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SUSTAINABLE PRODUCTION, GRADING AND MARKETING CHANNELS OF WOOL

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India is the 9th largest producer in the world contributing around 2 percent to the world's total wool production. The sheep population has increased from 65.06 million to 74.26 million, contributing 678.0 million kg mutton and 40.4 million kg of wool. Sheep husbandry is one of the valuable and important sources of income for small farmers and provides employment to nearly 6 million people in the Country. The demand for mutton and wool is growing in the country and the exiting woolen and carpet industry requires 100 million kg of wool annually. To meet the demand, India is importing 80-90 million kg of wool from Australia, New Zealand, and other countries (ICAR-CSWRI, 2019, Annual Report). In India, Rajasthan is the highest wool-producing state having around 70 wool processing units with a production of around 15 million tones of wool every year. About 12 lakh people are employed in organized wool sector and there are around 3.2 lakh weavers in carpet sector (Wool Division, 2018)

Table.1 Major wool producing states (2018-19)

Rank	State	Wool production (in 000kg)	% Share
1	Rajasthan	14880.57	36.81
2	Telangana	4800	11.88
3	Karnataka	4344	10.75
4	Gujarat	2300	5.69
5	Himachal Pradesh	1500	3.7

DAHD, 2020-21, Annual Report

Market and Export Destination of Wool

The wool industry in India is concentrated in Punjab, Haryana, Rajasthan, Uttar Pradesh, and Gujarat. Out of these states, Punjab has 40 percent of wool production units followed by Haryana (27%), Rajasthan (10%), and the rest of the states (23%). In India, there are 718 existing wool production units and around 27 lakh people employed in the woolen industry and sheep rearing in the rural areas (woolboardnic.in). US and EU are the key export destinations for Indian wool and wool blended products. Export of USD 2.79 million was reported for raw wool while USD 108.52 million for woolen yarn, fabrics, madeups during the year 2020-21 (Directorate General of Commercial Intelligence and Statistics, 2020).

Wool

The fleece obtained from a sheep is called as grease wool or raw wool. It is the animal fiber which grows from the follicle in the skin and has greasy coating. Indian wool is known for its coarseness and presence of medulla. Medullated fibers are characterized by central canal containing cell residues and air pockets running continuous and fragmented along the length. They appear chalky white and apparent unable to dye to the same shade as normal solid fiber. They make the fabric stiff. Wool is a protein fiber that has scales and crimps that make it easier to spin into the yarn because the fibers interlock with each other rather than slides loosely against each other. Crimp in the fiber allows wool fabrics to hold air and thereby retain heat. Wool fiber can absorb almost 1/3rd of its weight in water making wool fabrics excellent for wicking moisture. Wool fibers are elastic, thus retains their shape over the life span of a garment. Some wool fibers are fine and wearable close to the skin such as Merino, Rambouillet, Corriedale, etc.

Common Characteristics of Wool

Some characteristics determine what it can be used for. These are as follows:

1. Diameter (micros)
2. Staple length
3. Uniformity of fleece
4. Elasticity
5. Strength/Durability
6. Luster
7. Felt-ability

Factors Affecting the Wool Quality

Several factors are contributing to the maintenance and improvement of the wool clip. There are as follows

1. Breed suitability to farm context
2. Feeder design that reduces neck, back & shoulder rubbing
3. Nutrition and its impact on fiber strength
4. Contamination of wool with vegetative matter from field grazing
5. Age (Increased kemp or hair which won't take dye and devalues the clip)
6. Housing and choice of bedding
7. Timing of shearing before lambing to avoid wool breaks

Properties of Wool

Wool surface repels water, so woolen fabrics tend to feel dry even in damp weather. Inner core does absorb moisture almost double of its weight in water and this absorbency gives wool its natural resistance to wrinkles.

Physical Properties of Wool

1. Crimp- Wool fiber is more or less wavy or has twisted. Waviness is termed as crimp.
2. Effect of friction- Helps in maintaining smooth, soft texture of fabrics.
3. Effect of Heat- Low heat has no effect, but strong heat weakens the fiber and destroys the color of the fiber
4. Effect of moisture- Wool is hygroscopic
5. Felting- Wool fibers interlock and contract when exposed to heat, moisture, and pressure. Fiber gets softened in weak alkaline solutions due to expansion of scale at their free edges, with friction and pressure they again interlock to form a felt.
6. Heat conductivity – Poor conductor of heat and fabrics made from the fiber are suitable for winter wear.
7. Resiliency- Wool is highly resilient and comes to its original shape when hanged after being wrinkled or created.
8. Strength- Wool is stronger than silk. Wet wool loses 25% of its strength. The longer the fiber, the greater will be the strength of yarn.
9. Stretchability – Wool is highly elastic.

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10. Shrink ability- Wool is resistant to shrinkage, however long exposure to moisture may cause shrinkage.

Chemical Properties of Wool

Wool is resistant to acid. Cotton and cellulose is severely damaged if exposed to acid. Wool is treated with a solution of sulphuric/sulfuric acid and is then baked to destroy the impurities with only minimal damage to the wool.

1. Action of acids- Dilute acids has little effect but either hot or concentrated acids weaken or dissolve the wool fiber.
2. Action to alkalis- Alkalis tend to make white wool yellowish, strong solutions of sodium carbonate when heated destroys the fiber. Sodium hydroxide is highly injurious to the wool fiber. Borax and ammonia have no harmful influence on wool.

Table.2 Chemical composition of wool fiber

Content Name	Content (%)
Keratin	33
Dirt	26
Suint	28
Fat	12
Mineral matter	1

Grading of Wool

Grading- Grading refers to the average diameter or thickness of the fibers. It also means that placing entire fleeces in their grade piles according to fineness and length.

