and Coimbatore varieties). In addition, large numbers of Wattle and Eucalyptus trees are also available in the farm. During the year 1997, Government of Tamil Nadu had withdrawn 400 acres of revenue land and Forest department 801.5 acres of forest land and the centre is working on remaining 145.38 acres of revenue land.

Development of pasture: During the year 1966, improved varieties of legumes and cereal grasses suitable for the regional conditions were introduced namely: Cocks foot, Festuca, *Phlaris tubrosa*, Love grass, Red clover, Kikiyu, White clover, Lolium, Crimson clover, Rye grass and Pusa giant Napier. In addition, reclamation of the marsh land between the hill slopes was taken to provide proper drainage.

Performance of newly introduced forages to kodai hills (1973-1975): Seed, saplings and runners of various grasses and legumes were procured from Indo-Swiss Project, Mattupatty, Kerala and tried on small plots under rainfed conditions and their performances under sub-temperate climate of Mannavanur was as under:

Forages	Performances
Pongola grass	A runner, attained good growth, leafy but frost affected
Paspalum dilatatum	Leafy growth, leaves are broad, frost resistant, remains green in winter
Guinea grass	Grass is coarse, frost affected
Stylosanthesis gracilis	Growth is stunted
Setaria species	Broad leafy growth, soft and tender, long stem bearing lot of seeds, frost resistant
Desmodium silver leaf	Good kharif legume with profuse leafs, spreads well in native pasture, well relished by sheep, but heavily susceptible to frost
Dolichos axillaries	Good legume with profuse broad and tender leaves, but susceptible to frost

Development of livestock farming system: The study on the relative performance of sheep and goat under free range grazing without any supplementary feeding exhibited that over the years (1979-85), sheep and goat exhibited two and three fold increase in strength, respectively. However, the growth of lambs and kids at different ages remained more or less uniform.

Performance of Romney Marsh and South Down sheep: During the year 1966, two rams and nine ewes of South Down and five rams with ten ewes of Romney Marsh were procured from NTRS, Garsa to study their adaptability to the Southern sub-temperate climate of Kodai hills. Between the years from 1966 to 1973, the South Down sheep

could produce only three lambs. The Romney Marsh was able to produce only two lambs between the years from 1966 to 1971.

Cross breeding of Coimbatore sheep with Corriedale: During the year 1967, 136 sheep were imported from Australia and 100 Coimbatore ewes were locally purchased to initiate a project with the objective to evolve a dual purpose sheep by cross breeding. The results obtained indicated that, body weight of crossbreds were superior at all stages compared to native Coimbatore sheep, in feedlot trial 5/8th crosses gained maximum body weight, greasy fleece yield was higher in crossbreds than natives, mortality was higher in crossbreds having > 50% of exotic inheritance, castration of lambs improved gain in body weights specially in native Coimbatore sheep, dressing percent was 42.0 in Coimbatore and halfbreds and bone: meat ratio was 1: 2.6, 1: 3.3, 1: 4.0 in Coimbatore, halfbreds and 3/4th crosses, respectively.

Cross breeding Nilgiri and Coimbatore ewes with Corriedale and Merino rams: In the year 1977, a project was initiated for evolving a dual purpose fine wool sheep breed through cross breeding Coimbatore and Nilgiri ewes with Corriedale and Merino rams for sub-temperate climate of Kodai hills. It was found that Merino x (Corriedale x Coimbatore F-1) had better growth than Corriedale x Nilgiri, Merino x Coimbatore, Nilgiri and Merino x Nilgiri. Greecy fleece yield among crosses was highest in Merino x (Corriedale x Coimbatore F-1), followed by Merino x Coimbatore, Corriedale x Nilgiri and Merino x Nilgiri.

Performance of Karakul rams: It was found that Karakul sheep are not suitable for the sub-temperate climate.

Cross breeding of Coimbatore (C) ewes with Rambouillet (R) rams: Over a period of 3 years (1984-86), the results indicated that tupping rate on the basis of ewes available in Coimbatore ewes during autumn was 78.31 to 90.54% with lambing between 84.32 to 85.04% and in spring, the tupping was 86.57% with lambing of 86.21%. In R x C crosses, the tupping was 53.57% in autumn. The average birth weight in R x C crosses was 2.53 kg (7.66% higher than in Coimbatore sheep). In R x C crosses, the average weight at 6 and 9 month of age was 15.12 and 20.04 kg, respectively with 18.5 and 29.37% higher than Coimbatore sheep. Average annual GFY in R x C crosses was 1.126 kg (118.6% higher than Coimbatore sheep). The clean fleece yield was 75.8% in Coimbatore compared to 58.85% in cross breeds. Staple length was 5.22cm in Coimbatore sheep and 4.92cm in cross breeds. Survivability in Coimbatore sheep was 89.92, 97.41, 94.49 and 93.98% between 0-3, 3-6, 6-12 and adults respectively, whereas in crossbreeds in order was 93.63, 98.2, 95.28 and 100% respectively.

