# Legume as companion crop for cotton

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**ABSTRACT :** Cotton, one of the most important natural fibres, plays a dominant role both in agrarian and industrial economy of our country. Monocropping alongwith continuous use of inorganic without addition of organics encouraged pest attacks, which reduced its productivity and profitability, thereby making the sustainability issue, a greater concern even in many traditional cotton areas. Legumes–an essential component in sustainable agro-ecosystems–greatly contribute towards stability in production and profit, pest control, carbon sequestration, organic N addition, soil stabilization and nutrient recycling. Short duration legumes like greengram and blackgram appeared ideal, as these can additionally contribute 5-6 q of grain per hectare with minimal impact on seed cotton yield. Intercropping of greengram (mung) in cotton in 1 : 1, 1 : 2 or 2 : 1 row ratios was beneficial both in yield and economics as reported from several locations in Punjab, Haryana, Andhra Pradesh, Karnataka and Tamil Nadu. In many parts of the country, soybean intercropping in cotton gave a higher gross monetary return per hectare. Study on the multi-tier vegetables including legume, revealed that intercropping of radish, clusterbean and amaranthus planted between paired cotton rows registered higher gross return (Rs. 64,395/ha) and net return (Rs. 34,833/ha) and benefit : cost ratio (2.2) at Coimbatore. Cotton, when grown successively in the same plot without any other crop in the sequence led to less yield of cotton over a period of time. An yield increase to the tune of 11 per cent was recorded in a 2-year cotton-legume-corn rotation as compared to continuous cotton grown without legumes each year. The quantity of N fixed by legumes ranges from 17 to 171/kg per hectare per year. Nutrient management in organic farming solely depends on manures and legumes. Since availability and economical feasibility of using manure is less practicable, *in situ* green manuring with fodder cowpea and its burying at 40 days after sowing will ensure a steady N supply during the grand growth and flowering periods. Living plants and their residue on the soil surface protect the soil from impact of rain drops, reduce soil surface pore blockage and reduce the velocity of running water. Some good insectary plants, often used as cover crops, include alfalfa, sweet clover, vetch, red clover, white clover and cowpeas. Inclusion of forage legumes in cropping system can also be an effective approach to weed control. Insect-pest of 53 per cent showed lower abundance in multiple species mixtures than in sole crops, 18 per cent were more abundant in mixture, 9 per cent showed no difference and 20 per cent were variable in the response. Breeding of short duration, early, determinate, compact and high yielding legumes with suitability to intercropping and sequential cropping in cotton is warranted.

**Key words :** Cover cropping, income stability, intercropping, IPM, multi-tier cropping, organic cotton, sequential cropping, smother crop

Cotton inherits a tremendous significance in Indian economy, as nearly one-third of India's export earnings in the form of yarn, cloth and ready-made garments are from the textile sector. India ranks second in global cotton production scene after China and the country accounts for 29 per cent of world's total cotton area and 21 per cent of global cotton production. The share of cotton in world textile manufacturing is around 42 per cent as against 62 per cent in India. Moreover, as the most important natural fibre crop, it plays a dominant role both in agrarian and industrial economy. An estimated 60 million Indians get employment directly or indirectly through its cultivation, marketing, value addition and export.

Despite the global importance and need for the commodity and highest acreage in India (9.5 million ha), cotton productivity revolves only around 549 kg as against the world average of 780 kg per hectare (2008-2009). In addition, the spate of cotton farmers in the last decade traverses through agonies like the pest resistances to insecticides, higher cultivation cost, ever decreasing and unstable returns. Monocropping, erratic rains, pest attacks, poor soils and indiscriminate use of pesticides have added to the farmers' woes and taken their toll in reducing the crop's performance in terms of productivity and remunerability. Moreover, the cotton soils have been rendered lesser productive because of continuous monocropping, use of high analysis fertilizers and non-addition of organics. A study conducted by the Centre for Research in Rural and Industrial Development (CRRID) in seven villages of Punjab's Bhatinda district reveals that 85 per cent of cotton farmers are under debt trap. Hundreds of cotton farmers in the Vidarbha of Maharashtra are caught in the vicious cycle of debt and poverty because of its low productivity and high cultivation cost. Hence, the sustainability issue is becoming great concern for all of us.