Systems of Grading of Wool

1. American system or Blood system
2. British system/Numerical system/Spinning count system
3. Micron System

1. American System or Blood system

This system is of American origin and based on the fineness of the wool. Fleeces of the same diameter shorn from fully blooded merino called ‘fine’. Other grades such as halfblood, 3/8 blood, ¼ blood are described on the relative fineness of the wool obtained from sheep containing fractional amounts of merino blood.

2. Numerical System

It consists of the finest count to which it can be spun. This system is used in most of the countries of the world. It is based on the number of yarns or hanks that can be made from one pound of scored or combed wool. If fineness of the fiber is more, the length of yarn is greater. 1 hank is equal to 512m in length. A grade of 60’s means that 60 hanks could be made from one pound and it will be superior/finer to the wool of 50’s. Similarly, grade of 50’s would be finer than 40’s wool and so on.

3. Micron system

Increased emphasis on an exact and highly descriptive method of describing wool grade has produced a measuring system in which individual fibers are accurately measured. The unit of measure is micron, which is one millionth of a meter or 1/25000 of an inch. Fineness is expressed as mean fiber diameter.

Table.3 Grades of Wool by the Blood System

Fine wool	2½ inches in stable length	Very fine crimp
½ blood wool	3 inches in stable length	Medium fine crimp
3/8th blood wool	3½ in stable length	Medium crimp
1/4th blood wool	4 inches in stable length	Medium coarse crimp
Low 1/4th wool	4½ inches in stable length	Coarse crimp
Common	5 inches in stable length	Very coarse
Braid	6 inches in stable length	Most coarse

Table.4 Grading based on diameter of merino wool

< 15.5 microns	Ultrafine
15.6 to 18.5 microns	Super fine
18.6 to 20 microns	Fine
20.1 to 23 microns	Medium
23 inches	Strong

Wool Marketing Channels

Marketing channels consists of people, organizations and activities necessary to transfer the ownership of goods from point of production to the point of consumption. It is the route/path traced in the traced in the direct and indirect transfer of the product from a producer to an ultimate consumer. Marketing channels of wool can be as follows**:**

1. Farmer - Consumer
2. Farmer - Village Level - Textile dealer - Consumer
3. Farmer - Village Level - Textile dealer - Retailer - Consumer
4. Farmer - Village Level - Retailer - Consumer
5. Farmer - Village Level - Middle men - Textile dealer – Consumer
6. Farmer - Commission agent - Yarn manufactures - Textile dealers – Retailer - Consumer
7. Farmer - Middle men – Wholesaler - Retailer - Consumer
8. Farmer - Middle men - Textile dealer - Retailer - Consumer
9. Farmer - Village level - Middle men - Wholesaler - Retailer - Consumer

Conclusions

Sheep husbandry is one of the important livelihood alternatives that contribute significantly to boosting the economy of several smallholders in the developing world. Wool is the most reusable and recyclable fiber in the world. Due to its chemical structure, the fibers act as a spring when extended, allowing it to stretch and shrink back to its original size easily. These qualities make wool one of the most resilient, durable, and sustainable materials. Wool is graded for fineness and length. The length varies amongst sheep breeds. The world wool market is dominated by Australia, while China is the world's largest producer and consumer of wool. The dissemination of reliable market information to all segments of the marketing system is crucial for making it competent and efficient. Along with this it’s necessary to provide good market channels to shepherds at domestic and international level for selling wool at satisfactory price.

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KITCHEN GARDENING

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Kitchen Garden at the backyard of the house

- It’s importance
- How it is done

A kitchen garden is where herbs and vegetables are grown around the house for household use. Since early times a small plot near to the house has been used for growing a variety of vegetables according to the season.

Growing pesticide-free vegetables in the garden are now becoming a hobby for people. Kitchen gardening is affordable and doesn’t need a lot of space. You can even use your balconies or window sills for kitchen gardening. Local varieties such as radish, broad leaf mustard, chilli, beans, pumpkins, tomatoes etc. are can be grown.

Need of Kitchen Garden

For people to stay healthy it's very important to have a healthy diet. A healthy diet means a balanced mix of rice, bread, pulses, vegetables, herbs, fruit etc. For energy and protection against disease, vegetables play an essential role. Growing of vegetables without the use of chemical inputs, it is beneficial for health of the body.

1. Grow healthy, fresh vegetables yourself.
2. Cultivation in a small area facilitates the methods of controlling pests and diseases through the removal of affected parts and non-use of chemicals.
3. This will only facilitate successful production of our own requirement of vegetables.
4. To save the cost of buying vegetables and herbs.
5. Waste resources such as sweepings, kitchen scraps and dirty water can be recycled onto the garden.
6. Vegetables harvested from home garden taste better than those purchased from market.
7. Gardening gives dual benefits of food and income generation.
8. Gardens provide fodder for household animals and supplies for other household needs (handicrafts, fuel wood, furniture, baskets, etc.)

Beneficial Connections for Making Kitchen Garden

1. Collecting waste water
2. Sweepings pit
3. Living fence
4. Vegetable beds
5. Liquid manure

Main Points While Making Kitchen Garden

1. **Site selection-** There will be limited choice for the selection of sites for kitchen gardens and the final choice is usually the backyard of the house. The area where sunlight come from, can be easily accessed from the house. This is convenient as the members of the family can give a constant care to the vegetables during leisure .When these are kept in mind, site selection can be done and making garden is easier.

2. **Protection-** The kitchen garden area needs protection .It should not be possible for livestock to enter the area. A permanent fence should be made. Thorny plants can be cut

and used to make a fence, but the best method is to plant a living fence to protect the garden.

