Summary and Conclusion

5. SUMMARY AND CONCLUSION

Today textile industry is focussing towards manufacturing high tech, high performance fabrics designed to offer a significant added value in terms of functionality. The two main reasons which make the Indian textile industry strong are, export earnings and employment opportunities. Technical textiles is the fastest growing area of textile consumption in the world. Technical textiles are used in industry, civil engineering, medical, protective and leisure application. Technical textiles offer new ways, means and opportunities to the Indian textile industry to sustain its present growth and thrive in near future.

Natural fibres are bio-based and globally provide employment to millions of people. These are more environment friendly than synthetic fibres both in terms of production and disposal due to their biodegradable property. Growing awareness about risk to health and damages to the environment have been noticed in the last few years which necessitated eco-friendly approaches in production of articles of day-to-day use. There are many fibre yielding plants in our country, which have high potentiality for use in diversified fields but they remain unexplored so far. The less explored natural fibres belonging to leaf fibre category are receiving high importance as they are easily available and biodegradable. One such fibre that is obtained from the plant is *Agave americana*. Hemp is a stiff bast fibre with antimicrobial properties. Jute the bast fibre has high insulating and antistatic property. Cotton the king of fibres has a demand due to its excellent properties.

When the vegetable fibres or yarns are mixed, coarseness, stiffness, hairiness are noted on the fabric structures. Mixing of various yarns in a fabric help in exploiting the outstanding positive attribute of each fibre and also offers an effective means of minimizing the negative characteristics of the individual component. Further biopolishing with acid cellulases could reduce the negative attributes and enhance the positive ones. Nonwoven needle punched fabrics have gained importance in the field of technical textiles. Here the fibres are directly converted in to fabric and so the sequence operations followed in weaving and knitting are very much reduced.

The natural lignocellulosic fibres can be considered an important advantage in temporary applications in geo or agro textiles as synthetic materials need to be removed after a period of time due to the disturbance created to the environment. So

there is a need for innovation of natural geo textile and agro textile materials. Due to the demand for cotton fibres these should be replaced by some other natural fibre in the different fields of their use. Hence the researcher decided to take up a study on **"Extraction and Fabrication of *Agave americana* Fibres, into Woven and Nonwoven Structures, with Cotton, Jute and Hemp for Selected Technical Textiles"**. The objectives of the study were the following.

- Separation of fibres from *Agave americana* leaves.
- Conversion of *Agave americana* fibres into yarns and fabrics.
- Fabrication of *Agave americana* fibres into needle punched structure by blending.
- Application of special finishes on fabrics and evaluation.
- Construction of the selected fabric structure into apparel
- Creation of enduses for selected fabrics in home textiles
- Application of the selected structure in the field of agro textiles and
- Test the utility of selected fabrics for geo textiles.

EXPERIMENTAL PROCEDURE

Fibres were extracted from the leaves of *Agave americana* plant at a suitable stage of maturity by decortication method. These fibres were scoured and bleached so as to remove the impurities and make them bright.

The fibres were spun after softening, same way the procured jute and hemp fibres were also spun. These yarns were converted into plain woven mixture fabrics using handloom with warp-weft, namely *Agave americana*-*Agave americana*, *Agave americana*-jute, jute-*Agave americana*, *Agave americana*-hemp and hemp-*Agave americana*. Cotton yarn was procured and mixture fabrics of *Agave americana*-cotton and cotton-*Agave americana* were prepared. A ribbed woven structure was prepared with cotton-*Agave americana* in power loom, further these fabrics were scoured, bleached, lacdyed , fragrant finished and then converted into over coats and wear studied.

The same structure was madder dyed and then converted into runners, placemats, napkins and evaluated. The runner samples were wear studied and then evaluated. The cotton-*Agave americana* plain woven fabrics were scoured, bleached, catechu dyed and converted into rugs, wear studied and evaluated.

Needle punched fabrics were prepared after softening and blends of *Agave americana*-jute and *Agave americana*-hemp in proportions 50:50, 50:50 and cent per cent *Agave americana* were prepared. The untreated plain woven fabric structures of all the mixtures and the needle punched blends were applied for agro textile purpose as mulch sheets.

