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AGRO TEXTILES FOR CROP MANAGEMENT: A REVIEW

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ABSTRACT

A category of technical textile materials with varied functional benefits for the agricultural sector are known as Agro textiles. They help in improving the agronomics of the agricultural land as it has a direct impact on land productivity. Research carried out world over have scientifically proven that the use of agro textiles improves the crop yield and production over time, reduced incidence of weeds, decreased usage of insecticides and pesticides, improving the soil health by maintaining the moisture content and soil nutrients. Farming by using agro textiles is a way of sustainable crop production which preserves and enhances the natural resource base and environment and also reduces the impact of climate change. Agro textiles available in the market include shade nets, thermal screens, crop covers, mulch mats, root ball net, bird protection nets, fruit covers, anti-hail nets, grow sticks etc. This review paper presents the current scenario of agro textiles, their production, use, technical aspects in terms of fibre used, production method, agro waste as a potential source for agro textile production. In addition, the paper covers the current research on agro textiles, crop wise usage, and perceived benefits of agro textiles to the farmers. Agro textiles can help intensify crop production sustainably by allowing carbon neutral farming, by maintaining the soil moisture thereby reducing the risk of bacterial or fungal contamination, by not hampering the growth of the crop, trees and fruits, by being less toxic to farm animals or birds, by reducing or eliminating crop waste, by being protective to the crop against pests and harsh weather. Other benefits of agro textiles include extending the growing season of agricultural crops, reducing soil degradation and conserving water. Agro textile is an interdisciplinary technology which can relieve the stress of production and improve both crop quality and quantity. Adopting such 'farm to folk' agro-tech products by the farming community can be a good agro-technical practise.

Keywords : Agro textiles, bird protection net, crop cover, shade net, pest control

Introduction

A class of textile materials that have a very definite functional and performance characteristics rather than decorative or aesthetic characteristics defined as technical textiles. One component of technical textiles is the 'Agro textiles', which caters to the agriculture sector, horticulture applications, livestock protection, shading, insect and weed control (Restrepo-Osorio *et al.*, 2019). The functional features in Agro textiles are expected to increase the yield and quality of agriculture products. For Agro textiles, properties such as strength, stiffness, elongation, sunlight resistance, porosity, biodegradation, resistance to toxic environment etc are of paramount importance.

Agro textiles are made either with weaving, knitting or non-woven construction methods. These textiles help to increase the quality of the agriculture produce, while lowering the production costs, as less of resources like water and pesticides and weed killers are utilized. In addition, reduced use of these chemicals will not only assist to lower input costs but also avoid contamination of the environment and lessen the negative effects of widespread pesticide use on soil and human health. Controlled light transmission, assistance in regulating soil temperature and humidity, protection against pest infestation, defence against cold, hailstorms, and unexpected rain, and reduced likelihood of crop loss are the benefits provided by agro textiles. The soil

health can also be protected as the agro textiles help in moisture retention in soil. Several agro textiles such as weed control mats, crop covers reduce the resurgence of weeds in the agricultural fields. To maintain the greenhouse temperatures, agro textiles such as shade nets, thermal screens are useful. It is estimated that there is a savings of 40% energy when such agro products are used in the greenhouses. Fruit covers are expected to protect the fruits from advanced weather conditions as well as improve its quality prevent staining of roots and overall uniformity in colour (Sharma *et al.*, 2022). Agro textiles have also been used as a carrier for fertilizer delivery to the crop through absorption or adsorption principle. NPK When mixed with rice raw has a positive impact on the presence of extractable glomalin, soil Organic carbon total nitrogen content in the soil. (Nie *et al.*, 2007). Agro textiles can also be used as a suitable substrate for delivery of eco-friendly fertilizers (Geng *et al.*, 2015). The paper presents a comprehensive review of agro textiles.

Present scenario of agro textiles in India

Agriculture is the backbone of India and it is the second largest producer of food in the world. Textiles made exclusively for the agriculture sector has been growing at a steady pace. Materials created for agricultural applications like shade nets, mulch mats, bird nets etc are used to improve the productivity and efficiency and also increase functional benefits and reduce input costs. When compared with previous years, agro textiles usage in the current decade has increased. Farmers are willing to adapt new technologies to improve the crop yield and to protect crop from environmental stress. Indian government is also supporting farmers through various schemes and policies by providing subsidies to improve the agricultural productivity. Ibrant Gujarat 2024 – 10th global summit on textiles analysed that, the global agriculture textile market is projected to reach US\$20.99 Bn by 2029 from US\$1 Bn in 2022, at 5.1% CAGR from 2023 to 2029 (Figure 1.)