3. **Land preparation-** Getting the right mix of soil is an important step as the nutrients in the soil determine how healthy the plants would grow. Use cow dung to keep all organic. Sweeping pit, liquid manure, mulching, Green manure must be used for fertility of the soil. Firstly a through spade digging is made to a depth of 30-40 cm.

   - Stones, bushes and perennial weeds are removed.
   - 100 kg of well decomposed farmyard manure or vermicompost is applied and mixed with the soil.
   - Ridges and furrows are formed at a spacing of 45 cm or 60 cm as per the requirement.
   - Flat beds can also be formed instead of ridges and furrows.

- **Sowing and planting-** The main objective of a kitchen garden is the maximum output and a continuous supply of vegetables throughout the year. Direct sown crops like bhendi, cluster beans and cowpea can be sown on one side of the ridges . Amaranthus (meant for whole plant pull out and clipping) can be sown by broadcasting in the plots. Small onion, mint and coriander can be planted/sown along the bunds of plots.

  Seeds of transplanted crops like tomato, brinjal and chilli can be sown in nursery beds or pots one month in advance After sowing and covering with top soil and then dusting with 250 grams neem cake so as to save the seeds from ants.

  - The perennial plants should be located on one side of the garden, usually on the rear end of the garden so that they may not shade other crops, compete for nutrition with the other vegetable crops.

  - If seeds and seedlings are planted too wide apart, much of the space in between goes to waste, where weeds will grow . Weeds use precious water and compost, and cause extra work to keep clear.

- **Irrigation management-** It is important to provide enough moisture for the kitchen garden. To make sure your plants get optimum water, check the moisture of the soil by pressing it with your fingers and then water the plant as per requirement. if there is no irrigation for main food crops, it is likely that there is also not enough water to irrigate the kitchen garden. But if the water conservation methods that is saving rain water are used, then more water is conserved and so less is needed. Collecting and using waste water from the kitchen can be enough to water the garden. In the hot season, irrigate in the evening or at night, and not in the daytime.

Check plants regularly and prevent insects from breeding You can rotate crops to grow different crops one after the other. Top up with fertiliser once a month. Spray neem oil to keep mosquitos and other insects away. Take part in regular weeding to keep your plants’ growth stable. Aerate soil by loosening the top layer. Take part in regular weeding to keep your plants’ growth stable. Practice organic means to grow crops which will be good for health.

Be Organic Stay Healthy……!!!!!

Conclusion

Thus , Kitchen Gardening is an eco-friendly sustainable agricultural practice to improve food security and enhance economic growth. In the wake of a global food crisis and the soaring food prices, kitchen gardening comes out the better way for enhancing and building local food systems.

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Essence of Horticulture by M.S. Patil

The Old Farmer's Almanac Vegetable Gardener's Handbook

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THE THIRD-GENERATION BIOFUEL PRODUCTION FROM ALGAE

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A biofuel is any hydrocarbon fuel made from organic matter (living or once-living material) in a short period of time (days, weeks, or even months). From 2010 to 2040, demand for fossil fuels is expected to increase by 40% (Bhore, 2019). As a result, need of alternative energy sources have been investigatedin order to meet our energy demands. Renewable sources of energy include solar, wind, and biomass based biofuels. Biomass has been used to generate electricity from a biological precursor. Over the previous few decades, biofuels and bioproducts have been producedto meet the demand for fossil fuels. There are different types of biofuels, such as bioethanol, biodiesel, biogas, etc. Bioethanol, often known as pure alcohol or ethyl alcohol, is the most prevalent alternative biofuel utilized in cars today;it produces fromsugars from sugarcane or corn through fermentation.Biodiesel is gaining popularity, as it closely resembles standard petroleum-based fuel produce from recycled cooking grease, animal fat, and vegetable oils used to create this product. Biobutanol is the least known of thethree biofuels, and it has the greatest promise due to Isobutanol derived from algae or bacteria, known as biobutanol.

Algae

Algae are one of the oldest biological forms. They are primitive plants (thallophytes). They lackroots, stems, and leaves, do not have a sterile layer of cells around reproductive cells, and have chlorophyll as their principal photosynthetic pigment. Algae structures are essential for energy conversion, with no development beyond cells, and their simple development allows them to adapt to current environmental conditions and thrive in the long run.

Generation of Biofuels

Biofuels, in virtue of their positive carbon balance compared to fossil fuels, provide a huge potential for industrialized countries' sustainability and economic progress because they may be generated from locally accessible renewable materials.

First-Generation

Agrofuel is the first biofuel generation to employ specific cultivated plants as feedstocks, such as sugarcane, sugar beet, maize, palm, soybean, and sweet sorghum. Agrofuel is made by fermenting plant sugars or starches with yeast to make bio-ethanol, and extracting plant oils to make biodiesel. These processes severely harm both the food and water industries;this is the main drawback of 1st generation biofuels that create food insecurity.

Second-Generation

Non-food plants such as Jatropha, grass, switchgrass, silver grass, and non-edible components of current crops were used in the second generation of biofuels. Cultivating these second-generation biofuels requires vast land, water, and fertilizer to grow the biofuel-producing plants.

Third-Generation

Algal biofuel evolved as the third generation of biofuels with no competition to reduce land and water use andreduce excessive use of toxic pesticides. According to Lim *et al*. (2012), microalgal sources are a viable option for biofuel production and can meet worldwide demand for sustainable fuelsproduction (Saad *et al*., 2019).