Legumes–an essential component in sustainable agro-ecosystems–greatly contribute by way of carbon sequestration, organic N addition, soil stabilization and nutrient recycling. Legumes have long been recognized as an essential part of crop rotation even during ancient Roman times (Rogers, 1976). With increasing concern about the environmental and socio-economic sustainability of agricultural production system, there has been a renewed interest in diversifying agricultural production system through legumes alone and in combination/mixture with other crops.

## LEGUMES IN COTTON SYSTEMS

### Intercropping

Intercropping is growing of two or more crops simultaneously with distinct row arrangement in the same piece of land every year. Here, the plant interference is minimal. Plant interference is the response of an individual plant or species (pulses) to its environment as modified by the presence of another individual plant (cotton) or another species. In contrast to intercropping, mixed cropping is also in practice in areas of likelihood for crop failures where simply seed mixtures of two or more crops are sown. Cotton, relatively having longer life cycle (150-175 days) and slow growth in the initial stages, offers for raising a intercrop(s). Besides yield, these intercrops serve as an insurance against main crop failure, in the vast rainfed tracts in the country. Since suitability of an intercrop mainly depends upon branching habit, leaf area development and growth characteristics of the base cotton crop, the less competitive legume genotypes which are compact and early maturity ideally taken up as intercrop in cotton. The intercrops can reduce the menace of sucking pests and bollworms. Dominant intercropping systems are given in Table 1.

### Multi-tier Cropping

An extrapolation of different intercropping combinations is the multi-tier cropping, where multiple crops provide an efficient means of harvesting solar energy. Similar to the above ground canopy, the root systems of the component crops are also located at distinct soil zones for optimal exploration of moisture and nutrients (Palaniappan, 1985). Study under rainfed conditions revealed that introduction of tall crop was not advantageous due to competition for resources, especially for moisture. Study on the multi-tier vegetables, having different growth habits and requirement for resources in cotton based system, revealed that intercropping of radish, clusterbean and amaranthus planted between paired cotton rows registered higher gross return (Rs. 64,395/ha) and net return (Rs. 34,833/ha) and benefit : cost ratio (2.2). The crop growth, yield attributes, seed yield and quality of fibre were not influenced by such multi-tier systems (Sankaranarayanan *et al.*, 2006).

**Table 1.** Dominant cotton-based legume intercropping system

| States | Cropping system |
|---|---|
| M. P., Maharashtra and Gujarat | Cotton intercropped with blackgram, greengram, soybean, Groundnut and redgram |
| Andhra Pradesh | Cotton intercropped with blackgram, greengram, soybean and redgram |
| Tamil Nadu | Cotton intercropped with groundnut and blackgram |
| Karnataka | Cotton intercropped with groundnut, blackgram and greengram |

Adopted from Chittapur (2004).

## Sequential Cropping

Cotton, when grown successively in the same plot without any other crop in the sequence, led to less yield of cotton over a period of time. Even a fallow period intervening the two successive cotton crops did not sustain yields (Praharaj *et al.,* 2004; Praharaj and Rajendran, 2007). Thus, more productive, more efficient, yet remunerative cropping systems are to be taken up for attaining desired sustainability.

Study on one-year rotation in cotton based system found that cotton (Aug.-Feb.)-radish (Feb.-Mar.)-blackgram (Apr.-Jun.)-sorghum (Jun.-Aug.) was more remunerative (with 11.2 q seed cotton, 150 q of radish tubers, 5.30 q of blackgram and 38.8 q per hectare of sorghum grain). Another rotation studies on cotton conducted at Central Institute for Cotton Research, Coimbatore reveals that cotton-maize-tomato-wheat-sunflower-cowpea (six crops on a 2-year rotation) produced the maximum net income. The study further revealed that cotton (first year)-fallow (second year) performed significantly better than cotton grown every year in the same land. The levels of fertilizer tried in the rotations found that application of half of the recommended dose of fertilizers to respective crops performed statistically equal as compared to application of full dose.

A long-term crop rotation study on cotton at Auburn, Alabama showed that growing of cotton with out nitrogenous fertilizer and rotated with winter annual legumes [cotton (without N)-winter annual legume], produced equal seed cotton equivalent yield as compared to nitrogenous fertilizer applied monocropped cotton. Cotton-legume-corn (two-year rotation) had increased the yield to the tune of 11 per cent as compared to monocropped cotton [cotton (first year)-cotton (second year)].

