Exploitation of opportunities for use of bio-products for enhanced cotton (*Gossypium* spp.) productivity

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Cotton (*Gossypium* spp.) is currently the leading plant fibre crop worldwide with a total coverage of 34 million ha. India is the second largest cotton producer in the world (31.5 million bales), with the largest area (9.56 million ha) under cultivation. Cotton requires at least 16 nutrients for growth and reproduction. A deficiency in any one of those nutrients will reduce yield. Organic cotton production relies on non-chemical inputs and will decrease pollution. Organic farming helps to restore or preserve the natural equilibrium between different components of the ecosystem. Destruction of beneficial soil organisms may cause damage to soil health creating imbalance in the natural population of predators/parasitoids of cotton pests. Therefore, research needs to be focussed on alternative, eco-friendly, biological agents for sustainable organic cotton production where research opportunities are plenty.

Key words: Organic cotton, bio-pesticides, *Gossypium* spp., bioformulation.

INTRODUCTION

Cotton (*Gossypium* spp.) is currently the leading plant fibre crop worldwide and is grown commercially in the temperate and tropical regions of more than 50 countries (Smith, 1999), with a total coverage of 34 million ha. Specific areas of production include countries such as USA, India, China, the Middle East and Australia, where climatic conditions suit the natural growth requirements of cotton, including periods of hot and dry weather. Among the five major cotton growing countries, China holds the highest productivity level (1,265 kg/ha), followed by USA (985 kg/ha), Uzbekistan (831 kg/ha), Pakistan (599 kg/ha) and India (560 kg/ha). India ranks first in terms of cultivated area, occupying over a quarter of the world cotton area, followed by China, USA, and Pakistan. About 26.247 million metric tons of cotton is produced globally.

India is the second largest cotton producer in the world (31.5 million bales), with the largest area (9.56 million ha) under cultivation. The productivity in India is poor (560 kg lint/ha) despite being the only country to have successfully adopted hybrid cotton on significant area. The Indian cotton scenario has shown a positive trend with consistent increase in area, production, and productivity during 2001–2002 to 2008–2009. Among nine major cotton growing states, Maharashtra (3.2 million ha) has the largest area followed by Gujarat (2.5 million ha) and Andhra Pradesh (1.0 million ha). The three states contribute approximately 50% of lint to the Indian cotton basket. High productivity has been obtained in Gujarat (757 kg/ha), Andhra Pradesh (714 kg/ha), Tamil Nadu (654 kg/ha), and Punjab (583 kg/ha). These states cultivate hybrid cotton in approximately 50% of their cotton area. Species composition of cultivated cotton in India has also changed over the years. In 1947, 97% of the area was used for *G. arboreum* and *G. herbaceum*, while only 3% was occupied by *G. hirsutum*. Now, 19% of area is occupied by *G. hirsutum* varieties, and 66% of area is occupied by the intra-*hirsutum* and *hirsutum-barbadense* hybrids. About 0.01% of area is still occupied by *G. barbadense* (Gururajan, 2008).

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The cotton species recognized in the world are about 50, of which 4 are cultivated. Two of these (G. arboresum and G. herbaceum) are diploids, and two (G. hirsutum and G. barbadense) are tetraploids. More than 80% of the world’s cotton area is covered by tetraploids. However, diploid cottons are cultivated in Asia and the Middle East. India is the only country where all the cultivated species and some of their hybrid combinations are commercially grown.

Cotton requires at least 16 nutrients for growth and reproduction. A deficiency in any one of those nutrients will reduce yield. Most of those nutrients are obtained from the soil. For convenience, the nutrients may be grouped as: organic nutrients - oxygen, hydrogen and carbon; primary nutrients - nitrogen, phosphorus and potassium; secondary nutrients - calcium, magnesium and sulfur and micronutrients - boron, manganese, zinc, iron, chlorine, copper and molybdenum (Table 1).

The modern cotton production technology relies heavily on the use of fertilisers and on chemicals to control insect pests, diseases, weeds and growth regulators. Cotton cultivated on 5% cultivable land consumes 54% of total pesticides used in Indian agriculture, and in some pockets, the rates are higher than this, leaving immense ecological and human hazards as reported by World Health Organisation. Use of chemicals at such scale causes a lot of hazards to man, i.e., environmental pollution, soil health and agro-ecology and poor profitability in cotton farming. This has basically prompted the demand of organically cultivated, eco-friendly or ‘green’ cotton (Table 2).