Microalgae as a Source of Biofuel

As a third-generation feedstock, microalgae have enormous biofuel potential due to their rapid growth, high biomass yield, and high lipid and carbohydrate content. Algae create valuable biofuels such as biodiesel, biogas, bioethanol, and biomethane. Algal carbohydrates are used to make bioethanol, and algal oils are utilized to make biodiesel. After biofuel production, the leftover biomass can be utilized to make nutraceuticals, protein supplements, medicines, biocontrol agents, fertilizers, and animal feed. Microalgae were described as oleaginous because they can accumulate a significant amount of lipids. The algal lipid concentration is controlled by the habitat and environmentalparameters and ranges between 5%to 70%. Other than triacylglycerol (TAG), hydrocarbons, wax esters, sterols, and plenty derivatives, the membrane bilayer makes up the majority of algal lipids (Yu *et al*., 2011). When compared to land-based crops, microalgae have a high growth rate in a short period of time. Algal biomass yields per unit area are much higher than terrestrial biomass yields. Microalgae can thrive in a wide range of conditions. They can be grown on land or in water (both saltwater and freshwater).

Algal Biomass Production

Algae grow far quicker than food crops and can produce hundreds of times more oil per unit area than crops like rapeseed, palms, soybeans, and jatropha. The harvesting cycle for algae is 1–10 days, and that allows for multiple harvests in a short period of time. Microalgae cultivation can be done in open or covered ponds and in closed photobioreactors such as tubular, bag, and flat plate designs. Close systems are far more expensive than ponds, and they pose significant design and operational issues (overheating, fouling, gas exchange limitations, etc.). Above all, they can't be scaled up for individual growth units larger than a thousand square feet (100 m^2), often not even that (Benemann, 2009). This would imply thousands of such units, with expensive capital and considerably higher running expenses, for biofuels production, requiring hundreds of acres.

(Source - Benemann,2013)

Figure 1. Microalgae commercially cultivated and of interest in biofuels/feeds production

Open ponds, particularly shallow, mixed, raceway ponds, are far less expensive to build and run, maybe scaled up to several acres for a single growth pond (though the maximum size is currently unknown). Andis the method of choice for commercial microalgae production around the world. Almost all commercial microalgae biomass production is now done in open ponds, even for high-value nutritional items that sell for more than a hundred dollars per kilogram, when permitted costs for biofuels are less than a dollar per kilogram. Almost no such information is available on the design, operation, yields, and other critical features of commercial algae production systems.

Potential Fuels from Algae

Biofuel produced using algal biomass and oil to biodiesel, bioethanol, and syngas by transesterification fermentation and thermochemical proses, respectively -

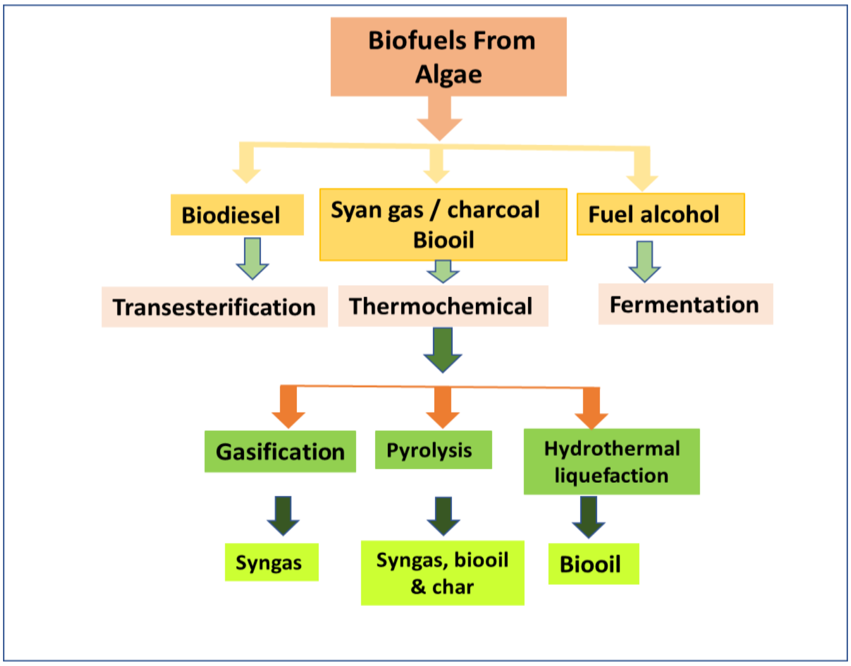
- Crude algal oil for direct combustion or conversion into other fuels such as diesel, biodiesel, jet fuel, and gasoline
- Biogas created through anaerobic digestion of biomass
- Biohydrogen
- Bioethanol is produced through the fermentation of sugars derived from algal carbs

All these given production details are discussed below

Biomass

In general, algal biomass could be burned directly in a boiler to generate steam and electricity. Biomass can be burned alone or in combination with coal in existing power facilities. Although some major (>100MW) commercial facilities for producing power from lignocellulosic biomass (mainly wood pellets) are in operation or being developed in many countries, algal biomass is not included in any of them.Biomass to fuels via thermochemical processing. Heat is used in thermochemical processes to convert biomass into various compounds that could be used as fuel. As mentioned in the preceding section, one of these processes is combustion, which involvescomplete combustion with sufficient oxygen to release energy. Gasification, pyrolysis, and hydrothermal liquefaction are the other major thermochemical processes (Chisti, 2019).

1. **Pyrolysis-** Pyrolysis processes are performed under the absence of oxygen; the thermal decomposition of dry biomass yields solid fuel (char), liquid fuel(condense oil), and gaseous fuel products. The pyrolysis of algal biomass is often performed at elevated temperatures ranging from 300 to 700 °C. The produced vapors must be condensed by Cooling to extract the oils, leaving behind a solid residue (char)



(Adeniyi *et al*., 2018).