## ADVANTAGES OF LEGUMES IN COTTON SYSTEMS

### Higher Productivity Ensured

Intercropping of greengram (mung) in cotton in 1 : 1, 1 : 2 or 2 : 1 row ratios was beneficial both in yield and economics as reported from Punjab and Haryana. The practice of raising greengram as an intercrop in cotton was advantageous in terms of higher net returns in rainfed areas, and was recommended at several locations in Andhra Pradesh, Karnataka and Tamil Nadu. Short duration legumes like greengram and blackgram appeared ideal, as these can additionally contribute 5-6 q of grain per hectare with minimal impact on seed cotton yield (Mudholkar and Basu, 1995). At Coimbatore, intercropping of three rows of greengram in the interspaces of cotton and application of 45 kg N recorded the higher seed cotton yield of 14.8 q as compared to sole cotton crop of 13.2 q per hectare (Kunesekaran and Iruthayaraj, 1980). Certain greengram genotypes *viz.,* T 44 and NPRG 3 are even more suitable in cotton systems, while TCH 665 cotton cultivar is more adopted to intercropping system over MCU 9. Yet, varieties MCU 9 and MCU 11 behaved similarly to a greengram intercropping system (Jaganathan *et al.,* 1994). Blackgram cultivar, APK 1 intercropped in cotton produced 28 per cent higher yield over that in check (Co 5) (Rajarathinam *et al.,* 1996).

At Nanded (Maharashtra), redgram as an intercrop in *desi* cotton did not differentiate the seed cotton yields obtained versus sole cotton. However, in Marathwada region of the state, cotton+pigeonpea was far superior to sole crop of *Tur.* Intercropping of cowpea with cotton produced differential response. Although no beneficial interaction was realized in Punjab, Haryana and Delhi, intercropping trials at Guntur recorded consistently higher monetary returns with reduced pest incidence and weed menace.

### Stability in Yields Achieved

Many a time, sustaining yield from a farming system in totality may be of prime consideration for farmers under resource scarce condition than maximizing yield or income from a single crop. Thus, biological diversity is more important in yield stability (Willey, 1979). Perhaps the most interesting biological and economic aspect of intercropping is the potential for compensation among the components of the system, often referred to as biological or economic "buffering" in the system that leads to greater stability in (total) yields of component crops.

In few cases also, intercropping happens to decrease the yield in cotton significantly. Yet these not only covered the loss accrued due to yield decrease in main cotton crop, but also raised overall productivity. Higher net field benefit was obtained from cotton+mungbean over sole cropping of cotton. Similarly, cotton+ blackgram raised in paired row system (2 : 1) produced highest mean seed cotton yield equivalent (1815 kg/ha).

In another trial, although cowpea suppressed cotton yields, the reduction in yield was compensated by cowpea grain yield (Rusinamhodzi *et al.,* 2006). Intercropping cotton with cowpea increased the productivity with land equivalent ratios (LER) of 1.4 and 1.3 for 1 : 1 and 2 : 1 intercrop, respectively.

In a rainfed system, intercropping of one row of soybean (JS 335) between cotton rows recorded the highest mean soybean grain yield (365 kg/ha) followed by greengram (Co-6) and blackgram (Vamban-3). The highest seed cotton equivalent yield of 18.92 q/ha was realized under cotton+blackgram system (Table 2) (Sankaranarayanan *et al.,* 2006). Additional grain yield and higher market price associated with blackgram cumulatively produced maximum seed cotton equivalent yield.

**Table 2.** Economics of intercropping system (Mean of three years)

| Cropping systems | Seed cotton yield (q/ha) | Intercrop yield (kg/ha) | Seed cotton equivalent yield (q/ha) |
|---|---|---|---|
| Cotton+Soybean | 13.85 | 365 | 16.25 |
| Cotton+Blackgram | 14.72 | 311 | 18.92 |
| Cotton+Greengram | 11.73 | 328 | 15.63 |
| Sole cotton | 14.12 | - | 14.12 |

Sankaranarayanan (2006).

### Higher Profitability Realized

The market demand for blackgram makes intercropping of blackgram in cotton remunerative with higher net monetary return at many locations in Tamil Nadu, Karnataka, Andhra Pradesh and Madhya Pradesh (Tomar *et al.,* 1994; Wankhede *et al.,* 2000) and was most profitable over cotton+soybean and sole cotton (Giri *et al.,* 2006). At Lam (A. P.), cotton planted in paired rows and intercropped with three rows of blackgram was most suitable for realizing higher monetary return.

