TRAINING MANUAL ON ORGANIC COTTON FARMING

CENTRAL INSTITUTE FOR COTTON RESEARCH

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Preface

The TRAINING ON ORGANIC COTTON CULTIVATION was conducted for forty two trainees from four non-Governmental Organisations of Warangal District of Andhra Pradesh. They came under the umbrella of Oxfam (India) Trust, Secunderabad, who approached Central Institute for Cotton Research Regional Station at Coimbatore. These trainees include NGO functionaries as well as farmers who are attached with them. Out of the forty two trainees, it is remarkable to find that seventeen are women trainees.

Warangal district of Telengana region of this state has been in intensive cotton cultivation for more than a decade and has ended up with serious cotton crop loss and enhanced heartburn for the growers. Integrated Pest Management that the Agricultural University of the state as well as the Agricultural department took up to these villages paid some dividends to reduce the injudicious use of pesticides. Interventions from NGOs led to a transformation of scenario due to their work to change the mind set of the farmers to go towards No Pesticide-based IPM. This is a crucial phase from where thoughts on organic farming can be seeded in the minds of these growers. In that regards the training is quite timely and appropriate. It is hoped that these trainees shall work as Master Trainers and groom multiple of qualified personnel and could become a resourceful force to reckon with in this district for educating the farmers.

The curriculum developed for these trainees focused on the management of soil and other natural resources in these farms. Progress made in organic farming practices in the country as well as the potential market for the products and processed food materials from organic farms were also included in the training. The practical training from established organic farms as well as one-to-one interaction with those farmers is expected to enhance the confidence and faith of the trainees so as to involve with organic farming in their villages.

It is visualized that this training shall fortify the willpower of the cotton farmers of Warangal district to enhance their confidence for cost-saving approaches in farming and utilizing internal farm resources for optimization of soil fertility and sustain good productivity.

Project Co-ordinator (Cotton improvement)

Foreword

Organic farming has been in recent years a major farming technique that has taken roots in various field crops. Cotton is a desirable candidate crop for this mode of cultivation. Central Institute of Cotton research has been in the forefront of research in this for over a decade and has come out for the first time in ICAR with a Technical Bulletin on Organic Cotton Cultivation. ICAR published in its NEWSLETTER organic cotton cultivation, as a promising technology. The futurism that the institute showed has paid rich dividends today since many cotton growers of drylands in Maharahstra, Madhya Pradesh and Gujarat have followed these principles for cotton cultivation.

It is very timely that Andhra Pradesh also has taken to such progressive thoughts. I congratulate the NGOs of Warangal district for planning out organic cultivation in various villages and cotton has been considered as a candidate crop.

It is gratifying for the institute for undertaking this training programme for forty two trainees from the four NGOs of this district. Such trainings could develop master-trainers in each state for promoting this method of farming. Recent interest in Planning Commission and Ministry of Agriculture of Government of India for seeking promotion of Holistic farming in the country. The trained manpower shall be an asset to Andhra Pradesh to widen the scope and enlarge their earnest efforts in organic farming in years to come.

I wish the trainees and their NGOs all the very best in this mission.

Director
Central Institute for Cotton Research

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Organic Cotton Cultivation – a pragmatic approach for resource poor and market-challenged farmers

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Cotton, the most important fibre crop of India plays a dominant role in its agrarian and industrial economy. It is the backbone of our textile industry, accounting for 70 per cent of total fibre consumption in textile sector, and 38 per cent of the country's export, fetching over Rs. 42,000 crores. Area under cotton cultivation in India (7.6 million ha) is the highest in the world, i.e., 25 per cent of the world area and employs seven million people for their living. Cotton is a crop most suited to drylands and has flourished there despite the vagaries of nature and poor monsoons. The old cotton varieties were suited to each region and its peculiarities. Hybrid cotton with its promise of high yields changed all that and now in some places farmers are convinced of the need to develop and grow varieties, which are locally suitable.

Cotton-an ideal candidate for organic farming

Cotton is grown over a wide range of climatic conditions and agricultural production systems. Improvements have occurred in cotton productivity over the lasts 5 decades, but at prohibitive costs, both social and environmental. It has seriously affected rural livelihood and environment of our country and today cotton production is at cross roads. Intensive cotton production areas have in recent years encountered severe adverse environmental impacts- reduced soil fertility, loss of bio-diversity, high insecticide resistance, pesticide persistence etc. This situation makes cotton an ideal candidate for organic cultivation. The following factors favour promotion of organic cotton farming:

i. High levels of pesticide application:

Today about 46 % of the pesticide produced in India is applied to cotton, which occupies only 5% of the cultivated area. In absolute terms the average pesticide consumption is 3.25 kg active ingredient per ha of cotton crop. While vast areas of cotton of Gujarat, MP and Maharashtra receive very less pesticides, their application rate is heavy in Haryana, Punjab, AP, Karnataka and Tamil Nadu. Despite such heavy pesticide use, unsatisfactory pest control is often the main reason for low productivity. With biocontrol based pest management strategies that are well-demonstrated and appreciated by farmers, cotton became a natural choice for organic pest management. More over every year 150,000 – 250,000 tonnes of technical grade pesticides are applied into the cotton ecosystem worldwide and it is high time to revert this trend for a better environment for our future generation.

ii. Consumer pressure:

Consumers are increasingly becoming concerned about the environmental impact of their lifestyles and consumption pattern and are willing to pay a premium price to eco-friendly garments. To promote environmentally benign farming practices, consumers are forcing trading community to evoke non-tariff barriers to prevent import of contaminated fibres. Organic cotton is the ultimate solution to counteract such pressures.

iii. Wide genetic variability:
With four cultivated species and several domesticated races, and a host of varieties and intra/inter specific hybrids cotton offers tremendous genetic variability. Several cultivars with compensation abilities, low fertilizer demand and tolerance to insect pests are available to fit into the organic production system.

iv. Long duration crop with ample scope for compensation:
Cotton is a semi-xerophyte and a forced annual with indeterminate growth habit. Its ability to put forth repeated flushes in response to pest pressures and moisture/nutrient supply is advantageous to minimize yield losses under organic conditions. Due to its long duration, ample of time is available for assimilating mineralized end products made available from slowly available organic sources. Its ability to absorb foliar applied nutrient formulations is higher than many other crops. These natural physiological mechanisms make cotton a forerunner for organic farming.

Organic farming has been aimed at conservation and optimised utilisation of all natural resources for a reasonable profitability under the guiding factors of sustainability of the farm. In order to keep a certain threshold of profit from the farms, all the farming practices have to be redesigned to undo the ill-effects that have crept in the current agricultural scenario while attempting to increase cotton production in the prevalent cropping systems. A sense of balancing act to moderate the resource utilisation with anticipation for suspected damage to mother earth is the essence of organic farming. The organic protocols of farming could accentuate and aid in imparting improved momentum to the bio-dynamism of crop fields. Less stable and poor bio-dynamism that has caused less-productive farms have alerted farmers on the question of long-term sustenance. The genesis for organic farming in our country lies in the adverse experiences that emerged from intensive cotton farming leading to depleting yields and mounting expenses. This was the time farmers were reading Bhaskar Save and Bharat Dabholkar or Masanobu Fukuoka, proponents of natural farming and were trying to experiment on their own. Farmers found they did not have to look elsewhere for natural farming as it was a tradition in India and had nurtured her soils for centuries since the days of ***Rishi kheti.*** They found that organic farming is not some esoteric idea but a means for the farmer to spend less and ensure he/she gets a yield which is not at the cost of the soil or financial abilities.

Many farmers are on their own realising the ill effects of chemical agriculture and it is the large chemical farmers who are setting the trend to adopt low cost techniques and reduce the dependence of farmers on external inputs- a healthy trend that is being slowly adopted in many parts of the country by the discerning farmer. The prospect of selling certified organic cotton, which fetches premiums of 10 to 30 per cent, is a major attraction in certain areas where organic cotton projects are underway. After the initial euphoria over hybrid cotton and the extensive use of fertilisers and pesticides, they is a loss of faith in the magic of the early years and now farmers experiment so as to reduce the use of chemicals and pesticides on their farms.

Pest management as a major risk in cotton cultivation

The modern cotton production technology relies heavily on the use of fertilisers and on chemicals to control insect pests, diseases, weeds and growth regulators. 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.

The wide acceptance of moderation in aggressive interventions came up in the world due to the publication of Silent Spring in 1962. From a broad platform of Smith and Allen's (1953) Integrated Control to narrowed one of Stern et. al., (1959) and Smith's (1964, 1975) sensitisation to bringing back balance in nature utilising applied pest control with the utilisation of biocontrol and chemical control.

Indian cotton plant protection also did not swerve from this pattern of thought till the last one and half decades of the last century. We are at the cross road of indecision in cotton protection to identify the road to safety of the agro-ecosystem and the survival of the farmers, who are compulsively tied up to cotton crop, being the saviour in their farmland in different agro-climatic zones of the country. Its implementation is virtually dependent on everybody involved in production and protection of cotton. Chemical insecticides dominated insect suppression in all crops in India from 1960s. For a while, all the insecticides seemed to control pests. But sooner, it was realised that the insecticides could not be a panacea for pest control. Then came the advent of need-based and supervisory control programmes in the late 1970s. Field scouting data on the prevailing pest and natural enemy populations in the crop decided the need of insecticide application. IPM began to be interdisciplinary with the introduction of various components such as pest-tolerant cultivars, modified crop husbandry practices, removal of alternate hosts and affected plant parts, utilisation of natural enemies, use of crop terminators and mechanical measures, etc.

A change in the pest species scenario was another historical perspective that found changes in the pest suppression approaches in the last four decades of the century in our country. The conventional pests were Spiny and Spotted bollworms as well as Pink bollworm in addition to the early season onslaught of jassids, aphids and thrips. But the dimension of pest incidence changed with changing cropping patterns and agro-climatic conditions such as the eruption in the population of whitefly and American bollworm. Other pests such as aphids, leaf miners, leaf rollers and even Red and Dusky cotton bugs became increasingly menacing towards the last few decades.

Seeking a reliable and resonant solution in mitigating the problems of protecting cotton crop from herbivory by the noxious pests, IPM was resorted to. However, the prevailing belief was that modulations in the choice, concentrations and timing of spraying of various chemical insecticides could be the major means of IPM. Thus the chemical-based protection of this crop flourished for over two decades from the sixties. The Operational Research Project at CICR Regional Station, Coimbatore and many other R&D approaches brought about consistent debate on the search for alternatives to chemical insecticides in the wake of various perceptible adversities that came to the fore in cotton cropping. Biological options including bio-pesticides such as those of botanical origin and biological control agents were integrated in the package of practice for cotton pest management.

The changes in cropping systems, cultivation practices as well as the change in pest scenario have added newer dimensions to the lack of profitability of cotton growers in the country. The oft-resorted pest suppression was the use of xenobiotic chemical molecules to suppress insect pests in the crop. The change in philosophy or mindset from IPM of yesteryears to NPM (no pesticide management), as practiced by cotton growers of Warangal and other districts of Andhra Pradesh brought in better understanding about herbivory and food chains.

Community plant protection (co-operatives)

Yet another major approach for improving the efficiency of protection of cotton farms from noxious organisms is by collective and co-operative steps at village level utilising the expertise available for this purpose. Synchronised and planned action would always be more beneficial to improve the effect of human interventions for ideal crop protection. Decision making regarding suitable and best steps for improving the efficiency of plant protection operations is possible when the entire geographical region, one village or a group of them, as the case may be, would initiate steps in this regard. If insect suppression in cotton has to be detached from constant and injudicious use of insecticides in the crops, much attention has to be paid to conserve natural enemy activity in the crop. This entails a close collaboration and co-operation of farmers on cultural methods in a geographic area. A harmonious pest management programme can be developed only by the integration of biological, chemical and cultural suppression methods, in addition to co-operative efforts of farmers, extension and research staff of all institutions in the region.

Organic cotton cultivation in India - a culmination of non- chemical pest management

Cotton, being a long-duration crop, with rank vegetation and high boll load is quite vulnerable to many biotic stresses including herbivory. Hence, it has become a major consumer of 20-23% of nutrient and hormone chemicals and 55% of the pesticide chemicals produced in our country. Out of the total agro-chemicals that are applied in cotton crop, 75% is used at peak boll development stage. The highly skewed pattern of pesticide use in relation to the crop area (Table:1) has caused many problems to the agro-ecosystem, viz., development of resistance to pesticides, resurgence of newer pests, elimination of natural enemies, environmental pollution and health hazards to the villagers.

Pesticide use pattern area in major crops

Crop	Area (%)	Pesticide use (%)
Rice	24	17
Oilseeds	10	2
Cotton	5	54
Vegetables & fruits	3	13
Plantations	2	8
Sugarcane	2	3
Others	5	3

Distressed by the negative effects of pesticides for insect suppression in cotton crop, some progressive farmers, reduced the chemical inputs and increased the use of organic manure, developed their own techniques to optimise resources in order to develop sustainable farm.

The avenues opened by the new movement of organic cotton in India in order to establish sustainability of cotton farms is remarkable. The cotton farmers, who are frustrated with continuous poor yield, incurring high cost for large scale pesticide use and its resultant bane, have now turned the corner in order to improve their farm soil microflora with renewed organic sources and to revive the natural ecological niche for the flourished activity of natural enemies for better performance of pest suppression in this crop with the expectation of reviving the lost stability in crop productivity. Indian cotton growers, especially of Maharashtra tend to pick up the thread of traditionality in attempts that help to sustain their farms.

Conversion to organic agriculture- essential requirements

INTERNATIONAL FEDERATION OF ORGANIC AGRICULTURE MOVEMENT (IFOAM) as well as *Codex Elementaris* of European Union manual has provided the essential principles involved in the conversion of farms into organic from conventional cultivation. It is understood that the AGRICULTURAL PRODUCTS EXPORT DEVELOPMENT AUTHORITY (APEDA) of the Ministry of Commerce, Government of India also have formulated standards similar to IFOAM. Conversion means a process of developing a viable and sustainable agro-ecosystem. The whole farm, including livestock should undergo the conversion according to organic standards over a given period of time. This time-frame could be decided by the Certification body. If a farm unit is not converted at once, it could also be done on field basis. The composition of farm unit may vary according to geographical conditions, ownership structure, time span etc. If a farmer or farming community operates two or more farms within a local area, the whole operation may be converted to organic mode.

Elements of organic cotton cultivation

Some key ingredients of the technology developed for organic farming at CICR, Nagpur are presented below (Kairon *et al.*, 1998):

Varietal selection
HYVs such as hybrids that respond very well to chemical fertilizers are not always suitable to this type of cultivation. Currently, many arboreum varieties such as **Turab (PA.255)** of Marathwada Agricultural University, **Jawahar Tapti** of *Jawaharlal Nehru Krishi Vishwa Vidyalaya*, Khandwa possess similar fibre qualities as odf hirsutum (American) cotton. Their fibre is spinnable at 40s count as in the case of NHH.44 or other simila hybrids that are popular in Andhr Pradesh.Straight varieties such as ANJALI (LRK.516), PKV.08, LRA 5166, DHY.286, RAJAT amongst hirsutum cottons and AKA 8401 in arboreum (*Desi*) cotton are found to respond well to organic mode of cultivation.

Seed rate and sowing
25 kg/ha of seeds at 75x15 cm spacing ensures a plant population of 85,000 to 90,000 is recommended. Fuzzy seeds that are mixed with wet clay containing some amount of FYM or compost is ideally chosen. One row of cowpea (*Vigna inguiculata*) should be planted between two cotton rows for being incorporated at tendril stage. This improves the fertility of soil.

Soil fertility

SOIL (Soul of Infinite Life) is the basis of agriculture. A fertile soil is a pre-requisite for organic cotton production. The native organic C content should be improved and stabilized at such a level that the anticipated production levels do not cause a decline in soil organic Carbon (C). Crop rotation with legumes, cover cropping, green manuring, compost (vermicompost, Trichocompost, FYM), bio-mulches, biofertilizers are generally employed to improve fertility status. Soil amendments and naturally mined permitted (or regulated) chemicals can be employed to supplement native fertility.

Farmyard manure @ 5 tonnes/ ha, *In situ* green manure with fodder cowpea incorporated between cotton rows at 40 days after swing (DAS), Spreading loppings from *sesbania* spp. obtained from 2-m dense rows after 10 cotton rows, in the entire field, Vermicompost @ 1-2 tonnes/ha, Seed inoculation of azotobacter @ 500g commercial product/seed required per ha or any such microorgamnisms such as cosortium of effective microbes (EM) and such many useful flora (Mwethylotrophs etc.), utilization of *Trichoderma viride* for composting farm-waste including cotton-stalks etc could improve soil physical properties, foliar application of specific preparations from cattle urine, Biodynamic preparations etc.

Weed management
Weed management is primarily achieved through preventive techniques (selection of perennial weed-free field, clean seeds, completely decomposed compost/ FYM, crop rotation, cover cropping, mulching, smother crop etc.) and soil solarization. Cultural, mechanical and manual methods can be employed to supplement preventive measures.

Pest Management

Pest management is achieved through the selection of pest tolerant varieties, conservation of natural enemies and inundative releases of predators/parasites pathogens and supplemented with botanicals.

Suppressing phytophagous insects using such options has thus realised a myriad of advantages to our society. Other institutions involved in these activities have taken lots of cues from this CICR effort. Today, Cotton Research Institute is a front-runner in modifying the conventional opinion of chemical-based insect suppression and also for popularisation of biocontrol-based pest Management. They have come a long way in their gratified dream of substantiating biocontrol as a broad- base of pest management in pesticide intensive crops like cotton.

Biocontrol based Pest Management

- Release of C*hrysoperla* sp, @500/ ha 20-25 DAS and again at 35 DAS
- Release of *Trichogramma chilonis* @ 5 cards /ha at 45 DAS
- Spray of H-NPV @ 250 larval equivalent/ ha (2 x 10^8 PIBS/larval equivalent) for young bollworms of *Helicoverpa armigera*
- Detopping after 80 days of growth
- Alternative spray with B. t. formulation@1.5litre/ha
- Application of neem-based formulations-neem oil @1.0 litre/ha and 1% neem-seed-kernel extract
- Release of *Bracon hebator* to kill bollworm larvae
- Bird perches @4/ha

Mass-production of these biological pest suppressants is possible. However, their quality can be well-maintained if only small scale production is designed instead of production in large volumes. Production by masses instead of Mass production shall be more pragmatic to achieve quality and effectiveness.

Issues of sustainability and stability of organic farming *vis a vis* conventional farming

An analysis of the productivity trend in the intensive chemical based cotton production system in the northern cotton zone of India, encompassing the states of Punjab, Haryana and Rajasthan indicate a declining yield trend from 467 kg lint /ha in 1986-87 to 206 kg lint /ha in 2001-02. The sustainability of such a production system needs closer introspection. Despite assured irrigation and use of adequate chemical fertilizers and pesticides, the Coeffient of Variation for yield (during the above mentioned period) was 29.0 % in Haryana and 34.9 % in Punjab. Such a system is not stable either. On the other hand, the rainfed organic farming systems operating in Central India, offer stable cotton yields albeit at non-exploitative productivity thresholds of 250-300 kg lint/ha. Data from a long-term fertilizer trial operating since 1986 at CICR farm indicate that a completely organic plot gave a mean yield of 390 kg lint/ha with a CV of 26.9 %.

The agriculture in the country passed through a difficult situation during post independence period when the food grain production was only 51 million tones during 1950-51, not enough to feed its population. The country was dependent for food on other countries. The condition became more precarious during drought of 1968 when even PL 480 was called off. This was the time when scientist, farmers, planners and extension workers of the country rose to the occasion and world witness the capability of the country to produce enough for their growing population through their own efforts. During this period country brought green revolution and the food grain production crossed 210 million marks. This could be achieved by adoption of high yielding varieties with high input technology i.e. by the use of high dozes of inorganic fertilizers, pesticides, weedicides and irrigation water. This has not only increased food production but area under monoculture and resistance in pests, thus on one hand we achieved self sufficiency in food production, but on the other our soils became sick, underground water depleted, environment polluted, cost of production increased. and chemical residues in food products causing hazards to human and animal population.

The scientists have also realized that the ' Green Revolution ' with high input use has reached a plateau and is now sustained with diminishing return of dividends. The nutrient use efficiency and factor productivity is on decline. Thus this agro chemical based technology is now not sustainable and has given rise to sustainability problems. This needs to be corrected, by adopting alternate technology of farming. A technology, which should be eco-friendly, farmer's friendly and low cost. It should help in preserving traditional biodiversity and knowledge. To know the suitability of such technology, the Government of India constituted a team in 1992 and a working group in 2001. They unanimously advocated 'Organic and Bio-dynamic Farming system as an alternative technology system. Although there are number of other systems prevailing in the world which are non chemical use systems, but in my view the system which can suits to our conditions is "Vedic Krishi'. This is a concept evolved thousands of years back and is a way of life for the Indian farmers. This involves traditional practices followed even by ancient civilization and can be an integrated form of organic farming system.

The experiences gained while working with such technology clearly indicates that there is no loss of productivity by its adoption, contrary to this it gives better production, it is cheaper, labour intensive and provides opportunities to increase rural employment. However there are challenges for adoption of this technology, as it requires scientific explanation, formulation of package and practices, post harvest technology for organic produce, quality of its inputs, consumer's awareness, and formulation of standards for inputs and produce, certification of farm, produce and process etc. Accordingly our strategy should be clearly worked which may be prioritization of area and crop for organic production, development of data base and market intelligence, development of equivalent standards for organic produce, involvement of organic farmers in production processing and marketing, development of courses and training models for organic agriculture, transfer of appropriate technology etc.

There is a global market for organic food, which is estimated to be worth £14 billion in 2002-03. This is likely to increase to an estimated £20 billion by 2004-05. At present U.S.A. is leading the market with £5.9 billion followed by Germany and U.K. If these countries can shift to an alternative organic technology why India cannot? It requires combined efforts of scientist, field functionaries and farmers. The Government has now come out to encourage in its adoption, obliviously in a phased manner through creation of infrastructure and tax incentives. The Planning Commission of the Government of India has provided adequate resource in tenth five year plan for the development of organic farming of various commercially potentially horticultural and agricultural crops in addition to patronizing crops of dry land including cotton. Organic, Vedic, Biodynamic, *Rishi/Agni Hotra* (*Homa*) or any name it may be, it appears that Indian farmers shall turn around to practice HOLISTIC AGRICULTURE that shall sustain their land, resources and ambition to make an enterprise in rural settings.

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APPROACHES TO ORGANIC COTTON CULTIVATION WITH SPECIAL REFERNCE TO SITE AND VARIETAL SELECTION

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Textiles fulfill basic need and is as old as history itself. Cotton has always been a major part of the textile industry and provide about half of the global fibre requirements. Cotton has a long history as a source of fibre for clothing and other textiles and goes back to several thousand years in parts of India, Nile valley and Peru.

World Cotton Scenario

Cotton is grown in over 30m. hectares in the world with an annual Production of about 19 m. tonnes. The average world Productivity is around 620 kg/ha.

2002-03

State	Area m. ha	Production M. MT	Productivity kg/ha
China	430	4.55	1089
USA	5.26	3.99	780
India	7.39	2.38	292
Pakistan	2.83	1.74	610
Others	10.83	6.50	-
Total	30.61	19.20	621

Cotton is the most important commercial crop of India and plays a vital role in the economic development of the country. The Indian Textile industry accounts for about 75 per cent of the total natural fibre consumption and account for more than one third of the country's exports, fetching over Rs.50,000 Crores per annum in foreign exchange.

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Indian cotton Scenario

India grows cotton in an area of about 8 million hectares and produces about 160 lakh bales of lint annually. The area, production and productivity for the year 2003-04 is furnished below.

State	**Area (lakh hectares)**	**Production (Lakh bales)**	**Productivity (kg/ha)**
Punjab	4.69	10.5	381
Haryana	5.26	11.0	356
Rajasthan	3.36	7.5	377
Gujarat	16.47	46.0	475
Maharashtra	27.66	31.0	191
Madhya Pradesh	5.81	16.0	468
Andhra Pradesh	7.82	26.0	565
Karnataka	3.34	4.0	204
Tamil Nadu	0.97	3.5	613
Others	0.76	1.0	-
Loose Supply		11.0	-
Total	**76.14**	**167.5**	**404**

Despite inroads made into textile production by synthetic fibres, cotton is successfully promoted in many countries in recent decades as a '***Natural***' fibre. However, the conditions of production and processing are often far from ***'Natural'.*** However, these are largely unknown or ignored by Consumers of the textile products.

PROBLEMS WITH CONVENTIONAL COTTON PRODUCTION

In many countries cotton is a major Cash Crop and is a main source of economic development. Hence, strenuous efforts have been made to increase cotton production mainly through use of chemical inputs, irrigation and high yielding varieties.

Increased yields are considered beneficial by those involved including farmers. However, they have also involved several hidden costs both environmental and social, which have not been reflected in pricing. Hence, despite its *'natural'* image, cotton production has become increasingly associated with severe negative environmental impacts which include reduced soil fertility, loss of bio-diversity, water pollution, adverse changes in water balance, social problems related to heavy use of pesticides. Cotton processing is a very resource consuming, polluting and unhealthy industry where large amount of water, energy and chemicals are used at different stages. To create finished goods, fabrics are often coloured with toxic dyes and finished with formaldehyde.

Of the total Pesticides used in agriculture in India, 54 per cent is used in Cotton, which accounts for only 5 per cent of the total land under cultivation. In addition, large amount of herbicides, fungicides and synthetic fertilizers are also used in cotton production. The over use of pesticides has led to pest resistance and farmers have given up cotton cultivation altogether. Pesticides used on cotton can also enter the human chain through cotton seed oil and other non target species and result in contamination of meat, milk, etc.

Concerns about cost and the detrimental effects on health and environment of the high use of synthetic pesticide and fertilizers have persuaded many small scale farmers to seek alternatives wherever possible.

ORGANIC COTTON CULTIVATION

Growing cotton organically entails using cultural practices, natural fertilizers and biological controls rather than synthetic fertilizers and pesticides. A system approach to organic production involves the integration of many practices like cover crops, strip crops, intercrops, crop rotation, etc. into a larger system. Through good soil and bioadversity management farmers can become increasingly self sufficient in fertility, while pest problems are diminished. A diverse rotation, using legumes and other cover crops leads to good humus and bioadversity management. Cotton would be, but one of the several crops organic farmers would grow.

Organic cotton production started in Turkey and USA in the late 1980. Other projects followed throughout the last decade in South Asia, Africa and Latin America. Most of the organic cotton projects involved small scale farmers. There has been a significant involvement of outsiders. The number of organic farmers is steadily increasing every year. In less than ten years organic cotton has spread to more than 15 countries. However, it still remains a small fraction of global production.

In 1995, when organic cotton production was over 12,000 tonnes, it still represented only a 0.06% of global production. However, the production came down to 8,000 tonnes by 1997 and again improved to about 14,700 tonnes. There is not only fluctuation in organic cotton production , but authentic information is also hard to get. In the absence of any Government agencies, most of the organic cotton production is done by different agencies spread world wide.

Organic Cotton Production

Country	**1997**		**1999**	
	Output (tonnes)	**% of total**	**Output (tonnes)**	**% of total**
Australia	400	5	-	-
Egypt	630	8	200	1
Greece	400	5	0	
India	930	12	1169	8
Peru	650	8	565	4
Turkey	800	10	6082	41
Tanzania	200	2	295	2
Uganda	800	10	1200	8
U.S.A.	2852	36	4963	33
Total	**7967**		**14752**	

APPROACHES FOR ORGANIC COTTON PRODUCTION

Since organic cotton production warrants the cultivation in the absence of agro chemicals, it involves careful selection of components right from the site selection stage till harvesting and even processing stages. Traditional production systems may be more attuned to the production of Organic cotton than the more intensive input production system. At the farm level it is necessary to form suitable packages keeping in view the local resources, agro climatic features and socio economic structures.

Selection of Site

Site selection is the most critical factor in organic production. Fields with high degrees of soil erosion, with perennial weeds and very poor fertility will limit the production capabilities. Further, the areas that support weeds are known to be the reservoirs of Fungi and may cause severe diseases. Potential drift and run off from other fields have to be avoided. It is better to avoid selection of areas from intense input production systems. Areas having high insect pressure, especially Boll worms may not also be suitable. Similarly, fields known to be infested with persistent soil borne fungi eg., *Verticillium* may be avoided. During the transition period the site may be improved in fertility by organic means. Tropical sun's heat can be harnessed to eliminate some of the soil borne pests and diseases by solarisation of soil in hot summer months. Repeated ploughing to expose the pests is advised.

Varietal Selection

Organic production begins with organically grown seeds. If certified, organic seed can not be obtained, untreated seeds may be selected as long as they are not genetically modified.

Selection of varieties for organic cotton production is not far different from varieties selected for conventional production system. Hence, varieties that perform well in a region can be selected. As the current high yielding varieties and hybrids are inadvertently selected for high input systems, they are likely to behave differently under organic conditions. The quality of the fibre may also be affected. Plants with natural tolerance to pests and diseases are ideally suited for organic production. Plants with earliness and compactness may be ideal. The desi varieties which are used to low input systems and with their high levels of pest resistance may be the ideal choice. It may be hoped that Bt cotton with their inbuilt bollworm resistance would be the ideal choice under organic cultivation. However, it has been decided that Bt cotton can not be certified as 'organic' even if grown under organic conditions.