Performance of Bharat Merino (BM) sheep: During August 1987, BM sheep were brought from semi arid climate of Avikanagar to sub-temperate climate of Mannavanur to study their adoptability as well as to obtain annual shearing for longer staple length. Over the years from 1987 to 1992, these animals adopted well to the southern sub-temperate climate of Kodai hills producing on an average annual GFY of 2.8 kg with fibre diameter of 20.24 µ, staple length of 9.4 cm, medullation around 1%. The average weights at birth, weaning, 6 and 12 months were 4.26, 20.11, 25.36 and 34.46 kg, respectively. The average annual lambing was 88.26%. Age at first lambing was 657 days and lambing interval was 358 days. The survivability among lambs, weaners (3-6 month), hoggets (6-12 month), rams and ewes was 99.03, 99.15, 99.47 99.23 and 98.56% respectively. Few rams at the age of 2.5 yr of age attained even 83.0 kg indicating excellent growth under the sub-temperate climate of Kodai hills.

Over the period from 1992-97, the least-square means of body weights at birth, weaning, 6 and 12 months was 3.87±0.04, 17.67±0.24, 23.07±0.34 and 32.00±0.42 kg, respectively. For birth weight, the year and season effects were significant. Lambs born in autumn were heavier compared to spring born lambs. Lambs born as singles

were heavier (4.37 kg) compared to twins (3.37 kg). The birth weight was higher in lambs born to ewes belonging to fourth parity. The regression on ewe weight was highly significant and it was observed that for every kg increase in the ewe weight at lambing, the birth weight of the lamb increased by 46 and 6 month body weight of lambs increased by 205 g. The least square means of first annual GFY was 2.304±0.31 kg and indicated that sire effects were highly significant. The least square means of stable length was 8.59±0.04 cm and fibre diameter was 19.19 ± 0.05 µ. After a decade of selection and multiplication it was found that BM sheep is capable of producing 3.0 kg of fine wool per year having average staple length of 8.0 cm, 19.0 µ fibre diameter and modulation of less than 1.0%. It is quite obvious that when environmental conditions are conducive, the genetic potential of an animal can be exploited to its maximum.

During the period from 1997-98 to 2009-10, the activity was focused for multiplication of BM sheep on the available grazing land and their distribution among interested farmers of Southern states for crossbreeding. During this period the average weights at birth, 3, 6 and 12 months of age were 3.81±0.07, 18.22±0.09, 25.16±0.17 and 34.99±0.21 kg, respectively. The overall average annual tupping was 88.56%. The average lambing on ewe bred and available basis was 82.25 and 73.01%, respectively. The annual survivability at 0-3, 3-6, 6-12 months, adult and overall was 92.63, 97.89, 99.16, 97.36 and 96.62%, respectively. The adult annual GFY was 3.65±0.057 kg in male and 2.15±0.061 kg in female. Irrespective of sex, the average adult annual GFY in BM flock was 2.38±0.052 kg. A total of 1577 BM sheep were sold during the period to 110 clients.

Performance of Avivastra sheep: During the year 1991, Avivastra sheep were brought from CSWRI, Avikanagar, to study their annual and half yearly GFY under the Southern sub-temperate climate of Kodai hills. On 6 monthly shearing, the average GFY varied from 1.32 (female) to 1.85 kg (male) with staple length of 5.54 to 6.29 cm, fibre diameter of 21.58 to 23.23 µ and medullation % of 4.63-11.24 in female and 8.0-12.0 in male. On annual shearing, the average GFY varied from 1.78 (female) to 3.0 kg (male) with staple length of 8.61 to 11.03 cm, fibre diameter of 19.63 to 22.40 µ and medullation % of 2.36-7.15 in female and 0.0-8.0 in male.