In north-western Rajasthan, intercropping of greengram in paired rows of cotton brought about higher net monetary returns over sole cotton crop. In the rainfed zones of Central India, the practice of raising greengram as an remunerative intercrop in cotton was recommended at many locations like Akola, Nagpur, Parbhani, Nanded, Achalpur, Indore, Badnawar and Khandwa. Greengram was also found to be ideal intercrop in cotton at Surat and Banswara in Gujarat and at many places in Andhra Pradesh, Karnataka and Tamil Nadu.

At Dharwad (Karnataka) and at Lam in Guntur, soybean intercropping was remunerative. In Nandyal region of A. P., soybean intercropping in cotton gave a gross monetary return of Rs.11, 247 per hectare. In field trial conducted at Banswara, Rajasthan, intercropping of blackgram, greengram or cowpea in rainfed crop increased the net profit compared with cotton in pure stand (Singh *et al.,* 1981). Cotton intercropped with soybean, blackgram and greengram also gave an additional per hectare profit of Rs. 1057, 748 and 708, respectively (Patel *et al.,* 1995).

A compilation on intercropping system reveals that all these systems recorded higher net returns per hectare than sole crop of cotton and groundnut (Koraddi *et al.,* 1991). Intercropping of groundnut and cotton in 1 : 1 row proportion with normal fertilization to cotton and 25 per cent of that to groundnut recorded the highest net income of Rs. 9,532 per hectare as compared to sole crop of cotton (Rs. 3,974).

At Guntur, moderate net return of Rs.11,855 per hectare was obtained from cotton intercropped with pigeonpea compared to Rs.10,400 from sole cotton crop. The practice of cotton-pigeonpea intercrop in the row ratios of 6 : 1 or 8 : 1 is popular among cotton farmers of Marathwada region of Maharashtra and

Warangal, Khammam and Adilabad districts of Andhra Pradesh.

## Income Stability Assured

Dimension of economic buffering is related to the nature of intercropping or mixture of species. The first factor is having an yield advantage, thus, if higher total yields result from intercropping, there will be an economic advantage as the most valuable species are well represented in the harvest. The second factor relates to the biological buffering described as that if two crops are planted throughout a field, rather than in half of field, and if a devastating insect, disease, or drought situation selectively eliminates or strongly suppresses one component, the remaining crop is likely to take advantage of the available resources and produce a relatively high yield over the entire area.

Cotton+blackgram intercropping both in paired row or skip row was more profitable with a net profit of Rs.1,005 over that in pure cotton (Rs. 825) in dry tracts of Kovilpatti in Tamil Nadu. Substantial higher net returns from cotton+blackgram system in coastal district of A. P. (Rs. 17, 208) alongwith cost : benefit ratio of 3.38 were recorded in two rows of blackgram as an intercrop in paired cotton rows (Krishnasamy *et al.,* 1995).

Intercropping studies with groundnut, blackgram and pearl millet under normal and paired row planting under two cotton genotypes revealed that Varalaxmi gave 23.5 per cent higher seed cotton yield and Rs. 603 more monetary returns from a hectare over MCU 5. Both planting methods recorded almost equal yields and gross income. Groundnut and blackgram did not reduce the seed cotton yield, while pearl millet reduced the yield. A maximum return of Rs. 14,124 resulted in cotton intercropped with clusterbean followed by cotton intercropped with blackgram (Rs. 9,511), greengram (Rs. 8,458) and mustard (Rs. 5,257) when compared to pure cotton crop (Rs. 5,007) (Sanandachari *et al.,* 1980). The cost : benefit ratio was also maximum in cotton intercropped with clusterbean.

## Improving Soil Fertility Status

A distinctive feature of most members of the Fabaceae family is the capability to fix atmospheric $N_2$ biologically. Biological nitrogen fixation (BNF) results from the establishment of a symbiosis between legumes and soil bacteria, collectively known as rhizobia. These microbes invade legumes root and form the structure called nodules hosting the rhizobia and where $N_2$ fixation takes place (Graham, 1998). The quantity of $N_2$ fixed by legumes ranges from 17 to 171 kg per hectare per year depending on the species and prevailing biotic and abiotic conditions (Table 3).

**Table 3.** Estimate of nitrogen fixation by pulses

| Pulse | Estimate (kg N/ha) | Reference |
|---|---|---|
| *Pisum sativum* | 17-69 | Mahler *et al.* (1979) |
| *Vicia faba* | 121-171 | Rizk (1966) |
| Lupine | 121-157 | Rizk (1966) |
| Chickpea | 67-141 | Rizk (1966) |
| Lentil | 62-103 | Rizk (1966) |
| *Arachis hypogaea* | 79 | Rizk (1966) |

Adopted from Larue and Patterson (1981).