Flow chart- 1 conversion method of different types of biofuels from algae

2. **Gasification-** At 700-1,000 °C, partial oxidation with controlled air, oxygen, or steam produces syngas (a combination of gases primarily composed of H2, CO, CO2, and CH4).

3. **Hydrothermal liquefaction-** Hydrothermal liquefaction is an alternative method that does not involve drying feedstock or using organic solvents. At elevated temperatures range between 300°C to 400°C and pressures between 40 to 200 bar, substantial dewatering operations are avoided. The product distributions typically vary from 10 to 73 percent biocrude, 8 to 20 percent gas, and 0.2 to 0.5 percent char. The biocrude produced has a similar energy value to fossil petroleum (Brand *et al*., 2014).

Fermentation

Fermentation is a biological conversion step that involves microorganisms hydrolyzing cell walls into fermentable sugars. The anaerobic breakdown of sugars into biogas, bioethanol, or biohydrogen is referred to as fermentation. After the oil extraction, a large amount of solid material known as biomass remains. This remaining biomass can be utilized to make bioethanol, another algae-based fuel. This can be performed by fermenting with yeast, which produces carbon dioxide, which can then be recycled back into the algae's growth process (Clarens *et al*., 2010).

Biodiesel by Transesterification of Algal Oil

The transesterification process involves the reaction between triglyceride molecules of oil and alcohol in the presence of an acid catalyst, which results in the formation of glycerol and mono-alkyl fatty acid esters. Because biodiesel is normally transesterified with methanol, fatty acid methyl esters (FAME) and glycerol are generated as byproducts. The transesterification process reduces the viscosity of FAME in comparison to the parent oil, but the fatty acid makeup remains the same. Methanol, ethanol, propanol, butanol, and amyl alcohol are commonly used alcohols; however, methanol is widely employed in the transesterification of microalgae oils due to its low cost and physical and chemical properties.

Sl. No	**Aspects**	**Issues**
1.	Environmental	➢ Water resource abuse ➢ Waterway damage ➢ Soil degradation, overexpansion of land usage, loss in land service expectancy, and soil erosion ➢ Animal habitat disruption ➢ Eutrophication, algae blooms, fish kills, and biological invasion
2.	Economic	➢ Expensive setup phase ➢ Requires significant maintenance investments
3.	Social	➢ Water contamination may have an impact on nearby wildlife, farm animals, and people. ➢ Concerns concerning the safety of genetically engineered algae ➢ Disease transmission
4.	Cultural	➢ It takes time to encourage people to accept unconventional microalgae use.

Table 1. The critical challenges of large-scale algae production for biofuel production

(Source Saad *et al*., 2019)

Conclusion

While the algae sector is well-developed for food, feed, and nutraceutical purposes, as well as high-value goods, algae for biofuel is still in its early stages. For algal biofuel manufacturing to be economically viable, the sector still requires a lot of research and development. The expensive infrastructure, operating, and maintenance expenses appear to be the most significant obstacles. To make algae biofuel production more appealing, need to incorporate new and efficient processes are required.

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MICROBIAL TECHNOLOGY FOR SEED BIO-ENHANCEMENT IN STRESS CONDITION: AN ECO-FRIENDLY METHOD FOR CROP IMPROVEMENT IN SUSTAINABLE AGRICULTURE

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Since the 18th century, soil helpful microorganisms, also known as plant growth-boosting rhizobacteria, have been widely employed in the agricultural ecosystem. The term was coined by Kloepper and Schroth and also who also explored their role in soil and plant growth development (Kloepper and Schroth 1978). Crop seed is an important component of agricultural production, and seed has a high value in India and other countries where agriculture is a major source of employment and GDP (Tyagi 2012). Some seed-borne diseases, biotic and abiotic stress and climate change all contribute to crop yield destruction. As a result, the most recent method employs a seed pre-treatment technique that is environmentally friendly, cost-effective, and requires less land to yield more crops (Sanjeev 2012; Reddy 2013). The soil and water ecosystems are harmed by chemical priming or seed pre-treatment with chemicals. Furthermore, this procedure is expensive and hazardous to both plants and humans (Rahman et al. 2018). Due to the limitations of chemical seed priming, researchers created a soil beneficial microbe priming technique that ensures long-term production by increasing germination, seedling emergence, and early seedling development features (Forsberg et al. 2003). Treating seed with rhizospheric microbes mitigate biotic and abiotic stresses and also amplify the efficacy of different biological agents present in soil (Mastouri et al. 2010). Microbial population helps to proliferate crop plant growth by increased nutrient uptake, biological control to different biotic stress as well as production of different plant growth regulators (Glick 2003; Saravanakumar et al. 2008; Dobbelaere et al. 2003). Thus, agroindustry is investigating the method of organic farming or seed priming (Dey et al. 2004) which could release different plant growth regulators, enhance symbiotic or asymbiotic nitrogen fixation, solubilizing phosphorus, and other element required for plant growth. Bacterial priming promotes iron absorption via chelation by generating siderophores and increases ACC deaminase, which decreases ethylene levels, resulting in increased root and plant development (Banerjee and Yesmin 2002; Dobbelaere et al. 2003; Glick and Pasternak 2003).

Agricultural technology with microorganisms is now working to disrupt traditional farming techniques by increasing yield or productivity while also protecting our agro ecology.

Bio Priming Featured by Microbes as One of the Recent Practices in Agro Ecosystem

Plant growth-promoting bacteria (PGPB) or plant growth-promoting rhizobacteria are microbes that are associated with the root rhizosphere and soil and are involved in improved crop production, increased yield, disease resistance, improved soil structure, bioremediation of contaminated soil, and so on (Zaidi et al. 2006). Treating plant seeds with an osmotic solution containing plant growth-promoting rhizobacteria is a cost-effective and environmentally friendly application strategy (O'Callagham 2016).