Why organic cotton?

Due to excessive use of fertilisers and insecticides, all the elements of the agro-ecosystem gets polluted by the conventional method. Organic cotton production relies on non-chemical inputs and will decrease pollution hazards. Pesticides residues in fibre may cause carcinogenic damage to users. Large scale discharge of untreated and unprocessed effluents by textile industry and dyeing units has not only caused health problems to man, cattle and fish in the rivers and canals, but yields of cotton are reported to be affected due to polluted water that is used for irrigation. Destruction of beneficial soil organisms may cause damage to soil health creating imbalance in the natural population of predators/parasitoids of cotton pests. Organic farming helps to restore or preserve the natural equilibrium between different components of the ecosystem. The use of bio-rational products and bio-control agents for pest management in organic farming will cause no such effects.

Table 1. Nutritional disorders presented in the cotton plant.

<table>
<thead>
<tr>
<th>Nutrient deficiency</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Yellowish younger leaves may be reduced in size. Plant height is also reduced, few vegetative branches develop, fruiting branches are short and bolls may be shed soon after flowering.</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>Plants may be stunted, leaves darker green than normal, flowering delayed, and boll retention poor.</td>
</tr>
<tr>
<td>Potash</td>
<td>Interverinal light green to gold mottling first on older leaves, with yellowing and necrosis developing at leaf margins under severe deficiency.</td>
</tr>
<tr>
<td>Sulphur</td>
<td>Leaves turn pale green to yellowish green similar to N-deficient leaves, but leaf veins tend to remain somewhat greener than interveinal tissue. Plants deficient in S are short and have few vegetative branches and small bolls.</td>
</tr>
<tr>
<td>Zinc</td>
<td>Interverinal chlorosis in younger leaves and results in leathery, upturned leaves and bronzing</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Magnesium deficiency appears first on the lower leaves as a purplish red colour with green veins</td>
</tr>
</tbody>
</table>

### Table 2. Major diseases in cotton plant

<table>
<thead>
<tr>
<th>Disease</th>
<th>Causative agent</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling Diseases (seed-rot, rootrot, and Damping off)</td>
<td><em>Rhizoctonia, Phytophthora</em>, Thielaviopsis spp., and several other fungi and bacterial diseases</td>
<td>Seed-rot, root-rot, preemergence and post emergence damping-off.</td>
</tr>
<tr>
<td><em>Fusarium Wilt</em></td>
<td><em>Fusarium oxysporum F. vasinfectum</em></td>
<td>Plants become stunted, yellowed, followed by defoliation. Yellowing first occurs around leaf edges and advances inward.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cross sections of infected stems usually reveal a brown discoloration which is more intense in outer layers of tissue. Infected plants fruit earlier and produce smaller bolls.</td>
</tr>
<tr>
<td>Boll Rots</td>
<td>Several fungi and bacterial disease</td>
<td>Boll rots usually first appear as water soaked spots. Later, as infection spreads, bolls turn black and may be covered with a moldy fungus growth.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Badly infected bolls may drop from plant.</td>
</tr>
<tr>
<td>Leaf Spots</td>
<td>Ascochyta, Cercospora, Alternaria spp. and some bacteria</td>
<td>Various types of leaf spots and blights.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Many spots occur on leaves toward maturity, but these are not usually damaging to the plant at this stage of growth.</td>
</tr>
<tr>
<td><em>Verticillium Wilt</em></td>
<td><em>Verticillium albo-atrum</em></td>
<td>Seedlings may become infected and turn yellow, dry out and die. Plants that become infected later in the season are stunted and exhibit a yellow condition along leaf margins and between the major vein. Severely affected plants will shed their leaves. A brown discoloration of the interior of the stem can usually be found later in the season. This discoloration is distributed evenly across the inside of the stem.</td>
</tr>
</tbody>
</table>

(Resource: http://www.jnkvv.nic.in/ipm20project/disease-cotton.html)

Inoculation with *Azospirillum brasilense* significantly increases cotton plant height and dry matter under greenhouse conditions (Bashan, 1998). Inoculation with *A. brasilense* significantly increases N contents of cotton up to 0.91 mg plant⁻¹ (Fayez and Daw, 1987). Hafeez et al. (2002) reported that inoculation with *Azospirillum+Bacillus* strains increased plant height; root proliferation, N contents and root shoot dry weight of cotton. Inoculation of cotton with bioinoculants *Azospirillum*+PSB+pink pigment facultative methylotrophs resulted in improvement of fibre quality (Dhale et al., 2010). Several reports have suggested that PGPRs also stimulate plant growth by facilitating the uptake of minerals such as N, P, K and other important micronutrients (Barea et al., 1976; Dobbelaere et al., 2003). The *Azotobacter* strains used by Narula et al. (2005) have been known to promote nutrient uptake and it has been observed that the isolates have the ability to excrete ammonia, produce IAA, siderophores, have antifungal property and are capable of fixing nitrogen (Narula et al., 2005). Plant growth promoting *Azotobacter* spp. from cotton-wheat cropping systems of India has been assessed for their growth promoting potential by Bhatia et al., (2008).