Since crop nutrition through fertilizers incurs a substantial cost and thus, it is essential to find economy in fertilizer use. In a trial with fast growing leguminous green manures *viz.,* sunnhemp (Praharaj *et al.,* 2004), lucerne, cowpea and clitoria with three N levels *viz.,* 40, 60 and 80 kg/ha in cotton under irrigated conditions, it revealed that growing and incorporation of all the green manures on 40 days after sowing increased the seed cotton yield (Janardhanan, 1989; Subramaniam *et al.,* 1995). In addition, 25 per cent of N fertilizer can be reduced if the green manures are grown and incorporated in the field. Incorporation of sunnhemp as green manure increased 9.85 per cent seed cotton yield and resulted in maximum nutrient uptake than without green manuring (Baskar, 2004). Several workers opined that growing of legumes, as an intercrop was beneficial to soil health and soil fertility (Basu, 1992).

Positive nitrogen balance was arrived with cropping of sole cowpea, cotton+cowpea (1 : 1) and cotton+cowpea (2 : 1), respectively, at the rate of 92, 92 and 48 kg/ha. However, the transformation of fixed N by cowpea to the companion cotton crop was very low, which was, respectively, 3.5 and 0.5 kg N/ha with respect to 1 : 1 and 2 : 1 intercropping of cotton+cowpea (Rusinamhodzi *et al.,* 2006). The incorporation of cowpea crop residues both under sole and intercropping situation increased succeeding maize yields more than incorporation of residues of sole cotton.

The practice of green manuring through cover cropping is widely adopted in the sub-tropical regions where winter fallow is common. At Sirsa, Haryana, *Melilotus indica* was observed to be promising. Intercropping of legumes helped to reduce the N requirements of cotton to the extent of 25 per cent. At Siruguppa, Karnataka, *in situ* green manuring of greengram (Praharaj *et al.,* 2004) and cowpea was found to substitute 25 per cent of recommended dose of nitrogen.

Studies carried out under rainfed conditions with multicut legumes, used as long year covers in chilli-*desi* cotton and hybrid cotton at Dharwad (Karnataka), revealed that chilli-*desi* cotton and *Stylosanthes hamata* as cover crop at 1 : 2 row proportion with a cutting interval of 45 days saved the recommended NPK nutrients (100 kg N+50 kg P+50 kg K/ha) by about 25-50 per cent in the subsequent year under continuous cropping (Anonymous, 2003). Cover cropping accounted to organic N addition to the extent of 144 kg/ha and increased soil organic carbon from 0.58 to 0.73 per cent (average of two years) leading to overall improvement in soil fertility.

In case of hybrid cotton cv. DHH-11, of the four legume covers (*viz.* lucerne, *S. hamata, S. scabra* and *Centrocema* sp.) screened, lucerne was found most suitable at 1 : 2 row proportions in cotton (120 x 60 cm) at 30 days cutting frequency. Cotton yield was increased by 13.62 per cent and the system reduced weed intensity to the extent of 91.0 and 59.8 per cent with lucerne and *S. hamata* over sole cotton, respectively. Besides soil moisture conservation, cover cropping promised a fertilizer reduction to the extent of 25-50 per cent in subsequent seasons. Lucerne green manuring with 50 per cent N recorded higher seed cotton yield comparable to sole cotton with NPK (Khamble, 2003). Thus, these studies reveal the possibility of sustained production and maintaining of soil fertility through intercropping of legumes in cotton.

**Organic Cotton Production**

Growing cotton organically entails using organic manures (with fertilizers in rock form), and biological controls rather than synthetic fertilizers and pesticides. A system approach to organic production involves the integration of suitable practices *viz.,* cover crops, strip cropping, crop rotation, etc. into a larger system. Through good soil and biodiversity management, farms can become increasingly self-sufficient in fertility, while pest problems are diminished, and some pests are even controlled outright. Thus, a diverse rotation, using legumes and other cover crops, is at the heart of good humus and biodiversity management.