Rhizospheric bacteria are an important element of the biogeochemical cycle because they develop symbiotic relationships with plants and act as free-living plant growth promoters (e.g. *Azospyrillum, Azotobactor, Providencia, Bacillus, Pseudomonas,* etc.) (Vessey 2003; Gray and Smith 2005). These bacteria also can apply via seed bio priming that enhances crops stress tolerance and increases plant growth (Dimkpa et al. 2009), increases water uptake capacity, and improves sugar and proline content in seedling conditions (Yan 2015) by enhancing metabolism (Farooq et al. 2006).*Azospyrillum*, a common plant growth-promoting bacteria found in a wide range of environments, has a significant impact on crop production and nitrogen production (Steenhoudt and Van-derleyden 2000). They also boost the rate of adventitious root formation and root elongation in crops (Fallik et al. 1994). *Azospyrillum* inoculated crop seed shown to exert a beneficial effect on plant- water relationship, mineral uptake, and root growth (Dobbelaere et al. 2001). Many studies have found that inoculating seed with live *Azospyrilum* has a substantial effect on reducing abiotic stress in agricultural plants. When subjected to waterlogging conditions, for example, maize and winter wheat seed primed with *Azosprillum* inoculum can considerably reduce water stress compared to control or nonprimed seed. (Casanovas et al. 2002).

Bio priming with *Pseudomonas fluorescens* inoculum stimulates plant growth and is tolerant against downy mildew in pearl millet (Raj et al. 2004). Germination rate is increased by priming with rhizobacteria in radish under saline stress (Kaymak et al. 2009). Maize is a major cereal crop that is afflicted by Fusarium, which causes ear rot and destroys 20% of grain storage. Fusarium in maize can be controlled by seed priming with *Trichoderma harzianum*. *Trichoderma* in a formulation of 1×10^{8} spore/ml and 10 g/kg of seed is effective in treating maize ear rot and stimulating plant development by boosting germination percentage, yield, and vigor index, among other things (Nayaka et al. 2008). Priming with *Stenotrophomonas maltophila* present in the root rhizosphere of *Sorghum bicolor* significantly affected the wheat plant by ameliorating the salt stress and stimulate defense response against the *Fusarium sp*. (Singh and Jha 2017). Many studies suggested that the co-application of different microbes may also activate new plant growth promoters those also linked with soil prolificacy (Stringlis et al. 2018). To maintain soil fertility, biofertilizers might be employed as a complement to the pre-showing treatment of crops with plant growth-stimulating bacteria, either alone or in consortia.

Cross Protection for Alleviation of Stress in Bacterial Primed Seed

Plant-associated microbes have unique characteristics that help them deal with the negative effects of stress. Abiotic stress can also be reduced by microorganisms that induce systemic tolerance (IST) and influence physiological and biochemical changes. (Yang et al. 2009). Endogenous glycine and betaine synthesis have risen under water deficit conditions as a result of bio priming, and the plant is now protected from water stress, chilling, and salt stress. During abiotic stress, however, the upregulation of

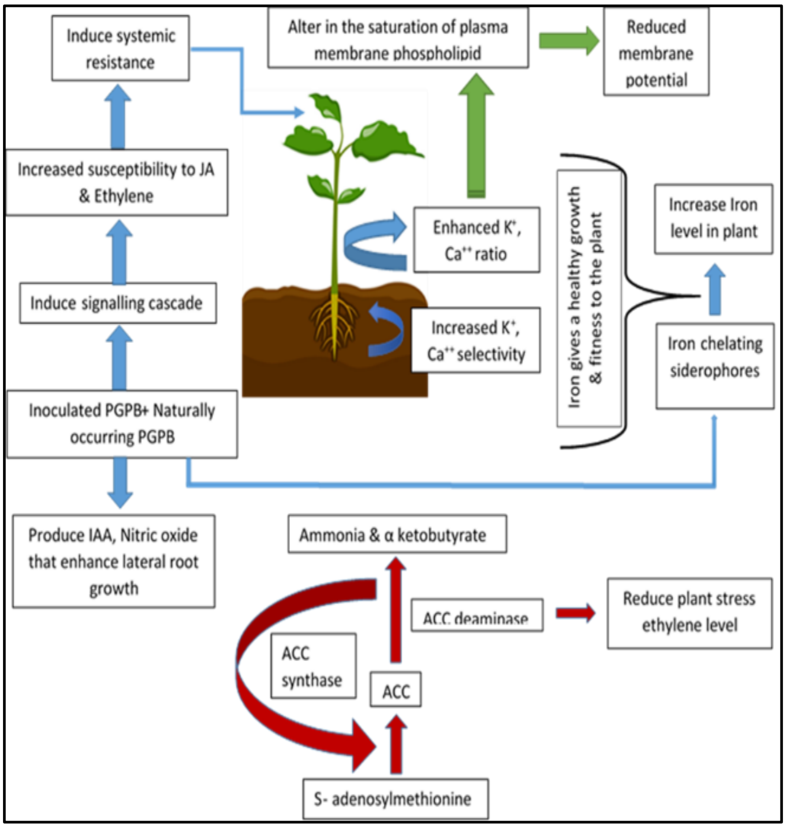

Fig1: Mechanism for alleviating biotic and abiotic stress in bio primed seed

superoxide dismutase (SODs) or the upregulation of other antioxidative enzymes causes a systemic reaction (Gratao et al. 2005). Several major studies have been conducted to elucidate the positive effect of inoculation or seed priming in overcoming various biotic and abiotic stresses. (Mayak et al. 2004a; Grichko and Glick 2001; Egamberdiyeva 2007). Inoculation of those microbes develops an induced systemic resistance which accelerates the resistance against the pathogen (Walters and Fountaine 2009). Some researcher showed that beta-glucuronidase have shown that the osmotin promoter low molecular weight proteins that assemble under salinity stress condition is very sensitive to ABA (Abscisic acid) and some other phytohormones also protect the plants against a pathogenic effect, physical effect, etc (Liu et al. 1995). This osmotin is also synthesized at the translation and posttranslational level (La et al. 1992) (Fig1).