A separate breeding program to evaluate genotypes under organic conditions may be necessary to breed lines suited for organic conditions.

Naturally pigmented cotton (Coloured Cotton) are now available for cultivation. Naturally coloured cotton in Green and various shades of Brown are now available. Naturally coloured fibres reduces chemical pollution in processing and eliminates the use of synthetic dyes to impart colour.

Seed Rate and Sowing

Acid delinted seeds are not accepted for sowing as per international norms. Hence, only fuzzy seeds are used for certified organic production. Seeds can be treated with cow dung slurry, dried and used. Higher seed rate is essential to get good stand which is a main input for high yield.

Manuring

Mineral nutrition of crops in organic systems comes from proper management of soil organisms that are responsible for releasing nutrients. The organic food sources are applied to the soil and then digested by the soil organisms to release nutrients for the crop.

Soil mineral levels are built up through the application of animal manure, compost, soluble rock powders, deep rooted cover crops. The overall cropping sequence fosters a system in which previous crop provides fertility benefits to a subsequent crop.

Weed Management

Tillage and cultivation are two traditional means of weed management in organic farming. Weed management is generally done through hand weeding. However, this may be costly at some places and labour not available at other sites. The negative aspect of improper management could be increased pest attacks. However, summer ploughing of fields and mechanical removal of rhizomes etc. may bring down the weed levels in a particular field. Growing live mulches may help smother weeds. Weeding should be aimed at as soon as the seeds start germinating or as soon as they are possible after irrigation or rain.

Insect Management

Biological and cultural insect control involves understanding the ecology of the surrounding agricultural systems and the cotton fields and making adjustments to production methods that complement the natural system to our benefit.

Growing of single crop of cotton in large areas often invite pest problems. When we have more diverse farmscape involving many types of plants and animals, the likelihood of severe pest out breaks diminishes. Use of trap cropping, strip cropping, managing border vegetation, crop rotation are some of the methods by which crop diversity and increased beneficial insect population is maintained, insect pests are attracted to crops other than cotton and a biological balance is maintained.

Early duration varieties are best suited to escape pest damage. Excessive nitrogen use, late irrigation and excessive stand will therefore increase exposure to pests.

Insecticidal soaps also can be used with advantage to control sucking pests. Biopesticides like *Bacillus thuringiensis*, a bacterium, Heliothis nuclear polyhedrosis virus or *Beauveria bassiana*, an insect disease causing fungi and some of the biological pesticides commonly used to control bollworm larvae. Pheromone traps as mating disruptors can also be used to control pink bollworm. Similarly, many of the predators like beetles, bugs and spiders and parasites like *Trichogramma* spp. *Chelonus* sp. can also be employed profitably to control bollworm larvae. These groups of natural enemies are usually enough to keep bollworms below economically damaging thresholds.

Disease management

Pathogen, susceptible host and favourable climate are the three factors responsible for a disease to occur. Eliminating any one of these factors will eliminate the disease.

Soil health and management is the key for successful control of all diseases. Use of regular compost and green manure crops will ensure good soil with sufficient organic matter, harbouring many beneficial pathogens which deter harmful fungi, bacteria and virus from attacking plants. Soil organisms like *Trichoderma viride* and *Pseudomonas* sp. have been found to be effective against seedling diseases.

CERTIFICATION OF ORGANIC COTTON

The International Food and Agriculture Organisation is interested in Organic Agriculture mainly because:

- Organic agricultures involves utilization of natural resources in a sustainable way.
- It is based on technologies that prevail in the developing world which therefore can provide employment and income to poor farmers and
- It contributes to food quality and safety.

All the objectives are of concern to FAO in view of its mandated goal to "ensure all people at all times with nutritionally adequate and safe food".

The demand for organic produce is increasing at a very rapid rate in the international market. Under conditions of excess demand for organic products, there should be good market for production. The term 'Organic' in organic agriculture is a process claim and not a product claim. In other words the products are defined in terms of technology and input used rather than the product itself. Hence, the label 'Organic' denotes products that have been produced in accordance with organic production standards and certified by a duly constituted certification body or authority.

Certification of Organic cotton production adds credibility to the final product, assures the buyer of Organic status, encouraging premium price to the farmers. Certification is a system which sets standards and ensures that set standards are met.

Certification programmes and standards vary from country to country in response to regional differences. The International Federation of Organic Agriculture Movement (IFOAM) has produced basic standards covering organic products and also textile processing.

In the European Union and certain other countries the term Organic is defined by Legislation. In such regulations, the rules of production, labeling and inspection of all products are clearly defined. The requirements for organic certification as obtained in the European Regulation (EEC No.2092/91) are used by various agencies including IFOAM as the basis for Certification. The main requirements are:

i) Maintenance of soil fertility by organic means.
ii) Use of certified organic seed
iii) Documentation of all farm activities.
iv) Demarcation of organic farm limits
v) Conversion to undergo two years (annual crops) or 3 years (for perennial crops) transition period.
vi) Proper labeling throughout the chain
vii) Every farm need to be inspected and certified once a year by an accredited Certification Agency.

There are several IFOAM accredited Certification Agencies which are guided by European Union Regulations. The international Organic Accredition Service (IOAS) also exists to accredit certification systems. Some of the accredited Certification Agencies are:
AGRECO, Germany
IMO (Institute for Market Ecology), Switzerland and
Skal International, Netherland.

The certification by any one of the IFOAM accredited agencies is essential for the International trading of organic products including cotton and textiles.

In addition to the above compulsory certification, there are a wide range of private organic label schemes all over the world viz., Demeter Naturalland, Bio Suisse, SKAL etc. As some of these standards exceed the European regulations, people have great faith in these labels also.

In India, many voluntary organizations like VOFA (Vidharbha Organic Farmers Association), MOFA (Maharashtra Organic Farmers' Association) in Maharashtra and MAIKAAZ - BIORE in Madhya Pradesh, have started producing organic cotton in a small way. However, until now, organic inspection and certification has been carried out almost exclusively by foreign agencies. These are not only expensive but they also lack adaptation to Indian problems and conditions.

The Indian Government has taken to organic agriculture very seriously. A detailed organic legislation, based on IFOAM criteria has been worked out. With the help of Research Institute of Organic Agriculture (FiBL), Switzerland an independent local certification body, INDOCERT, is being established not only for the purpose of inspection and certification but also for the development of the Indian Organic movement.

Soil – the living dynamic system
"Soul of Infinite Life"

Prof. Dr. K.K.Krishnamurthi, Former Dean, Tamil Nadu Agricultural University
President, Indian Society for Certification of Organic Products (ISCOP)
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An unknown poet long back in the history of mankind has said that "The soil locks within its embraces the beginnings of all life and receives, atlast, their discarded forms. It will outlive all the works of man and transcend all human thought. It traces the progress of history and shelters its ignoble end. It speaks eloquently and is dumb. It is the imperishable storehouse of eternity".

What has been said by this poet of unknown time about soil still holds good and will hold good for ever in the future.

WHAT IS SOIL ?

To the geologist, it is a mute evidence of the past which unravel certain ancient activities. To the engineer, it is the base on which he can put up the road or building. To the physicist, chemist and biologists it is a material replete with vast amount of unsolved problems involving the greatest skill to solve. But to the agricultural scientist and the farmer it is the medium in which the crops could be grown which in turn sustains the human kind on the earth.

PERSPECTIVES OF THE SOIL

Soil is defined as the mantle on earth ranging in thickness from a few inches to several feet in depth consisting of the solid, liquid and gaseous phases in varying proportions. It is a heterogeneous complex with superficial simplicity and deep seated complexity posing serious challenges to unravel its mysterious nature.

SOIL IS DYNAMIC

Normally it is considered that soil is static. But in reality soil is very dynamic, ever changing and evolving. It is the continued response of the soil to its environment that determines its state of productivity.

SOIL IS VARIABLE AND HETEROGENEOUS

Soils are not homogeneous. They are variable within themselves and from place to place. They are as variable and different and difficult to define as the people inhabiting the earth. Just as the people in different parts of the country and in different countries of the world differ in their cultural, social and economic traits and traditions soils of the world also vary in their physical, chemical and biological characteristics and their fertility and productivity.

SOIL IS NOT INERT

Rocks crushed to the finess of earth would not possess the intangible factor called "life" since soils inhabit millions and billions of micro-organisms and other species of living beings like earthworms, which are inherent part of the soil and without which there is no soil.

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SOIL IS NOT DIRT

Generally soil is considered as 'dirt'. But the correct meaning of "dirt" is "matter out of place". If for that matter, we consider soil as matter out of place, well, everything else in the world will become out of place including human beings. Hence, soil is not dirt.

SOIL RESPONDS TO STIMULUS

The most important difference between the living and the non-living is the response to the stimulus by the living and non-response to the stimulus by the non-living. Soil actually responds to the stimulus. We speak about the response of soil to the nutrients which are applied to the soil. Soil which is cared for and managed well responds well for good yield, whereas, a soil which is not cared for and not managed well does not respond well and yields poorly.

SOIL IS A LIVING DYNAMIC SYSTEM

The study of the plant as a living system is known as Botany. The study of animals and birds as living systems are known as Zoology and Ornithology. Similarly, the study of soil as a living system is "Edaphalogy" or "Soil Science". Any living system such as plants, animals or human beings have certain attributes and characteristics like colour, structure and the various metabolic systems.

COLOUR

Colour shows the adaptability of the animal or human being to a particular climatic condition. In temperature regions, the colour of the man is white. In tropical regions, the colour of human being is brown or black. In semi tropical regions, the colour is yellowish brown or yellowish red. Likewise, soils have different colours such as black, red, brown, yellow etc. which indicate the adaptability of the soil supporting a particular crop and certain properties and specific characteristics. For example, black soil is said to plough itself and is highly suitable for the cultivation of cotton.

STRUCTURE

Structure is possessed by animal or human being and is constituted by the skeletal system enclosed by the flesh and skin. Soils also possess different structures called platy, columnar etc. and this is constituted by the various soil components such as gravel, coarse and fine sand, silt and clay. The mucous colloidal membrane spread throughout the body in the human or animal system helps in the absorption and assimilation of food. Similarly, the clay colloid present throughout the soil helps in the absorption of nutrients and release of nutrients to the plants and acts similarly as the mucous membrane.

DIGESTIVE SYSTEM

The human beings or other living beings are able to digest the food like the complex proteins. carbohydrates and fat and convert them by the digestive juices, enzymes etc. to simpler materials like ammonia, nitrate, glucose, carbon, hydrogen. In the same manner any material like compost, fertilizers, organics, etc. added to the soil are digested and decomposed by the simpler units like nitrogen, phosphorus which are absorbed by the plant roots and the innumerable number of organisms inhabiting the soil. Thus, there exists a digestive system in the soil.

CIRCULATORY SYSTEM

Just as the blood an lymph circulation constitute the circulatory system in the biological entities of human and animal, in the case of soil a circulatory system is constituted by the "soil solution" and "soil water" which is in constant movement throughout the soil particles. In the same way, as blood carries the nutrients and oxygen to various parts and cells of the body the soil water carries the plant nutrients to the soil particles and to the roots of the plants.

RESPIRATORY SYSTEM

Respiration in the case of human beings and other organisms constitutes, the exchanges of gases, i.e., oxygen is taken in and carbon-di-oxide is given out. Similarly in the soil also continuous gas exchange takes place which is comparable to the respiratory system. The innumerable roots and soil organisms which are inhabiting the soil do respire which constitutes the respiratory system.

EXCRETORY SYSTEM

Just as the undigested food and unwanted materials are sent out by the human being or animal the excretory system of soil also excretes out and sends out the excessively present and unwanted materials such as salts.

CLAY AND BRAIN

Usually when one scolds the other, the question being asked is "Is there clay inside your head?". As a Soil Scientist, this struck me very much and I wanted to known why of all the other things clay is chosen. After thorough analysis and research. I found the answer. It is astonishing to know that clay in the soil and brain in the human head are very similar in structure and functioning. Brain does the function of reception, retention and recapitulation (remembering) or retrieval. In the same way clay also receives the nutrients, retains them and releases them exactly like brain. A man without brain is infertile. So also, a soil without clay is infertile. Hence, if one says that there is clay in our head, we should not get hurt, but only be proud that we have good brain.

INDIVIDUALITY AND IMPRINT

Though we are human beings, yet one does not resemble the other. For example, taking the face, though each of us has the appendages like hair, ears, forehead, eyes, nose, lips, mouths etc. yet one does not have the face as the other and it is wonderful to know that how people differ from each other. Even in the case of identical twins, the idiosyncrysis would vary. Besides this, each one has a distinct type of fingerprint, characteristic of only that particular individual which does not match with anybody else's. Similarly, the voice of the individual is characteristic of the particular individual though one can artificially mimicry as the other. In the same manner each soil has its own individuality and imprint just as the human beings.

SOIL IS SYMBOL OF MOTHER EARTH AND GOOD LADY

In all our ancient literatures like Vedas, Upanishads, Puranas, Ethikasas, Religious and Spiritual treatises mother and earth are considered as one and the earth and the soil is called "Mother Earth" or "Bhooma Devi" Saint Thiruvalluvar even two thousand years ago, has written in two couplets comparing soil / land to a good lady.

i) *"If the land owner does not visit the land and does not care for her she would defect as that of a wife who is not cared and nurtured by her husband".*

ii) *"If a person is lazy and sitting idle without doing any work in the soil / land, the good land lady would yell and laugh at him".*

This amply personifies the soil / land as the Mother and Good Lady.

SOIL, A SCAVENGER AND PURIFIER

In the human life, utmost love and intense affection are showered between couples (husband and wife) parents and children, friends and the like so long as they are alive. Once the life is out, that it the person is dead, nobody wants to have the "dead body". It becomes a horror to be discarded as immediately as possible. But the only one who receives even the corpse with open hand of welcome is the soil. And dead organism even like a rat, left on the soil purifies and emanates bad smell. But once it finds a place inside the soil. i.e., it is buried even within a few inches down from the surface there is no foul smell or odour.

CAPACITY OF MAN AND CAPACITY OF SOIL

A man takes in the night "elixir" (Amirtham) in a golden cup with platinum spoon. What happens to it after a few hours? In the morning he has already converted the elixir into the obnoxious smelling stool which he has to excrete of human being is added to the soil, it is converted into "elixir" by the soil in the sense that the obnoxious and awful smelling material is degraded, decomposed and deodourised and split into simple components like the important plant nutrients as like nitrogen, phosphorus, potassium, hormones, vitamins, enzymes, etc.

We are aware of the fact that many life saving drugs like antibiotics are isolated only from the micro-organisms inhabiting the soil.

ALL LIFE BEGINS IN THE SOIL AND ENDS IN THE SOIL

It is very interesting to know by analysis and backward integration that even the human being has the origin in the soil. One may say that life of man begins in the womb of the mother. It is true. If we think very deep, we realise that origin of the child is the foetus which is formed by the fusion of sperm from the man and the egg from the woman. The sperm and egg were produced by the blood. The blood is produced from the chyme of the food consumed. The food comes from various sources like cereals, pulses, fruits and vegetables which have their origin the respective crops. The crops are grown in the soil. Following is the sequences of the cycle.

Soil→ Nutrients → Crop→ Food → Blood → Sperm → Egg → Foetus → Child → Main → Soil

Man is ultimately made of the five elements : soil, water, fire, air and space. On death, the body is decomposed and again becomes the five elements. Thus life begins in the soil and ends in the soil. Whether one is buried or burnt after death, ultimately the end place is the soil.

SOIL IS THE RESPONSIBILITY OF ANYTHING AND EVERYTHING WE THINK OF

All the industries have their origin in soil since all the raw materials needed for the various industries emanate only from soil. Right from the diamond, gold, aluminium, lignite, coal-all are obtained from the soil. The raw material of cotton for the textile industry, wood pulp for the rayon and paper industries, sugarcane and beetroot for the sugar industry, calcium and rocks for the cement industry etc. have the origin of the raw material from the soil only. Thus soil supports everything and soil supports all.

TOLERANCE AND FORBEARANCE OF THE SOIL

Even when we dig the soil, trample and do all kinds of abuses soil forbears and tolerates everything just as a mother is able to appreciate and enjoy the mischieves of her child. We have to learn from the soil several lessons, the most important of which is that one should have the patience and tolerance and one should be productive and anything undesirable an not needy should be converted into desirable and needy.

GOOD AND BAD KARMA IN RELATION TO SOIL

It has been said in the Vedhas that one earns a bad karma if he bequeths his land to his successors with less fertility level that how he got if from his predecessor. Whereas, if one is able to hand over the land soil with added fertility (enhanced fertility) he earns good karma. Hence it is imperative that we have to either maintain the fertility of the soil or to enhance it; but we cannot afford to reduce it at any cost and any time.

SOIL CONSERVATION AND PRESERVATION

It takes millions of years for the formation of an inch of soil on the earth's mantle. But it is easier to destroy it, degrade it and abuse it in no time. Soil once lost is lost once and for all. While soil is eroded and taken away ultimately to the sea through rivers and water courses millions of tons of valuable nutrients are lost worth several crores of rupees which are not recoverable. Therefore, it is the bounden duty of everyone of us to bestow our best attention and care to preserve and conserve the soil lest we are committing a sin on this score.

SOIL PHYSICAL PROPERTIES

The important soil physical properties are : Structure, texture, bulk density, porosity, permeability, infiltration capacity, water holding capacity, soil consistence, tilth, soil colour and soil temperature.

Soil structure is strictly a field term descriptive of the gross, over all aggregation or arrangement of soil solids. There are different types of structures such as single grain massive, crumb polyhedral, prismsatic, columnar and platy.

Soil texture is concerned with the size of the mineral particles Specifically it refers to the selective proportion of the various size groups in a given soil. The different textures are clay, clay loam, sandy, sandy loam, silty etc.

Soil bulk density is defined as the mass (weight) of a unit volume of dry soil including both solids and pores. The bulk density of clay, clay loam and silt loam-surface soils normally may range from 1.00 to as high as 1.60 grams per cc depending on their condition. A variation from 1.20 to 1.80 may be found in sands and sandy loam.

Pore space of a soil is that portion occupied by air and water. Addition of organic matter increases aggregation and improves pore space.

Soil consistence is a term used to describe the physical condition of the soil at various moisture contents. Term that are commonly used to describe soil consistence are non-sticky, sticky, plastic, nonplastic loose, friable, hard, very hard, strongly cemented, indurated.

Soil tilth : Tilth refers to the physical condition of the soil in its relation to plant growth and hence must take cognizance of all soil physical conditions that influence crop development.

Water holding capacity is the capacity of the soil to retain soil moisture. Permeability and infiltration capacity of the soil is the rate and manner with which soil water moves. These are determined by the other physical parameters like texture, structure, porosity, aggregation, etc.

Soil colour : There are different colours of soil such as black, brown, red, yellow, ashy, etc. which is determined by the different properties of minerals like iron oxide. The higher the organic matter the darker would be colour of the soil. Colour indicates the adaptability of the soil for the suitability of crops which could be grown it.

Soil temperature : The temperature of the soil affects markedly its usefulness of man. Plant processes such as seed germination and root growth occur only above certain critical soil temperatures. Likewise, adsorption and transport of water and nutrient ions by higher plants is adversely affected by low temperatures. For example corn germination requires a soil temperature of 45-50°F. Dry matter production for corn is optimum when soil temperature is 80-85°F. Potato tubers develop best when soil temperature is between 60 and 70°F. Oats grow best at about 70°F. The use of organic mulches and addition of organic matter to the soil will give lower and more uniform and optimum soil temperatures for the best growth of crops.

SOIL CHEMICAL PROPERTIES

The important soil chemical properties are : pH (soil reaction) EC (Electrical Conductivity), Cation Exchange, Capacity, Anion Exchange Capacity, Availability Major, Secondary and Micronutrients and Buffering Capacity.

pH of the soil is defined as the negative logarithm of the hydrogen ion activity of a soil. It ranges from 1 to 14. 7.0 is the neutral point. Soils with a pH range of 1 to 6 are acidic and 8-14 are alkali in nature. The range of pH of soil from 6-8 is quite ideal for the growth of many crops. This is achieved by adequate amount of organic matter to the soil. The salinity and alkalinity problems can also be solved by judicious application of organic matter to the soil.

Electrical Conductivity of the soil measured in the 1 : 2 soil : water solution which gives the estimate of the total soluble salts in the soil. EC less than 2 mmhos/cm is good and beyond which it is critical for crop growth. The EC can be brought to the optimum level by the addition of organic matter especially farm yard manure.

Cation Exchange Capacity is the sum total of exchangeable cations that a soil can absorb. Sometimes called "total exchange capacity", "base exchange capacity' or "cation-adsorption capacity" expressed in milliequivalents per 100 grams of soil (or of other adsorbing material such as clay organic matter and humus which have very high cation exchange capacity in the soil. High Cation Exchange Capacity is the indication of high soil fertility.

Anion exchange capacity is the sum total of exchangeable anions that a soil can adsorb expressed as milliequivalents per 100 grams of soil (or of other adsorbing material such as clay). This property of the soil is also regulated by the addition of organic matter to the soil.

Buffering Capacity : The buffer compounds in the soil are the clay, organic matter, and compounds like carbonates and phosphates which enable the soil to resist appreciable change in pH.

Availability of the Nutrients : The availability of various nutrients like major nutrients such as nitrogen, phosphorus and potassium and secondary nutrients such as, calcium, magnesium and sulphur and micronutrients such as iron, copper, manganese, cobalt, zinc, boron, molybdenum and chlorine in governed by various factors such as pH, CEC, moisture, temperature. Organic matter contains almost all the essential nutrients as a package in right proportions and by the activity of microorganisms in the soil the nutrients are made easily available to the plants.

SOIL MICROBIOLOGICAL PROPERTIES

Microorganisms have existed for over millions of years and they shaped the earth's atmosphere, first colonized land, recycled elements and mediated life processes. "Without microorganisms the life on the planet (earth) would come to a standstill" is a famous statement by the renowned microbiologist, Selman A. Waksman. Although the role of microorganisms in different ecosystems is diverse, plant - soil - microbe interrelations play a significant and long term role in soil sustainability and crop production which brings out the importance of microorganisms and their activities in soil and other environment. The soil is teaming with billions of microorganisms and the living and dynamic property of the soil is conferred on it only by the microorganisms inhabiting it.

Microorganisms are prevalent in this earth in varied and diversified forms. They could be bacteria, actinomycetes, fungi, algae, protozoa etc. The population load of these organisms varies with different environments; in normal soil they occur at varying levels.

i) Bacteria : 10^5 to 10^6 / gram of soil

ii) Actinomycetes : 10^4 and 10^5 / gram of soil

iii) Fungi : 10^2 to 10^3 / gram of soil

iv) Algae : 10^2 to 10^3 / gram of soil or less

The load of these organisms is known to get enhanced when the moisture content is increased due to rainfall or irrigation. This might be due to the availability of nutrients. All the environmental factors like temperature, moisture, organic matter content are known to play significant role in the population dynamics of microorganisms in soil.

Addition of organic matter in any form not only provides a conducive environment for the proliferation of their population, but also enhances their activity in building up humus in the soil and increase soil fertility.

CONCLUSION

In a nutshell, it may well be said and understood that the addition of organic matter which culminates in Organic Farming enhances and optimises all the properties of the soil – physical, chemical and microbiological which in turn assures increased soil fertility and sustainability of crop production.

SOIL ORGANIC MATTER AND ITS MANAGEMENT FOR ORGANIC FARMING

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What is soil organic matter (SOM)?

SOM is a vast array of carbon compounds in soil. Originally created by plants, microbes, and other organisms, these compounds play a variety of roles in nutrient, water, and biological cycles. For simplicity, organic matter can be divided into two major categories: **stabilized organic matter** which is highly decomposed and stable, and the **active fraction** which is being actively used and transformed by living plants, animals, and microbes. Two other categories of organic compounds are living organisms and fresh organic residue.

Thus, SOM encompasses the soil biodata and plant and animal tissues at varying degree of decomposition. Its most important component is humus - well decomposed, dark coloured organic material in the soils.

Stabilized organic matter

Many soil organisms decompose plant and animal tissues, and transform the organic matter into new compounds. After years or decades of these transformations, what remains are large, complex compounds that few microbes can degrade. Other compounds become bound inside soil aggregates where microbes cannot reach. These hard-to-decompose, or stabilized, substances make up a third to a half of soil organic matter. Stabilized organic matter is divided into three chemical groups: humic acids, fulvic acids, and humins. Fungi and actinomycetes create many of the humic acids that combine in soil to become stable compounds. Much of the stabilized matter in the soil originated from plants that grew centuries ago. Some of these old compounds are bound to clay, and are important in gluing together tiny aggregates of soil particles.

Stabilized organic matter acts like a sponge and can absorb six times its weight in water. In sandy soils, water held by organic matter will make the difference between crop failure or success during a dry year.

Both **organic and clay particles can hold on to nutrients** electrochemically. The amount of nutrients that the organic compounds and clay could carry and make available to plants is called the soil's cation exchange capacity (CEC). Although amount of clay in the soil cannot be changed, the CEC can easily be decreased or (with more difficulty) increased by altering the amount of organic matter.

The active fraction

Up to 15% of soil organic matter is fresh organic material and living organisms. Another third to one half is partially and slowly decomposing material that may last decades. This decomposing material is the active fraction of soil organic matter.

The active organic matter, and the microbes that feed on it, are central to nutrient cycles. Many of the nutrients used by plants are held in organic matter until soil organisms decompose the material and release ammonium and other plant-available nutrients. Organic matter is especially important in providing nitrogen, phosphorus, sulfur, and iron. A soil with 1% organic matter contains about 1,000 kgs of nitrogen/ha. Depending upon the decomposition rate, 25-100 kg may become available to plants in a year.

The Changing Forms of Soil Organic Matter

1. **Additions**. When roots and leaves die, they become part of the soil organic matter.
2. **Transformations**. Soil organisms continually change organic compounds from one form to another. They consume plant residue and other organic matter, and then create by-products, wastes, and cell tissue.
3. **Microbes feed plants**. Some of the wastes released by soil organisms are nutrients that can be used by plants. Organisms release other compounds that affect plant growth.
4. **Stabilization of organic matter**. Eventually, soil organic compounds become stabilized and resistant to further changes.

Importance of SOM:

SOM or humus and its association with soil minerals is essential for soil functions.

- It keeps nutrients (nutrient resource) in the upper soil where roots can access them.
- It increases CEC of soils
- It imparts tilth,making soils easier to work
- It helps in retaining more water
- It provides energy source to diverse communities of microorganisms and soil animals (earth worms) which help in ecosystem services (i.e. recycling of C and other nutrients).
- It imparts micro structure to the soils (improves water infiltration, WHC, aeration and reduces soil strength, surface crusting)
- It affects nutrient cycles by chelating (chemically holding on to) nutrients, and preventing them from becoming insoluble and therefore unavailable to plants. For example, humic substances help make iron available to plants, even in medium-to-high pH soils.
- It is a critical component of global C balance.

The relative importance of these different functions varies with the soil type, climate and farming system. The maximum SOM content of a soil (achievable) within a climatic zone is determined by the silt + clay fraction. This is due to the physical protection of SOM mediated by texture and structure. SOM content of agricultural soils are only 25-50% of the corresponding natural ecosystem from which they are derived.

Regular additions of organic matter are important food for microorganisms, insects, worms, and other organisms, and as habitat for some larger organisms. The beneficial effects of soil organisms on agricultural productivity and ecological functioning may be through:

- organic matter decomposition and soil aggregation;
- breakdown of toxic compounds both metabolic by-products of organisms and agrochemicals;
- inorganic transformations that make available nitrates, sulphates, and phosphates as well as essential elements such as iron and manganese
- nitrogen fixation into forms usable by higher plants

Why Manage Soil Organic Matter?

An ideal soil is one in which:

- crops would thrive, even through dry spells,
- roots would grow extensively,
- implements would pull easily, and
- there is resistance to erosion and compaction.

These can happen in a soil with high organic matter levels. It allows high crop yields and reduced input costs. Building soil organic matter may be the most important thing you can do to enhance long-term soil performance.

What Does Organic Matter Do?

Nutrient cycling

- Increases the nutrient holding capacity of soil (CEC)..
- Is a pool of nutrients for plants.
- Chelates (binds) nutrients, preventing them from becoming permanently unavailable to plants.
- Is food for soil organisms from bacteria to worms. These organisms hold on to nutrients and release them in forms available to plants.

Water dynamics

- Improves water infiltration.
- Decreases evaporation.
- Increases water holding capacity, especially in sandy soils.

Structure

- Reduces crusting, especially in fine-textured soils.
- Encourages root development.
- Improves aggregation, preventing erosion.
- Prevents compaction.

Other effects

- Pesticides break down more quickly and can be "tied-up" by organic matter (and clays).
- Regulates soil temperature
- Many of the effects of organic matter are related to the activity of soil organisms as they use soil organic matter.
- Plant residues and other organic material may support some diseases and pests, as well as predators and other beneficial organisms.
- Prevents soil degradation under semi-arid conditions

What Determines Soil Organic Matter Levels?

The amount of organic matter in soil is the result of two processes: **the addition of organic matter (roots, surface residue, manure, etc.), and the loss of organic matter through decomposition**. Five factors affect both additions and losses.