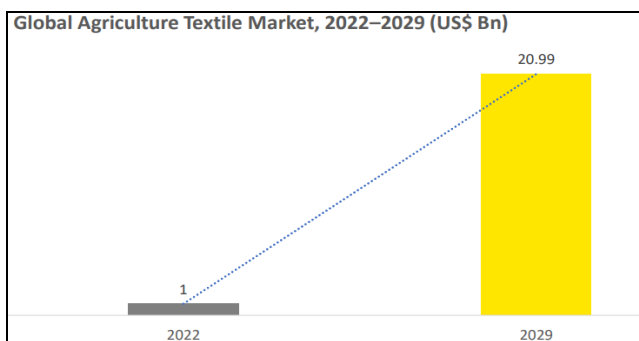


Fig. 1 : Global Agricultural Textile Market
(Source: Ibrant Gujarat 2024 – 10th global summit)

Now a days most of the manufacturers are focusing on innovative and advanced technologies to manufacture agro textiles to meet the diverse needs of farmers with high quality and eco-friendly products. But man-made fibers are preferred over natural fibers in farming because of their great strength, endurance, and other relevant features. In spite of the growth, industry has to face many challenges like regional variations along with varied agricultural practices.

Technical aspects of agro textiles in terms of fibre used, production method, agro waste, etc.

Most agro textiles available in the market draw their sources from synthetic fibres such as nylon, polyester, polyethylene, polypropylene and polyolefin etc. Polypropylene and polyethylene have also been used for making shade nets with improved UV resistance, by adding chemicals during doped dying stage. Bird protection nets are made through knitting technique using polypropylene or high-density polyethylene monofilament yarn which are UV stabilised during manufacturing stage. Other products such as sunscreens, insect meshes, weed control fabric, mulch fabric, greenhouse covers have also been made of UV resistant polyethylene fibres. The reasons for widespread use of synthetic fibres are their ease of availability, long shelf life, low price as well as beneficial properties such as high mechanical strength, modulus and elongation and low moisture absorption. The greatest disadvantage of using synthetic fibres is their lack of recyclability thus posing environmental hazard.

Synthetic textile fibres used in Agro textiles

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Minor textile fibres used in agro textiles

Lignocellulose fibres obtained from sources like corn, banana, straws of wheat and rice, pineapple leaf, bagasse, Sisal etc., have been studied for their potential application in the area of Agro textiles. These sources are suitable due to their inherent chemical and physical properties. Moreover, they are carbon neutral, biodegradable and renewable. In addition, these natural fibres retain soil moisture, reduce evaporation, and prevent the soil from drying (Restrepo-Osorio *et al.*, 2019). Agricultural residues such as straws of wheat and rice, corn have been used for preparation of composites suitable for horticulture applications. Some of the minor fibre's usage in Agro textiles is presented here:

Coir has been used to make a variety of products for agricultural use such as erosion control blankets, basket liners, bio rolls, grow sticks etc. The purpose of an erosion control blanket is three-fold - to protect the seeds and seedlings from wind and rain, preventing soil erosion, act as a mulch mat. Coir basket liners help in good aeration of plants and help in vigorous growth of roots. Another non-woven composite product made from coir is bio-rolls, helps in rapid root growth. A grow stick made from coir fibres wrapped onto a wooden stick act as a plant supporter for a creeper and also helps to maintain a steady supply of moisture to the plant.

Sisal, a shrub usually grown on the peripheries of agricultural land acts as a fence for the crop. The leaves of Sisal have been explored for fibre extraction which in turn is used for many agricultural applications. Baler twines made from Sisal have been used for wrapping the crop produce.

Biopolymers use in the production of agro textiles has gained momentum since they are a better alternative to the synthetic polymers. Biopolymers include polylactic acid (PLA), polyhydroxybutyrate (PHB), polybutylene succinate (PBS), cellulose esters, soy, starch, cellulose derivatives, zein, casein, chitosan, sodium alginate, polycaprolactone, gelatin etc. out of these, PLA is more popular as its properties are closer to the synthetic fibres, has good sunlight resistance, and at the same time degrades easily (Restrepo-Osorio *et al.*, 2019).

Production method employed in making agro textiles

The techniques used to produce agro textiles are based on the type of product and its end use to improve crop production, protection of plants, and soil management. The commonly used techniques are woven, knitted, nonwoven etc. along with these coated, laminated and biodegradable techniques are also employed. The methods have been summed up and presented below Table 1.