Plants under stress conditions stimulate endogenous ethylene production which positively affects the plant vigor as well as all overgrowth of the plant (Jackson 1985). The biomolecule ACC is a precursor of ethylene production which is cleaved by the ACC deaminase (Saleem et al. 2007; Wang et al. 2001). Bacteria used for priming increase the level of ROS (Reactive Oxygen Species) scavenging antioxidant and upregulated the gene engage with this enzymatic synthesis. PGPB (Plant growth-promoting bacteria) significantly produced some phytohormones such as gibberellic acid, IAA, auxin, etc. which trigger plant root development also amplify shoot growth as well as increasing biomass of crop plants to alleviate abiotic and biotic stress conditions (Patten and Glick 2002). Bacteria generate exopolysaccharides, which are mostly made of humic substances and aid in soil aggregation, soil porosity, and plant root proximity under abiotic stress, particularly water stress. PGPB also helps the plant to nutrient uptake from unhealthy soil where micronutrients (such as potassium, zinc, copper, phosphorus, etc.) are not available due to fixation by increasing root adhering tissue and soil ratio (Oades and Waters 1991). This issue can also be caused by salinity stress. Increased salinity reduces the availability of nutrients in the soil ecosystem, but growth-promoting bacteria can aid by solubilizing nutrients from organic matter or allelopathic substances, as well as making the insoluble form of nutrients available to plants. (Richardson et al. 2009).Gene expression has also looked at the positive effects of stress on their environmental situation. According to certain studies, inoculation with Paenibacillus polymixa B2 in Arabidopsis thaliana increased drought stress tolerance in plants (Wang et al. 2009).

Conclusion and Future Scope of Research

Microbial technologies can give greater protection against many soil-borne diseases, therefore farmers should be encouraged to use this technology, which can improve soil health, increase yield, and raise agricultural plant development without posing any environmental or health risks. It might be a non-chemical or non-hazardous alternative to chemical priming. More study on the survivability, presence, mode of mechanism, and gene expression on the primed seed of plant growth-promoting microorganisms is urgently needed. Genetic modification of those rhizospheric bacteria investigated on seed for global food need and to safeguard the agro-ecosystem must also be changed in next-generation research. Under biotic and abiotic stress, these microorganisms function as a biostimulant for plant growth, nutrient absorption, and increased production. This article discusses about microbial technology for crop development to promote sustainable agriculture by minimizing the use of pesticides and chemical fertilizers at high rates. These priming technologies are becoming increasingly viable, low-cost, and simple ways to combat stress and soil-water pollution in underdeveloped countries

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PLANT GROWTH PROMOTING RHIZOBACTERIA: APPLICATION IN AGRICULTURE

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The use of plentiful chemical fertilizers with higher nutrient content has no doubt increased the crop yield by many folds in recent years which substantially reduced global hunger. However; the half-century-long application of these chemical fertilizers has raised the issue of sustainability and consequence on ecology, human and animal health. As a result, alternative methods are the need of the hour; be it a single strategy or as an integrated approach. In modern days use of beneficial microbes in agriculture is not a new phenomenon rather gaining momentum as a cost-effective, environment-friendly, and sustainable approach to meet the plant demand as well as maintaining ecological symphony. PGPRs are a group of soil bacteria that are free-living in nature which tends to colonize the root zone (Rhizosphere) and promote plant growth.

In this regard, the rhizosphere is particularly important than other soils in agricultural land due to the thoroughly researched fact that the number of beneficial bacteria in the zone is generally 10-1000 times higher than the bulk soil of other facts. This is due to the complex nature of the rhizosphere owing to the secretion of multiple organic compounds including organic acid and sugar from the plant root, higher moisture activity, and higher pH buffering capacity. However; all the microbes which reside in the rhizosphere are neither equally competent nor desired. As a result, selective preference should be given to the most beneficial one. The selective preference is a two-way mechanism where either metabolite can be altered or the strains. However; the real challenge which is faced in this scenario is that lab-grown strains are not highly competitive as compared to the native ones with very high adaptation rate evolution capacity. This is the prime reason why the PGPR amendment does not work promisingly in well-watered, well compost amended soils rather works great in a scarce scenario where the growth of inherent microbes is already compromised due to extreme environmental conditions.

Function and Mechanism of PGPR

The growth-promoting function of PGPR is dependent upon the secretion of metabolites by PGPR. The process is not a standalone one; rather a combination of several actions including secretion of indole acetic acid (IAA), gibberellins, cytokinin, nitrogen fixation, solubilization of phosphate, and other minerals.