Management. Practices that increase plant growth (cover crops, irrigation, etc.) will increase the amount of roots and residue added to the soil each year. Conversely, intensive tillage increases the loss of organic matter by speeding decomposition. While tillage primarily burns younger organic matter, older, protected organic compounds can be exposed to decomposition if small aggregates are broken apart.

Soil texture. Fine-textured soils can hold much more organic matter than sandy soils for two reasons. First, clay particles form electrochemical bonds that hold organic compounds. Second, decomposition occurs faster in well-aerated sandy soils.

Climate. High temperatures speed up the degradation of organic matter. In areas of high precipitation (or irrigation) there is more plant growth and therefore more roots and residues entering the soil.

Landscape position. Low, poorly-drained areas have higher organic matter levels, because less oxygen is available in the soil for decomposition. Low spots also accumulate organic matter that erodes off hill tops and steep slopes. Less organic matter is produced on the drier hilltops, and some is lost to soil erosion and deposited in low spots.

Vegetation and farming history. In grasslands, much of the organic matter that dies and is added to the soil each year comes from grass roots that extend deep into the soil. In forests, the organic matter comes from leaves that are dropped on the surface of the soil. Thus, farmland that was once a grassland will have different amounts of organic matter deep in the soil than lands that were previously forest.

How do organic matter levels change?

To build organic matter levels in topsoil, more organic matter must be added than is lost to decomposition and erosion.

Intensive tillage aerates the soil and accelerates decomposition process. Decomposition is desirable because it releases nutrients and feeds soil organisms. But if decomposition is faster than the rate at which organic matter is added, soil organic matter levels will decrease. Reducing decomposition is only half the equation. It is just as important to increase the amount of organic matter added to the soil. Organic matter can be either grown in the field or brought to the field.

How long does it take? Building organic matter is a slow process. First, the amount of residue and active organic matter will increase. Gradually, the species and diversity of organisms in the soil will change, and amounts of stabilized organic matter will rise. It may take a decade or more for total organic matter levels to significantly increase after a management change. Fortunately, the beneficial effects of the changes appear long before organic matter levels rise because of changes in the active pool. These improvements, however, can be reversed in a year or two by returning to previous practices.

However, you cannot simply add 10 tons of manure or residue and expect to measure a one percent increase in soil organic matter. Only ten to twenty percent of the original material becomes part of the soil organic matter. Much of the rest is converted over several years into carbon dioxide.

How to build up organic matter?

1) Add organic material.
2) Reduce losses.
3) Manage the new dynamics of the system.

1) Add organic matter

- **Grow** more organic matter, grow healthy and productive crops, and plan a high residue rotation that includes- sod crops, cover crops and legumes
- **Apply** livestock manure. Manure is an excellent way to build organic matter.
- **Locate** off-farm sources of organic matter, such as food processing wastes

2) Reduce organic matter losses

- **Reduce tillage**. Merely maintaining soil organic matter levels is difficult if soil is intensively tilled.Reducing leaves more residues
- **Control erosion**. The soil that erodes from the surface of your land is the soil with the highest concentration of organic matter. Erosion is especially detrimental where topsoil organic matter is low and soil is shallow. Any biological or mechanical mangement option recommended to the location can be adopted to reduce erosion losses. Biological options may be slow in their effect but will also increase the SOM content.

3) Manage the changes in your new system

- **Plan** how to manage changes in weed or pest problems associated with increased surface residue (including FYM). Weeds and pests are not necessarily greater problems with increased residue, but may require different management strategies.
- **Monitor** soil and keep records so you know what effects your practices are having. Include an organic matter test in your regular soil testing. Labs are beginning to offer tests (such as the particulate organic matter test) that measure the active fraction.

Management of SOM:

Why is the carbon-to-nitrogen ratio important?

Each organic amendment has a characteristic amount of carbon in proportion to nitrogen. (See table 1). A low carbon-to-nitrogen ratio means the material is high in nitrogen. Materials with a high C:N ratio (low nitrogen) decompose slowly and may trigger nitrogen deficiency in plants as they decompose.

How can adding organic matter trigger nitrogen deficiency?

Plants depend on microbes to break down organic matter and make the nutrients available to them. Most microbes get energy from carbon compounds such as sugars, carbohydrates, fats, and other substances. Mixing organic material into the soil triggers a feeding frenzy and a burst in microbial growth. To grow, microbes need carbon for energy and nitrogen to build proteins. For every twenty to thirty carbon atoms they consume, they use about one nitrogen atom. If that nitrogen is not available from the newly-added organic material, microbes will take it from the soil, and deprive growing plants of nitrogen. **As a rule-of-thumb, materials with C:N ratios less than 30:1 will not trigger temporary nitrogen deficiency.**

The nitrogen is not lost from the soil - it is still present in the cells of microbes - but plants cannot use it. During this initial decay process, microbes are giving off large amounts of CO_2 to the atmosphere and the carbon-to-nitrogen ratio of the remaining organic material declines. Microbial activity slows because the remaining compounds are more recalcitrant (difficult to decompose). At this point, nitrogen from the dying microbes becomes available to plants.

Table 1. C:N ratios for common organic materials

Organic material	C:N when applied	Remarks
soil organic matter	10:1	
composted soil	10-30:1	
young sweet clover or alfalfa	3-10:1	If the ratio is less than 20:1, the residue has more than 2% nitrogen, and N will be quickly available to growing plants.
sheep manure	13-20:1	
cow manure	11-30:1	
barnyard manure	20:1	
Corn/sorghum stover	60:1	If the ratio is more than 40:1, the residue has less than 1% nitrogen, and N will be tied up (unavailable to plants) for a few weeks, or much longer in the case of low-nitrogen woody materials.
Grassy weeds	80:1	
Small grain straw (rice, wheat)	80:1	
sawdust	100-400:1	

Management of organic matter for nutrient supply and soil improvement.

Decomposition of organic materials and the release of nutrients from them is regulated by the-

- physico-chemical environment
- chemical composition (quality) of the resource.
- decomposer community.

The above regulatory factors can be manipulated through the quality, quantity, timing and location of inputs (organics) to the soil.

SOM and Synchrony

SOM is a sink and source of plant nutrients and it helps in temporal and spatial patterns of nutrient availability. The quantity and quality of SOM is influenced by the nature of above and below ground litter inputs.

Synchrony-

The release of plant nutrients from the above and belowground litter can be synchronized with the plant growth demands.

Synchrony hypothesis - Quantity, quality, timing and placement of organic inputs.

- Increasing the proportion of low-quality (e.g. low N and P, high lignin content) litter inputs at the onset of rains extends the time period of availability of nutrients to the plant.
- The availability of nutrients to plants (e.g. from external sources) can be delayed through microbial immobilization on low quality litters, thus decreasing the risk of losses through leaching.
- Below-ground litter is a more important source of immediately available nutrient than above-ground litter.

Current understanding about synchrony-

- High quality organic materials are equally effective as mineral N sources
- Organic materials high in lignin result in low mineralization but this is not followed by any substantial residual mineralization.
- Organic materials high in tannins exhibit delayed N release or immobilization, immobilization can be quite prolonged and the subsequent mineralization phase is rarely at rates or levels high enough to meet crop demand.
- Application of low N content materials can reduce losses of N through leaching and denitrification compared to high N materials but the subsequent remineralization is at rates and levels insufficient to meet crop demand.
- Mixing high and low quality nutrient sources generally results in an intermediate N release.

No single organic material releases N in perfect synchrony to the plant demand- giving slow initial mineralization or immobilization followed by a large rapid mineralization. High quality materials (high N, low lignin, low polyphenol/tannin) release N in a pattern similar to mineral fertilizers and a large proportion of N is available in advance to the main period of cotton plants uptake (70-130 days). Poor quality organic materials (high lignin or high polyphenol/tannin or low N) has a time lag and then releases N at a slow rate and is not followed by a period of rapid mineralization. Thus mixing of low quality and high quantity organic inputs generally results in a mineralization pattern equal to the weighted average of the patterns of the two separate materials.

SOM hypothesis – Maintaining soil fertility through manipulation of different SOM factors

- Increasing the proportion of low quality litter results in increased SOM pools, particularly of the more recalcitrant fractions (humus).
- Increased nutrient availability to plants (from high quality organics) results in increased litter input and reduces the recalcitrant pool of SOM.
- Below ground litter contributes relatively greater component to SOM formation than above ground litter.
- Active or labile pool of SOM is small but is more important than slow and passive pools for nutrient release.
- Polyphenol rich materials may be a fast route for enhancing SOM contents.

SOM hypothesis contradicts synchrony theory. Organic materials that provide short term nutrient release do not provide the substrate for SOM. Maintenance of a large pool of SOM, through large organic inputs, will ensure greater rates of nutrient mineralization once the SOM has increased significantly. Effect of SOM on nutrient availability would depend upon the total SOM content and the relative proportion of different fractions.

Inputs that have both high N and lignin provide an opportunity for attaining SOM and synchrony e.g. FYM.

Net mineralization occurs when N concentration is >25 g/kg, lignin is < 150 g/kg and soluble polyphenols is < 40g/kg. Based on these values a decision tree is attempted to define quality of organic materials in terms of nutrient release (fig 1. and table 2) and the same information has been simplified in fig 2.

Fig 1. Decision tree for biomass transfer of plant materials for soil fertility management:

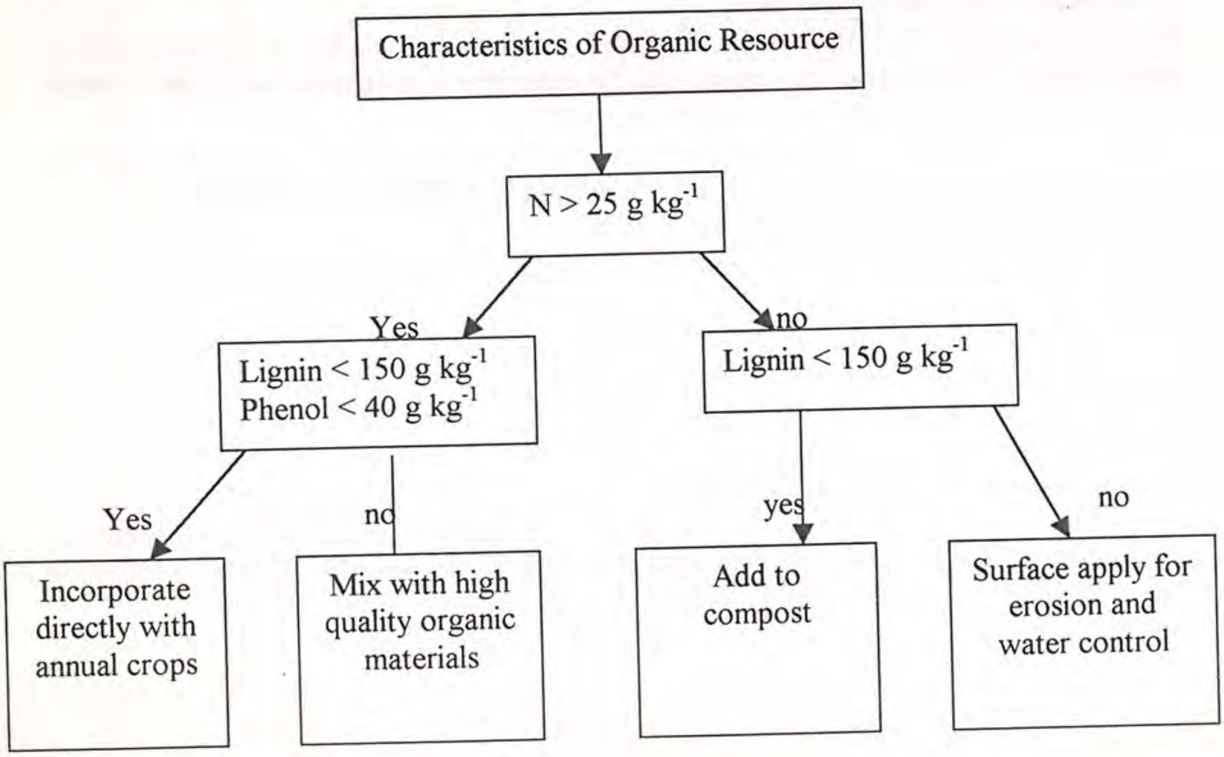
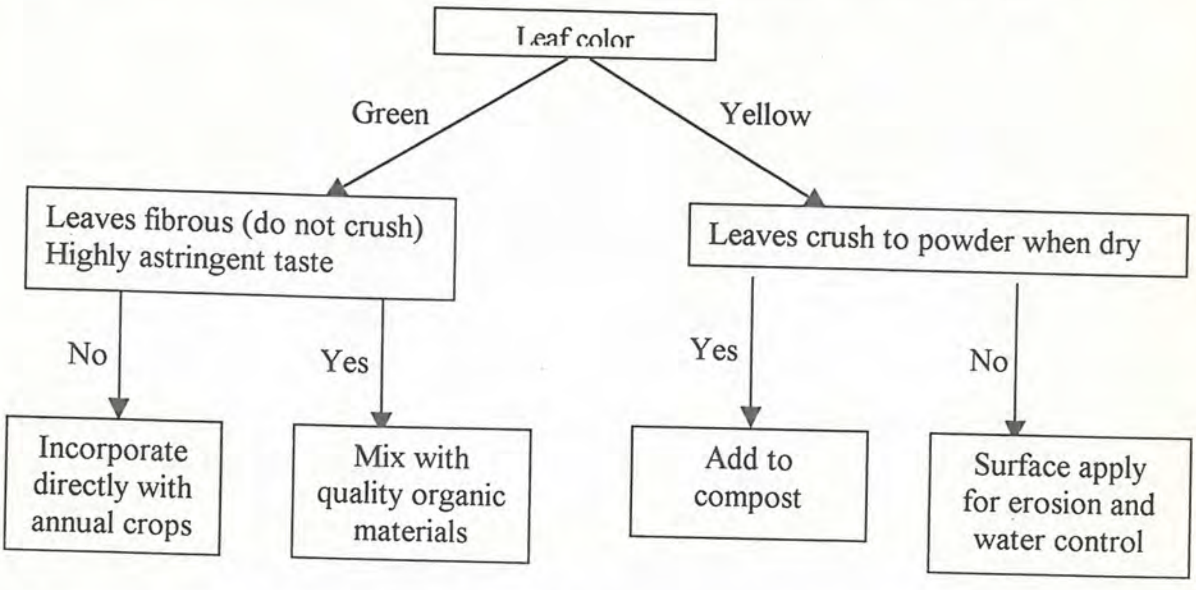


Table 2 Proposed categories of organic materials based on N, lignin, and polyphenol contents and their hypothesized effect on nitrogen supply and soil organic matter

	Resource Quality Parameterss N, lignin, soluble polyphenols (g kg^{-1})	Nitrogen supplying capacity	Soil organic matter formation
High quality	N>25, lignin < 150 and polyphenol < 40	High and immediate	Little or negative effect on total SOM; increased active fraction (soil microbial biomass)
Intermediate-High quality	N>25, lignin > 150 or polyphenol > 40	Delayed, short or long term	Increased particulate (light) and passive fractions
Intermediate-Low quality (Short term)	N<25, lignin < 150 and polyphenol < 40	Low-Short term immobilization	Little effect on total SOM
Low quality (Long term)	N<25, lignin >150 or polyphenol > 40	Very low and possible long term immobilization	Increased particulate (light) and passive fractions

Fig 2: Farmer decision tree for assessing organic matter quality and management



Several aspects of the role and function of OM in tropical soils are yet not clear. But the immediate challenge is to apply the existing knowledge on the marginal tropical lands that are threatened by massive degradation and where the pressure to produce more is the greatest.

NUTRIETNT POTANITAL OF ORGANIC SOURCES FOR SOIL FERTILITY MANAGEMENT IN ORGANIC COTTON PRODUCTION.

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Organic cotton is grown in living-soil fields which have been free of synthetic pesticides, herbicides and fertilizers for at least three year. Organic cotton is produced with animal or vegetable matter fertilizers and is free from toxic chemicals. Organic farming relies on crop rotation, mechanical cultivation and botanical or biological controls.

Products made form organic cotton support sustainable cotton farming practices, help reduce contamination of the earth and increase the quality of our health.

Maintenance of Soil Fertility for Organic Cottons Production

Vertisol are swell-shrink type soils with high water retentively, low infiltration rate and high cation exchange capacity. Improvement and maintenance of the organic matter these soils is an essential precondition to sustain reasonable levels of organic cotton production as this would increase water infiltration, reduce erosion, improve soil structure and aggregate stability, besides enhancing the supply of nutrients, particularly, N, P and S. Hence, a good organic matter management programme is needed for fertility management under organic production system. Rainfed cotton crop in Central India removes around 5.8 kg N, 2.0 kg P and 6.6 kg K per 100 kg seed cotton produced. With many such alternate uses of FYM, such huge quantities required to meet the crop's nutrient requirement is generally not available. Hence, a combination of sources with different biological properties must be resorted.

MANURES

Manures are plant and animal wastes that are used as sources of plant nutrients. Manures can be grouped into bulky organic manures and concentrated organic manures based on concentration of the nutrients.

Bulky Organic Manures

Bulky organic manures contain small percentage of nutrients and they are applied in large quantities. Farmyard manure (FYM), compost and green manure are the most important and widely used bulky organic manures. Use of bulky organic manures have several advantages: (1) they supply plant nutrients including micronutrients, (2) they improve soil physical properties like structure, water holding capacity etc., (3) they increase the availability of nutrients, (4) carbon dioxide released during decomposition acts as a CO_2 fertilizer, and (5) plant parasitic nematodes and fungi are controlled to some extent by altering the balance of microorganisms in the soil.

Farmyard Manure

Farmyard manure refers to the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages or fodder fed to the cattle. On an average well decomposed farmyard manure contains 0.5 per cent N, 0.2 per cent P_2O_5 and o.5 percent K_2O. The present method of preparing farmyard manure by the farmers is defective. Urine, which is wasted, contains one per cent nitrogen and 1.35 per cent potassium. Nitrogen present in urine is mostly in the form of urea which is subjected to volatilization losses. Even during storage, nutrients are lost due to leaching and volatilization. However, it is practically impossible to avoid losses altogether, but can be reduced by following improved method of preparation of farmyard manure. Trenches of size 6m to 7.5m length, 1.5 m to 2.0m width and 1.0m deep are dug. All available litter and refuse is mixed with soil and spread in the shed so as to absorb urine. The next morning, urine of the trench from one end should be taken up for filling with daily collection. When the section is filled up to a height of 45 cm to 60 cm above the grow level, the top of the heap is made into a dome and plastered with cowered earth slurry. The process is continued and when the first trench is completely filled, second trench is prepared. The manure becomes ready for use in about four to five months after plastering.

Compost

A mass of rotted organic matter made from waste is called compost. The compost made from farm waste like sugarcane trash, paddy straw, weeds and other plants and other waste is called farm compost. The average nutrient contents of farm compost is 0.5 per cent N, o.15 per cent P_2O_5 and 0.5 per cent K_2O. The compost made from town refuses like night soil, street sweepings and dustbin refuse is called town compost. It contains 1.4 per cent N, 1.00 per cent P_2O_5 and 1.4 percent K_2O.

Farm compost is made by placing farm wastes in trenches of suitable size, say, 4.5 m to 5.0 m long, 1.5 m to 2.0m wide and 1.0 m to 2.0m deep. Waste is placed in the trenches layer by layer. Each layer is well need by sprinkling cow-dung slurry or water. Trenches are filled up to of 0.5 m above the ground. The compost is ready for application five to six months.

Sewage and Sludge

In the modern system of sanitation adopted in cities and town, human excreta is flushed out with water which is called sewage. The Solid portion in the sewage is called sludge and liquid portion is sewage water. Both the components of sewage are separated and are given a preliminary fermentation and oxidation treatments to reduce bacterial contamination and offensive smell.

Green Manure

Green, undecomposed plant material used as manure is called green manure. It is obtained in to ways: growing green manure crops or by collecting green leaf (along with twigs) from plants grown in wastelands, field bunds and forest. Green manuring is grown in the field plants usually belonging to leguminous family and incorporating into the soil after sufficient growth. The most important green manure crops are sunhemp, dhaincha, *pillipesara,* clusterbeans and Sesbania rostrana

Nutrient content of green manure corps and green manure crops and green leaf manure

Plant	Scientific Name	Nutrient content (%) air dry basis		
		N	P_2O_5	K_2O
Green Manure Crops				
Sunnhemp	*Crotalaria juncea*	2.30	0.50	1.80
Dhaincha	*Sesbania aculeata*	3.50	0.60	1.20
Sesbania	*Sesbania speciosa*	2.71	0.53	2.21
Green leaf manure				
Forest tree leaf		1.20	0.60	0.40
Green weeds		0.80	0.30	0.20
Pongamia leaf	*Pongamia glabra*	3.31	0.44	2.39

Application to the field, green leaves and twigs of trees, shrubs and herbs collected from elsewhere is known as green-leaf manuring. The important plant species useful for green-leaf manure are neem, mahua,wild indigo, glyricidia, Karanji (*Pongamia glabra*) calotropis. avise (*Sesbens grandiflora*), subabul and other shrubs.

Several advantages accrue due to the addition of green manures. Organic matter and nitrogen are added tot he soil. Growing deep rooted green-manure crops and their incorporation facilitates in bringing nutrients to the top layer from deeper layers. Nutrient availability increases due to production of carbon dioxide and organic acids during decomposition. Green manuring improves soil structure, increases water-holding capacity and decreases soil loss by erosion. Green manuring helps in reclamation of alkaline soils. Root-knot nematodes can be controlled by green manuring.

Sheep and Goat Manure

The dropping of sheep and goats contain higher nutrients than farmyard manure and compost. On an average, the manure contains 3 per cent N, 1 per cent P_2O_5 and 2 per cent K_2O. It is applied to the field in two ways. The sweeping of sheep or goat sheds are placed in pits for decomposition and it is applied later to the field. The nutrients present in the urine are wasted in this method. The second method is sheep penning, wherein sheep and goats are allowed to stay overnight in the field and urine and fecal matter is added to the soil which is incorporated to a shallow depth by running blade harrow or cultivar.

Poultry Manure

The excreta of birds ferments very quickly. If left exposed, 50 per cent of its nitrogen is lost within 30 days. Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures. The average nutrient content is 3.03 per cent N, 2.63 per cent P_2O_5 and 1.4 per cent K_2O.

Concentrated Organic Manures

Concentrated organic manures have higher nutrient content than bulky organic manure. The important concentrated organic manures are oilcakes, bloodmeal, fish manure etc. These are also known as organic nitrogen fertiliser. Before their organic nitrogen is used by the crops, it is converted through bacterial action into readily usable ammoniacal nitrogen and nitrate nitrogen.These organic fertilisers are, therefore, relatively slow acting, but they supply variable nitrogen for a longer period.

Oilcakes

After oil is extracted from oilseeds, the remaining solid portion is dried as cake which can be used as a manure. The oil-cakes are of two types:

Edible oil-cakes which can be safely fed to livestock, e.g.: Groundnut cake, coconut cake etc.,

Nonedible oil-cakes which are not fit for feeding livestock: e.g.: Castor cake, neem cake, mahua cake etc.,

Both edible and non-edible oil-cakes can be used as manures. Nutrients present in oil-cakes, after mineralisation, are made available to crops 7 to 10 days after application. Oil-cakes need to be well powdered before application for even distribution and quicker decomposition. The average nutrient content of different oil-cakes are presented.

Average nutrient contents of oil-cakes

Oil cakes	Nutrient content (%)		
	N	P_2O_5	K_2O
Nonedible oil-cakes			
Castor cake	4.3	1.8	1.3
Cotton seed cake	3.9	1.8	1.6
Karanji cake	3.9	0.9	1.2
Mahua cake	2.5	0.8	1.2
(Decorticated)	4.9	1.4	1.2
Edible oil-cakes			
Coconut cake	3.0	1.9	1.8
Cotton seed cake (Decorticated)	6.4	2.9	2.2
Groundnut cake	7.3	1.5	1.3
Linseed cake	4.9	1.4	1.3
Niger cake	4.7	1.8	1.3
Rape seed cake	5.2	1.8	1.2

Safflower cake (Decorticated)	7.9	2.2	1.9
Sesamum cake	6.2	2.0	1.2

Other Concentrated Organic Manures

Blood-meal when dried and powdered can be used as a manure. The meat of dead animals is dried and converted into meat-meal which is a good source of nitrogen.

Crop residues

Substantial quantities of crop residues are produced in India every year Major crops like rice, Wheat Sorghum, Peal mullet and Maize alone yield approximately 236 m.t. straw per year. The nutrient potential of cereal straw/residue from five crops coms to 1.13 m.t N. 1.41 t + P2O5 and 3.54 m.t. K2O. Crop residues can be recycled either by composting or by way of mulch or direct incorporation in the soil.

Table 6. Potential of farm residues and plant-nutrients in them

Crop	Residue production (mt)	Per cent over dry basis		
Rice straw	106.01	0.58	0.23	1.66
Wheat straw	80.99	0.49	0.25	1.28
Sorghum	21.04	0.40	0.23	2.17
Pearl millet	15.58	0.65	0.75	2.50
Maize	12.50	0.59	0.31	1.31
Total pulses	13.70	1.60	0.15	2.00
Pigeonpea	6.65	1.10	0.58	1.28
Chickpea	5.05	1.19	N.A	1.25
Sugarcane	40.92	0.35	0.04	0.50
Oilseeds	35.78	-	-	-

Soil Physical Properties

Use of organic amendments improve the various physical properties of the soil. Yin-po Wang and Chen-Ching Chao (1995) reported that the bulk density, total porosity and aggregate stability of surface soil improved by the organic farming and this can be attributed to the higher organic matter levels of the organic farming soil.

Soil chemical Properties

Yin-Po Wang and Chen-Ching Chao (1995) reported that application of green manure continuously after four cropping cycles the soil pH of the organic farming increased to as high as 76 to 8.3 than conventional farming (pH 5.7 to 6.6) .

Soil Microbial Population

Organic farming have direct contribution to soil organic matter levels therby increase the microbial population. Scullion and Ram Shaw (1987) showed that earth worm population increased due to FYM application. Application of poultry manure encourage costing and burrowing to the surface whereas application of inorganic fertilizers of high rates discouraged these activities.

Effect on Organic carbon

Biswas et al (1971) earlier and Kanwar and Prihar (1992) reported that continuous application of FYM increased the organic carbon content as well as nitrogen contents. Yadav (1995) reported that pressmud application increases the organic carbon content.

Effect on Micronutrients

Continuous application of FYM at 15 t ha-I for 3 years increased zinc level from 0.48 to 0.87 percent (Radhav and Takkar. 1975,Biogas slurry poultry manure compost and pressmud have been found to be superior sources of Zn a compared to Zinc sulphate particularly in Zn deficient calcareous soil (Prasad et al.1981, 1984, 1985) Azolla incorporation increased the availability of Fe and Mn in soils (Sing 1992).

ROLE OFBIOFERTILISERS IN COTTON

Biofertiliser is one of natural and sustainable nutritional input . Mainly there are two types of biofertilisers which are used on mass scale. These are nitrogenous and phosphatic biofertilisers.

The nitrogenous biofertiliser for cotton are *Azotobacter* (A.*chroococcum*) and *Azospirillum* (A. brazilense). These organisms with the help of nitrogenase enzyme fix atmospheric nitrogen known as biological nitrogen fixation. The phosphorus biofertilisers consist of several bacteria (*Bacillus megatherium, Pseudomonas striata*) and fungi (*Aspergillus awamori* and *Penicillium digitatum*).

. It has been estimated that 1 ton *Azotobacter/Azospirillium* is equivalent to 40 ton Nitrogen @ 20 kg N fixed /year/crop at 500g/ha dose and 1 ton PSM is equivalent to 24 ton Phosphorus (P_2O_5).

The use of *Azotobacter* enhances the yield of cotton depending on variety and strain efficiency. Pandey and Kumar (1989) reported 7 to 28% increased yield in cotton with *Azotobacter* inoculation.

Response of Azospirillium

It is reported that *Azospirillum* has positive response in increasing seed cotton yield and better dry matter production (Marappan and Narayanan, 1993). The application *Azospirillum* recorded 430 kg/ha has increased yield over the control. Further, the residual effect of *Azospirillum* was also found positive in terms of yield and population.

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CROP NUTRITION IN ORGANIC FARMING

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Cotton (*Gossypium* spp.) is called "white gold". Nearly one-third of India's export earnings are from textile sector of which cotton alone constitutes 70 % raw material. Cotton is grown in all 3 agro-ecological region viz., north, central and south. India is producing cotton to the tune of 167.5 lac bales (one bale=170 kg) in 2003-04 from 76.14 lac ha with productivity of 404 kg lint/ha (the corresponding figures for Andhra Pradesh is 7.82 lac ha, 26 lac bales and 565 kg/ha) which is low against the world average of 588 kg/ha, yet it is within the limits of our agro-climatic situations. Cotton widely grown, as a semi-xerophytic forced annual, its productivity is linearly related with water availability during reproductive season of the crop, more specifically during boll development stages requiring life saving irrigation during the period. Good variety, timely planting, crop nutrition, effective control of weeds up to 60 DAS, irrigation, effective and judicious pest control care in harvest are important for realization of higher yield.