The plain woven structures of *Agave americana-Agave americana*, *Agave americana*-jute and hemp-*Agave americana* and nonwoven, needle punched *Agave americana*, *Agave americana*-jute and *Agave americana*-hemp blends were used for filtration purpose as screens and separators. These were used with gravel / charcoal / sand in four different proportions and the best two proportions were selected for further study.

Agave americana fibres were evaluated for various physical properties and chemical constituents. The yarns were evaluated subjectively and objectively – for essential physical properties. All the woven structures were evaluated for the basic physical properties. Both the woven and nonwoven fabrics were evaluated for dynamic cone drop perforation test. Some exclusive tests carried out for nonwoven structures were bursting, water retention capacity and thermal conductivity. Soil burial test was done for both woven and nonwoven structures for visual assessment and for objectively for fabric weight loss as well as for growth of microorganisms.

The ribbed woven cotton-*Agave americana* fabrics used for overcoat were evaluated subjectively and objectively for physical and comfort properties. The dyed samples were also evaluated for colour fastness. Similar tests were carried for fabrics used as runner and cotton-*Agave americana* plain woven fabric used as rug. After the application of agro textiles, the soil samples from mulched and unmulched plots were evaluated for soil moisture content, temperature, macro nutrients and micro nutrients. The weed count and biometric parameters of the plants were also assessed. The fabric samples were assessed for SEM appearance too.

As for the geo textiles, the filtered water was evaluated for qualitative and quantitative parameters and the best screen was selected for further filtration and geo textile tests.

FINDINGS OF THE STUDY

Fibres, Yarns and Fabrics

- The matured leaves yielded strongest fibres with length of 100-125 cms and diameter of 235 μm with chemical constituents of cellulose, hemicellulose and lignin of 68.36, 22.32 and 3.42 per cent respectively. SEM study showed the presence of fibrils in the *Agave americana* fibres. A slight swelling of fibre was noted in the scoured fibres and reduction of fibrils was noted in the bleached fibres.
- The strength of *Agave americana*, hemp and jute yarns has reduced on scouring and bleaching though twist per inch has increased in the bleached samples. The direction of twist introduced to the yarns was 'z'-twist.
- The elongation of all the yarn samples increased on scouring and bleaching.
- The *Agave americana* yarn diameter has decreased on scouring and regained on bleaching. The diameter of hemp yarn has increased on scouring and bleaching whereas in jute yarn samples, it had decreased after each process.
- The yarn count was increased in all the samples of *Agave* americana, hemp and jute on scouring, whereas on bleaching it increased only in *Agave americana* yarns.
- The maximum number of judges have suggested, the use of the ribbed woven cotton-*Agave americana* sample for apparel, curtains and table linens ; the samples *Agave americana*-jute, and *Agave americana*-hemp mixtures for package goods and cotton-*Agave americana* mixture fabric for floor coverings.
- Among the fabric samples in dry and wet conditions, in warp direction the samples *Agave americana*-jute, *Agave americana*-hemp and *Agave americana*-cotton exhibited the highest strength values of which the sample AC showed the maximum strength in both untreated and treated states. Strength loss was the least in sample AH in dry condition on scouring.
- Among the fabric samples in dry and wet conditions, in weft direction, the samples jute-*Agave americana*, hemp-*Agave americana* and cotton-*Agave americana* exhibited the maximum strength values.
- The wet strength was observed to be lesser than dry strength in almost all the samples in both warp and weft directions.
- The maximum dry and wet strengths were observed in the warp and weft directions in samples with *Agave americana* yarn as warp and weft respectively.

The same trend was noted in treated samples also. Flex abrasion resistance, also proved that the sample with *Agave americana* yarn as warp and weft could withstand the maximum rotations in those directions.