Demonstration unit of Avikalin sheep: Avikalin sheep were introduced to SRRC, Mannavanur in the year 2003 to study their overall performances under sub-temperate climate of Kodai hills and to distribute in the plain of Tamil Nadu to upgrade the body weight and wool yield of local sheep. During the period from 2003 to 2008, the average weights at birth, 3, 6 and 12 months of age were 3.15±0.05, 17.03±0.70, 25.26±0.68 and 38.29±1.51 kg, respectively. The overall average annual tupping was 73.91%. The average lambing on ewe bred and available basis was 88.24 and 65.22%, respectively. The annual survivability at 0-3, 3-6, 6-12 months, adult and overall was 93.70, 98.48, 100.00, 93.41 and 95.07%, respectively. The adult annual GFY was 2.88±0.18 Kg in male and 1.86±0.07 kg in female. Irrespective of sex, the average adult annual GFY in Avikalin flock was 2.06±0.08 kg. A total of 86 sheep were sold to breeders during the period.

Epidemiological studies on sheep and rabbit diseases and developing suitable prophylactic and eradication measures: Investigation carried out to find out the etiopathology of debility and anemia in sheep in sub-temperate Tamil Nadu revealed microstatic hypochromic anemia and gastrointestinal parasites were adjudged as the main cause of anemia. Rainy and autumn seasons (June-November) were found best suited for survival and migration of pre parasitic stages of nematodes. The survivability of infective larva was more in rainy season (>11 weeks). The main nematode larvae found on pasture were of *Haemonchus contortus* and *Trychostrongylus colubriformis. H. contortus* seemed to be very active and playing a dominant role in rainy and autumn season and their availability was very poor during winter and spring. On the contrary *T.colubriformis* larvae were found throughout the year. The larvae can even over winter in fecal parts. The worm remained in inhibitory stages as early 4th stage larva in sheep grazed in winter

season contaminated pasture followed by autumn season. The least inhibition was observed in rainy and spring season contaminated pasture. Low temperature exposure to the infective larvae was adjudged the factor responsible for hypophysis of *H.contortus.* Looking into their behaviour only tactical anthelmintics dosing cannot be the only control measures in intensive management of sheep in such an agroclimate. Rotational grazing in one form or the other along with strategic drenching schedule could be the answer.

A combination of rotational and clean grassing was formulated with anthelmintic dosing at strategic points based on etho-biology of the parasites. It was observed that the clean pasture, provided after winter drenching in January, can be grazed for more than three months, whereas, clean pasture provided after rainy season drenching in June showed high pasture contamination in the second month of grazing in most parts of other season except winter, monthly rotation of pasture was practiced as pasture larval burden reached above critical level with in a month of grazing. Similar findings were also observed in EPG values and worm counts. This improved grazing management with strategic anthelmintic dosing proved to be beneficial in controlling ovine parasitic gastroenteritis in south Indian sub-temperate climate. Studies on pasture infectivity index suggested that the conventional 'W' pattern pasture sampling is convenient and effective measures to monitor pasture larval burden. The index of pasture infectivity can be used as a reliable guide to assess the periods of risk in intensively managed sheep farms provided total worm count and randomly collected pasture samples are analysed.

Eimeria stiedai sporulated oocysts at the concentration of 10^5 proved lethal where most of the rabbits died between 2nd and 3rd week post infection. The varying grades of *Eimeria stiedai* infection did not affect the body weight and carcass characteristics. However, livers from the infected animals were significantly heavier (up to 10 fold) when compared to control. Histopathologically, hepatic cells showed extensive necrosis in the periportal area and increase in fibrous tissue with glucocytic infiltration. There is also biliary hyperplasia and hypertrophy of bile duct epithelium with enlargement of biliary canal. Bile duct epithelium showed various developmental stages of coccidia. Biliary epithelium revealed desquamation and cellular debris along with oocysts are seen in the biliary lumina with thickening of biliary wall.

Evaluation and improvement of rabbit breeds for meat production: During January 1983, four breeds of broiler rabbit i.e White Giant (WG), New Zealand White (NZW), Grey Giant (GG) and Soviet Chinchilla (SC) were introduced to SRRC, Mannavanur to study their performance under Southern sub-temperate climate. The average body weight varied from 0.570 (WG) to 0.619 kg (NZW), from 1.386 (GG) to 1.439 Kg (NZW) and from 2.819 (NZW) to 3.207 kg (WG) at 6, 12 and 24 weeks of age. The reproductive performance exhibited that average kindling was 73.63, 70.00, 62.79 and 59.61%, average litter size at birth was 7.47, 6.63, 6.51 and 6.63 and litter size at weaning was 6.22, 6.48, 5.83 and 6.05 among WG, GG, NZW and SC, respectively. The survivability ranged from 78.71 (WG) to 88.31% (GG) in kits, from 94.38 (GG) to 98.09% (WG) in weaners, from 92.85 (GG) to 98.55% (SC) in grower and from 78.58 (WG) to 78.95% (SC) in adult.