Organic production refers to organically grown crops, which are not exposed to any chemicals right from the stage of seed production to the final post-harvest handling and processing. It is based on recycling of natural organic matter, crop rotation, green manuring, animal manures etc. for soil fertility; cultural, crop rotation, mechanical practices for effective weed management and mechanical, biological and bio-pesticides for pest and disease management.

Components in Organic farming

Three broad components have been visualized in case of organic farming which are as under:

1. Nutritional Management
2. Irrigation management
3. Insect and pest (including weeds) management

The followings pertain to details of nutritional management in organic farming in cotton

Nutritional Management in cotton

Usually nutrients requirement are based on soil and/or plant analyses. These tests are specific to a particular soils, climate, yields levels and can not be extrapolated easily to other areas. However, some basic principles of mineral nutrition, nutrient uptake and concentration are given here.

Nutrition affects the yield of cotton to a far greater extent than it affects lint quality, which is largely determined by genotypes and weather. Since cotton production covers a wide range of environments and economic circumstances, yield and hence nutritional requirements vary greatly. In cotton, nitrogen deficiencies is very common, P & K deficiencies are common, Mg, Zn, B, Mn deficiencies are occasional, deficiencies of Ca, Fe and Cu are rare and Mo & Cl deficiency are unknown.

Deficiency of essential nutrients reduces plant growth and yield. Deficiency of one group of nutrients (P, K, Mg, B and Zn) limits fruit production to a greater extent than vegetative growth whereas deficiencies of a second group of nutrients (N, S , Mo & Mn) restricts vegetative and fruiting growth to an equal extent. Most of the nutrients in the first group may affect the fruiting efficiency because the function in the control of carbohydrates translocation. The role and deficiency symptoms for individual nutrient element are given here and also summarized in Fig.1.

NITROGEN

Plants absorb N as nitrate and ammonium ion. It is the basic molecular component of proteins, chlorophyll, nucleic acid, amino acids and cytochromes and is vital for plant establishment, root, vegetative growth and yield.

Deficiency of N especially at flowering and boll formation results in leaf chlorosis (first in older leaves), premature senescence of leaves with red pigmentation and square/boll shading (deficiency of N is apparent when petiole N < 1000 ppm (0.1%). Excess of N also delays maturity by enabling it growing indeterminately and has a deleterious effect on yield and quality of fiber. Thus, balance N supply is the key for sustainable growth & development.

PHOSPHORUS

It is absorbed by plant as $H_2PO_4^-$ & HPO_4^{2-}. It is an component of nucleic acid and phospholipids, coenzymes viz., NADP and ATP (plant energy balance). It helps in root development, improvement in soil structure and inhibition of surface crust formation. P is found to having positive interaction with water for higher WUE. It plays a crucial role in production of seed, its oil and protein content Moreover, P has balancing effect on excess N thereby, hastening maturity of the crop. Deficiency of P (petiole P is <1000ppm or <14 ppm available soil P) leads to stunted plants with dark or blue green coloration of leaves and leaf necrosis, short & brittle internodes with small and thickened leaves, lower seed production and poor quality fibers.

POTASSIUM

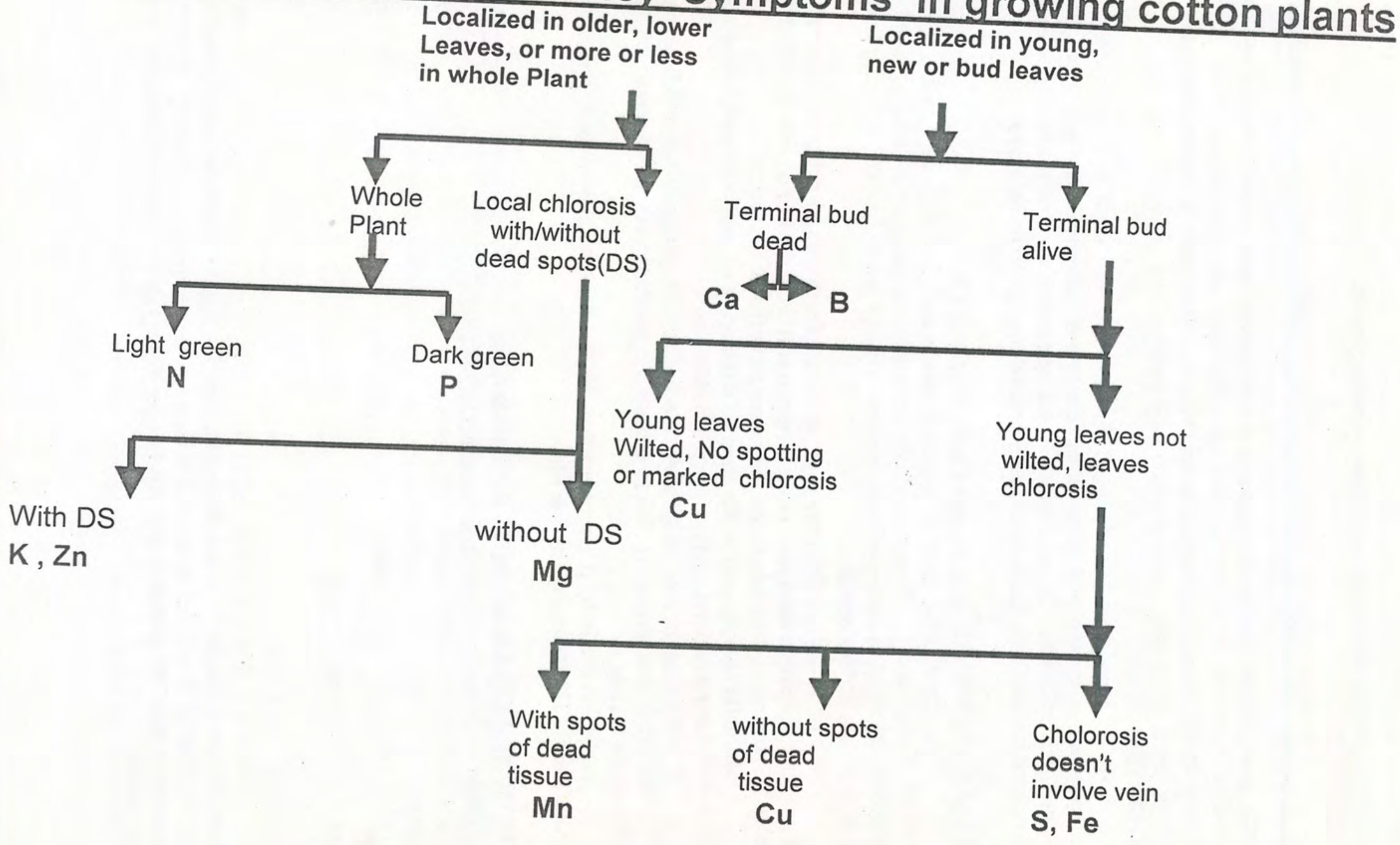
Plant absorbs potassium as K^+ ion. K plays role in carbohydrate metabolism and protein synthesis, It induces lodging resistance, mild protection from pests/diseases (e.g. effect of jassids at Hisar), improves fiber quality and bundle strength besides hastening maturity. Deficiency of potassium is associated with rusty or bronze colored and shriveled leaves (leaf chlorosis) followed by necrosis at the tip margin of older leaves, curling and shortening of internodes, decline in yield and quality of fiber.

Thus, P & K requires long term strategy (as biological and chemical transformations don't add or deplete P & K from the root zone easily) for required P & K inputs ensuring adequate soil P & K supply so that the crop growth is not limited and N use efficiency is not reduced.

MAGNESIUM

It is a component of chlorophyll and cofactor for enzymatic reaction. It Increases resistance to drought, diseases and infections. Cotton is sensitive to Mg deficiency (3-4 kg MgO/ha removed by 100 kg of cotton). Deficiency of Mg is associated with chlorosis

Fig.1 Generalized Deficiency Symptoms in growing cotton plants



between veins of older leaves mostly in patches in cotton. Mg content to the extent of 0.20 - 0.25 % is taken as the minimum for mature leaves.

SULPHUR

It plays an important role in plant cell energetics (like P) and a component in amino acids. It helps in assimilation of other nutrients. Sulphur deficiency is associated with young leaves turning light green and then yellow, and growth is stunted and yield decline. Moreover, deficiency is also associated with chlorosis between veins of older leaves mostly in patches. Sulphur content viz., 0.30 % is taken as the average content in cotton plant. An average yielding cotton crop removes 5 kg of S/ha.

CALCIUM

It is more a soil conditioner than a plant nutrient. It plays a specific role (enzymatic) in growth and metabolism (membrane integrity), influences plant water supply and utilization. Its availability in soil determines the availability in plants. The estimated loss of Ca by leaching and crop removal may go up to 500 kg/ha.

TRACE ELEMENTS (Zn, Fe, Mn,Cu, B, Mo,Co & Cl)

Plant removes the essential micronutrients as Zn^{2+}, Fe^{2+},Fe^{3+}, Mn^{2+}, Cu^{2+}, H_3BO_3, MoO_4^{2-} ,CoO_4^{-2} and Cl^-. These are mostly component of enzymes & coenzymes and are indirectly involved in photosynthesis, electron transfer and N fixation, thus play crucial role in growth & development.

In case of zinc deficiency, younger leaves develop mild chlorosis followed by appearance of maroon coloration of the marginal portion of the leaf lamina. Zn deficiency leads to shortening of the internodes and reduction in flower formation.

Mn deficiency is seen in the form of discoloring of lamina of middle and some old leaves. Later this develops into interveinal chlorosis.

B deficiency is seen as chlorotic patches on the young leaves which becomes thick and brittle and ultimately fail to expand and middle leaves show inward cupping followed by wilting.

In Andhra Pradesh, it is reported that 49 % of soil samples is Zn deficient, <1% is Cu, 3 % Fe, 1% Mn and nil in B & Mo.

CRITICAL LEVELS OF NUTRIENT IN SOILS

Nutrients	Critical levels in medium available soils
Available N	= 280 - 560 kg/ha
Available P	= 10.0 - 24.6 kg/ha
Available K	= 108 - 280 kg/ha
OC	= 0.50- 0.75 %
OM	= 0.86- 1.29 %
pH	= 6.5 - 8.7
Ec (ds/m)	=0.8 -2.5

Thus, if soil-N is less than 280 kg/ha , it will be rated as low and crop response to N will be there. Similarly, if soil-N is more than 560 kg/ha , it will be rated as high and crop response to N will not be there. But crop response to N in a soil having 280-560 kg available N will be probable and depends on many factors. Similar description is for other items.

Nutrient uptake

The soil-plant system is a dynamic system and uptake of nutrients is influenced by several factors. The amounts of nutrients removed in the economic yield are an indication of the crop's nutritional requirements.. Nutrient uptake or accumulation is related to yield level. Nitrogen, phosphorus and potash are the nutrients removed in the greatest amounts. The process in which plant takes nutrient from soil and the interaction between the nutrients for uptake by the plants are given in Fig.2 and 3.

Under long growing condition (under Brazil & other American countries), it is estimated that for every 100 kg of fibers produced, the cotton crop will require approximately 19 kg N, 8 kg P, 15 kg K, 15 kg Ca, and 4 kg Mg. However, under Indian condition, it has been found that for each 100 kg of seed cotton yield, the cop removes 5.8 kg N, 2 kg P and 6.8 kg K (3:1:3 ratios).

NUTRIENT DISTRIBUTION & PARTITIONING IN PLANTS

Cotton lint is pure cellulose and has negligible amounts of NPK. The seeds contain about 3.7 % N, 0.55% P and 0.95 % K. However, cotton burs has significant amounts of nutrients (the whole boll i.e., bur + seed + lint on average contains 2-3% N & K & 0.2-0.3% P). Cotton leaf at maturity contains also high amounts of nutrients (2-3% N, 0.3-0.4 % P and 2-3% K). The stems contain more N & K (1-2% N,0.1-0.3%P & 2-3%K). During initial 3-week phase of boll enlargement, N, P & Mg were drawn from bur to seed and fiber but the bur accumulate K up to maturity (5.5%).

Concentration of most mineral element decline initially in seed and then increased markedly (90 % of boll N in seed at boll opening). The most abundant mineral in fiber is potassium.

SOIL HEALTH CARD

Soil health card is required

1) To monitor the health of the soil as a function of its physical, chemical and biological characteristics
2) Based on visual observation, farmers experience and soil analysis results
3) Helps to keep tracks of a farm soil health and to advocate site specific technology to maintain a healthy soil with sustainable productivity

SOIL FERTILITY MANAGEMENT

1) Soils vary in their ability to supply nutrients.
2) Species/variety vary in their demand for nutrients.
3) Nutrient losses by erosion, leaching and runoff vary temporally and spatially.

Fig.2 Process of nutrient uptake in soil-plant system

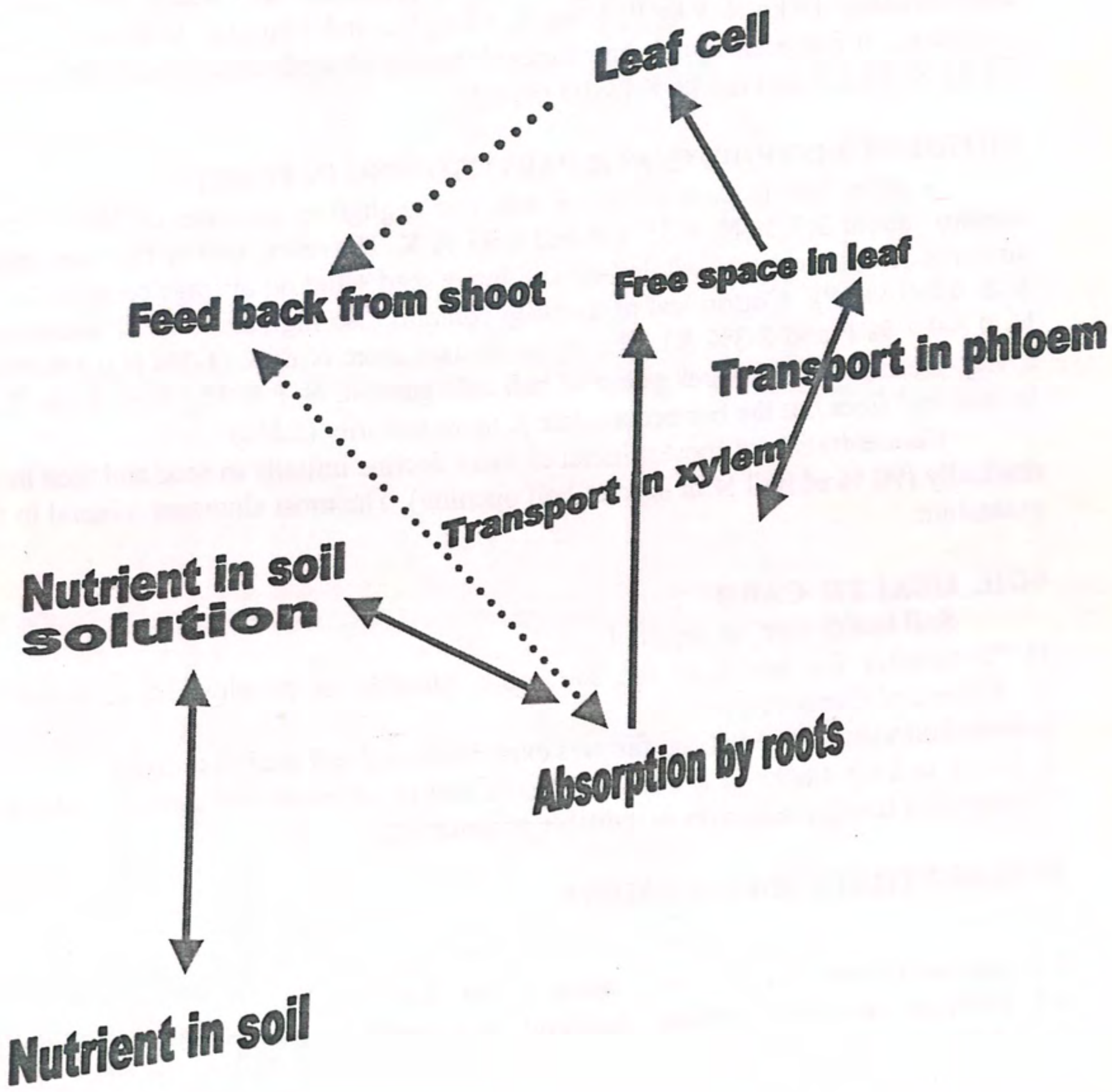
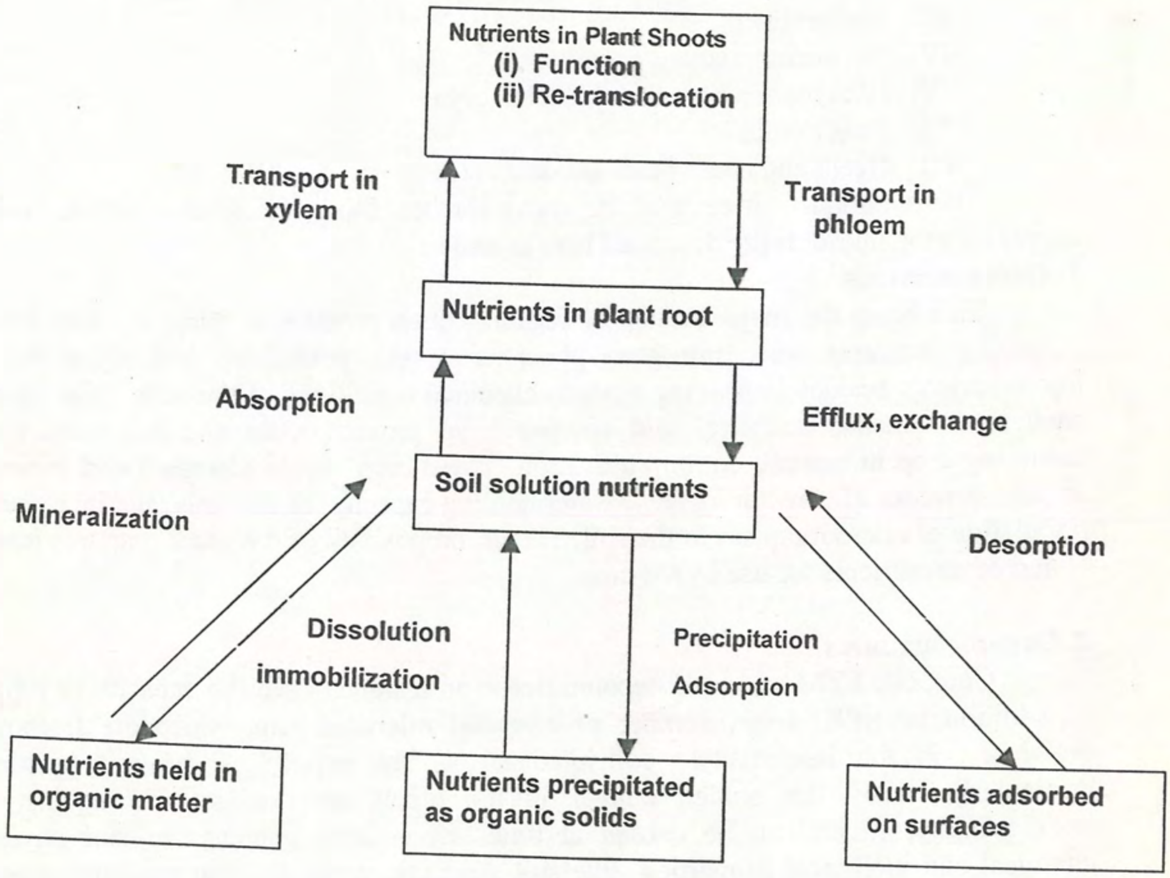


Fig. 3 Processes in soil and plants where interactions between nutrients may occur (From Robson and Pitman, 1983)



The details of soil fertility management involving various nutrient sources are enumerated here.

NUTRIENT SOURCES AND THEIR ROLE IN ORGANIC COTTON PRODUCTION

The important sources supplying nutrients in cotton for organic farming include

I. Green manures
II. Organic manures including FYM, compost and crop residues etc.
III. Biofertilizers
IV. Vermicompost and vermiwash
V. Biodynamic approach (Panchakavya)
VI. Cover crops
VII. Neem and neem based products etc.

The importance of each of the above for benefiting soil & crop system besides supplying crop nutrients are described here as under:

1. Green manures

This being the major source of organic cotton production, plays a major role in supplying nutrients viz., nitrogen, phosphorus and potassium and some of the micronutrients besides improving physico-chemical conditions of the soils. The species such as Dhaincha, Sunhemp and cowpea have proved better and important green manuring crop in organic cotton cultivation. These crop when ploughed and buried at about 6-8 weeks of sowing increase water holding capacity of the soils and increase the population of microorganism in the soil. The decomposition of the green manures release N and other nutrients for use by the crop.

2. Organic manures

Compost, FYM and well decomposed crop residues have the capacity to supply, in addition to NPK, large number of essential micronutrients which are becoming deficient in the intensively cultivated areas. The supply of the micronutrients particularly satisfy the hidden hunger in the plants and safeguards against the toxicity/injury, which can be caused at times when improvement of soil physico-chemical and biological properties like soil structure, water holding capacity, nutrient supply and the benefit to the soil microbial population have been well proved.

The improved/enriched compost is prepared by blending the products of organic origin in desired proportion out of several carbonaceous and nitrogenous material available within the farm and utilizing the (cotton) composting fungi *Trichoderma viridae*. The nutritive value of organic manure can be further enriched by addition of nutrient products in natural form viz., leguminous material, rock phosphate, bone meal, slaked lime, blood and fish meal.

Organic manures based on cow dung and urine are very important component in bio-farming. Besides soil conditioner, the manure contains lot of nutrients for assimilation by the crop. Moreover, cow urine is an important source of copper, iron, calcium, phosphorus, carbonic acid, potash and lactase. The urine also is a disinfectant and prophylactic and these purifies and improves the fertility of the land.

3. Biofertilizers

These are bacterial cultures of appropriate species which have the capability of fixing atmospheric nitrogen such as *Azotabacter* and *Azospirillum*. The phosphate solubilizing bacteria (*Azophos or Phosphobacter*) have proven their utility in making phosphorus available to the crop. The biofertilizers as a source of nutrition in organic production may be seed or soil inoculated during planting of the crop.

4. Vermicompost and vermiwash

Vermiculture is an important aspect in organic cotton production where it involves the use of earthworms as versatile natural bioreactors for effective recycling of non-toxic organic wastes to the soil. These earthworms harness the beneficial soil microflora, destroy soil pathogens and convert organic wastes into valuable products such as biofertilizers, bio-pesticides, vitamins, enzymes, antibiotics, growth hormones and proteinous biomass.

The participation of earthworm in farming process involve their influence on soil pH, physical decomposition, formation of humus, soil structure and above all, soil fertility.

The vermiwash is prepared from the heavy population of earth worms reared in earthen pots or plastic drums (or filtering the mixture of vermicompost and water in 1:1 ratio only after keeping it for 24 hours). The extract contains major nutrients, micronutrients, vitamins and hormones such as gibberellins secreted by the earthworm for readily assimilation by plants (vermiwash sprayed @ 3 % solution) for higher growth, yield and quality.

5. Biodynamic approach (Panchakavya)

It is systematic and synergistically harnessing energies from cosmos, mother earth, plats and cow for quality production and proper maintenance of ecosystem. These are essentially organic preparations which are component of biological agriculture capable of affording long term sustainability to the agriculture particularly to the ecosystem. Basic principle of biodynamic farming are to restore the soil and the organic matter in the form of humus, increasing microbial population skillful application of factors contributing the soil life and health, treating manure and compost in biodynamic way. The biodynamic preparation includes BD 502, BD 508, Cow-pit-pat, biodynamic liquid manures and liquid pesticides.

The advantages in such a farming includes sustainable development of the system, minimum residual toxicity, improvement in soil fertility and quality of the produce including self life and higher availability of nutrients (viz., N,P,K,Ca, Mg, S , Fe & Si). Incorporation of biodynamic preparations catalyses fermentation process which influences the nutriment availability.

Besides biodynamic approach, by-products of cow are the key component in other methods of organic farming such as *Agnihotra* (Cow ghee, dung), *Rishi Krishi* (Cow dung) and *Panchagavya* farming (cowdung, urine, milk, curd, ghee).

6. Cover crops

These crops can be are beneficial for intensive organic production by way of providing better water penetration and infiltration for improved root growth of the crop and by returning organic matter to soils. If leguminous crops are grown, soil N can be increased through biological N fixation. Grasses are particularly helpful in promoting soil structure and soil aggregates stability because of their fibrous root system. Microbial activity often stimulated by cover crop root exudates and organic matter additions to soils, has also been shown to promote aggregate stability. Since microbes decompose organic matter, nutrients are released in the soils for readily assimilation by the plants. Weed suppression for the next crop in rotation is another advantage of the cover crop.

Even crop diversification (of cotton) by rotating it with jowar (*Sorghum bicolor)* for both grain and fodder is found to having definite quantitative & qualitative advantages over others. Long term studies conducted for a decade on a clay loam soil at Coimbatore (Tamil Nadu) indicates that an additional seed cotton and jowar grain yield to the tune of 4.3 and 77 q/ha respectively can be realized (along with 20.5 t/ha of jowar dry straw) by simply following cotton-jowar system (jowar grown on residual fertility after cotton) over traditional cotton-fallow system prevalent in the region. Winter irrigated cotton (August sown) is followed by jowar in April and both the crops are grown following standard package of practices for crop production (Fig. 4).

Cotton when grown after jowar has shown to produce more number of sympodia, picked bolls, seed cotton per plant and even flower/form bolls early in the season and mature earlier for higher marketability and return on cotton over that in monocropping of cotton. Improvement in fibre quality traits especially higher micronaire value was observed in cotton grown after jowar. Besides yield and quality attributes, other important aspect of cotton-jowar system is uniform nutrient absorption from different soil strata by the cropping system leading to reduced nutrient loss (& higher nutrient use efficiency) and weed suppressing ability of jowar on the cotton crop. In addition, there is reduction in pests and diseases problem on cotton following Malvaceae - Gramineae rotation. Similar yield benefits were also accrued when FYM 15 t/ha was applied to cotton irrespective of the cropping system.

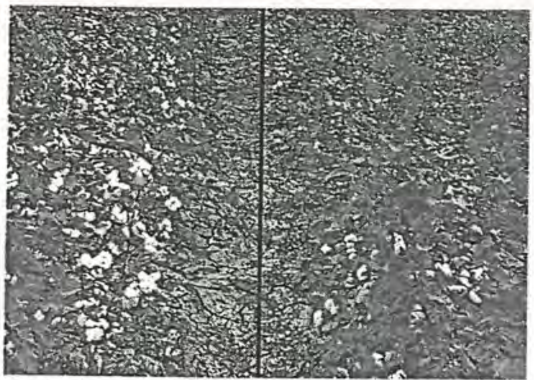


Fig. 4 Perfomance of cotton in Cotton-Jowar (left) and cotton-fallow (right) system

Integrated Organic Management (IOM) system

Thus, in organic production system, emphasis is given for healthy soil and healthy plants less prone to pests and diseases infection. Now integrated organic management (IOM) system which includes 1) mechanical, ii) cultural, iii) biological, iv) use of bio-pesticides and v) growing of tolerant varieties are permissible in integrated fashion in organic production.

Thus, in order to realize an economic harvest, fertility of the soil has to be maintained. It can be maintained primarily through applications of compost and decomposed livestock manure from sources like cattle-feeding operations, animal husbandry or production facilities including horses, poultry and dairy manures. Suitable crop rotations will have to be found which cause the least depleting effect on the soil. The cropping intensity might also be affected. Legume cover crops (grown without inorganic fertilizers) may be necessary to increase organic matter and soil nitrification. Fertilizers such as granular fish emulsion, humate or other blended organic fertilizers have to be added to the seed row and used for starter fertilization. Supplemental nutritional needs are supplied through foliar applications of sea weed, fish emulsion, humate, cytokinin or other approved organic fertilizers. Micronutrients have to be supplied through organic formulations so that the fibre quality is not affected. Biological enhancers are also permitted to be used for improving nutrient availability and their uptake. Green manuring can improve the fertility status of the soil in addition to its texture. It is also anticipated that the use of organic fertilizers on suitably hard varieties will result in lower pest infestations Moreover, abrupt availability of nitrogen from synthetic fertilizers causes rapid cell elongation, but weakens the cell structure causing more stress and less tolerance to penetration by pests. Thus, cotton grown using organic fertilizers will be less vulnerable to sucking insects.

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Biodynamic agriculture and its preparations

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Biodynamic Agriculture

It is a method of organic agriculture, which considers farm as a living system and where one activity affects the other. Thinking about the interactions within the farm ecosystem naturally leads to a series of holistic management practices that address the environmental, social, and financial aspects of the farm. Rudolf Steiner (1924) from Central Europe was founder of Biodynamic agriculture. In a very real way, it is an ongoing path of knowledge rather than an assemblage of methods and techniques.