The cotton crop suffers from many fungal diseases, of which foliar diseases take a heavy toll. Among the foliar diseases Grey mildew (*Ramularia areola*), Alternaria blight (*Alternaria macrospora*) and Bacterial blight (*Xanthomonas axonopodis pv.malvacearum*) are the important ones. The use of fungicides has become inevitable in controlling the foliar diseases in the absence of suitable resistant cultivars. Seed treatment with *Pseudomonas fluorescens* @ 10 g per kg + foliar spray @ 0.2 per cent was useful in controlling foliar disease of cotton and also improved yield significantly in comparison to chemical fungicides (Chattannavar et al., 2010). A strain of *Bacillus subtilis* and *Trichoderma harzianum* was reported to control *Pythium* and *Fusarium* diseases of cotton. The cotton bollworm (*Helicoverpa armigera*), pink bollworm *Pectinophora gossypiella*, tobacco caterpillar (*Spodoptera litura*), whitefly (*Bemisia tabaci*) and Jassids (*Empoasca devastans*) are some of the major pests of
cotton that have the potential to reduce yields by 20 - 80%. *H. armigera* (bollworm) was also controlled successfully using nuclear polyhedrosis virus. In India, it has been reported that insects are collected by shaking larvae off pea plants onto blankets. *Ha* NPV is then produced by feeding the larvae virus contaminated chickpea seeds (Szewczyk et al., 2006). 50 to 75% pest control cost savings have been reported within the first two years by cotton growers transitioning from chemical farming to a more sustainable ecological approach utilizing beneficial organisms. Bollworms, semi-loopers, aphids, whiteflies, leaf miners, spider mites, and other potential pests seldom pose major problems in cotton fields where the indigenous pest-fighting natural enemies are preserved. Among the hundreds of beneficial species commonly devouring cotton pests are green and brown lacewings, pirate bugs, big-eyed bugs, assassin bugs, damsel bugs, mites, spiders, and several dozen parasitic wasp species, including *Trichogramma*. Farming ecologically with biological control inputs gets easier each year, as a reservoir of natural enemies becomes established. Where pesticides have not killed off the natural enemies, most potential pests go unnoticed, as they are so effectively squelched by resident beneficials. *Trichogramma* and other beneficials help restore the natural balances found in unsprayed agro-ecosystems.

Despite the use of available means of plant protection, about one third of the crops produce by pests and diseases. The discovery of synthetic chemicals has contributed, greatly to the increase of food production industry by controlling pests and diseases. However, the use of these synthetic chemicals during the last three decades has raised a number of ecological problems. In the recent years, scientists have diverted their attention towards exploring the potential of beneficial microbes, for plant protection measures. Bio-control agents are easy to deliver, improve plant growth, and activate resistance mechanism in the host, and increase biomass production and yield. These antagonists act through antibiosis, secretion of volatile toxic metabolites, mycolytic enzymes parasitism and through competition for space and nutrients. Though bio-control with PGPR is an acceptable green approach, the proportion of registration of bio-control agents for commercial availability is very slow. In addition, the present day bio-products can be further improved to obtain greater levels of disease and pest incidence reduction. Development of formulations with increased shelf life and broad spectrum of action with consistent performance under field conditions could pave the way for commercialization of the technology at a faster rate.

**Characteristics of a successful biological formulation**

To develop a successful formulation, rhizobacteria should possess

a) High rhizosphere competence
b) High competitive saprophytic ability
c) Enhanced plant growth
d) Ease for mass multiplication
e) Broad spectrum of action
f) Excellent and reliable control
g) Safe to environment
h) Compatible with other rhizobacteria
i) Should tolerate desiccation, heat, oxidizing agents and UV radiations (Jeyarajan and Nakkeeran, 2000).