Estimation of genetic parameters in broiler rabbit: The objectives were to estimate the heritability of various traits by different methods and to estimate the genetic and phenotypic correlation between the traits in White Giant rabbits.

Heritability (h^2) for body weight traits: The h^2 from full-sib component of variance for body weight at 16, 20 and 24 weeks are quite high. As the age advanced, the estimate showed a tendency to decline. The h^2 for body weights at 6, 7, 8, 9, 10, 11 and 12 weeks were more than one. The full-sib and dam component contains in addition to additive genetic variance, the variance due to dominance and maternal effects (variants due to common environment). It is possible that during the early stages of weaning the maternal effects are so large and tend to be very high, there by making the estimation of additive genetic effects difficult. The h^2 from sire component of variants could not be obtained due to the reason that the sire variances tended to be negative (partly due to few number of sires).

Heritability for litter traits: The litter traits viz. litter size and weight at birth at 21 days and at weaning were analysed. The values for these traits of the daughters were regressed on those of the dams. The litter weight at birth had a h^2 of 0.34±0.26.

Genetic and phenotypic correlations between body weights at different ages: The phenotypic correlations between the body weights at different ages were positive and high. The estimates tended to decrease in value as the differences between the two ages increased. The estimates of genetic correlation from dam component among body weights were positive, high and significant. The genetic correlations from full-sib component were also positive, moderate to large and significant. It can be inferred from the values of genetic correlations that rabbit body weights at earlier ages can be used for selection and improvement of body weight at later ages. These results of this study indicate that it would be appropriate to undertake a selection study in rabbits. As for as body weight are concerned, the individual's own performance can be taken as the criterion for selection. The genetic correlations in this study indicate that rabbit body weight at earlier ages can be used for selection and improvement of body weights at later ages.

Evaluation of carcass from White Giant and Soviet Chinchilla rabbits: The male kits were fed 80 g of pelleted feed/day with sufficient water without any green fodder supplementation. The average weaning weights were 0.695±0.23 and 0.665±0.04 kg for WG and SC rabbits, respectively. The final weights on 84th day were 1.930 and 1.975 Kg in WG and SC rabbits, respectively. There was no significant difference between the two breed with respect to their carcass traits such as slaughter weight, carcass weight without offals, offal weight, inedible offal and skin weight. The carcass yield (without edible offal) in WG and SC was 50.27 and 51.08%, respectively. It was concluded that there is sufficient scope for improving the carcass yield in both the breed through selection.

Selection studies in White Giant rabbits: This study was undertaken with an objective to evolve a broiler rabbit which could attain 2.0 Kg body weight at 12 weeks of age with a litter size of at least 5.0 at weaning. After producing four generations of progeny, it appears that the 12 week body weight is a function of litter size at weaning. Since, it is now clear that kits belonging to smaller litter sizes would achieve higher 12 week body weight; selection for body weight alone may not result in increased body weights. The litter size at weaning of about 5.0 would be appropriate for attaining heavier body weights at 12 weeks of age.

Commercial evaluation of Soviet Chinchilla rabbit: During the period from 1992 to 1995, the average litter size at birth was 7.12 with litter weight of 401 g. The litter size at weaning was 5.85. The body weights at 4 and 12 week of age were 383.0 g and 1.53 kg, respectively. The number of kindling/doe/ year was 4.11 (28.07 kits born /doe). Number of kits weaned /doe/year was 17.62 and kg weaned was 2.29. The kit mortality was 46.2%. The survivability was 77.95% in weaners, 98.17% in growers and 92.59% in adults. Since the revenue obtained was only 33.76% of the recurring expenditure, it was felt that rearing broiler rabbits on concentrate feeding is not commercially viable. Further, the revenue obtained is only 85.62% of the amount spent on concentrate feeding which also indicates that the project is not commercially viable unless until some cheaper feeding system for broiler rabbit is developed.