A basic ecological principle of biodynamics is to conceive of the farm as an organism, a self-contained entity. Plant life is intimately bound up with the life of the soil. A farm is said to have its own individuality. Emphasis is placed on the integration of crops and livestock, recycling of nutrients, maintenance of soil, and the health and well being of crops and animals; the farmer too is part of the whole. Biodynamics recognizes that soil itself can be alive, and this vitality supports and affects the quality and health of the plants that grow in it. Therefore, one of Biodynamics fundamental efforts is to build up stable humus in our soil through composting.

Organic farming vs. Biodynamic farming

The biodynamic farming is more than just another organic method. It stands for a truly scientific way of production humus. It does not involve in the application of organic matter in a more or less decomposed form but the use of completely digested form of crude organic matter known as stabilized and stable humus. In this aim, the method differs from organic farming. In the case of biodynamic farming the organic material to be used as basis for compost is transformed either by means of the biodynamic compost preparations or starter. Thus, biodynamic agriculture was the first ecological farming system to develop as a grassroots alternative to chemical agriculture.

Principles behind biodynamic farming

Biodynamic farming aims to restore status of the soil ecosystem to hold its fertility and productivity. Also it helps to restore the soil for a balanced functioning of flora and fauna. Because soil is a living system wherein the microbes can be established and maintained. The biodynamic farming does not deny the role and importance of mineral nutrients of the soil like nitrogen, phosphate, potash, calcium, magnesium etc., and it considers the skilful use of organic matter as the factor for soil life. It involves skilful application of all the factors contributing to soil life and health. Because a plant grows under the influence of abiotic factors like temperature, oxygen, Co_2 light, water etc. And these energies are transformed in the plant system into chemically active energies by way of photosynthesis.Biodynamic farming considers a plant as living entity, which consists not only of mineral elements (like N, P, K, Ca, Mg, Mn, Cl, Fe etc.,) but also of organic matter such as protein, carbohydrates, cellulose, starch.Biodynamic farming gives importance to enzymes and growth substances. To restore the soil fertility, biodynamic farming gives priority to proper crop rotation Soil exhausting crops should be cultivated alternatively with fertility restoring crops.It also provides recognition to green manuring and cover cropping.To restore the soil environmental conditions, forests wind protection and water regulation are important. Biodynamic farming also gives importance to maintain the soil structure (physical characters like but density, pore space, water holding capacity and texture).In nutshell the principles are,

1. Use of Biodynamic preparations
2. Sowing / planting in accordance with moon movement
3. Attending cultural operations in accordance with cosmic rhythm.

The Cosmic Influence on Plant Growth

Light of the sun, moon, planets, and stars reaches the plants in regular Rhythms. Each contributes to the life, growth, and form of the plant. By understanding the gesture and effect of each rhythm, you can time your ground preparation, sowing, cultivating, and harvesting to the advantage of the crops you are raising.

Sowing and Planting Calendar 2004

- January 4 - Earth at Perihelion (nearest approach of Earth to the Sun)
- February 25 - Moon occults Mars @ 9:05 pm
- March 25 - Moon occults Mars @ 6:36 pm
- April 19 - Solar eclipse @ 9:21 am
- May 4 - Lunar eclipse @ 4:33 pm
- May 21 - Moon occults Venus @ 8:13 pm
- June 8 - Transit of Venus across the Sun (6+ hours) @ 4:42 am peak (last occurrence of a Venus transit was in 1900; the next will be in 2012)

Best seed periods

- Friday, January 9 @ 11:00 pm through Monday, January 12 @ 3:00 pm
- Thursday, February 5 @ 6:00 pm through Sunday, February 8 @ 8:00 pm

- Thursday, March 4 @ 3:00 pm through Sunday, March 7 @ 10:00 am
- Thursday, April 1 @ 1:00 am through Saturday, April 3 @ 1:00 pm
- Wednesday, April 28 @ 10:00 am through Saturday, May 1 @ 1:00 am
- Tuesday, May 25 @ 6:00 pm through Friday, May 28 @ 10:00 am
- Tuesday, June 22 @ 12:00 am through Thursday, June 24 @ 5:00 pm

Best sequential spray periods

- January - No favorable times except for abbreviated sequence
- Friday, February 13 @ 4:00 pm through Sunday, February 15 @ 3:00 pm
- Tuesday, March 2 @ 11:00 pm through Thursday, March 4 @ 11:00 pm
- Saturday, March 20 @ 2:00 am through Monday, March 22 @ 11:00 pm
- Friday, April 16 @ 8:00 am through Sunday, April 18 @ 9:00 pm
- Monday, April 26 @ 5:00 pm through Wednesday, April 28 @ 8:00 am
- Thursday, May 13 @ 3:00 pm through Sunday, May 16 @ 1:00 pm
- Wednesday, June 9 @ 9:00 pm through Friday, June 11 @ 10:00 pm
- Tuesday, June 29 @ 12:00 pm through Thursday, July 1 @ 7:00 am

Biodynamic Farming Practices

- Green manures, Cover cropping, Composting, Companion planting, Integration of crops and livestock, Tillage and cultivation, Special compost preparations, Special foliar sprays, Planting by calendar, Peppering for pest control, Homeopathy, Radionics etc.,

The Biodynamic Preparations

Rudolf Steiner pointed out that a new science of cosmic influences would have to replace old, instinctive wisdom and superstition. Out of his own insight, he introduced what are known as biodynamic preparations. Naturally occurring plant and animal materials are combined in specific recipes in certain seasons of the year and then placed in compost piles. These preparations bear concentrated forces within them and are used to organize the chaotic elements within the compost piles. When the process is complete, the resulting preparations are medicines for the Earth, which draw new life forces from the cosmos. Two of the preparations are used directly in the field, one on the earth before planting, to stimulate soil life, and one on the leaves of growing plants to enhance their capacity to receive the light. Effects of the preparations have been verified scientifically. A distinguishing feature of biodynamic farming is the use of nine biodynamic preparations described by Steiner for the purpose of enhancing soil quality and stimulating plant life. They consist of mineral, plant, or animal manure extracts, usually fermented and applied in small proportions to compost, manures, the soil, or directly onto plants, after dilution and stirring procedures called dynamizations. The original biodynamic (BD) preparations are numbered 500-508. The BD 500 preparation (horn-manure) is made from cow manure (fermented in a cow horn that is buried in the soil for six months through autumn and winter) and is used as a soil spray to stimulate root growth and humus formation. The BD 501 preparation (horn-silica) is made from powdered quartz (packed inside a cow horn and buried in the soil for six months through spring and summer) and applied as a foliar spray to stimulate and regulate growth. The next six preparations, BD 502-507, are used in making compost. Finally, there is BD preparation 508, which is prepared from the silica-rich horsetail plant (*Equisetum arvense*) and used as a foliar spray to suppress fungal diseases in plants.

Biodynamics compost preparations

Preparations of Biodynamic manures	Base material
Bio dynamic No. 500	Horn manure
Bio dynamic No. 501	Horn silica
Bio dynamic No. 502	Yarrow blossoms (*Achillea millefolium*)
Bio dynamic No. 503	Chamomile flowers (*Chamomilla officinalis*)
Bio dynamic No. 504	Stinging nettle (*Urtica dioca*)
Bio dynamic No. 505	Oak bark (*Quercus robur*)
Bio dynamic No. 506	Dandelion (*Taraxacum officinale*)
Bio dynamic No. 507	Valerian (*Valeriana officinalis*)

Biodynamic Compost

Biodynamic compost is unique because it is made with BD preparations 502-507. Together, the BD preparations and BD compost may be considered the cornerstone of biodynamics. Biodynamic compost serves as a source of humus in managing soil health and biodynamic compost emanates energetic frequencies to vitalize the farm. After the compost windrow is constructed, Preparations 502-506 are strategically placed 5-7 feet apart inside the pile, in holes poked about 20 inches deep. Preparation No. 507, or liquid valerian, is applied to the outside layer of the compost windrow by spraying or hand watering.

Research achievements in biodynamic farming

Biodynamic organic spray preparations have several positive effects with increase in yield in number of crops like carrot and beetroot as proved in experiments carried out in Germany, America and Sweden. There is also increase in quality parameters like percentage of carbohydrate, protein, nitrate, soluble amino acids and vitamins (Gielen, 1973). Alela (1973) stated that several research projects carried out in Germany and Sweden have shown that the use of biodynamic organic spray increased the yield of sugar beet by 8-14 per cent, stimulating the growth of leaves by 8-26 per cent. Samaras (1977) have stated that the use of biodynamic organic preparations showed an improvement in the keeping quality of carrots. These sprays applied during the growth reduced the losses during the storage. They reduced the production of carbon-di-oxide, enzyme activity and the number of epiphytic bacteria. An experiment conducted by the Swedish Biodynamic Institute together with the University of Uppsala, showed higher relative content of protein, high vitamin C content, less darkening and better preservation of taste in potato (Peeterson, 1977).

A field experiment conducted by the Biodynamic Institute in Jarna, Sweden, over a period of forty years showed that the biodynamically treated organic plots showed improvement in the organic content and bulk density of the sub soil. And also it encouraged the activities of earthworms, which in turn aerated the soil to a deeper level. At Horticultural Research Station, Ooty research work on biodynamic farming has already been initiated in vegetable crops like potato, cabbage and carrot by using various biodynamic preparations. By biodynamic farming system, there is a reduction in cyst nematode population in potato crop (Devarajan *et al.,* 2001). In cabbage crop under biodynamic cropping system, yield was two and half times more than the conventional method of cultivation. Encouraging results have been recorded in other crops also. Further research programmes are under progress.

Preparations	Herb/material	Elements	Result	Planet
502	Yarrow Flower *Achillea millifolium*	Sulphur (S) Potassium (K)	Permits plants to attract trace elements in extremely dilute Quantities for their best nutrition.	Venus
503	Chamomile Flower *Chamomila officinalis*	Calcium (Ca) Sulphur (S)	Stabilizes Nitrogen (N) within the compost and increases soil life so as to stimulate plant growth	Mercury
504	Stinging Nettle *Urtica dioca*	Sulphur (S) Potassium (K)	Stimulates soil health, by	Mars
		Calcium (Ca) Iron (Fe)	Providing plants with the individual nutrition components needed enlivens the earth (soil).	

505	Oak Bark	Calcium (Ca)	Provides healing forces (or qualities) to combat harmful plant diseases	Moon
506	Dandelion Flower *Taraxacum officinale*	Silicon (Si) or Siliclic Acid Potassium (K)	Stimulates relation between Si and K so that the Si can attract cosmic forces to the soil.	Jupiter
507	Valerian Flower *Valeriana officinalis*	Phosphorus (P)	Stimulates component is properly used by soil	Saturn

Conclusion

Biodynamics uses scientifically sound organic farming practices that build and sustain soil productivity as well as plant and animal health. The philosophical tenets of biodynamics – especially those that emphasize energetic forces and astrological influences – are harder to grasp, yet they are part and parcel of the biodynamic experience. That mainstream agriculture does not accept the subtle energy tenets of biodynamic agriculture is a natural result of conflicting paradigms. In mainstream agriculture the focus is on physical – chemical – biological reality. Biodynamic agriculture, on the other hand, recognizes the existence of subtle energy forces in nature and promotes their expression through specialized "dynamic" practices. The fact remains that biodynamic farming is practiced on a commercial scale in many countries and is gaining wider recognition for its contributions to organic farming, food quality, community supported agriculture and qualitative tests for soils and composts. From a practical viewpoint biodynamics is proven to be productive and yield nutritious, high quality foods.

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Composting: Production and agricultural application

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The growth in MSW (municipal solid waste) generation in India has outpaced the growth in population in the recent years. The daily per capita generation of municipal solid waste in India ranges from about 100 g in small towns to 500 g in large towns. The recyclable content of waste ranges from 13% to 20% (CPCB 1994/95). The survey conducted by CPCB puts total municipal waste generation from Class I and II cities to around 18 million tonnes in 1997 (CPCB 2000b). The reason for this escalating trend is a mix of the changing lifestyles, food habits and changes in standard of living.

The TERI 'Green India 2047' study made the following observations on the situation of municipal solid waste management in the country (TERI 1998):

- increasing urbanization and changing lifestyles has led to, the solid waste generated in Indian cities having increased from 6 million tonnes in 1947 to 47.8million tonnes in 1997.
- The production and consumption of plastic increased over 70 times between 1960 and 1995.
- The collection of municipal solid waste is inefficient (more than 25% of the total is not collected at all), its transport is inadequate, and its disposal is unscientific.
- More than one-fourth of the municipal solid waste is not collected at all, and the landfills to dispose of the waste are neither well equipped nor managed efficiently.

The organic fraction of MSW (less plastic, rubber and leather) is converted into an earthy, humus-like, material by the action of bacteria and other microbes.

- Objectives:
- Convert the MSW into a biologically stable material which is reduced in volume.
- Destroy unwanted biologicals: pathogens, weeds, insect eggs.
- Retain the maximum nutrient (N, K, pH).
- To produce a valuable, soil amendment product. Not a fertilizer. Lousy C:N ratio.

Process Description:

- Howard *et al* in India in 1930.
- Three basic steps:

1. Preprocessing MSW: - Segregating degradable matter, removing engine blocks, tin cans.
   - moisture content. - fertilizer content perhaps by adding sewer sludge
2. Decomposition:- windrow - static pile - in-vessel
3. Preparation for market: - grinding- screening- blending - additives - bagging

Design and Control:

- Particle size- Seeding, mixing and turning- Oxygen requirement (aerobic process)
- Moisture content- C:N ratio

Composting Techniques:

- Agitated and Static. With agitated, the material is turned; with static, air is blown through the material.

- Windrow composting. :- Most common agitated method.- The material to be composted is shredded into 1-3" pieces and the moisture is adjusted between 50-60%.-The material is formed into triangular shapes called windrows which may be 6-7' high and 1'4-16' at the base.- The windrows are tuned twice a week to maintain aerobic decomposition and the temperature is maintained at 131°F (55°C).- Takes 3-4 weeks and cured for an additional 3-4 weeks without turning.
- Aerated Static Pile (Fig. 9-40, p. 307) (also Beltville or ARS process):- MSW is placed on top of exhaust piping in mounds 7'-8' high.- Each pile has its own blower to deliver air, oxygen.- 3-4 weeks of processing with an equal period for curing.
- In-Vessel. Inside an enclosed vessel. Proprietary.- Plug flow and dynamic systems.- Takes 1-2 weeks and 4-12 weeks of curing.

What Can Be Composted (Applications)

- Yard wastes T9-9, T9-10 and T9-11, p. 310. Ranges from minimal which may take 3 years to high level in container which can be done in several weeks.
- MSW (organic fraction). Metals or household hazardous waste can easily contaminate the compost. If a high quality product is desired, source separation is a must.
- MSW (commingled, partially processed). Not suitable as a gardener's compost; use as an intermediate cover if allowed.
- MSW (with sewer sludge). May avoid sludge dewatering. Increases the nutrient and moisture contents of the mix; may also contain heavy metals. A 2:1, MSW: sludge is recommended as a starting point.

Issues With Composting Facilities

- Odors. Usually caused by:- Low C:N ratios- Poor temperature control- Excessive moisture
  - Poor mixing- Can be controlled with various towers and facilities and odor-masking agents and enzymes.
- Pathogens. Usually destroyed by normal composting parameters of 55°C for 15-20 days
- Heavy metals. Particles are created when the waste is shredded and these particles may become attached to the lighter fractions.
- Definition of acceptable compost

The organic fraction of MSW (less plastic, rubber and leather) is converted into an earthy, humus-like, material by the action of bacteria and other microbes.

Proteins
Amino acids
Lipids
Carbos + O_2 +Nutrients+MOs → Compost + New Cells + Dead Ce
Cellulose
Lignin
Ash

$CO_2 + H_2O + NO_3 + SO_4$ +heat

The characteristics of MSW collected from any area depends on a number of factors such as food habits, cultural traditions of inhabitants, lifestyles, climate, etc. Table 6 below presents the changes in the characteristics of waste in past two decades. The changes in the relative shares of different constituents of waste in the past several decades, as shown by the data, can be attributed largely to changing lifestyles and increasing consumerism.

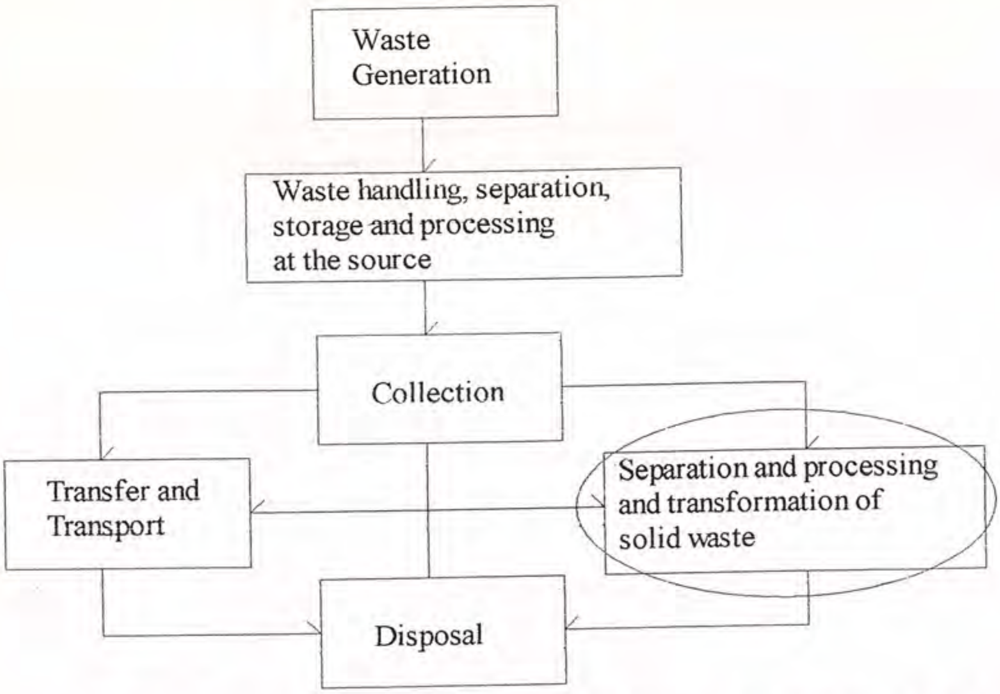
Table 1 Physico-chemical characteristics of MSW

Component	% of wet weight	
	1971-73† (40 cities)	1995‡ (23 cities)
Paper	4.14	5.78
Plastics	0.69	3.90
Metals	0.50	1.90
Glass	0.40	2.10
Rags	3.83	3.50
Ash and fine earth	49.20	40.30
Total compostable matter	41.24	41.80
Calorific value (kcal/kg)	800-1100	<1500
Carbon-nitrogen ratio	20-30	25-40

Source. † Bhide and Sundaresan 1983, ‡ EPTRI 1995

Disposal of waste is a major issue of concern in India Respective municipalities collects MSW in cities and transports it to the designated disposal sites, which is normally a low-lying area on the outskirts of a city. The choice of a disposal site is more a matter of what is available than what is suitable. Only a few cities follow good practices such as organized dumping of wastes, using mechanized equipment for leveling and compacting the wastes, and covering the top layer with earth before compacting it further. Of late, some cities have also started to practice composting the organic fraction of waste.

Management of biomedical waste is another issue of concern for municipalities. This waste produced in hospitals generally has high contamination of pathogens, making it hazardous. It also includes scalpels, needles, bandages, and other wastes from operating theatres and laboratories as well as infectious items, e.g. amputated body-parts, body fluids, cultures of contagious viruses, excreta from patients with highly contagious diseases, etc. Though waste from hospitals and nursing homes are required to be collected and treated separately, in most cities and towns such waste continues to form a part of the MSW in absence of any dedicated disposal facilities for hospital waste. The MoEF, Government of India has issued the Municipal Solid Wastes (management and handling) Rules in the year 2000, which identify the CPCB (Central Pollution Control Board) as the agency to monitor the implementation of these rules. For the management of bio-medical waste, the MoEF has notified Bio-Medical Waste (management and handling) Rules in 1998 under sections 6, 8 and 25 of the Environment (Protection) Act of 1986.



There are a variety of parameters used to access both compostable feedstocks and to classify finished compost product. These include criteria such as pH, electrical conductivity (to measure salt content), heavy metal concentrations, pathogen levels, presence of physical contaminants, toxin levels, nutrient concentrations (such as C:N ratios) and particle size. Processing methods used to produce compost will largely be determined by the nature of the feedstocks used and are ideally selected to minimize as many potential problems as possible.

The choice of preprocessing techniques such as manual or mechanical sorting, screening, separation and grinding depends upon the need to remove contaminants from feedstocks and to reduce or homogenize particle size. Complex feedstocks containing high levels of contamination require a greater degree of preprocessing before they can be composted. C:N ratios can be manipulated by mixing feedstocks of different ratios. pH may be adjusted by adding acidic materials (such as fruit residue) to alkaline feedstocks or by adding basic amendments (such as lime) to acidic feedstocks. Feedstocks containing large pieces of organic matter need to be ground before they can be processed. Collection methods of some feedstock material (especially MSW) affect their nature and composition and should be considered.

Selection of feedstocks and processing methods are also determined, in part, by the intended end-use of the compost product. For example, compost destined for use in food production must be freer from unwanted components than compost used for non-agricultural purposes such as landfill cover or the reclamation of disturbed soils. Given the wide range of compostable materials available, testing of both feedstocks and finished materials by environmental or soil laboratories is recommended on a regular basis to ensure product quality. Reference to the applicable sections of this resource guide will assist managers of composting operations in optimizing the composting process to produce a product suitable for the markets they have developed.

Where did the Composting Tradition Begin?

Most traditional societies recognized the wisdom and practical benefits of composting. References have been found pertaining to compost dating to ancient Mesopotamian, Israelite, Greek and Roman civilizations. Arab scholars and Christian monks helped keep ancient appreciation for composting alive during the Middle Ages in Europe. The Chinese have been returning their organic wastes (including human fecal material) to the soil for millennia. This fact has been used to help explain how they have been able to keep their farmlands productive for thousands of years. In more primitive societies, compost heaps may have provided the additional benefit of being the "first source of beneficial fire for mankind" given their ability to generate heat and, occasionally, fire [Biocycle, 1991].

More recently, many of the founding fathers of the United States were advocates of composting. George Washington and Thomas Jefferson were both farmers who conducted composting experiments. Washington constructed a special building at Mount Vernon, called a "stercorary", used for the collection and composting of manures. Jefferson developed the practice of mixing manures with muck (natural organic residues taken from waterlogged environments). James Madison eloquently summed up the idea of the "Law of Return" (i.e. the returning of nutrient-rich organic wastes to the soil) when he said:

> "Nothing is more certain that continual cropping without manure deprives the soil of its fertility. It is equally certain that fertility may be preserved or restored by giving to the earth animal or vegetable manure equivalent to the matter taken from it. That restoration to the earth of all that naturally grows on it prevents its impoverishment is sufficiently seen in our forests where the annual exuviae of the trees and plants replace the fertility of which they deprived the earth." [Minnich et al., 1979]

The term "manure" is used above in the widest sense, referring not only to human and animal excrement, but also to other organic materials (such as crop residues that have fertilizing capabilities).

How did Composting become an Industrial Process?

Many of the traditional examples of composting mentioned above were probably more akin to "natural decomposition" of wastes collected and randomly piled together than to modern "controlled composting". One of the first people to develop a systematic methodology for large-scale composting was Sir Albert Howard, a British scientist trained in mycology and interested in the relationship between soil health and plant disease. Sir Howard had traveled widely to study traditional farming systems and while in India between the years 1924 and 1931, developed a composting process inspired by his research. It involved the placement of organic materials (mostly crop residues and manures) in long, shallow pits or in six feet high piles [Howard, 1945]. Since the residues were turned infrequently, composting by his method was largely anaerobic. The process was later modified to an ~~an~~aerobic process. Sir Howard noticed the need to aerate (or turn) compost piles to keep their interiors from developing anaerobic conditions. He (along with others of his time) began to recognize the potential of composting for disinfecting urban wastes and transforming them into an amendment capable of replenishing soil humus.

The rapid expansion of urban areas in the early twentieth century necessitated more rapid processing of wastes. Mechanized systems were developed to aid in refuse handling and in the acceleration of the composting process (especially by pre-processing techniques such as shredding and mixing). Giovanni Beccari, of Italy, was the first to patent a mechanical process (in 1922).

The composting of municipal wastes grew most rapidly in Europe where arable land was scarcer and where several governments provided financial support for state-run operations. The first full-scale composting facility was opened in the Netherlands in 1932 . This facility employed a low-technology process using overhead cranes to arrange and turn unground wastes. Several other European composting plants were successfully operating before W.W.II, and by the 1950's composting was widely recognized in Europe as a viable solution to the growing waste problem.

The composting industry developed later in the United States. Research had been conducted as early as the 1880's [Epstein, 1998], and early twentieth century conservationists and proponents of sustainable agriculture issued solemn warnings about the perils of organic matter depletion in soils (especially after the Dust Bowl problems of the 1930's). However, composting did not receive widespread public support until much later. The growing complexity of early modern American cities made the retrieval of organic wastes difficult. Large distances between urban and agricultural areas (and the enormous size of some farms themselves) presented obstacles to both the transportation of wastes and the application of finished product. Emphasis of the agricultural industry on the chemical strength of synthetic fertilizers (and neglect of the physical and biological benefits of compost) acted as a further disincentive to the establishment of large-scale composting enterprises. Nuisance concerns and public fears of potential problems arising from the inappropriate application of compost also dissuaded authorities from encouraging composting on a large scale.

It wasn't until the 1980's that circumstances became more favorable to the growth of the compost industry as a whole. Greater environmental awareness and a desire to divert organic wastes from increasingly strained waste management systems led policy makers to encourage and support the composting alternative. Economic changes (such as increased costs involved in land filling wastes) have made composting more competitive and viable. Air pollution controls now seriously limit incineration as an option in many regions. Today, many municipalities are separating organic materials out of MSW (municipal solid wastes) in an effort to reduce their disposal costs and extend the life of their landfills.

The combined efforts of many other industry, scientific and governmental agencies and professionals have helped to improve the engineering of processing facilities and to understand the factors involved in composting such as microbial processes, pathogen control and heavy metal uptake by plants. Continued research and development will ensure the future success of composting operations.

Is Large-Scale Composting Always Practical and Profitable?

As the compost industry has expanded, so have the possibilities to profit from composting enterprises. Waste generators and municipalities are finding they can save money by decreasing their disposal costs, and they are finding ready markets for the compost they are generating. Gardeners, landscapers and farmers alike are all rediscovering the potential compost has in improving their soils, and they are willing to pay for it. As a result, compost markets are blossoming and opening up new opportunities for composters. Revenues from the sale of compost are helping operators to become more self-supporting. Even where composting is not a profit-generating venture, it is a valuable service to the community and can obviate the disposal costs involved in other waste management schemes.

Composting has yet to be fully utilized in the reclamation of all of the organic byproducts generated by modern societies. Some potential suppliers to the composting industry are not currently converting unwanted organic materials into compost. Where they are not already being composted, more efficient use can be made of a wide range of organic materials including (but not limited to) agricultural and horticultural wastes, animal carcasses, manure from livestock operations, slaughterhouse wastes, fishery and aquaculture wastes, food processing residues, viticulture pomace, papermill sludge, non-salvageable paper and cardboard, unusable fabrics, cotton gin trash, wool and leather processing residuals, municipal wastes and biosolids.

Composting is a form of recycling. Recycling is encouraged by both state and federal waste management authorities. It is second in preference only to "source reduction" in waste management hierarchies. Reclamation of wastes is usually considered more desirable than disposal of wastes (as by landfilling or incineration). Composting is now widely accepted as a viable alternative to the disposal of organic material and has become a key component in "integrated" waste management strategies.

In an effort to promote the composting of organic materials, many local governments are offering incentive programs and grants to composters and potential suppliers of organic material.

Within the composting industry, better engineered systems and an expanded industry infrastructure are helping to make composting on a large scale more economically viable. Research on the composting process over the past few decades has clarified many of the factors involved in compost production, thus improving operational efficiency. Better understanding of the nature of compost has also helped to validate the benefits and inherent safety of agricultural and horticultural applications of compost. Educational programs promoting the values of composting and a growing environmental awareness in general are both increasing public acceptance of this ancient art form. Finally, the need for quality organic amendments by a diverse group of potential compost users is helping to ensure a market for the compost produced. Compost is of proven value on farms, in nurseries, in landscaping and forestry operations, to golf and turf managers, in parks and public grounds operated by municipalities and to homeowners. Compost not suitable for some growing scenarios may still be of use in erosion control, bioremediation, and land reclamation and even as an alternate daily cover (ADC) in landfill operations.

Increased governmental promotion, industry support, scientific validation, economic viability, public acceptance and demonstrated need in sustainable soil management all bode well for the future of the composting industry. Nevertheless, there are many concerns which potential composters must take into consideration before starting an operation. Plans to initiate a composting enterprise must be well thought out in advance and include overall goals, financing methods, design criteria, siting requirements, management techniques, availability of feedstocks and market potentials. Large scale composting is a business and requires time and money. Equipment, labor and management needs must be addressed before any composting operation can become successful. Local and regional considerations (such as proximity to residential or business districts and weather patterns) can affect the placement and management of a composting facility and must be accounted for. Before a product is generated, strategies must be in place for its marketing and distribution. Potential sources of competition should be analyzed (especially in areas where disposal alternatives for organic materials are relatively inexpensive). A composter must also be able to handle public concerns, which can arise in spite of growing acceptance for the composting industry as a whole. Nuisance and environmental concerns such as odor, noise, dust, vectors, runoff, litter and visual aesthetics need to be dealt with effectively, particularly when a composting facility is located near where people live and/or work.