Table 1 : Fabric construction techniques used for different agro textiles production

Woven	Knitted	Nonwoven
<ul style="list-style-type: none"> • Sulzer projectile weaving machine is used. • Products with wide width are possible. • Width range: 540 cm to 846 cm. • Net mesh width ranges from 1.8 mm to 40 mm. 	<ul style="list-style-type: none"> • Warp knitting is used widely. • Raschel knitting machines are used. • Individual yarn is converted into fabrics. 	<ul style="list-style-type: none"> • Most widely used technology for agro textiles. • Spun bonded technique is mainly used due to its high tensile strength in all directions. • Needle punched, stitch bonded, thermally bonded and hydro entangled methods are also used for different applications.
Ex: Crop covers, Shade nets.	Ex: Monofilament nets used for bird protection.	Ex: Fruit covers, weed control mats, mulches, water retainers.

Agro waste as a source for agro textiles

Agriculture is one of the largest sectors in India and every year it generates billion tons of agricultural waste. Traditionally, agro waste like rice bran and corn husk have been utilized for animal feed to supplement the nutrition and reduce the feed cost of animals. Agro waste can be used as a source for agro textile production in several ways like composites, soil, water retention mulches, eco-friendly and bio degradable

fruit, vegetable packaging materials and plant growers etc.

Role of agro textiles in sustainable agri production

Sustainable agri production in the wake of climate crisis, reduced arable land, reduced natural resources like water, soil, new types of pests and insects attacking the crops, weed management etc has been a challenge for agriculture sector. Meeting the growing demand for the increasing population of India is also a concern that is being addressed by the Government.

Novel ideas of the scientific community and the farming community to address the above challenges are being validated and tested and promoted through digital media to every nook and corner of the nation. Integrated pest management (IPM) advocated by the agricultural scientists help in bringing sustainability into agriculture production systems. One challenge in IPM is the resistance of crops to herbicides, chemical pesticides and weedicides. To address these challenges, agro textiles with very specific functional properties can be used in conjunction with sustainable agri practices. Textiles in the form of fruit covers, insect trapping nets, spacer fabrics working on the principle of providing a circuitous path for the insects to enter the micro climate of the crop in the greenhouses, etc can be a viable solution.

Mulching films

Mulching film is an agro textile which helps to create a soil microclimate favourable for the plant roots. They are also helpful in eliminating weeds which therefore will reduce the amount of herbicides used on the plant, ultimately reducing the cost of production. Fruit damage and soiling is reduced upon usage of mulch mats. High quality fruits can be produced if the soil is covered with mulching mats. The advantage of biodegradable mulching mats is that they are eco-friendly and can decompose into CO₂ and H₂O, with time as opposed to the synthetic mulches which need to be removed from the fields and significantly increasing the labour costs. White biodegradable mulching film decomposes faster than the coloured ones. A decrease in the soil temperature underneath the biodegradable black mulching film was observed when compared to the black polyethylene film. (Ngouajio *et al.*, 2008, Kijchavengkul *et al.*, 2008)

Root ball net

This agro textile is useful in transplanting trees and shrubs by carefully wrapping the plant roots in the net. It also helps to hold the soil together and protect the roots from damage during transportation and storage. It is usually made in knitted construction and the net sizes may vary from 200 to 500 mm in diameter. Non-woven method of construction can also be used to make root bags, which stops the root from uncontrolled spreading.

Bird protection nets (HDPE, LDPE)

Most fruit farmers are facing serious problems of birds pecking the fruits, which results in huge loss of income and yield. To combat this problem, a mesh like net fabric can be used to cover the fruits to prevent birds from picking it. The bird net is designed with small holes to allow the movement of bees and air to

pass through, provide shade to prevent rot and mould, and allow the light for fruit growth. These nets are made with lightweight knitted fabrics of 25-40 GSM with strong, durable and tear resistant properties. The standard net size ranges from 1 to 6 meters width and 10 to 100 meters length. High performance monofilament polyethylene yarns are used for making the bird nets. These fabrics are given UV protection finish. Green, blue and white are commonly used colours.

Anti-hail nets

Anti-hail nets are used to protect the crops in high altitude and hilly areas. Each individual tree like apple and litchi are covered with anti-hail net. These nets are woven using high modulus or high-performance polyethylene yarn or combination of mono filament. UV finished knitted tapes are also available in market. Anti-hail nets are transparent with small hole structure and GSM ranges from 60 to 100. These are flexible, light weight, strong and can be placed easily on simple support structures.