- Fabric count and cover factor, of all the fabric samples were increased but the weight and thickness were decreased on scouring and bleaching over the original samples.
- The maximum thickness was observed in cent percent *Agave americana* fabric structure, in untreated and treated conditions. The thickness was decreased in the fabric samples on scouring and bleaching.
- Dynamic perforation resistance was the maximum in cent per cent *Agave americana* fabric sample.
- Stiffness, of the fabric samples, was reduced on scouring and bleaching in both warp and weft directions. In warp direction the sample AA showed the greatest stiffness in original as well as treated samples.
- Seam strength was the highest in cent per cent *Agave americana* sample of all the fabric structures.
- Seam strength was the maximum in warp direction in which the *Agave americana* yarns were incorporated in warp direction and in weft direction in the samples in which the *Agave americana* yarns were incorporated in weft direction.
- The moisture regain of all the fabric samples showed a reduction in all the scoured fabric samples over the original samples. Of all fabric samples the maximum moisture regain was observed in original sample of cent per cent *Agave americana* and treated samples of *Agave americana*-hemp.
- Dimensional changes were noted in woven samples after scouring and bleaching except in sample of cent per cent *Agave americana*.
- Water absorbency of all the fabrics samples increased drastically on scouring and bleaching which was proved by increased wicking height and decreased sinking and absorbency. Sinking and absorbency tests showed highest water absorbing capacity in cent per cent. *Agave americana* fabrics of all fabrics in original, scoured and bleached conditions.
- The visual assessment of the soil buried fabric sample for biological degradation was noted to have black spots on the surface. The soil buried woven samples showed higher bacterial and fungal colonies over the control soil sample

expressing the degradation property of the fabrics. SEM study showed fibre damages.

- The plain woven cotton-*Agave americana* ribbed fabric lends itself for special finishes namely water, oil and aqueous liquid repellent finishes. The plain woven cotton-*Agave americana* fabric lends itself for the flame retardant finish.
- The needle punched sample with cent per cent *Agave americana* fibres showed the highest values in bursting strength, dynamic perforation resistance, seam tensile strength, weight, thickness, stiffness and also showed the best water absorbency characteristics.
- Air permeability was the greatest in needle punched sample of *Agave americana*-jute blend.
- Thermal conductivity was the lowest in cent per cent *Agave americana* sample.
- The soil burial test showed the minimum weight loss in *Agave americana*-hemp sample of needle punched structure. The fabric buried soil samples showed higher bacterial and fungal colonies than the control soil sample.

Evaluation of Ribbed Woven Fabrics as Apparels

- The visual assessment of original, scoured and bleached samples of cotton-*Agave americana* ribbed woven structure showed improvement in general appearance, colour, lustre and texture on bleaching.
- The subjective assessment of lac dyed sample of ribbed woven cotton-*Agave americana* was observed to be uniformly dyed, bright in colour, smooth in texture, high in lustre and good in general appearance, whereas the wear studied sample of the same showed slight reduction in evenness, brightness, lustre and general appearance.
- The feedback obtained from the subjects about wear study samples on various parameters of comfort, stiffness, warmth and fragrance, it was observed that after the fifth wash, the over coat was judged to be more comfortable, due to the reduction in stiffness. The warmth of the garment was rated to be high by the maximum number of subjects even after seventh and eighth washes which reduced in subsequent washes. The fragrance reduced in the apparel after ninth and tenth washes slightly.
- Colour fastness of the wear studied over coat samples showed slight reduction in colour change to alkali perspiration, light, and wet and dry crocking over the original dyed samples.

- Fabric count of the dyed and wear studied ribbed woven fabrics used as over coat was increased in both warp and weft directions.
- The weight, thickness, tensile strength, elongation, abrasion resistance, stiffness and drape coefficient were reduced after washes in the fabric samples.
- All the absorbency characteristics namely wickability, sinking and absorbency test showed an increase after wear and subsequent washes proving the increase in comfort qualities.
- Moisture regain and air permeability were decreased in the sample after washing.
- Thermal conductivity, of the samples was reduced in the lac dyed samples but increased drastically in the wear studied sample.

Findings of the Tests Carried for Woven Fabrics in Home Textiles as Rug and Runner

As Runner

- Cotton-*Agave americana* ribbed woven madder dyed original sample was rated as good in general appearance, bright in colour, high in lustre, smooth in texture and uniform in dye shade by majority of judges ; whereas the wear studied sample showed decrease in ratings in the above parameters. The colour fastness properties of cotton-*Agave americana* ribbed woven scoured, bleached, biopolished, madder dyed and wear studied sample (CARSBBMW) showed a marginal difference to crocking and light, over original sample.
- The tensile strength, elongation and stiffness were reduced in wear studied runner samples (CARSBBMW) over original sample in both warp and weft directions. Weight and thickness were also reduced in the wear studied samples, whereas fabric count, wicking, sinking speed and drop immersion speed increased in the same.