In composting ventures, as in any business, special concerns unique to the individual enterprise will arise and require appropriate handling. With wise planning and good management practices, many potential obstacles to a successful operation can be avoided. This resource guide is intended to provide potential and existing composters with the tools needed to maintain a profitable, efficient and safe operation in this vital and growing industry

WHAT IS COMPOSTING?

Composting is a biological conversion of heterogenous organic substrate, under controlled conditions, into a hygienic, humus rich, relatively biostable product that conditions soils and nourishes plants.

METHODS OF COMPOSTING

The Indore Method

The Indore method was developed by Howard and Wad (1931) at Indore. This method requires a heap of trapezoidalcross section. The heap is about 4 m to 5 m in length, I am in breadth and I am in height. The heap is alternatively layered with carbonaceous and nitrogenous wastes, starting with 20 cm of carbon rich and 10 cm of nitrogen rich material. Finally it is covered with soil or hay as thermal insulator. Under these conditions, the rate of decomposition is very rapid and high temperatures develop quickly. The process is accelerated by periodically turning the materials. In this method, losses of organic matter and nitrogen are very high, amounting to 50 to 60 per cent of the initial levels.

The Bangalore Method

Acharya (1939) developed the Bangalore Method to produce compost from city refuse and night soil in pits. Pits of about I am depth, breadth and length are used. In this process, at first the refuse is dumped into the trench and spread out with rakes to make a layer of 15 cm. Night soil is then discharged and spread over the refuse in a layer of about 5 cm. This is then covered with 15 cm layer of refuse. The night soil and the refuse thus follow in alternate layers until the pit is filled to 15cm above ground level, with a final layer of refuse on the top. This may be dome-shaped and covered with a thin layer of soil. The decomposition of dumped materials in the pit takes place large in the absence of air except in the surface layer. This anaerobic decomposition is comparatively slow but markedly less wasteful.

High temperature compost

High temperature compost is prepared from night soil, urine, sewage and animal dung and chopped plant residues at a ratio of 1:4. The materials are heaped in alternate layers starting with chopped plants stalks and followed by human and animal wastes. Water is added to optimum amount.

At the time of making the heap, a number of bamboo poles are inserted for aeration purposes. After the heap formation, it is sealed with 3 cm of mud plaster. The bamboo poles are withdrawn after one day of composting, leaving the holes for aeration of the heap. Within four to five days, the temperature rises to 60 to 70 C and the holes are then sealed. The first sealing is usually done after 2 weeks and the moisture is made up with water or animal or human excreta; the turned heap is again sealed with mud. The compost is ready for use within two months and is considered free from pathogens.

The Windrow Composting

The windrow composting is a traditional and widely practiced method of composting in USA (Kychenrither et al., 1984). In this process, the waste materials are piled in long rows of 2 to 4 m width and 1 to 2 m height on a hard surface and usually in the open area. Aeration of the windrow is by periodic turning using equipment such as front-end loader or by specially designed machinery. Occasionally forced aeration in conjunction with turning has been applied to the windrow process.

The Static pile Composting

In static pile method of composting a mixture of solid wastes is stockpiled in the open air and turned occasionally for aeration. This technology is considered to waste both ammonia and energy. But these disadvantages have been substantially mitigated by mechanical forcing of air through perforated pipes at the bottom of the static pile by (a). Continuous air suction, or (b) continuous air blowing or (c) alternate air blowing or (d).alternate blowing and sucking or (e) intermittent air blowing to keep the temperature below 60 c. There are two kinds of static pile composting system. One, the Beltsville process in which piles are aerated by time controlled system (Willson et al., 1980). Another, the Rutgers process, involves blowing air through the compost mass in response to a thermistor and fan both controlled by a microcomputer to maintain temperatures below 60 C (Finstein et al., 1980). In the enclosed mechanical composting system, the process takes place in a vessel or bio-reactor. Advantages of these systems are that external environmental factors do not affect the process, less land is required and that better odour and operational control are possible. Disadvantages are that these systems require high equipment, maintenance and energy costs.

Synthetic compost

In the preparation of synthetic compost, the organic nitrogen in the form of dung required by microorganisms can be completely substituted with inorganic nitrogen compounds like ammonium sulphate or urea which are utilised equally effectively for decomposition of carbonaceous materials into compost. This facilitates utilisation of large quantities of various organic waste materials where supplies of dung are limited or not available at all as in mechanised farms. The manure becomes ready for application in about 4 to 6 months (Gaur and Sadasivam.1993).

Accelerated Composting and enrichment

The conventional method of composting takes a logn time to produce quality compost. In order to hasten the process and to improve the quality of the end product, the material to be composted is inoculated with microbes such as celluloytic, ligninolytic, and nitrogen fixing and phosphate solubilising organisms. Addition of sources of nitrogen and phosphorus may also be desirable when the materials to be composted lack much of these elements. The best additive for a compost mix is to add mature compost that will produce a suitable starting population throughout the composting mass and furnish bioavailable minor elements essential to life.

There is a great deal of information on a few key areas of UA in India, particularly composting, which consists of aerobic composting and vermicomposting (i.e. using worms) and the cultivation of the worms themselves (vermiculture), horticulture and aquaculture. Calcutta is known internationally for urban and peri-urban waste fed aquaculture in the extensive wetland areas near the city. These areas are under threat of redevelopment which, depending on the outcome, may have serious repercussions for food-security, livelihoods, waste management and environmental quality in the Primate City of West Bengal. Since the advances in dairying in peri-urban areas have made international headlines over the past several years and are therefore quite well documented, this report simply highlights some of the main case studies and literature related to that topic.

The development and implementation of both types of composting is well documented in India, and the use of composting has attracted a great deal of attention from those outside the South Asian region. Reliance on composting is perhaps a case of necessity being the mother of invention. Indian cities, particularly megacities, are fraught with the challenge of dealing with increasing reams of garbage. Kitchen waste, as well as organic waste from industry (food service, hotels, and slaughterhouses) is being composted in schemes of various scales throughout the country though there is certainly potential to further the practice, given India's vast amounts of organic waste[1]. The nutrient rich compost is then used to grow fruits and vegetables – much of it being sold to farmers in rural areas and peri-urban areas. It is unknown to what extent compost is being purchased by urban householders for their own gardens, but it is clear that many city farmers, such as Dr. R.T. Doshi, are producing compost for their own use. Composting can therefore potentially be a significant

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attracted to worms in urban composting schemes (Furedy 2000). This report only amalgamates secondary sources of information and does not evaluate the information and schemes discusssed.

lvelihood activity for urbanites. Currently, all types of composting appear to be well developed in *rural* India (Furedy 2000)[2].

Examples from Mumbai, Pune and Bangalore are the most prominent places for various types of composting activities. A special issue of the *Worm Digest* published in Oregon, details many vermicomposting initiatives in a short, accessible and easy to read format.

Government Agencies

There is one arm of government that needs to be profiled here. The very existence of the Karnataka Compost Development Corporation is a testimony to the importance of vermiculture within the state. The KCDC manufactures compost from city waste. They supply compost in the city for kitchen gardens through a mobile unit and they also have dealers in the city and other nurseries that sell their compost.

In a recent publication by Inge Lardinois and Rogier Marchand (in Bidlingmaier *et.al.*1999) it was found that KCDC's plant on the outskirts of Bangalore was producing 27 tonnes of compost per day. Despite this remarkable figure, the KCDC's output only accounts for 1.5% of organic waste composted in and around Bangalore.

Civil Society Organisations

There are a number of prominent civil society organisations that have advanced the cause of promoting worm composting in urban areas. In Mumbai the work of Prakruti and the Institute for Natural and Organic Agriculture has drawn widespread attention, as have the relentless efforts of Shantu Shenai of the Green Cross Society and SOS (Save Our Selves).

In Bangalore, the work of Waste Wise, led by Anselm Rosario and Agriculture Man Ecology (in consort with ETC Netherlands) are examples of civil society organisations active in waste management in general and composting in particular. Swabhimana and Civic are other prominent examples of community-based organisations working to promote urban sustainability through effective waste-management.

Exnora (an acronym of EXcellent, NOvel and RAdical Ideas) was founded in 1989. The organisation has been extensively involved in promoting effective solid waste management at the community level. All their schemes revolve around extensive public participation in community-ownership. There are now more than 3000 community-based Exnora "chapters", known as Civic Exnoras, which promote integrated SWM involving rag pickers (scavengers), separation at source and extensive composting of organic waste.

According to Exnora:

> The households in this street have formed a Civic Exnora. Every house segregates their waste at source. The Civic Exnoras has distributed a green colour basket to every household, into which the residents store organic wastes. The street beautifier collects these wastes in one compartment of his tricycle, and the other inorganic recyclable waste in another. The organic wastes are converted to manure through aerobic composting, which is used in their own gardens. The street beautifier separates inorganic waste, sells it to waste buyers and earns an additional income. A small quantity of waste that cannot be recovered is transported to secondary collection points for collection by the Municipal authorities.

Exnora is also involved in a program in Cochin (Kotchi) the largest city in the State of Kerala. This SWM program is a joint project of the Corporation of Cochin, Greater Cochin Development Authority (GCDA), Institutions of Engineers, Rotary and Exnora with the support of

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[2] Dr. Furedy suggests contacting Dr. Satyawati Sharma (satyawatis@hotmail.com) in New Delhi who specialises in rural vermicomposting research.

Indian Express and Mathru Bhumi. The scheme involves separation at source (i.e. the household level), the development of a municipal composting facility resulting in the construction of a three-chambered compost shed depicted in

The composting process in the shed takes about 20 days[3] and involves "inoculation of organic waste by a bacterium called 'garbactum' by spraying, or by mixing with bio-dung. The process does not generate foul orders and the resulting soil conditioner is given to local farmers, gardeners and other agriculturists.

With respect to all of the civil society initiatives described above, there is a need for further research to quantify how much are they producing, how much waste are they processing, their selling price, and who the buyers of the compost are. Also, the effectiveness of the above schemes needs to be fully evaluated.[4]

In composting ventures, as in any business, special concerns unique to the individual enterprise will arise and require appropriate handling. With wise planning and good management practices, many potential obstacles to a successful operation can be avoided. This resource guide is intended to provide potential and existing composters with the tools needed to maintain a profitable, efficient and safe operation in this vital and growing industry. There are several approaches for the testing of compost quality of which few are more important.

Qualitative tests for composts

i. Humificatotion
ii. Respirometer
iii. Spectroscopic and
iv. Plant growth tests

Humification parameters

It is based on the fact that during composting low molecular components are converted into heavy molecular humus like product. Hence, increase in humic substances is associated with stabilisation of organic matter. The following parameters are applied to evaluate the humification of organic matter in compost.

Humic acid per cent	Cha / Cex X100

[3] An unusally short period given that most composting activity usually takes a minimum of six weeks according to Christine Furedy.
[4] I would like to thank Dr. Christine Furedy for making this very important remark.

Where C ha	Carbon content in humic acid fraction
C cx	Carbon content in alkali cxtract
Humificaion index (HI) (Sequi et al., 1986)	
HI	NH/HA + FA
Where NH – organic carbon content in the non humified fraction	
HA and FA	Organic carbon content in the humified (Humic acid and fulvic acid) fractions
Degree of humification (DA) (Ciavatta, Vittori Antisari and Sequi, 1988; Ciavatta et al., 1990)	
DH %	HA + FA / TEC X 100
Where TEC – organic carboncontent in the alkali extract	
Humification ratio	Cex / C o X 100
Where C ex	Carbon content in alkali extract
C o	Oxidizable carbon content
Humification rate (HR) (Ciavatta et al., 1988; 1990)	
HR %	HA + FA / TOC X 100
Where TOC	Total organic carbon content in the solids
Polymerization ratio	Carbon in fulvic acid
	Carbon in humic acid

Respirometery

Changes in compost stability or degree to which composts have been decomposed can be predicted with oxygen respirometry (Iannotti et al. 1993). In this method, maturity is predicted based on the rate of oxygen uptake per kg of volatile solids per hour. The oxygen uptake rate is determined with dissolved oxygen respirometery.

$$\text{Mean oxygen uptake} = \frac{-C\ VS\ 60\ D}{K\ Wt\ VS}$$

Where C – Oxygen content by volume in the air, usually 0.2%

V – Volume of air in the flask (ml0

S – Slope of relative oxygen uptake rate (% saturation / min)

D – The density of the oxygen (g/lit) at experimental conditions is converted from STP.

60 – Factor change from minutes to hours.

K – Compost dry matter weight in flask (g)

VS – The fraction of volatile solids (from 0 to 1)

Iannotti et al. (1994) used this respiration bioassay to determine the stability of municipal solid waste composts. The oxygen uptake rate has been found to decrease with age of the composts indicating the depletion of biodegradable organic material which is essential for microbial growth.

Spectroscopic Analysis

Compost maturity discussed above is related to the degree to which fresh organic matter has been transformed into a stable end product. Recently, tests have been developed to determine the amount of stable organic end products which are lignin and humic substances. These procedures do not distinguish residual biodegradable carbon from that resistant to biological decomposition. Hence, it is essential to analyse the bulk organic matter. The quantitative procedures developed to study the bulk organic matter are solid state Cross Polarization Magic Angle Spinning 13 C0Nuclear Magnetic Resonance (CPMAS 13 C – NMR) and Infra Red (IR) spectroscopy (Inbar, Chen and Hadar, 1990 b). A 13CNMR spectrum can provide carbon "finger prints" of various solid samples such as peats, whole soils and humic substances etc. IR spectroscopy indicates the transformation of organic matter during composting. Therefore, with these specptroscopic procedures, it is possible to develop direct correlations between maturity and

i) The rate of decomposition of biodegradable components during the composting process
ii) The potential for regrowth in compost of pathogens'
iii) Biocontrol of plant diseases and
iv) Plant growth response (Inbar et al.1990b).
v) Heavy metals and complexes

Unfortunately, these studies require sophisticated and expensive equipment.

Plant growth response test

Blanco and Almendros (1995) assessed the factors potentially connected with the positive or depressive effect of composts in soil by involving mineral fertilisation and successive harvesting of rye grass. Based on the results obtained, they have concluded that the most classical maturity indices (germination index, water soluble organic fraction, spectroscopic analysis of water extracts) applied to straw composts have limited diagnostic value as regards forecasting plant yield. These parameters may have applicability in differentiating raw materials from those subjected to composting, but they do not correlate with the crop yield when different composts are simultaneously evaluated.

Compost

Physical

1 Particle six *
2 Colour*
3 Moisture *
4 Porosity
5 Bulk density
6 Water holding capacity
7 Temperature
8 Total solids
9 Volatile solids
10 Total ash content

Chemical

1 pH * ■
2 EC * ■
3 C/N ratio * ■
4 Nitrogen test *
5 Sulphur test *
6 Starch – Iodine test *
7 Heavy metals
8 Pesticide residues
9 Plant nutrient content * ■
10 Cellulose
11 Lignin
12 Protein

Biological

1 Microbes *
2 Annelids
3 Worms
4 Collembola
5 Aerobes
6 Anaerobes
7 Thermophiles
8 Pathogenic microbes ■
9 Verticillium test *
10 Amoena
11 Plant growth response test *

13 CEC * ■
14 Humification index
15 Organic acids content
16 Solid state C 13 NMR Spectroscopy □
17 Infra Red Spectroscopy □
18 Analyses of water extract □

Regular tests * Quality control tests ■ Quick screening □

Methods to evaluate maturity of compost

- Mature compost should have a tea brown colour, no noxious smell and a good stability which would no longer produce high temperatures.
- The maximum diameter should not exceed 10 mm, with 5 mm as the optimum and the water holding capacity should be below 30 per cent.
- The most common pH values range between 6.5 and 8.0. Compatibility with plant growth is within the range of 5.5 to 8.0. If pH values are higher or lower than the above mentioned range, the reason for that should be specified.
- Total salinity should not exceed 2 g salt / 1 (expressed as NaCl) and the concentration of sodium and chloride ions should be specified in mature composts.
- Irrespective of the sources of composting mass, C/N ratio of the mature compost should be less than 20 and cation exchange capacity should be more than 70 meq/100 g of ash free material.
- Absence of transitory or permanent bio inhibiting factors such as ammonium, water soluble aliphatic acids, amino acids, proteins and polysaccharides in the water extract of compost indicates the maturity of compost.
- Decomposition of the organic matter involves both mineralisation and humification. Hence, formation of water insoluble humus is a characteristic of complete decomposition of organic matter. Atleast 10 per cent of the total organic carbon present in the original material should be humified at the end of the composting.
- A good quality compost should contain minimum levels of toxic components and non-biodegradable materials.
- Composting process should give complete inactivation of *Salmonella sp* in infected eggs of parasites (Ascaris as indicator organism), a reduction of four logs of paravirus and fecal Streptococci (indicator microorganism for bacteria) and five logs of Enterobacteria.

A marketed compost should posses the following specifications on the label.

- Origin
- Composition
- Moisture content
- pH
- Electrical conductivity
- C/N ratio
- Cation exchange capacity
- Organic matter content
- Mineral nutrients content
- Heavy metals concentration, and
- Inert materials.
-

Compost (final produce) exceeding the concentration limits stated as below, shall not be used for food crops. However it may be utilised for purposes other than growing food crops. Ministry of Environment & Forests – Municipal Solid Waste Waste (Management & Handling) Rules under the Environment Protection Act of 1986 has made it mandatory for all municipalities to set up waste process and disposal facilities by 01.12.2003, and has also laid down standards for composition and concentration limits of MSW compost, which can be used for food crops.

Ministry of Environment & Forests vide gazette notification S.O.908 (E) dated 03.10.2000 has set guidelines and maximum permissible limits of heavy metals and impurities as per following table, which need to be followed for selling urban compost for production of food

Concentration not to exceed:

Parameter	
	(mg./kg dry basis, except p^H value and C/N ratio)
Arsenic	10.00
Cadmium	5.00
Chromium	50.00
Copper	300.00
Lead	100.00
Mercury	0.15
Nickel	50.00
Zinc	1000.00
C/N ratio	20/40
p^H	5.5-8.5

Soil nutrients – relevance to Indian agriculture

The present demand of 200Mt of Food Grain production will rise to 300M.T. by 2020. 57% of Indian soils are degraded with different types and degrees of problems. Soil erosion is the biggest hazard, covering 50% of the soils, followed by water logging (3.5%) and salinisation (3.1%). The degradation is more pronounced in the fields of small and marginal farmers, representing 78% of the farming community.

Recognition is necessary that what is taken out from the soil as nutrients in food, has to go back from the waste into the soil, instead of being dumped into rivers and land fills uselessly. This means that the **cities will feed the rural farms with nutrient inputs**. This will also be less energy intensive than chemical fertilisers, toxic pesticides being applied currently. This calls for **integration with our agricultural practices, where we should use more and more of organic manures,** instead of chemical fertilisers.

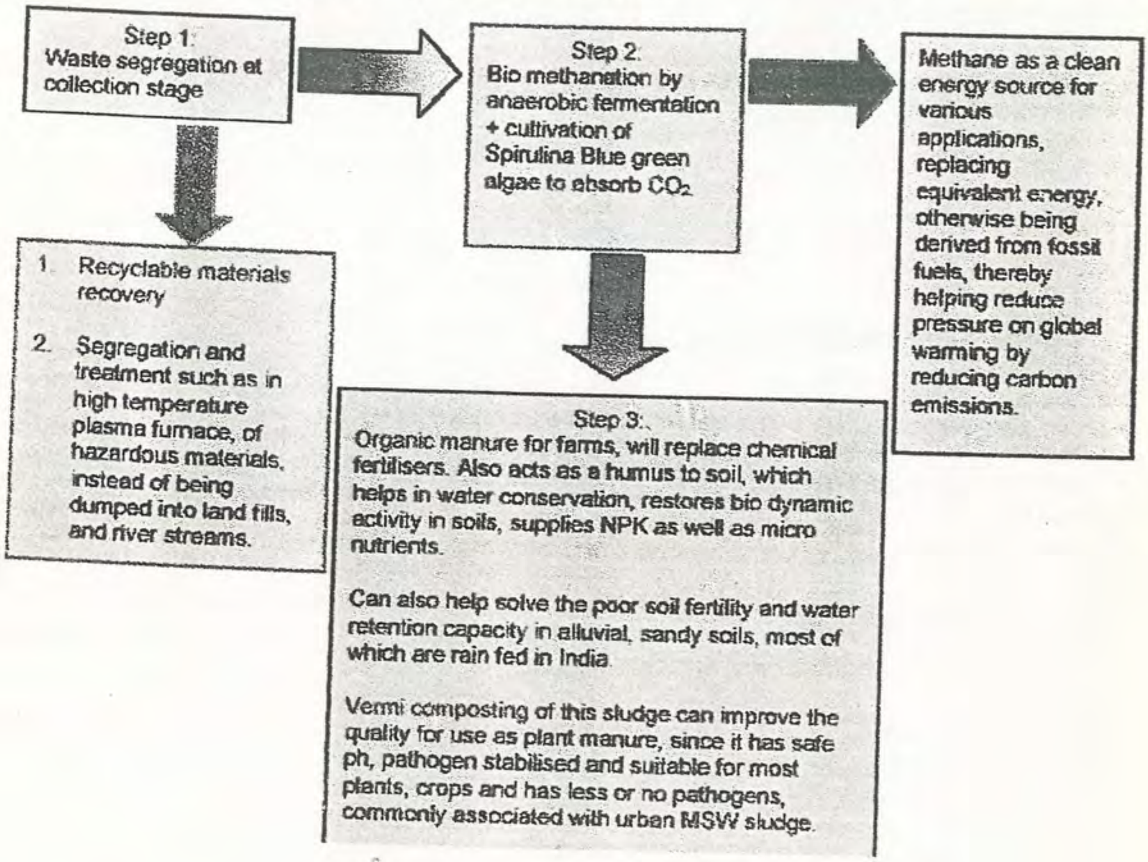
It is now being widely recognised by scientists that practices of applying chemical fertilisers, pesticides are not sustainable in the long run. The soil requires biodynamic activity with teeming life forms, which are continuously active and keep the soil naturally fertile and make available the necessary nutrients to crops. Application of NPK fertilisers kills this activity and introduces a non-sustainable cycle. In the long run scientists have found that increasing doses of fertilisers are required. Most of it washes away into rivers, groundwater, thereby polluting them and causing irreparable damage to the environment. Such costs are not estimated in monetary terms, but are externalised with short term view points.

Currently chemical fertilisers play no doubt an important role in ensuring India's food security. However they come at a price both to the exchequer and the ecology. Subsidies for fertilisers are more than Rupee 17,000 crores, at present in India. The developed world also subsidises its agriculture to the tune of more than U.S.$ 360 billion per annum! Instead of playing follow the (rich) leader, India can take the lead for managing the transition to an organic agriculture. It has already shown its mettle at the Cancun WTO Ministerial meet.

While planning for the recycling of MSW care should be taken to avoid the incorporation of biosolids derived from heavymetal contamination. Europe and USA have experienced the difficulty and they restrict the use only in forest land or in silviculture. Use of sewage sluge in composting of MSWshould be discouraged for this specific reason.

Summary and schematic view of the suggested approach

A holistic approach to energy, environment and agriculture can solve many problems at one stroke! Following sequence of proven technologies can be put to productive use:



MSW after segregation by the local community along with the recovery of a valuable resource in the form of

compost. The non-biodegradable materials in the unsegregated wastes which do not decompose are .nally separated mechanically and from them are retrieved some recyclable components. The balance residue in the form of inert materials is safely disposed in an adjacent land-.ll site (Scheu and Coad, 1997). The technology was developed by Ms. Excel Industries, Bombay, India. The Bombay Municipal Corporation (BMC) is participating in the project by providing a part ofa umpyard on lease and required delivery ofgarbage onto this waste dump site. The BMC takes 25 percent royalty on the sale ofthe compost which is marketed in the trade

Typical municipal solid waste (MSW) components
from Indian cities (Source: Sinha and Sinha, 2000)

Waste components	Percentage
Vegetable, fruit and animal matter	27_0
Dry grass and leaves	5_6
Paper and paper products	10_9
Plastic materials	5_4
Leather, foam and human hair	3_7
Cotton, jute and burlap	6_1
Rubber including cycle and auto tyres	2_9
Metals (tins, iron and aluminum)	2_0
Concrete, pebbles, earth, sands and dust	25_0
Ash and coal	9_0
Wood	0_4
Glass and ceramics	2_0
Total	100_0

Properties of CELRICH compost (Source: NEERI, 1994)

Physical properties

Dark brown in color and a humus-like material Free from smell, live weed seeds and extraneous matter Has high moisture holding capacity (170 percent)

Biological properties Total bacteria count 10^{10}	
Actinomycetes/gm	10^4
Fungi/gm	10^6
Azotobacter/gm	10^6
Root nodule bacteria (*Rhizobium*)	
Phosphate solubilizers	10^6
Nitrobacter/gm	10^2
Chemical properties	
pH	7–8.2
Organic carbon	16.0
percent Nitrogen	1.50–
percent Available phosphorus	1.25
percent Potassium	1.05–1.20
percent Calcium	1–2
percent Magnesium	0.7
percent Sulphates	0.5
percent Iron	0.6
percent Zinc	300–700 ppm
Manganese	250–740 ppm
Copper	200–375 ppm

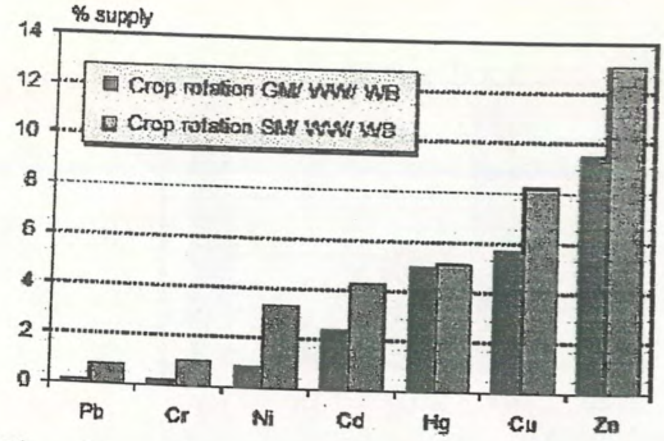


Figure 1 Relation between uptake of heavy metals by harvest products and supply of heavy metals by composts
Compost application rate 6 - 10 t DM/ha and year. Crop rotation: SM - Silo-Maize, GM - Grain-Maize, WW - Winter-Wheat, WB - Winter-Barley

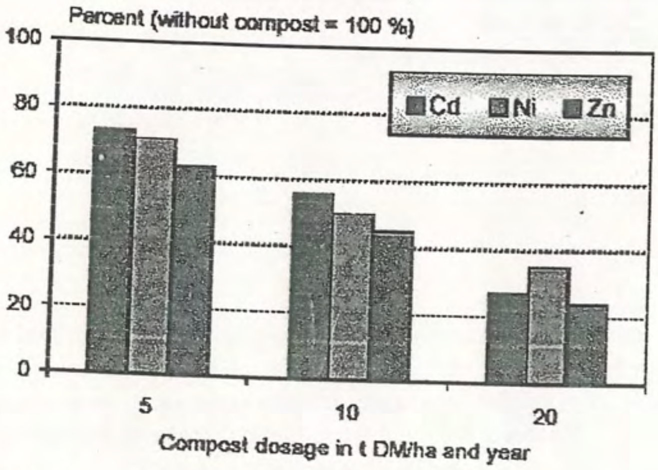
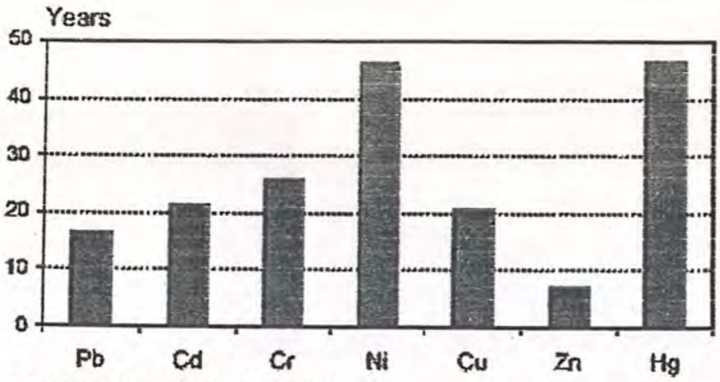


Figure 2 Mobile heavy metal contents of soils in relation to compost dosage (relative terms: control without compost = 100 %)
Soil extraction with 1 M NH_4NO_3



Heavy metal soil contents in mg/kg

Mean	30	0,20	30	30	20	50	0,20
Increase	1,5	0,02	1,5	1,5	2,0	2,5	0,02

Figure 3 **Period of time for measurable increase of heavy metal soil contents**
Based on:
a) Mean heavy metal freights of compost dosage of 6 – 7 t DM/ha and year
b) Mean - heavy metal contents of soils
c) Increase - smallest analytically measurable increase of heavy metal content

Soil-Plant Interactions

Trace elements in compost form various compounds or associations when applied to soil, which can affect their uptake b plants and their mobility through soils. They can be complexed by organic compounds, co-precipitated in meal oxides, in a water soluble state, or in an exchangeable form on soil or organic matter colloids. Measuring the total trace element content does not predict the soil-plant interactions.