**Organic/non-organic carriers**

The organic carriers used for formulation development include peat, turf, talc, lignite, kaolinite, pyrophyllite, zeolite, montmorillonite, alginate, pressmud, sawdust, and vermiculite, etc. Carriers increase the survival rate of bacteria by protecting it from desiccation and death of cells (Heijnen et al., 1993). The shelf life of bacteria varies depending upon bacterial genera, carriers and their particle size. The carriers with smaller particle size have increased surface area, which increase resistance to desiccation of bacteria by the increased coverage of bacterial cells (Dandurand et al., 1994).

**Talc / Peat / Kaolinite / Lignite / Vermiculite based formulations**

The fermentor biomass was mixed with different carrier materials (Talc/ Peat/ Kaolinite/ Lignite/ Vermiculite) and stickers (Vidyasekaran and Muthamilan, 1995). Krishnamurthy and Gnanamanickam (1998) developed talc based formulation of *P. fluorescens* for the management of rice blast caused by *Pyricularia grisea*, in which methyl cellulose and talc was mixed at 1: 4 ratio and blended with equal volume of bacterial suspension at a concentration of $10^{10}$ cfu/ml.

Nandakumar et al. (2001) developed talc based strain mixture formulation of fluorescent pseudomonas. It was prepared by mixing equal volume of individual strains and blended with talc as per Vidyasekaran and Muthamilan (1995). Talc based strain mixtures were effective against rice sheath blight and increased plant yield under field conditions than the application of individual strains. Talc and peat based formulations of *P. chlororaphis* and *B. subtilis* were prepared and used for the management of turmeric rhizome rot (Nakkeeran et al., 2004).
Microencapsulation

Microcapsules of rhizobacteria consists of a cross linked polymer deposited around a liquid phase, where bacteria are dispersed. Microparticles are characterized based on the distribution of particle size, morphology and bacterial load. The process of microencapsulation involves mixing of gelatine polyphosphate polymer pair (81:19 w/w) at acidic pH with rhizobacteria suspended in oil (Charpentier et al., 1999).

Talc formulation

Talc is a natural mineral referred as steatite or soapstone composed of various minerals in combination with chloride and carbonate. Chemically it is referred as magnesium silicate [Mg₃SiO₅(OH)₂] and available as powder form from industries suited for wide range of applications. It has very low moisture equilibrium, relative hydrophobicity, and chemical inertness, reduced moisture absorption and prevents the formation of hydrate bridges that enable longer storage periods.

Peat formulations

Peat (Turf) is a carbonized vegetable tissue formed in wet conditions by decomposition of various plants and mosses. It is formed by the slow decay of successive layers of aquatic and semi aquatic plants, e.g., sedges, reeds, rushes, and mosses. Peat soils are used as carrier materials to formulate PGPR. Though Peat carriers are cheap to use, it harbors lot of contaminants. The quality of peat is variable and not readily available worldwide. Sterilization of peat through heat releases toxic substances to the bacteria and there by reduce bacterial viability (Bashan, 1998). Peat based formulation of *Azospirillum brasilense* had a shelf life up to 4 months. The population load after 4 months of storage was 10⁷ cfu/g of the product (Bashan, 1998). This population was sufficient for successful plant inoculation (Garcia and Sarmiento, 2000).

Press mud formulation

Press mud is a by-product of sugar industries. It was composted using vermin-composting technique and later used as a carrier for *Azospirillum* spp. This carrier maximizes the survival of *Azospirillum* spp than lignite, which is predominantly used in India. (Muthukumarasamy et al., 1999).

Vermiculite formulation

Vermiculite is a light mica-like mineral used to improve aeration and moisture retention. It is widely used as potting mixture and used as a carrier for the development of formulations for harbouring microbial agents. Vermiculite based formulation of *P. fluorescens* (PF1) retained shelf life for a period of 8 months.

Conclusion

In view of the growing concerns of the damage caused due to the over usage of chemical fertilizers and pesticides for enhanced productivity of cotton is threatening the safety of its usage due to health hazards associated with chemical pesticides/ insecticides. Therefore, a viable alternative would be to switch to the usage of bio-products which are safe, cost-effective and research proved that they are effective in enhancing the growth of cotton. Organic cotton awareness is increasing among the users globally and research opportunities for the enhancing the production of organic cotton are ample. As the cotton plant is affected by major pest attacks, usage of specific insect pathogenic viruses and fungi also is a viable alternative to prevent unprecedented crop loss in cotton.

REFERENCES