Shade netting

Shade nets are most widely used agro textile to protect the plants from extreme environmental conditions and also to maintain water reduction. The usage of shade nets is more significant in India as it is the second largest producer of flowers, fruits and vegetables. The application areas of shade nets are much wider than any other agro textiles. These shade nets are used in horticulture crops for growing and preserving of flowers, fruits and vegetables. Shade nets are also used for cattle shed, feed and grain storage area coverings. The nets also maintain humidity in plant nurseries and greenhouses. Presently, these are also used in house balconies, building construction works, parking areas and water pools to protect from sunlight and dust.

Shade nets are either woven or knitted with different sizes ranging from 2 to 8-meter width to 25 to 100 meters length with varied thickness and texture. The shade nets usually measure 3 meters width by 50 meters lengths with weight of 120 to 180. Commonly manufactured colours are green and black. Based on the application type, the colour depth percentage of shade nets varies from 25 to 90 %.

Crop covers

Crop covers are mesh like large sheets with small holes and are used to cover the crops to create an exceptional microenvironment for seed germination and growth of small plants. These are placed over the plants and sometimes on newly planted saplings to

transfer to the fields and also to protect from extreme heat or cold. They will help to maintain humidity for rapid growth and early harvest, and also protect from insects, heavy rain, hails, wind and snow. Cross pollination is one of the major advantages of the crop covers, which helps improve the crop quality. Crop covers are manufactured in lightweight materials and GSM ranging from 17 to 30 based on the climate. Lower GSM is suitable for hot weather and high GSM is for cold weather. Construction technique may be woven, non-woven, films and sheets, and are available in the form of rolls in different lengths and widths.

Capillary mats

Capillary mats are made with absorbent materials to retain the water and moisture in plants. These mats help in providing consistent and even distribution of water and its release slowly to the plant, thereby ensuring that the plants receive adequate amount of water regularly. Capillary mats not only help to maintain water but also maintains soil moisture level and promotes uniform plant growth. These mats are more suitable for container plants, raised beds and seed coating.

Fishing nets

Fishing nets are used to catch the fishes in both the oceans and the lakes. These are made from strong materials like polypropylene and nylon with different knotting techniques like single knot, double knot and U – knot, with varied lengths ranging from 100 meters to 1000 meters. The design of the net is created in such a way that, the fish can swim inside the net but, it cannot escape from it. The holes of the net are designed to accommodate different sizes of the fishes. They are built to be tough, resistant to wear, and designed to move easily through the water. Many nets are invisible or transparent, making them less noticeable to fish.

Crop wise use of agro textiles

Tomato: Plant nets made of polyolefin fibres have been used for tomato crops. These nets allow the fruit to grow vertically and protect the young branches and flowers against harsh weather conditions prevent sand and wind erosion, keeps the fruits away from the damp soil. Root ball nets protect the roots and help in easy transplantation of plants the advantage being the roots can protrude through the spaces in the next. In addition, they protect the root system by keeping them intact and help in safe and speedy growth of plants. Mulch fabrics prevents the growth of unwanted weeds in an environmentally friendly manner, and at the same time allowing the air water and fertiliser to percolate through the fabric to the soil. Non-woven fruit covers help in enhanced fruit harvest by protecting them

against harsh weather conditions of snow, rain, frost, and heat. (Sharma *et al.*, 2022).

Several coloured mulching films were used for tomato crop to assess the development and yield of the fruit. Coloured plastic film mulches had an impact on soil temperature in fall winter and spring summer seasons. Higher soil temperatures were noted when dark coloured mulching films were used. Yellow silver plastic mulch film showed a positive impact on the plant growth while silver plastic mulch film improved tomato yield to up to 34%. (Mendonça *et al.*, 2020)

Synthetic mulching films and biodegradable mulching films were used on tomato crops by Poland scientists in their agricultural field in the years 2011 to 2013. The study revealed that tomato plants merged with polyethylene and biodegradable mulch showed a higher yield. It was noted that the early yield of tomato fruits increased by 28% on an average by use of mulching material when compared with non-mulched fields (Adamczewska-Sowińska and Turczuk, 2018)

The presence of residual mulch film in the soil was investigated by Zou *et al.* (2017). Residual film has a detrimental effect on the soil hydrodynamic parameters destroys soil texture impedes the movement of soil water and solutes thereby having an impact on the crop growth and the tomato fruit quality. Use of mulch film to more than 80 kgs per hectare has contributed to reduction in the growth indexes, dry biomass and tomato yield. Fruit shape index, organic acid, lycopene was decreased when mulch residue in the field increased while soluble sugar content, vitamin C, nitrate content increased.