Commercial evaluation of White Giant rabbit: During the period from 1994 to 1996, the average litter size at birth was 6.74 with litter weight of 385.3 g. The litter size and weight at weaning was 5.60 and 2.298 kg, respectively. The body weights at 4 and 12 week of age were 410.0 g and 1.46 Kg, respectively. The number of kindling was 58%. The number of kindling/doe/yr was 5.60, the number of kits born/doe/yr was 37.72, the number of kits weaned/doe/yr was 25.76 and kg weaned/doe/litter was 2.298 and kg weaned/doe/yr was 12.87. The survivability in kits, weaner, growers and adults was 68.30, 74.24, 76.54 and 68.75, respectively. The cost of producing rabbit meat works out to be Rs. 33.37/kg.

Evolving cheap feeding systems for commercial rabbit production: Each grower in Gr-I consumed about 6.72 kg of pellet feed in 84 days and gained 1171 g weight with a cost of Rs.85.68/grower. The average daily gain was 13.98 g

and pellet feed cost/g gain was Rs.0.72. In Gr-II, grower consumed about 3.26 kg of pellet feed and gained 748 g weight with a cost of Rs.42.84. The daily gain in this group was 8.9 g/day/grower and the cost /g gain was Rs.0.57. The growers in Gr-III gained 894 g in 84 days without consuming the pellet feed with a daily gain of 10.6 g and the cost/ g gain was nil. In Gr-I and III, the growth was steady and increasing, while in Gr-II, it depressed after 4 weeks and again increased after 8 weeks due to non-nutritional factors which could be the reason for the low performance of the growers in Group-II. The per day gain in body weight was 13.9, 8.9 and 10.6 g in growers fed with pellet feed at the rate of 80, 40 g and on sole feeding with mixed greens, respectively.

Demonstration and training unit of broiler and German Angora rabbits: In 1983, the four broiler rabbits and the German Angora rabbits were received at SRRC Mannavanur and studies were undertaken for their adaptability and production performance. Based on the performance the best two broiler rabbit breeds viz. SC and WG were retained for further multiplication and distribution to interested farmers. The breeds are distributed to the farmers after getting them trained at this centre. In the initial years the response was poor though some sporadic attempts were made in a bigger way by one or two NGOs which stopped abruptly. However, in 2003, again an upsurge was seen in development of rabbitries by many farmers. SRRC could conduct regularly trainings almost every month since November 2003, so far 39 trainings were held and 215 farmers have been trained. Rabbitries have come up in almost all districts of Tamil Nadu and also in adjoining states. A total of 232 rabbits (82 of WG, 130 of SC breeds and 20 of German Angora breed) were sold to interested clients from Kinathukadavu, Pondicherry, Kodaikanal, Mangalore, Kochi, Coimbatore, Velemcherry, Kaikatti, Amaravathi Nagar and Ambathurai. Veterinary College and Research Institute, TANUVAS, Namakkal, Animal Husbandry Department, Kodaikanal were among the buyers.

During first ten years no significant presence was shown in southern states may be because of initial resistance by farmers as well as marketing problems. During last fives years, sincere efforts were made by SRRC and Department of Animal Husbandry, Kolar to popularize BM sheep in Kolar District of Karnataka and as a result it gained popularity in this area. In addition to that, the presence of BM is also seen in Sathyamangalam and Thalavadi areas of Erode District in Tamilnadu. A total of 426 Bharat Merino Sheep were supplied to farmers of Kolar district for breeding through different agencies during the years of 2001-07. Among the three main agencies, SBA Kolar has received highest (56%) followed by Mr.Veera Kempanna (33%) and Sheep Breeders Association (SBA) Gouribidanur (11%). Year-wise distribution of animal reveals that initially highest numbers of animals were distributed and later on approximately 40 animals per year were supplied regularly. As per the information collected from agencies, each farmer was supplied one male and two females or one male only as per the need of the farmer. As a result, about 200 farmers were benefited over the years.

Adoption level of sheep and rabbit rearing farmers in Coimbatore district and status of sheep in Tamil Nadu: Most of the marketing by the farmers (80%) was being carried out at their houses itself. Frequent outbreak of diseases and scarcity of quality sheep to the markets are the major constraints. Mutton production in Tamil Nadu witnessed a sharp decline during 1997-98 (11,457,398 kg) as against 13600, 298 kg during 1996-97. Majority of non-vegetarians preferred chicken. The city dwellers preferred mutton. The sale realization per sheep on slaughter in Tamil Nadu comes to around Rs.350.00. The share of Tamil Nadu in India's sheep skin availability is 15.2%. The red hair sheep skins of Tamilnadu have good market value. Sheep skins are preferred for leather garments and shoe uppers. About 833 tanneries are there in Tamilnadu. Of the 310 leather garment units in the country, Chennai has 151 of them.