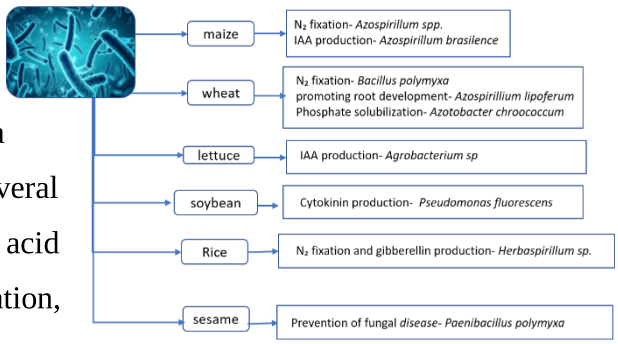

Fig1: PGPR bacterial strains and their host plant with potential functions

PGPR are classified into two groups based on their association with the plant roots which are iPGPR or extracellular ePGPR and PGPR or intracellular PGPR. ePGPR infests the zone of the rhizosphere, rhizoplane, and intercellular spaces between cells of the root cortex while the iPGPR infests inside the nodule structure of the root. The ePGPR category includes bacterial genera such as *Agrobacterium, Arthrobacter, Azotobacter, Azospirillum, Bacillus, Burkholderia, Erwinia, Flavobacterium, Micrococcus, Pseudomonas, and Serratia.* Apart from fixing nitrogen and solubilizing phosphorus and other nutrients, several PGPR has proven their function against phytopathogenic microbes by producing siderophores, synthesizing new antibiotics, enzymes and also competing with their valuable resources. PGPR has attracted more attention in the case of cereal crops, like legumes, in general, can have a significant amount of symbiotic association with nitrogen-fixing bacteria. On the other hand, cereals do not have such association ata significant level hence require external manipulation of the rhizosphere to enhance yield and quality. The yield was always a prime focus and numerous research finding has indicated that combination of multiple PGPR strains is more beneficial than a single strain. For example, a combination of *B. megaterium, A. chlorophenolicus, and Enterobacter*is more effective to increase plant height and yield in wheat.

Multitude Factors Affecting the Abundance of PGPR

The abundance and survival of PGPR are highly space and time-dependent. Although the inherent location of the land is the prime factor of PGPR diversity; the availability of different essential nutrients. Other important factors are the host plant's species and variety, biotic and abiotic stress, root exudates which determine the PGPR diversity. Other environmental factors and agronomic management factors also significantly alter the diversity of PGPR. An important point that has been reported by much long-term research is that in general compost amendment increases the biomass and diversity of PGPR, however; if the compost is contaminated with heavy and pollutant metals; it significantly reduces microbial diversity and biomass which ultimately hampers different nutrient cycles, soil quality and ultimately undermines the plant growth and development. Other severe geo-temporal factors including severe drought, salinity, and alkalinity disturb the diversity of PGPR; in such conditions only, the extremophiles can survive. The magnitude of change in PGPR diversity is less affected by agronomic management practices like crop rotation although little research also suggests that the diversity is enhanced by cereal-legume crop rotation.

PGPR Specific Functions

Phosphorus solubilization:

The importance of phosphorus in agriculture is only next to nitrogen, its management is one of the most critical activities in the whole nutrient management arena. The complexity is related to the fact is that, unlike nitrogen, more than 98% of the phosphorus is either fixed, immobilized or precipitated form which is beyond the reach of plants. PGPR is particularly helpful in this regard, it releases low molecular weight organic acid such as gluconic and keto gluconic acid which solubilizes the phosphorus. PGPR bacteria possess both solubilization and mineralization activity which is very helpful as a cheaper alternative to chemical means. The majority of the soils are very deficient in phosphorus due to several issues which are even more amplified by the high cost of phosphatic fertilizers. Several phosphate solubilizing bacteria such as *Bacillus, Rhizobium, and Pseudomonas* are the potent bacterial genera that are very competent to hydrolyze the inorganic phosphorus into a soluble form and makes it accessible by the plants. Interestingly, two commonly found modulating rhizobium strains of chickpea *Mesorhizobiumciceri*and*MesorhizobiumMediterranean*are also effective phosphate solubilizes.

Siderophore production:

Siderophores are specific kinds of organic molecules produced by some microorganisms under specific circumstances especially under iron deprivation conditions to improve their potential to uptake iron. Several bacterial species like *Pseudomonas sp*produces iron under iron limiting condition. This is even more useful when uptake of iron is limited due to competition from other metallic irons like cadmium or nickel which can be altered by producing ferric- siderophore complex. Siderophore is not a single chemical structure rather a group that possesses electron-rich atoms i.e., oxygen or nitrogen electron donor atom which can bind with metal ions. Recent studies also indicate microbes such as *Azotobacter vinelandii* which is a nitrogen fixer also possess the ability to help the uptake of molybdenum which is a nitrogenase cofactor. Apart from these functions, the same strains can control several diseases like *fusarium* wilt. However; the recent study is quite limited in this field and needs more exploration.

Exchange of nutrients:

Microbes residing in soil depend primarily on plan roots for their essential carbon source. This transfer of carbon can be through root exudates, or plant residue inputs. Soil microbes are the end point to several nutrient cycles such as carbon, nitrogen, phosphorus where they essentially act as decomposers. Several nutrient cycles are also entangled due to microbes which can be effectively utilized as PGPR.

Production of phytohormones:

Phytohormones canaffect the metabolic activities of the plant by inducing, enhancing, or restricting physiological functions. In general; phytohormones are auxin, cytokinin, ethylene, gibberellins, and abscisic acid while some other newer phytohormones like brassinosteroids, jasmonates, and strigolactones are added to the list which can be effectively used to control stress-related issues. Strains like *Pseudomonas*sp, are well known to produce IAA, which has a role in cell differentiation and cell division and ultimately increases plant height. Abscisic acid is another important phytohormone that is particularly essential in drought-related issues. Strains like *Bacillus amyloliquefaciens* have been found to produce ABA and help the rice to sustain drought conditions.

Conclusions

PGPR holds huge potential for sustainable agriculture in the future. It has the potential to reduce a load of chemical fertilizer on one hand and on the other, it can enhance better recycling. Apart from nutrient management; PGPR can be effectively used to enhance growth and yield under stressed conditions and pathogen suppression. However; modern studies are in their infancy and more rigorous studies are needed to explore possible identification, application, and mechanism related to PGPR.

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