As Rug

- The visual assessment of catechu dyed sample of cotton-*Agave americana* plain woven original sample was good in general appearance, very bright in colour, high in lustre, smooth in texture and even in dye uptake ; whereas the wear studied sample showed slight reduction in general appearance and dye evenness after washes.
- The catechu dyed wear studied sample showed a slight reduction in colour fastness to washing and rubbing over original sample.

- Though the cotton-*Agave americana* plain woven sample showed reduction in certain physical properties after various treatments, there was an increase in the comfort qualities.

Findings of Woven and Nonwoven Samples as Mulch Sheet in Agro Textiles

- The findings from the survey of farmers expressed that the farmers were not aware of the natural mulching sheet and if some eco-friendly product was let into the market it would be of great use for them as weeds cause major problems to the main plants.
- Due to mulching the plants were protected from high fluctuations observed in relative humidity and temperature during the cropping period.
- A reduction in temperature at 15 cm and 30 cm depths and increase in moisture content were observed in all the mulched plots over unmulched plots.
- The maximum soil moisture content and the minimum temperature were observed in the soil mulched with woven sample of *Agave americana*-hemp mixture and nonwoven sample of *Agave americana*-hemp blend.
- The evaluation of the presence of macro and micro nutrients showed an increase in the soil from mulched plots over the pre-experiment and control soil samples. The pH of the soil showed a slight increase in all the mulched plots except soil sample from *Agave americana*-hemp mulched plot over pre experiment and control soil samples. The EC of the soil sample decreased in the mulched plots of AA, AJ, AH, HA, CA and AJN and AHN over pre experiment and control soil samples.
- The weed suppression was observed to be cent per cent in samples AJ, JA, HA, AC, CA, AAN and AJN as no single weed was detected in the plots mulched with these samples.
- The observation of biometric parameters namely germination per cent, root length, shoot length and vigour index were observed to be the maximum in woven mixture sample of *Agave americana*-hemp and nonwoven sample of *Agave americana*-hemp blend over the control plots. In both the woven samples of *Agave americana* and hemp mixtures and nonwoven *Agave americana*-hemp blend, the germination per cent was noted to be cent per cent. The vegetable yield was also observed to be the maximum in sample *Agave americana*-hemp mulched plots among other mulched and control plots.

- The visual assessment of the samples used as mulch sheet showed fair general appearance, dull colour, very low lustre and very soft texture over their respective original sample.
- The black spots were observed to be the maximum on the surface of the woven fabric samples CA and AC whereas it was little in both the samples of *Agave americana* and hemp mixtures of woven and the needle punched *Agave americana*-hemp sample.
- The scanning electron microscopic appearance exhibited the damage of the fibrils of fibres present in the mulched sheet. More damage occurred in the fibres from nonwoven fabrics than fibres from woven fabrics.

Findings of Filtration Capacity of Woven and Nonwoven Screens for Physical Parameters

- Hydraulic efficiency was the maximum in the combinations $P_1S_4M_1$, $P_2S_1M_1$, $P_1S_1M_4$ and $P_2S_1M_4$ among all the combinations.
- Sediment removal efficiency was the maximum in the combinations $P_1S_3M_1$, $P_1S_4M_2$, $P_2S_2M_2$, $P_2S_3M_3$, $P_1S_4M_4$, $P_2S_4M_4$, $P_1S_2M_5$ and $P_2S_2M_5$ of all combinations.
- Among all the combinations, the electrical conductivity reduction efficiency was the highest in the combinations $P_1S_1M_1$, $P_2S_1M_1$, $P_2S_3M_1$, $P_1S_1M_2$, $P_1S_3M_2$, $P_2S_1M_2$, $P_1S_1M_3$, $P_2S_1M_3$, $P_1S_1M_4$, $P_1S_4M_5$ and $P_2S_3M_5$.
- The combinations $P_1NS_4M_1$, $P_1NS_1M_4$ and $P_2NS_1M_4$ showed the best result in hydraulic efficiency among all the combinations.
- Electrical conductivity reduction efficiency was the maximum in combinations $P_1NS_4M_2$, $P_1NS_3M_3$, $P_1NS_2M_4$ and $P_1NS_1M_5$ of all combinations.
- Among different combinations, the sediment removal efficiency of the nonwoven screens was observed to be the best in the combinations $P_1NS_3M_1$, $P_2NS_1M_1$, $P_1NS_2M_2$, $P_1NS_3M_3$, $P_2NS_3M_3$, $P_1NS_4M_4$ and $P_1NS_1M_5$.