Several investigators have attempted to fractionate trace elements in compost in order to identify in what form the element exists. This knowledge could possibly predict their potential uptake and bioavailability as well as mobility through soils. The more common extraction procedures are the water soluble, $KNO_3$for exchangeable, $Na_2P_2O_7$for organic matter bound, EDTA for carbonate and sulfide precipitates, and HNO_3 for residual form of the trace element.

In compost the water-soluble fraction that is readily available to plants is small. Leita and De Nobili (1991) observed that during the early stages of composting, the water-soluble fraction of Cd initially increased; however, towards the later stages of composting the water-extractable Cd fraction decreased to non-detectable levels.

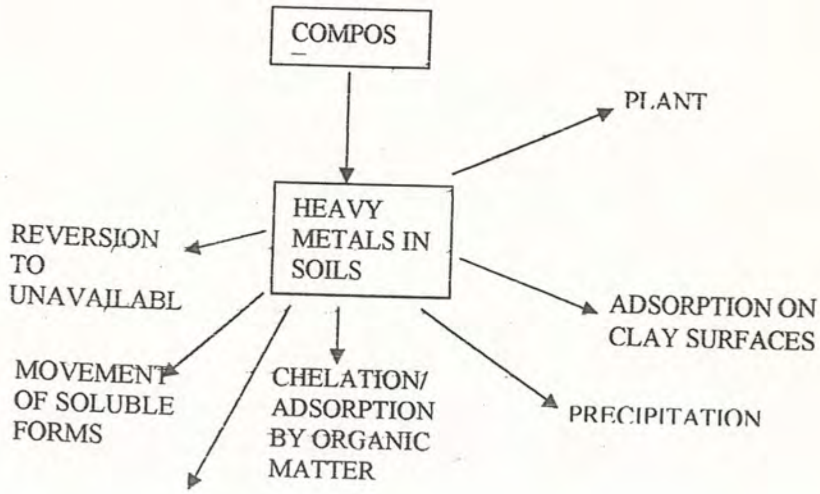
Canarutto et al. (1991) indicated that the concentrations of extractable heavy metal are lower at the end of the composting period is the process is carried our properly. Humic and fulvic acids have strong affinities to divalent cations with reactions being strongly pH dependant (Schnitzer and Skinner, 1966). Humic substances are some of the most powerful metal-binding agents among organic substances (Buffle, 1988).

Understanding the sol-plant relationship is extremely important in managing our soils so as to reduce uptake of trace elements or their movement to water resources. One of the most important aspects of beneficial use of compost an other organic materials is the ability to mange and control their application in order to reduce or eliminate potential harmful effects. The use of organic residues in themselves reduces potential uptake by the plants of heavy metals. Other factors such as pH and phosphorus also influence plant uptake. Management involves such aspects as crop selection to reduce potential uptake and accumulation of trace elements, soil pH control and organic matter maintenance.

When compost is applied to soil, there are many potential pathways for the trace elements: uptake by plants, movement with water to ground or surface water sources, volatilization from surface-applied compost, and immobilization in the soil matrix. Immobilization refers to exchange on the soil colloidal system and fixation in forms unavailable to plants. Figure below shows these potential pathways.

The particular pathway depends on the soil-plant-water relationships of the trace element in question as well as on the amount of the trace element, and interactions among soil-plant-water factors. Trace elements applied to soil may pass through the soil unchanged, react with organic and inorganic compounds to form soluble or insoluble compounds, be adsorbed on the soil colloids, and volatilize from the soil or taken up by the plants (Epstein and Chaney, 1978). Various factors

Major pathways of heavy metals in compost applied to soil



influence the potential pathways. These include:

- type if trace element and chemical state
- soil acidity
- organic matter
- cation exchange capacity
- reversion to unavailable forms

Conclusion

Based on the waste generated from urban population can be segregated and bioprocessed for energy and nutrient recovery. If the segregation is practically executed for the purpose and accelerated composting is practices with proper microbial inoculants, the derived product is free from any heavy metal or toxic material. However, admixture of sewage sludge or any other sludge biosolid results in enhanced heavy metal concentration in compost. Compost derived from such admixtures should be tested for quality and plant reaction. Otherwise most of the plants will mobilize heavy metal through the rhizosphere activity resulting in increased bioavailability and accumulation in plant parts. Judicial activism and environmental controls directing for MSW composting should be taken in the positive side to provide quality compost to plant nutrients and to support organic agriculture. Any deviation will result in dilution of pollutants in the ecosystem with an ultimate reaction for a biomagnifications.

Further reading

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PEST MANAGEMENT – BIOAGENTS – PARASITES PORADATORS AND HOST PLANT RESISTANCE

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Cotton is an important commercial crop of India cultivated in an area of 8.5 million hectares with a production of 15.6 million bales. India ranks first in area and fourth in total production. The productivity of cotton in India (310 kg / ha) is about half of world's average. The main reason for low productivity is pest and diseases attack in addition to 70% of area under rain grow condition. The loss due to pest and disease is estimated is 50-60% with a monetary loss of RS. 31,050 million. The share of different species of cotton in India is as follows hybrids 40%, hirsutum 32%, arboreum 17% barbadense very negligible area. The hybrids and hirstum are pest susceptible as compared to desicotton *arboreum* and *herbaceum*. About 200 species of insect are mite pests and pathogens are affecting cotton in our country of which 30 are most important.

Use of agrochemicals such as pesticide and fertilizers have increased tremendously in the conventional production systems and cotton has emerged as the major consumer of agrochemicals in the world. Though, cotton is grown in about 5% of the area in India it is estimated that 55% of total pesticide are sprayed on cotton crop. Since large quantity of agrochemicals are used in cotton cultivation. There has been a thinking on the methodology on the cotton production and processing. In recent years, there has been a growing concern on the damage caused to man kind, domestic animals and the pollution to soil and water by indiscriminate use of agrochemicals. To attain the twin objective of reducing cost of production and minimizing pollution hazards efforts have sprung up world over to grow cotton organically and sell at premium price.

'Organic cotton' is cotton grown without synthetic inorganic fertilizers, insecticides, fungicides, growth regulators and duly certified by a recognized certifying organization.

Role of bioagents in the management of cotton pests

Several natural enemies play important role in reducing the pest. Though several hundreds of natural enemies have been documented in association with cotton pests under different agro-ecosystem, the following are common in cotton.

A. PREDATORS

Coccinellids beetles (Ladybird beetles)

1. *Coccinella septumpunctata*
2. *Menochilus sexmaculata*
3. *Coccinella* p
4. *Scymnus* sp
5. *Virania* sp.

   Chrysopa

6. *Chrysoperla carnea*
7. *Chrysopa* sp.
8. Assassin bugs

   Coranus spincutis

9. Rober flies

   Allocolosa sp

10. Dragon flies
11. Syrphids – *Syrphus* sp.
12. *Paedurus* sp.
13. *Deraaecoris indianus*

Non insect predators

1. Spiders
2. *Amblyseius* sp.
3. Birds, Drongo, mynaha etc.

B. PARASITORS

1.	*Rogas aligarhensis*	Earias sp
2.	*Agathis* sp	- Do -
3.	*Isotira* sp.	- Do -
4.	*Brachymeria nosatoi*	- Do -
5.	*Trichogramma chilonis*	On Boll worm eggs
6.	*Trichogramma* sp.	-Do-
7.	*Telenomus* sp.	
8.	*Campoletes chloridae*	On *Helicovera armigera*
9.	*Charaps aditya*	On *Helicovera armigera*
10.	*Carcelia illota*	On *Helicovera armigera*
11.	*Bracon greeni*	Pink bollworm
12.	*Bracon* sp.	
13.	*Microchelonus blackburni*	PBW
14.	*Apantelus angalete*	PBW
15.	*Camptothlipsis flavidus*	PBW
16.	*Eriborus* sp.	PBW
17.	*Eretmocerus mundus*	Whitefly
18.	*Encarsia* sp.	Whitefly
19.	*Aphelinus* sp.	Aphids

C. PATHOGENS

1.	NPV on *H. armigera*	Ha NPV
2.	NPV on *Spodopterc litura*	NPV
3.	*Nomuraea rileyi*	On caterpillars
4.	*Beauveria bassiana*	- Do -
5.	*Metarhizium ainsopliae*	On Boll worm eggs
6.	*Entomophora* sp.	On Aphids
7.	*Verticillium*	On whitefly
8.	*Aspergillus*	- Do -
9.	*Bacillus thuringiensis*	On Caterpillars
10.	*Hexamermis* (Nematode)	On Caterpillars

HOST PLANT RESISTANCE

The host plant acceptance by an insect and its growth and development is strongly influenced by the biophysical characters as well as the chemical profile of the cotton plant. Among the biophysical characters of the plant, the colour, variation in foliage size shape and the presence or absence of nectare secreting glands, leaf pubescences, tissue toughness may regulate host acceptance and its utilization by an insect. The phytochemicals which influence the abundance and activity of an insects are the essential nutrients such as sugars and aminoacids and other growth factors in proper balance and the toxic principles such as gossypol or tannins which offer antibiosis nature of resistance to host plant.

Management of bollworms using parasitoids

The cotton bollworms, *Helicoverpa armigera, Earias* sp. and pink bollworm, *Pectinophora gossypiella* are the most destructive pest of cotton. About 30-40% of insecticide used in India alone are targeted against these bollworms. This injudicious are indiscriminate use has resulted in the development of resistance to most of the chemicals.

It has been reported that release of the egg parasitoid *Trichgramme chilonis* at the rate of 2.5 lakh per hectare reduces the boll worm attack successfully.

Similarly release of *Chrysoperla* at the rate of 1-2 / plant also observed to be beneficial it not only reduces soft body insects like aphids and jassids but also prey on larvae of *H. armigera.*

NPVs against *H. armigera*: Among the several alternative methods of pest management tried for organic cotton production entomopathogen like nuclear polyhedrosis virus is most promising and its efficacy has been tested against this pest on a number of crops particularly on cotton. The virus at the rate of 400 LE / ha sprayed four times in the evening hours at an interval of 5-10 days, when the pest was in the early stages controlled the post effectively. Addition of various adjuvants like crude sugar 0.5%, cotton seed kernel powder 1% groundnut oil cake 3% acted as phago-stimulants increased the efficacy the NPV. Similarly spraying of *Spodoptera litira* NPV successfully controlled the pest when the NPV was sprayed at the rate of 250 LE / ha effectively checked the pest.

Host plant resistance

Leaf Hopper

The nymphs and adults remain on the under surface of leaf as a suck the sap. Due to their feeding the leaf edges curl downwards, the colour of leaf changes from dark green to pale green, yellow and red and brown. In severely infested field the crop appears as though burnt with fire and this symptom is called as "hopper burn".

The colour of the foliage does not have any relation with its susceptibility or resistance to jassids. But the leaf pubescence and the size of the leaf and toughness of leaf vein largely determine its susceptibility. Hairy varieties impede the leaf hopper mobility, interfere with the feeding, egg laying process and thus offer resistance. Leaf hair density and length of the hair are negatively correlated with Lessia population. Hair density without length is ineffective. The hairy cotton varieties viz., SRT-1, B 1007, h 777, Khandwa, Bikandi Narma, PKV081, Rajat, MCU 5, LPK 516, SUPR 2 and SCPR 3 are resistant to jarsid.

The biochemical parameters which give antibiosis nature of resistants are reduced sugar, high gossypol and tannin content. In resistant varieties, the fecundity was less, nymphal period was longer and only fewer nymphs reached adulthood.

Whitefly, *Bemisia tabaci*

It is generally concluded that hairy leaved cotton varieties are more heavily attacked by whitefly than glabrous one. The glabrous culture Kanchana, LK861 and supriya harboared fewer adult and found to be tolerant to whitefly, hair density had positive relation with whitefly population. Adults prefer to fed and oviposit on hairy cultivars. By contrast to the normal leaf, plants with okra and super okra leaf forms the lamira are deeply divided. Plants with these characters allow better air movement sunshine and thus reduce relative humidity and increase the temperature within the plant canopy thus the favourable environment for whitefly is altered leading to reduced whitefly population.

The aphelinid parasitoids play key role in reducing the whitefly population. It was observed that the parasitic activity was more or resistant cultivar than on susceptible one. The leaf hairs and honeydew in susceptible varieties impede and interfere with parasitic activity.

Bollworms

The important characters which offer resistance to the bollworms are glabrous leaf, fregobract, short bract, thick bollrind, rough boll surface, high gossypol and tannin content, less protein and sugars.

Intercropping to increase natural enemy

It has been observed that the parasitic activity increased on cotton grown with cowpea and soybean as intercrop.

It has also been observed that cowpea intercropping increased the population of coccinellids which prey on aphids, jassids and eggs of bollworm.

NEEM BASED PESTICIDES MICROBIAL BIOPESTICIDES – BEHAVIOURAL CONTROL AND SEX PHEROMONES

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Annual crop losses in India due to various pests are estimated to be worth Rs.6000 crores. While synthetic chemical pesticides have played an extremely important role in reducing the crop losses, it is observed that these chemicals have one or more associated ill-effects such as development of insect resistance, insect resurgence, toxicity to non target organisms, prolonged environmental persistence of residues and resultant contamination of soil and water. Hence there is an urgent need to evolve an alternative pest management programme which would be environment friendly and yet able to provide effective pest control.

Among the natural insecticides investigated, the constituent of neem tree (*Azadirachta indica)* have sown great promise in controlling numerous insect pests of cultivated crop plants. Neem formulations derive their pest control properties from multiple compounds including *Azadirachtin salanin*, maliantriol, nimbidin etc.

The continuous and indiscriminate use of synthetic insecticide has resulted in serious problems, of which the major ones are

i. Development of insect resistance
ii. Insecticide – induced resurgency of insect pests or non insect pests.
iii. Toxicity to non-target organism seed as natural enemies of insects (prasites and predators, honey bees and pollinators.

iv. Toxicity to human beings and other organisms. World Health Organisation statistics indicate that nearly one million human being suffer from poisoning of pesticides and nearly 10000 die per year due to these causes.

v. Long persistance of residues in soil water are other ecosystems resulting in poisoning of the food-chain.

Botanical pest control

Over the past 10-15 years numerous plant species have shown potential for pest control of which the neem, Karanj (*Pongamia glabera_*, Mahua (*Bassia latifolial)* custard apple (*Annona squamosa*) are important. Neem which grows well in many parts of tropical and subtropical regions of the world, has shown great promise in controlling over 200 species of insect pests of cultivated crop plants.

Mode of action of neem

Neem preparations are effective in and or other way at each stage of the metamorphosis on the life cycle of the insect (egg, larval, pupal, adults or egg, nymph and adult). These effects are

1. Settling behaviour – repellency
2. Feeding behaviour – antifeedancy
3. Ovipositional deterrency
4. Metamorphosis disruption – 1GR – (insect growth regulator)
5. Reduced fecundity and egg sterility
6. Reduced fitness and vigour

Neem based products are devoid of all effect associated with synthetic chemicals.

Neem in cotton

Application of neem cake at the rate 250 kg/ha reduces the stem weevil infestation. Basal application of neem cake followed by neem oil 1% drenching on 20 and 40th day effectively reduced the stem weevil infestation in Tamil Nadu. Neem cake application is also observed to have less thrips and jassid in the early stages of crop growth. Investigations made at Punjab revealed that application neem oil or commercial neem formulation effectively controlled jassids. Neem oil 0.5% and neem seed kernal 5% suppressed the population of jassids. Neem oil in combination with Karanj oil effectively checked the jassid.

Investigations carried out at CICR-Coimbatore indicated that application of neem oil 0.5% or neem seed kernal 3-5% effectively checked the whitefly population. Neem oil acted as ovicides causing 40-50% egg mortality followed with exhibition of insect growth regulator property. Both suppressed the development of nymphs and only 14% reached the adult stage, out of these many adults had crippled distorted wings and they could not move and died. Many commercial formulations like Biosol, Neemark, Neemrich and Margocide gave effective control of this pest.

Neem products – bollworm

Neemoil and neem seed kernal extract effectively checked the growth and development of *Helicoverpa armigera*. Laboratory experiments indicated that neem prolonged the larval duration, reduced the growth and the adult emerged had croppled wing and died early. Neem products showed strong antifeedant effect and checked the larval and pupal survival as well as adult emergence in *Earis* sp.

Neem – Sapodoptera litura

Neem products viz., neem oil and NSK effectively checked the larval buildup of *S. litura*.

Neem rich 20 EC at 1.5 t/ha, effectively checked the build up of pink bollworm and spotted bollworm.

Pheromones for pest management

Pheromones, particularly the sex pheromones of cotton boll worm is a chemical components of blends of aliphatic alcohols, aldehydes, esters and epoxides. The pherones are being used as one of the important component in the organic cotton production for the management a cotton bollworms. The investigation carried out at CICR, R.S. Coimbatore on the usefulness of sex pheromones of *Helicoverpa armigera* in cotton ecosystem indicated that it can be used as an effective monitoring tool to detect early invasion of moth activity and infestation. Investigations revealed positive correlation between moth catches and larval population in the field. In Coimbatore maximum moth activities was observed in the first week of December.

The pink bollworm (PBW) activity and abundance can be monitored by erecting pheromone traps with gossyplure. In addition pheromone as mating disruption tool or as male annihilation methods can be used. In the mating disruption, when the field is covered with pheromones, the male moths get confused to detect the female for mating resulting that the female lay unfertilized eggs.

The moth activity of spotted bollworm can also be successfully monitoring by erecting pheromone traps. The moths of *Spodoptera litura* can also be monitored using lure and trap.

Behavioural approach for the management of cotton pest

Several insects particularly moths are attracted to light sources. The bollworm moths can be attracted to light trap by fixing light trap.

The cotton whitefly and jassid are attracted to yellow colour. By fixing yellow sticky trap the activity of whitefly in particular can be monitored and reduced.

NON-CHEMICAL METHODS OF WEED MANAGEMENT IN COTTON

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Indian economy has a substantial support from the most important commercial crop of the country, cotton, known as the "king fibre" world over. India was exporting 13 to 16 lakh bales of raw cotton (cotton lint) during 1995-97. However, the country became a net importer during last two years and cotton fibre import was to the tune of 18 lakh bales from USA, Australia, China and other countries for manufacture of yarn and its export.

The achievements in the growth of the agricultural productivity have been possible as a result of continuous influx of technologies into the agricultural production systems. The cultivation of high yielding crop varieties responsive to fertilizers and irrigation and the new intensive cropping systems have brought to the forefront the problems of weeds, which cause tremendous losses to crops and their produce. According to Kulshrestha and Parmer (1992), the yield losses due to weeds (33%) in India are more than those from insect pests (20%), diseases (26%), miscellaneous pests (8%), stored pests (7%) and rodents (6%).

1. Nature of crop- weed competition

Cotton being a widely spaced crop facilitates severe competition by weeds, particularly in the early stages. The total effect of the competition as reflected in the crop growth and yield results from competition for space, moisture, light and nutrients. When weeds were allowed to compete with cotton after first and second irrigations, reduction in yields of cotton to the extent of 20 per cent have been reported.

The weeds deplete enormous amount of plant nutrients from the soil. For every kilogram of nitrogen removed by weeds, there was an yield reduction of 12 kg of seed cotton per hectare.

Interception of light by canopies of cotton occur more slowly than canopies of weed. Cotton requires require 6 – 12 weeks for 80 % interception of light while weeds take 8 weeks to reach maximum cover, while cotton takes 16 weeks to reach 90 % cover.

2. Critical period of weed competition

In cotton crop-weed competition is maximum during germination and early phase of crop growth. The first 6-8 weeks of cotton crop is the critical period for the crop-weed competition.

Competition after the first 70 days of growth had no significant effect on seed cotton yield. During seedling stage with abundant factors conducive for growth of weeds, depress crop growth mainly by way of toxic root secretions and later on as the crop develops, the competition for dry matter accumulation becomes dominant limiting factor in crop growth . Weed control in the early stage of crop is more important and delay in weed control may not compensate losses that the crop suffered in the early stage

Competition of carpet weed was more during initial 50 DAS. The competition of barnyard grass was more between 50 and 100 DAS. Initial 60 days were more critical for crop-weed competition in cotton.

3. Impact of herbicide in agro-ecosystem

Chemical weed control has been largely a post 1939-45 war development but it rapidly picked up in developed nations. At present nearly 400 herbicides are registered or in the process of registration. Increased use of pesticides over years has, however resulted in multiple problems. The environmental safety has been doubted with increased pollution hazards, that apart, certain weed species have developed resistance to chemical toxicants. Added to this, there is also problem of secondary pests and resurgence of weeds. As a result changes in weed communities are observed.

4. Non-chemicals methods of weed management

The negative impacts of herbicide use make it imperative that non-chemical and alternative weed management strategies are to be adopted. A thorough understanding of long-term weed population dynamics and the forces control those dynamics would help to manipulate populations using techniques other than herbicides. This does not mean that herbicides are not important components of weed management programmes. They are, and will likely to continue to be important weed management tools. However, a fully integrated weed management programme will include techniques other than herbicides based on a fuller understanding of impact of each technological component of long term population dynamics.

4.1 Tillage methods

Timely and appropriate cultivation prior to establishment of a crop is the foremost preventive weed control in an organic system, either through burying the seeds to die or by bringing seeds to the surface and encouraging them to germinate. The most important aspect of this is to allow sufficient time between successive cultivation for weeds to germinate, so that reserves in the seed bank are diminished. Various methods of preventive weed control are based on these properties.

Depth of tillage

Depth of tillage influences the vertical distribution of weed seeds in soil layer. Inversion tillage such as mould board ploughing results in burial of larger proportion of seeds in the tillage layer compared to non-inversion tillage such as chisel (Table 1). Weed seeds buried deep germinate, but fail to emerge due to thick soil layer over it, resulting in death of weed seedlings.

Table 1. Influence of tillage on vertical distribution of weed seeds in the soil

Soil depths (cm)	Total weed seeds (%)	
	Ploughed	Chiseled
0-5	20	63
5-10	27	20
10-15	53	17

(Hosmani & Meti, 1993)

Stale seed bed technique

Another approach to weed control is the stale seed bed techniques. After primary tillage, weeds that emerge following rain or irrigation are destroyed by chemicals or by cultivation. The crop is then seeded with minimum disturbance. Later weedings may be reduced or delayed using this method.

Blind cultivation

The cultivation of the soil after sowing a crop either before the crop plants emerge or while they are in the early stages of growth is practiced in upland rice or sorghum to break the soil crust, to create conditions favourable for crop emergence and stand establishment and to kill young weed seedlings.

4.2. Cultivar competitiveness

Increased competitiveness of cultivars has been attributed to early emergence, seedling vigour, increased rate of leaf expansion, rapid creation of dense canopy, increased plant height, early root growth and increased root size. Fast ground covering is the main reason for weed suppression by canopy forming crops viz., horsegram (*Dolichos uniflorus*), Cowpea (*Vigna sinensis*), soybean (*Glycine max*) and sweet potato (*Ipomea batatus*) (Hosmani and Meti, 1993).

Cultivated crops are planted in rows primarily to facilitate inter-tillage or cultivation operations. It is not surprising that weed growth is suppressed with narrow row spacing without adverse effect on yield (Table 2).

Table 2. Weed dry weight and canopy spread (60 DAS) as influenced by crops

Crops	Canopy spread (cm)	Weed dry weight (q/ha)
Groundnut	38.8	28.3
Soybean	49.8	18.1
Greengram	40.7	19.4
Cowpea	65.5	11.1
Blackgram	46.1	20.5
CD 5%	4.05	2.76

(Hosmani, 1991)

The interrelationship of row spacing, seeding rate and canopy influence on crop-weed relationship has been investigated in a limited way. There is an evidence that these factors can be successfully manipulated to give a competitive advantage for the crop, often at the expense of weed flora.

4.3. Intercultivation

The objectives of intercultivation are weed control, aeration, soil moisture conservation, earthing up and creating soil mulch. Wider rows permit effective intercultivation for longer period with reduced hand weeding cost. Increased yield due to intercultivation by the way of not only checking the weeds, but also improving soil physical conditions. (Raja Rajeswari and Ranganadha Charyulu, 1996).

First dry hoeing should be done with the wheel hand hoe. For this sweep/blade can be used depending on the soil conditions. Subsequent hoeing can be done by bullock drawn weeders having adjustable types.

Tractor drawn high clearance cultivator using full and half sweeps has given good results. Bullock drawn lister plough may be used at the later stages of plant growth. Ridger should be used between the rows for inter-row cultivation and for collecting soil around the crop rows.

Hoeing after 3,6 and 9 weeks from sowing recorded significantly higher yield (Deshpande *et al.*, 1987). In rainfed cotton three weeding at 15, 45 and 75 days after sowing with three intercultures at 30, 60 and 90 DAS registered highest seed cotton yield (Jadhav *et al.*, 1995).

4.4. Mulching

Mulch is a protective covering material maintained on soil surface. Benefits include soil moisture conservation, reduced temperature fluctuation, increased soil organic matter content, improved soil structure and better suppression of weeds.

Black or transparent polyethylene mulch or pendimethalin applied at 1.5 kg / ha followed by a hoeing at 40 DAS provided similar weed control (Panwar *et al.*, 1994).

Increased yield by intercropping of pearl millet and mulching with sunflower residues at 5 t /ha was reported by Rajavel *et al.*, 2002.

4.5 Irrigation management

Control of weeds due to flooding is accomplished by the interaction of the changes in the physical, chemical and biological properties of submerged soils. Factors which probably inhibit growth of some weeds in flooded soils are reduced oxygen level, accumulation of carbondioxide and toxic gaseous products of anaerobic decomposition and presence of reduced forms of chemical radicals and gases such as methane, nitrogen, nitrogen oxides and sulphides.

4.6. Nutrient management

The extent of competition due to weeds differs with the time and method of nutrient application. Among the plant nutrients required for both crop and wed, nitrogen is the most important. While concluding on the time of N application for rice. Moody (1982) observed that nutrient application should be timed to prevent weed proliferation and yet to obtain maximum benefit for the crop.

4.7. Cropping system approach

The behaviour of the weed flora in response to various cropping systems is sometimes an important considerations in an agroecosystems where certain weed species threaten to interfere seriously with crop growth. Crop rotations can play a long-term role in controlling crop-associated an crop-bound weeds.

Crop rotation also plays a significant role in the management of parasitic as they are host specific. Cotton (*Gossypium sp.*), sunflower (*Helianthus annus*) and cowpea are identified as trap crops for striga and linseed (*Lincum usitatisimum*), sunhemp (*Crotalaria juncea*) and sorghum (*sorghum bicolor*) for orabanche (Hosmani, 1991).

Intercropping suppresses weeds better than sole cropping following the formation of the canopies. Due to competitive planting pattern and thus provides an opportunity to utilize crops themselves as a tool of weed management.

In a cotton - soybean intercropping system, single hand weeding operation resulted in a substantially higher seed cotton yield than the yield of sole cotton crop supplemented with two hand weedings. So the growing of soybean, as an intercrop in cotton is an effective method for checking the weeds population as well as enhancing the yield potential in rain fed cotton and also labour saving by minimizing one hand weeding (Gnanasambandan *et al.*, 2001).

Growing of greengram and cowpea as weed smother crop effectively suppressed total weed population and enhanced growth, yield parameters and seed cotton yield (Siva kumar and Subbian, 2002).

Table 3. Seed cotton yield (kg ha^{-1}) as influenced by integrated weed management in scotton (mean of 2 years)

Cropping system	No weeding	Manual weeding once	Manual weeding twice	Fluchloralin (0.90 kg/ha)	Mean
Cotton sole	859	1220	1432	1317	**1207**
Cotton + Soybean	1196	1528	1679	1492	**1474**
Cotton + Sesame	1014	1326	1551	1387	**1320**
Mean	**1023**	**1358**	**1554**	**1399**	

LSD at 5%: Cropping system (C) = 102 Weed control (W) = 102 C X W = 203

5. Direct manual and mechanical intervention to weeds

Manual and mechanical weed control involves the removal of weeds with various tools and implements, including hand weeding and pulling. In addition to weed control, there are other effects associated with mechanical weed control cultivations which can help to stimulate crop growth. Cultivations helps to aerate soil and root penetration easier, increasing the rates of nutrient release and the ability of the plant to exploit them. However, cultivations for weed control are highly weather dependent and timing can be crucial.

6. Alternative approaches to weed management

6.1. Soil solarization and weed control

The possible mechanisms of weed control by soil solarization are: direct killing of weed seeds by heat, indirect microbial killing of seeds weakened by subleathal heating, killing of seeds stimulated to germinate in the moistened mulched soil and killing of germinating seeds whose dormancy is broken.

6.2 Allelopathy and weed control

Allelopathy refers to the positive or negative influence of one plant without or with microbial action upon another through chemical means other than nutritional ones. The allelochemicals may come from roots of living plants or from leachate of plant organ or seeds or from decomposition of dead plant parts. Practical suggestions of Altieri and Doll (1978) on the use of allelopathy in the field include:

- Mulching of allelopathic fresh residues
- Spraying extracts of plant parts containing high concentrations of inhibitors at optimum dose and appropriate time
- Planting of strips of species toxic to weeds but not to the crops
- Integration of allelopathic strategies with other methods of weed control
- Hormonal stimulation on inhibitor production in crops and specific weeds
- Genetic incorporation of allelopathic properties into cultivars

6.3. Biological method of weed control

Biological control of weeds utilizes living organisms to attach a weed population such that it is maintained at or below desirable low level without significantly injuring desirable plants. They include insects, pathogens, nematodes, parasitic plants and competing plants.