Chinese researchers have focused on the effects of plastic film mulching on environmental pollution, and proposed an alternative solution of using a biodegradable film for tomato crop. A comparison was made between polyethylene film and biodegradable film on the parameters such as crop growth yield and economic benefits in tomato crop. It was found that a biodegradable film with a thickness of about 8 µm would be beneficial for mechanical operation. Biodegradable film was comparable to PE film in terms of getting net profits, most of the biodegradable film (50 % to 70%) was ruptured and degraded during harvesting, and also improved the efficiency of harvesting and commodity rate of tomatoes (Abduwaiti *et al.*, 2021).

Scientists from Italy studied the differences in tomato yield and quality when black biodegradable film and black low-density polyethylene (LDPE) mulches were used. In comparison to bare soil farming, both the mulches showed a 25% increase in yield,

9.9% increase in total soluble solids, and 57% increase in carotenoid content. The black biodegradable film showed signs of degradation after 71 days of transplant in 2014 and 104 days in 2014. Hence, use of biodegradable films is environmentally safe and agronomically sustainable practise (Di Mola *et al.*, 2023).

Indian researchers also studied the effect of synthetic and biodegradable mulches on different varieties of tomatoes. Four wet varieties showed increased yield when mulch mats were used during cultivation. For the synthetic mulch, weed density was the lowest, with the transparent polythene mulch unable to suppress the growth of weeds, as sunlight seeping through the transparent material helped in growth of weeds. Rice straw, kans grass and dencha husk based organic mulches in the study showed varied response to the growth of weeds with the highest being that of rice straw and the lowest being dencha organic mulch. Dencha based mulch degraded fast. The availability of fruit (crop duration) almost doubled when inorganic mulches were used as opposed to organic mulches (Agarwal *et al.*, 2022).

Recycling of agro textiles

Most Agro textiles used for horticulture application have been made using synthetic fibres, which can pose a serious environmental hazard as they are not biodegradable. Hence, the scientific community have focused on the use of biodegradable materials such as lignocellulosic fibres, natural polymers such as starch, cellulose, chitosan etc. for making biodegradable pots. The advantages of such pots are multiple which include easy degradation by soil microflora, providing a safe microclimate for plant growth, improved growth and yield of crops. (Santagata *et al.*, 2014)

Next-generation of agro-textiles

3D spacer fabrics provide protection to the crops from insects by acting as a plant armour. It acts as a physical barrier in reducing insect penetration and also promotes the plant growth. The 3D spacer fabric was made of three layers – the outer layers made from 150-denier dull multifilament polyester separated by inner connecting layers made of 20-denier polyester monofilament in a warp knitting machine. Another 3D spacer fabric with 70-denier bright polyester multifilament infused with TiO₂ and 9-denier polyester monofilament as the inner layer were made on a weft knitting machine, and studied in the lab by Cave *et al.* (2022). The three-layer knitted fabric parameters include pore size of $49.13 \pm 18.15 \mu\text{m}$ (mean \pm SD) in diameter for the top layer, $99.24 \pm 12.90 \mu\text{m}$ for the

bottom layer for the fabric made in warp knitting machine and thickness of $8.9 \pm 0.06 \text{ mm}$, weight per unit area of $49.21 \pm 1.63 \text{ g/m}^2$. Another fabric made on weft knitting machine has a pore size of $15.58 \pm 2.97 \mu\text{m}$ for both layers and thickness of $1.07 \pm 0.01 \text{ mm}$. weight per unit area of $14.59 \pm 0.10 \text{ g/m}^2$. These two knit fabric constructions were compared with a commercially available Proteknet fabric. The penetration rate of sunlight was 80,75, 100 for 3D spacer fabric 1, fabric 2 and Proteknet.

Conclusion

Indian agro textile industry reflects significant growth and potential. Agriculture is the back bone of India and it remains vital part of the economy. The growth and diversification of agro textile products are increasing in day by day from shade nets to soil protection mulch films are offering sustainable to solutions for improved productivity. In spite of many advantages, agro textiles need continuous research and development to meet the challenges like regional variations and innovative materials to protect against extreme weather. Agro textiles not only helping in improving the crop yield but also securing food production for growing population through sustainable agricultural practices.

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