Findings of Filtration Capacity of various Woven and Nonwoven Screens for Chemical Parameters

- As for the reduction of Total Hardness, Ca, Cl, Mg and NO_3 the maximum occurrence as per ANOVA of proportion P_1 (1:1:1) screen S_1 (hemp-*Agave americana*) and Media M_4 (coir fibres) were noted among the combinations of those that gave the best results in hydraulic efficiency.

- Among the combinations of those that gave the best result in sediment removal efficiency, as for chemical reduction, the maximum occurrence of proportion P_1, (1:1:1) screen S_3 (AA) and media M_3 (jute fibres) confirms the best filtration capacity.
- In combinations of those that gave the best result in electrical conductivity reduction efficiency, the chemical reduction was observed to be the maximum in proportion P_1, (1:1:1) screen S_1 (HA) and media M_2 (*Agave americana* fibres).
- Among the combinations of those that gave the best results in hydraulic efficiency, the proportion P_1, (1:1:1) screen S_1 (AHN) and M_4 (coir fibres) showed the best results in chemical reduction efficiency also.
- The combinations which gave the best result in sediment removal efficiency, the proportion P_1, (1:1:1) screen S_1 (AHN) and media M_3 (jute fibres) and M_5 (hemp fibres) showed the best result in removing chemicals too.
- Among the samples of those that showed the best reduction in electrical conductivity, the proportion P_1, (1:1:1) screen S_1 (AHN) and media M_5 (hemp fibres) showed the best results in chemical removal efficiency also.
- All the screens act as the best separators in preventing the mixing of sand, gravel or charcoal fibres with each other.

Findings of Physico Chemical Examination of Unfiltered and Filtered dosed Water Using HA Woven Screen and Coir Medium

- Hemp-*Agave americana* woven fabric screen along with gravel, coir fibres and sand gave the best result in chemical reduction efficiency as well as turbidity, TDS and EC from dosed water of agricultural runoff water.

Findings of Evaluation of Hemp-*Agave americana* Fabric by Geo Textiles Tests

- The mass of woven hemp-*Agave americana* sample was 587.6 g/m^2, thickness was 2.67 mm, trapezoid tear was 225.8 N in warp and 484.4 N in weft directions, and wide strip strength 11.4 KN/m and 35.2 KN/m in warp and weft directions respectively. The CBR puncture strength of the hemp-*Agave americana* sample was 2557 N and the elongation of 22.9 per cent and 10.5 per cent in warp and weft directions respectively expressing the suitability of the woven fabric structure (hemp-*Agave americana*) in the field of geo textiles.

CONCLUSION

Agave americana is a nonfood carefree crop available in plenty in and around Coimbatore. The long and strong fibres could be extracted from the leaves of the *Agave americana* plant successfully converted into yarn and then into mixture fabrics with jute, hemp and cotton. The affinity of the mixtures of *Agave americana* cotton and cent per cent *Agave americana* fabrics, towards various natural dyes and finishes is appreciable. The woven fabric structures were successfully utilized for cloth tex, home tex, agro tex and geo tex purposes. *Agave americana* fibres were satisfactorily blended with jute and hemp fibres to obtain needle punched nonwoven fabrics which were used for agro tex and geo tex purposes successfully.

LIMITATIONS

- Due to very low cohesiveness of *Agave americana* fibres blending of these fibres with other vegetable fibres was not possible in yarn preparation.

RECOMMENDATIONS FOR FURTHER STUDY

- Effective softening treatment could be tried to the *Agave americana* fibres to make it suitable for blending.
- Suitable treatments could be innovated to enhance the durability of the *Agave americana* mixture fabrics to be used for the long span agro and geo textiles purposes.
- Composites could be prepared from both woven and nonwoven structures.
- Due to greater affinity of these mixtures towards natural dyes, these could be dyed with various other natural sources of dye.
- These fabric structures could be applied in various other fields of technical textiles also by giving suitable finishes.