The idea of biological control originated for dealing with noxious weeds on non-crop lands, and later it was extended to water bodies. But now, some success has been achieved in the biological control of weeds in crop fields. A very good example of this is the control of *Ludwigia parviflora* in rice fields using Steel Blue Beetle (*Haltica cyaanea*) and larvae of *Bactra verutana* have been found to bore into shoots of *Cyperus rotundus.*

Table 4. Some of the commercial mycoherbicides available for use

Product	Agent	Target weed	Crop
College	*Colletotrichum gloeosporioides*	*Aeschynomene virginica*	Rice, soybean
Devine	*Phytophtora citrophtora* *Phytophtora palmivora*	*Morreia odorata*	citrus
Velgo	*Fusarium lateritium*	*Abutilon theophrasti*	Soybean
Casst	*Alternaria cassiae*	*Casia obtusifolia*	Groundnut, soybean

(Powell and Justum, 1993)

Biological control can only be seen as a useful alternative to herbicides as part of an over all change in approach to ecosystem management and needs to be implemented with extreme caution where alien bioagents are involved.

Thus none of the individual weed control measures of their own can be expected to provide acceptable level of weed control. However, if the various components of integrated weed management are implemented in a systematic manner, acceptable level of weed control can be achieved.

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PEST CONTROL IN ORGANIC COTTON

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Selection of varieties and time of planting

In organic cotton cultivation selection of resistant / tolerant varieties and time of planting will help the plants to tolerate the pest attack or will help to escape from harmful insect pests. LRA 5166, Surabhi and Sumangala are tolerant to sucking pests and Supriya, Kanchana and LPS 141 are resistant to whitefly. The variety Abhadita is tolerant to bollworms. Synchronized sowing in a contiguous block at proper time will reduce aggravating pest problem particularly stem weevil and pink bollworm.

Crop diversity

Trap cropping : Small plantings of a susceptible or preferred crop may be established near a major crop to act as a trap. After the pest has been attracted to the crop, the pest is destroyed or the infested plant parts or plants may be removed. Growing castor surrounding the cotton will attract *Spodoptera* for egg laying. Pigeon pea and marigold mask the odour emanated from volatile compounds of cotton and offer less preference for oviposition by *Helicoverpa* in cotton.

Intercropping : Intercropping with blackgram and chillies will reduce the intensity of bollworms infestations in cotton.

Bund cropping : Cowpea planted as a bund crop encourages predators such as coccinellids, syrphids etc. which will keep the sucking pests under check.

Ecofeast crop : Maize grown along the border provides food and shelter for number of lepidopteran parasites and thus serve as ecofeast crop. It also act as a barrier crop for sucking pests. Cowpea is also a good ecofeast crop encouraging multiplication of coccinellids and other predators.

Agronomic practices :

Crop rotation : Crop rotation minimizes pest infestation to a greater extent. Cotton should be followed by crops which are not favourable or less preferred by cotton pests. Cotton followed by cereals like maize / sorghum reduce the incidence of whitefly, bollworms, soil born insects and nematodes.

Cotton free period : Cotton should be grown only once in a year. Cotton double cropping and ratooning should be avoided to prevent carry over population as they provide continuous food supply for the pest multiplication.

Cultural practices

Proper spacing : Close spacing and dense canopy will encourage the faster rate of multiplication of bollworms and other pests of cotton. Hence optimum spacing and density are to be maintained.

Nutrition management : Proper nutrition management should be followed, apply fertilizer based on soil testing. Avoid high dose of nitrogenous fertilizers to prevent excessive vegetative growth (luxuriant green growth) which otherwise attracts more pests.

Field sanitation : Summer ploughing destroys the resting stages of insects in the soil should be followed. Removal of alternate weed hosts which harbour cotton pests. Collection and destruction of affected squares, dried flowers and grown up larvae will significantly reduce the pest intensity and buildup.

Timely harvest and stalk destruction are among the most effective method managing pink bollworm. These practices reduce the habitat and food available to the pink bollworm, *Helicoverpa* and *Spodoptera.* Efforts should be made to destroy the green bolls, cracked bolls and other plant debris left at the end of the season.

Mechanical measures

Topping : Removal of terminals of cotton crop ("Topping") at 80-90 days of growth should be made to reduce *Helicoverpa* oviposition and also to encourage sympodial branching which bears more fruiting bodies.

Bird perches : Erection of bird perches (@ 10 / ha) encourages the predation by carnivorous birds.

Hand picking of larvae : Hand picking of grown up larvae should be done in the morning between 6.30 to 10.0 am and in the evening hours. It will eliminate the possible development of insecticide resistance. It also helps to minimize heavy build up of future population.

Scouting, monitoring and crop protection decisions

Regular field scouting / monitoring is a vital component of any pest management programme because it is the only way by which reliable information can be obtained to decide if and when pest reaches the economic threshold level. It will determine the pest density and damage levels through the use of standardized sampling techniques. Control measures should be taken in time when pest population reaches a level at which further increases would have resulted in losses beyond sustainable level.

Pheromone monitoring : A sex pheromone released by one sex only triggers off a series of behavioral patterns in the other sex of the species. It is referred to as sex attractant or sex lure. Generally females produce sex pheromone which attracts males. The sex pheromones are specific in their biological activity, the males responding only to a specific pheromone of the female of the same species. Males of the American bollworm and pink bollworm are attracted by synthetic pheromones, Helilure and Gossyplure respectively. Pheromone traps @ 5 / ha help to identify the brood emergence for synchronization of insecticide application and release of parasites.

Botanical pesticides : In view of sustainable approach and to utilize the biodiversity, it is essential to promote use of locally available neem seed as a botanical pesticide. Neem acts as antifeedant and oviposition deterrent. So NSKE 5 % and neem oil 0.5 % can be used to prevent the egg laying of *Helicoverpa* and also to deter the adult moths from cotton.

Method of neem seed kernel extract preparation

- Five kg of dried and cleaned neem seed should be taken a day before spraying, powder the seeds by grinding.
- Soak the powder overnight in 10 liters of water. Stir with wooden plank in the morning till solutions become milky white.
- Filter through double layer of muslin cloth and make volume to 100 litre by adding fresh water. Add 200 g of detergent soap and spray the solution to cover upper as well as lower foliar portions of the crop.

Bioagents : Parasitoids and predators are effective in suppressing the pest population. The parasitized eggs of *Corcyra* glued on a paper strip (Trichocard) has to be pinned an the lower surface of the cotton leaves. The emerging *Trichogramma* adult searches and parasitize the eggs of bollworms and perpetuate to some extent in nature to suppress the bollworm population. Two to three releases of egg parasitoid *Trichogramma chilonis* @ 1.5 lakh / ha during peak egg laying of *Helicoverpa* and other bollworms will help to reduce the bollworms infestation significantly.

Release of *Chrysoperla* sp. @ 500-1000 / ha according to the intensity of jassid damage between 20 – 25 days of crop growth will reduce the jassid population.

Insect pathogen : Entomopathogenic viruses are widely prevalent in nature and are specific to pests hence NPV effective against *H.armigera* was used. Spraying of H-NPV @ 500 LE / ha will be targeted against young larvae of *H.armigera*. Occasionally, the virus affected larvae will be seen hanging head downwards with shriveled body. This can be repeated after 15 days for retaining good inoculum of the pathogen. This may be alternated with commercial Bt formulations @ 1.5 l / ha.

Management of diseases of cotton through organic approaches

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Why organic?

We have been using pesticides for many decades for the control of insect pests and diseases of plants. The excessive use of pesticides has attracted world attention. The recent research findings indicate that

- ❖ Pesticides and other unnatural chemicals are detected in the body tissues of all people tested
- ❖ Once released in to the environment, the spread of pesticides and other chemicals cannot be controlled; traces of insecticides used in tropical areas have been detected in arctic trees.
- ❖ Our children are born with a deposit of pesticides and other foreign chemicals in their bodies, caused by a shift of maternal pesticide "body burden" through the placenta; after birth, children "inherit" further load through breast feeding.
- ❖ Pesticides have a cumulative multigenerational destructive impact on human health, especially behaviour. Pesticides are serious threat to the physical, emotional and mental development of children and future generations.
- ❖ We risk the continued existence of humanity as we know it, if we continue with the indiscriminate use of pesticides.

(Gilka, 2000)

In view of the basic similarity between humans and other forms of life at sub-cellular level, it is impossible to achieve target selectivity of chemical pesticides. The synthetic organic chemical pesticides are powerful biological poisons and can cause

- ☞ Direct toxicity to the applicator or consumer, especially pregnant women and children.
- ☞ Development of strains of pests that are resistant to a pesticide.
- ☞ Destruction of non-target organisms such as parasites and predators of pests, honey bees and other pollinators; fish, birds and other wild life. Out break of other pests that are no longer controlled by natural enemies

- Accumulation of harmful residues in crops.
- Harmful impact on domestic animals, wildlife and the environment
- Potential to contaminate surface and under ground water.
- Continuous exposure to pesticides creates health hazards such as cancer, brain tumors etc. in humans.

Due to the reasons cited above, it is better for humanity as well as environment to look for alternative methods for the management of pests and diseases. The best method as of now is organic agriculture or natural agriculture.

Organic agriculture minimizes children's exposure to toxic and persistent pesticides in the soil in which they play, the air they breathe, the water they drink and the food they eat. In this we shall discuss about managing diseases of cotton through organic approaches.

Cotton diseases and their identity

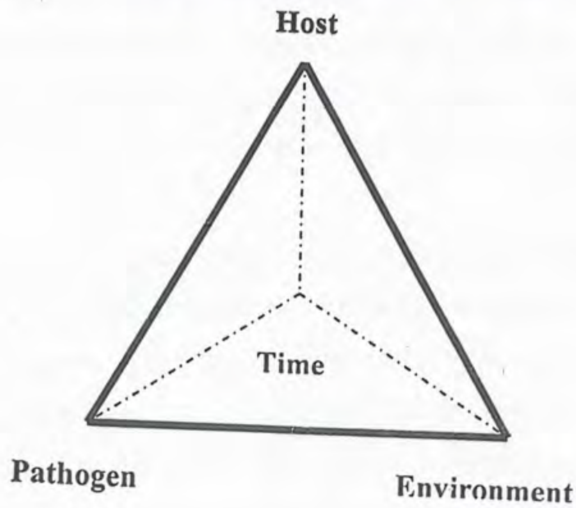
Plant diseases create challenging problems in commercial agriculture and pose economic threat to both conventional and organic farming systems. Plant pathogens are difficult to manage due to several reasons

1. Plant pathogens are hard to identify because they are small. The positive identification of a pathogen often requires specialized equipment and training and in some cases accurate diagnosis in the field is difficult.
2. Plant pathogens are constantly changing and mutating resulting in new strains and new challenge to growers.
3. Disease management is complicated by the presence of multiplicity of pathogens like fungi, bacteria, viruses, etc.

Cotton crop in south zone states of Andra Pradesh, Karnataka and Tamil Nadu is affected by number of diseases caused by soil inhabiting fungi like pre and post emergence damping off and root rot (*Rhizoctonia solani*, *Pythium* sp., and *Phytophthora* sp.), Wilts (*Verticillium dahliae* and *Fusarium oxysporum* f.sp. *vasinfectum*), Leaf spots (*Alternaria macrospora* – *Alternaria* leaf spot, *Ramularia areola* – Grey mildew, *Myrothecium roridum* – *Myrothecium* leaf spot), Boll rots pathogenic and saprophytic (*Glomerella gossipii*, *Aspergillus* sp.). Virus disease (Cotton Leaf Curl Virus Disease) also occurs, but it is limited to northern states of Rajasthan, Punjab and Haryana.

The plant disease occurs when there is an interaction between a plant host, a pathogen and the environment. Most plants are immune or completely resistant to almost all pathogens.

However, some pathogens have the ability to overcome the natural resistance mechanisms of particular hosts. The host is then regarded as being susceptible to that pathogen and the pathogen described as being virulent. When the environmental conditions are conducive, the virulent pathogen attacks the susceptible host and definitely the disease develops. Therefore, any disease management strategy should focus on the host, the pathogen and/or the environment. Hence, an "Integrated Disease Management through organic methods" involves the selection and application of harmonious range of control strategies that minimize losses and maximizes returns.



The following are the strategies for the organic management of cotton diseases.

1. **Planting resistant varieties/cultivar**

One of the most important components in an integrated disease control programme is the selection and planting of varieties that are resistant to pathogens. These plants resist or retard the activity and progress of the pathogens and are non-destructive to environment. These plants also eliminate or reduce the use of chemicals. However, we may not able to get variety resistant to all diseases. In cotton number of varieties resistant to individual diseases is available like MCU 5VT and Surabhi resistant to *Verticillium* wilt. Several lines resistant to *Fusarium* wilt, bacterial blight etc. are available.

2. **Proper site selection – avoid endemic areas**

Before planting the cotton crop, the farmer should examine whether the site is infested with pathogenic organisms like *Verticillium* and *Fusarium* (wilt causing pathogens) or an endemic area for foliar pathogens like *Alternaria* leaf spot, grey mildew etc. These areas should be avoided for planting cotton crop. However, for pathogens like *Pythium*, *Phytophthora* or *Rhizoctonia*, it is very difficult to avoid since they are present in most of the soils.

3. **Exclusion of infected plant materials**

The practice of keeping out any materials or objects that are contaminated with pathogens or diseased plants and preventing them from entering the production system is exclusion. In cotton, the only major seed borne pathogen is *Xanthomonas axonopodis* pv. *malvacearum* causing bacterial blight. Infected seeds should be kept out.

4. **Application of control measures** – Biocontrol agents as seed (to protect the seed), Soil (to compete with soil borne wilt and other pathogens) and foliar spray (to control leaf pathogens)

Disease control using microorganisms (biocontrol) or chemical byproducts made by microorganisms is generating lot of interest and attention. Several soil borne bacteria (Plant Growth Promoting Rhizobacteria (PGPR)) belonging to the genera *Bacillus*, *Burkholderia*, *Pseudomonas* and *Streptomyces* and fungi belong to *Trichoderma* and *Aspergillus* have been identified, tested and found effective against number of pathogens. They are, in addition to being protectant, also have several growth promoting entities. The talc powder formulations are nowadays available in the market and recommended as a seed dresser and soil application to protect the seeds and seedlings against soil borne pathogens and also foliar spray against foliar pathogens. The following are some of the advantages and disadvantages of the bioagents.

- Large scale production feasibility
- Small amounts of inoculum requirement
- Simple method of application
- Survives independently (energy sources)
- Systemic spread along the roots
- Antagonistic activity at crucial stage of growth

- Eco-friendly
- No resistance development in pathogen

Disadvantages

- Narrow spectrum of activity
- Inconsistent performance in practical agriculture
- Environmental sensitivity
- Short shelf life

Number of companies are marketing the talc powder formulations of *Trichoderma* and *Pseudomonas* under different brand names.

The beneficial fungi *Trichoderma harzianum* locate and attack the damping off pathogen *Rhizoctonia solani*. The beneficial fungal strands entangle the pathogen and release enzymes that dehydrate *R. solani* cells eventually killing them (Fig. 1). In some other cases they parasitize the pathogen and killing them (Fig. 2). The rhizobacteria and fungi are also known to control the pathogens through competition or antagonism. In addition, they also induce systemic resistance against the pathogens.

5. Cultural practices

There are number ways to incorporate cultural practices in the integrated disease control system. As a general approach the farmers should take steps to sow only high quality seed materials. Seeds having above 80% germination will have vigorous growth and there by they do not suffer from infection due to soil borne organisms. The farmers can have good stand.

Crop rotation is another important aspect which should be taken into consideration especially for diseases like *Verticillium* wilt. Converting *Verticillium* infested fields to paddy crop will greatly reduce the microsclerotial population in the soil. It is also known that growing *Chrysanthemum* will be inhibitory to *Verticillium*.

Time of sowing is also important. If the farmers are able to take up sowing during warmer temperature (i.e. at 65°F temperature and above) there will be better germination and seedling growth.

Irrigation management is an important factor involved in disease control. Timing and duration of irrigations should satisfy crop water requirement without allowing for excess water. Over watering will favour soil borne pathogen, where as use of over-head sprinkler systems will favour diseases affecting leaves. Accordingly the farmers should manage crops.

Excessive application certain organic manures like poultry manure will induce high vegetative growth. Dense crop growth is conducive for foliar diseases like *Alternaria* leaf spot and grey mildew.

Field sanitation is another essential part of disease management. The main source for the development and spread of the foliar diseases is only through previous year's crop residues and also weed hosts near the fields. Hence, destruction of the crop residue as well as weed hosts around the field is essential.

6. Application of compost

Incorporation of composts in to the soil is a fundamental cultural practice in organic cotton production. Composts increase the soil fertility and also help in disease management. The disease control is possibly effected through

(i). Successful competition for nutrients by beneficial microorganisms

(ii). Antibiotic production by beneficial microorganisms

(iii).Successful predation against pathogens by beneficial microorganisms and

(iv).Activation of disease resistant genes in plants by composts.

One can enrich composts through incorporation beneficial microorganisms like *Trichoderma* spp. which compete against pathogens and antagonize them. It is well known that application of town compost having high percentage of cellulolytic materials will increase the population of *Trichoderma* spp. there by helping in the management of *Verticillium* wilt as well as root rot due to *Rhizoctonia solani*.

Organic cotton - Disease Management Programme

Application timings	Produce	Rate of application	Application methods	Purpose
Pre-plant	Compost	As required	Soil	Improves soil fertility and health
	Bioagents	2.5 kg /ha	Soil	Improve soil health
At planting	Bioagents	10 g/kg of seed	Seed	Seed protectant
During crop growth	Bioagents	0.2% spray	Foliar (40 days onwards at 15 days interval for atleast 3 times)	Protective and curative against foliar diseases

Fig. 1. Hyphae of the beneficial fungus *Trichoderma* wrap around the pathogenic fungus *Rhizoctonia*

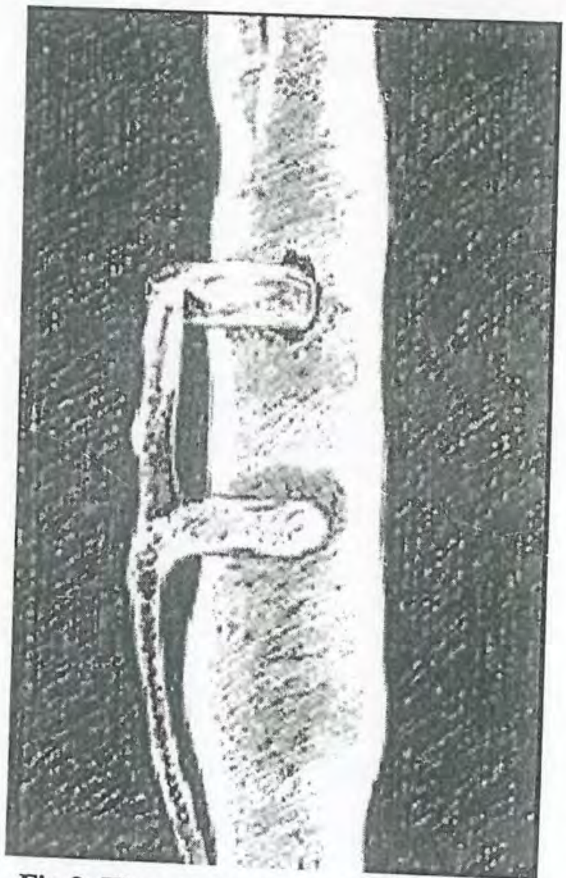


Fig 2. The non-pathogenic strain of *Pythium* fungus penetrates the pathogenic fungus *Phytophthora*

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Socio – Economic Analysis of Organic Cotton

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SETTING :

Cotton is the most important agricultural and industrial commodity of world wide. India has secured a place of pride at the Global cotton scenario due to several distinctive features such as first rank in the world cotton acreage, second rank in textile processing capacity, third in cotton production, second largest producer of extra-long-stable cotton and native home for coloured cotton. No crop of commerce in the world can compete with cottons potential in processing for value. For Example, by exporting one lakh bales of raw cotton, India can earn Rs.100 crores , but by exporting cotton in the form of Garments we can earn Rs.800 crores. Cotton is not only a highly value added crop, but also a highly Pollutant crop. Cotton is a chemical intensive crop. Nearly 25% of world Agricultural Chemical applied to cotton which uses 3% of Earths Agricultural land. In India 55% of Agricultural Pesticides are applied to cotton crop which share only 5% of total cultivated area. Every year USA is exporting Rs.1,400 crores worth of pesticides which are legally prohibited from use in USA . Of the total agricultural pesticides applied in India 70% of them are prohibited from use in the developed countries. Because they are very dangerous to human health. To many of us, cotton is the " Natural Fibre" – the environmentally healthy alternative to man-made chemical fibre But it will, come as a shock to learn that the growing and processing of cotton over the last 300 years has led to some of the greatest social and environment disaster in all human history. Fortunately an alternative is on the horizon. Organic cotton is poised to revolutionize the way cotton is produced and processed.

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Area, Production and Productivity of Organic Cotton

Organic cotton is already successfully being grown in 18 countries around the world including U.S.A, Turkey, India, Peru, Isreal, Egypt, and Uganda. The demand for organic cotton is increasing in Germany, Switzerland, the Netherlands, Sweden, Australia, Europien Countries and U.S.A. Organic cotton production at present is 6000 tons of which 5000 tons are produced in U.S.A. (I.O.C.D 2001) The U.S.A has been the initiator in the organic cotton cultivation. In U.S.A about 16,000 acres of organic cotton are planted in 2001. In 1990 only 900 acres of organic cotton were planted. Then 1991 it was 3290 acres. It reached a peak in 1995 to 25,000 acres. Due to lack of demand the price of organic cotton fall down and farmers lost their money and thus area dropped to 9,000 acres in 1997. The market is again growing for organic cotton from 2001.

In India the 'PRAKRUTI' a voluntary organization for organic cotton cultivation in Viderbha, in collaboration with German voluntary organization initiated a project of organic cotton. In Viderbha nearly 1200 hectares of organic cotton cultivated by 135 farmers and their average yield was 500-750 Kgs of seed cotton per hectare. In the south, at Kerala, a Coimbatore based textile mill launched an organic cotton project called 'SRIDA-BIORE'. In this project 150 acres of land owned by 130 rain fed tribal farmers were included. The average per hectare yield realised was 640 Kgs of seed cotton. The average yield of organic cotton at San Joaquin Valley of U.S.A was 3,065 Kgs seed cotton per hectare.

COST OF CULTIVATION OF ORGANIC COTTON :

In order to compare the cost of producing organic cotton at Maharastra, Kerala, and U.S.A the production cost data were collected from the organic cotton project farmers. Secondary data were collected in Maharastra from "Prakruti" organic cotton project, in Kerala from SRIDA – BIORE project and in U.S.A from the northern San Joaqin valley and compared below in Table No.-I.

Table-1. COMPARATIVE COST OF CULTIVATION FOR ORGANIC COTTON 2001

(Rs./ Hectare)

S.No	Particulars	Prakruti Project – Maharastra (Rainfed)	SRIDA-BIORE Kerala (Rainfed)	North San Joaqin valley in U.S.A (Irrigated)
01	Direct Cost	9,850	9,318	74,140
02	Indirect Cost	2,550	2,675	22,200
03	Total Cost of Production	12,400	11,933	96,340
04	Seed Cotton Yield (Qtl)	8.75	7.25	30.65
05	Price per Qtl (Premium Price per Quintal)	2,400 (400)	3,200 (500)	9,900 (3,500)
06	Income	21,000	23,200	3,03,435
07	Profit	8,600	11,207	2,07,095
08	Per Quintal Cost of Prodn.	1,417	1,654	3,143
09	Output / Input Ratio	1:1.70	1:1.93	1:3.15

The above Table reveals that the total cost of producing organic cotton in Maharastra, Kerala and in U.S.A are Rs.12,400, Rs 11,993 and Rs.96,340 respectively. In Maharastra and Kerala the organic cotton were raised under rainfed condition whereas in U.S.A it is produced in irrigated condition. The per hectare yield realised are 8.75, 7.25 and 30.65 quintals of seed cotton respectively for Mahasrastra, Kerala and U.S.A. The American organic cotton farmers have enjoyed the maximum price of Rs.9,900 per Quintal whereas in Maharastra and Kerala farmers has received Rs.2,400 and Rs.3,200 per quintal respectively. The output input ratio estimated are 1:1.70, 1:1.93& 1:3.15respectively for Maharastra, Kerala and U.S.A. organic cotton production system. It means that in Maharastra the organic cotton farmers have realised the net profit of Paise 70 per every rupee invested. Similarly the Kerala farmer's net profit is Rupee 0.93 and U.S.A. farmer's net profit is Rs.2.15 per every rupee invested . The very interesting feature of this table is that to produce one quintal of organic cotton, the American farmers have to invest Rs.3,143 whereas in India the cost is 50% cheaper than U.S.A. The poor yield in India is due to low investment on organic cotton system.

ECONOMICS OF ORGANIC COTTON OVER THE YEARS :

The financial viability and the risk analysis of organic cotton production has been studied in detail by the National Bank for Agriculture and Rural Development (NABARD) with the Yavatmal district as a case study. The NABARD's data are adopted in this economic analysis of organic cotton over the years. It is understood that the first year of organic cotton the yield will be very poor. But over the years yield will buildup with the increase of organic strength of the soil. From the NABARD analysis the data are computed and presented in the following Table-2.

Table –2 ECONOMICS OF ORGANIC COTTON OVER THE DIFFERENT YEARS

Year	Yield (Q/ha)	Gross Income (Rs.)	Premium (20%)	Total (Rs.)	Net Income (Rs.)	Surplus / deficit over conventional cotton (Rs.)
Conventional	10	20,000	0	20,000	9,000	0
First Year	5	10,000	0	10,000	750	(-) 8,250
Second Year	5.75	11,250	0	11,250	3,750	(-)5,250
Third Year	6.25	12,500	2,500	15,000	7,000	(-) 1,500
Fourth Year	7.50	15,000	3,000	18,000	10,500	1,500
Fifth Year	8.75	17,500	3,500	21,000	13,500	4,500
Sixth Year	10.00	20,000	4,000	24,000	16,500	7,500

The above Table reveals that by the conventional system of cotton production the yield realized is 10 quintal per hectare, the gross income is Rs.20,000 and the net income is Rs.9,000. In the first year of organic cotton cultivation the yield declained to 5 quintals and the farmer incurred a loss of Rs.8,250 per hectare. In the subsequent years the organic cotton yield started increasing and from the fourth year onwards the organic system started yielding profits. In the sixth year the yield of organic cotton regained to the conventional system's yield level.

OPPORTUNITIES FOR GROWING ORGANIC COTTON IN INDIA :

India leads in World cotton acreage by sharing 25 %. Nearly 65% of 9 Million hectares of Indian cotton area is rainfed and risky crop. The yield and income will be fluctuating in the rainfed tract, therefore the farmers are discouraged to apply costly inputs like pesticides and fertilizers. More over in the rainfed cotton area the local varieties of G.ARBOREUM and G.HERBACIUM are commonly grown. They are locally called as KarunKanni and Uppam cotton respectively. These varieties are highly resistant to insects and pests. These local varieties occupy nearly 45% of rainfed tract of India. The dominant micro size farms in India with a high family labour are more suitable for organic way of weed control and mechanical method of pest management in cotton. Compare to other countries the per hectare consumption of pesticides is very low in India. For eg. the per hectare consumption of pesticides in Japan is 10,000 Gms, in U.S.A. it is 1,800 Gms. Whereas in India it is only 400 Gms. Per quental production cost of organic cotton in India is Rs.1,500 whereas in U.S.A it is around 3,150. Therefore India is having a very high potentiality to meet the organic cotton demand of the world.

POLICY ALTERNATIVES :

1. The yield and price of the organic cotton is highly volatile. Hence the loss of yield and income to the farmers must be compensated with the suitable policy.

2. Certification system for organic cotton may be simplified and transparent to protect both the producer and the consumer.

3. Quality control of Bio Fertilizer and Bio-Pesticides needs Government attention.
4. A separate organic cotton mission may be created to promote cultivation and the processing of organic cotton at the the F.A.O.
5. To encourage the cultivation of eco-friendly cotton an effective organic cotton insurance programme may be launched so as to ensure the income and employment opportunity for the farmers.
6. A special co-operative organization may be created for producing, processing, marketing and trading of organic and colorganic cotton.
7. Organic cotton projects may be streamlined to co-ordinate supply and demand for a healthy international trade.

CONCLUSION :

People everywhere are waking up to the necessity of conservation and preservation of environment. The cottons effects on the environment has been a completely devastating. To Produce 3Kg of cotton lint we have to use 1 Kg of chemicals. In the World nearly 50 million tons of textile fibre are produced . For processing this fibre and to give them attractive colour nearly 8,00,000 tons of dyeing chemicals are used. Therefore cottons history is bleak, but an organic alternative is a visible beacon of a brighter future.

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