Nutrient management in organic farming solely depends on manures and legumes. Since availability and economical feasibility of using manure is less practicable, *in situ* green manuring with fodder cowpea and its burying at 40 days after sowing will ensure a steady N supply during the grand growth and flowering periods, when the N demand peaks up in the crop. It hastens microbial activity of soil, reduces the weed growth and enhances the natural enemy build-up. This provides around 400-500 kg dry matter per hectare with 2.5 per cent N and contributes 10-12 kg N/ha during squaring. Other benefits include smothering of weeds, controlling soil erosion and nurturing natural enemies of cotton pest (Rajendran *et al.,* 2000). *In situ* incorporation of legumes in biomass production, cotton yield and nutrient status of soil is given in Table 4.

Daincha (*Sesbania aculeate*), a legume, can be raised around cotton field at a width of 2 m; its lopping made cut and are spread between cotton rows at 65-70 DAS. Its fast decomposing leaves provide N during early boll development period and stalks act as temporary mulch, preventing soil moisture evaporation (Rajendran *et al.,* 2000). Even cultivation of green manure crops also supplies optimal quantities of N that is ideal for cotton production (Saraswathy, 2003).

At Dharwad (Karnataka), raising and incorporation (45 DAS) of three rows of horse gram, sunhemp and lucerne between the normally spaced cotton (120 x 60 cm) resulted in higher lint yield of 14.67, 14.4 and 13.9 q/ha, respectively, as compared to sole cotton

**Table 4.** *In situ* incorporated legumes biomass production (45th DAS), cotton yield and nutrient status of soil

| Intercropping system | Seed cotton yield (q/ha) | Organic carbon (%) | Total N (%) | Av. $P_2O_5$ (kg/ha) | Av. $K_2O$ (kg/ha) |
|---|---|---|---|---|---|
| Cotton sole crop | 11.0 | 0.53 | 0.06 | 54.3 | 238.0 |
| Cotton+sunhemp | 14.4 | 0.54 | 0.08 | 57.5 | 269.0 |
| Cotton+cowpea | 12.1 | 0.61 | 0.09 | 61.8 | 266.0 |
| Cotton+blackgram | 12.7 | 0.59 | 0.07 | 58.6 | 254.0 |
| Cotton+lucerne | 13.9 | 0.50 | 0.07 | 45.6 | 253.5 |
| Cotton+soybean | 11.6 | 0.63 | 0.07 | 40.5 | 257.5 |
| Cotton+soybean (black) | 12.8 | 0.62 | 0.07 | 60.3 | 263.0 |
| Cotton+Horsegram | 14.7 | 0.61 | 0.09 | 59.9 | 296.5 |
| Cotton+FYM 10 t/ha | 12.8 | 0.63 | 0.1 | 45.8 | 294.5 |
| S. Em. | 0.44 | 0.01 | 0.003 | 1.7 | 6.29 |
| C. D. (P=0.05) | 1.28 | 0.03 | 0.007 | 4.97 | 18.08 |
| Initial soil analysis | - | 0.54 | 0.06 | 47.0 | 212.4 |

Adopted from Gidanavar *et al.* (1992).

(Gidanavar *et al.,* 1992). At Coimbatore, cotton yield increased by 16-20 per cent with the application of 12-18 t/ha of green manure (Venugopal *et al.,* 1999). Green manuring of intercropped cowpea/sunhemp/horse gram was also beneficial in cotton and reduced N requirements by 25 per cent.

A combination of organics is suitable for higher yield realization. At Coimbatore, combined application of FYM @ 5 t/ha and sunhemp seeded @ 15 kg/ha in inter-rows as green manure (buried at 45 DAP) with or without cotton residues @ 2.5 t/ha produced highest seed cotton yield and was significantly higher over control and NPK (Praharaj and Rajendran, 2007). Thus, application of cost effective organics, available locally, could play as an effective substitute for inorganic fertilization and sustaining the yield.

## Cover Cropping

Besides protecting soil and associated erosion, cover crop provides N to the subsequent cotton when tilled into the soil, thereby improving soil tilth by adding organic matter. Sometimes cover crop serves as a catch crop when planted to reduce nutrient leaching following a main crop. Dense and quick growing cover crops are also used to suppress problem caused by weeds as a smother crop or allelopathic cover. Even mere presence of most cover crops reduces the competition from weeds. When crops are planted into such covers, and cover crop is not killed, then it is referred to as live mulch. Thus, live mulch involves planting of suppressed legume sod that can recover following harvest of the grain crop. Legume live mulches can provide ground cover for erosion control and suppress weeds during crop growth (Worsham and White, 1987).

Living plants and their residue on the soil surface protect the soil from impact of rain drops, reduce soil surface pore blockage and reduce the velocity of running water (Hargrove and Frye, 1987).Crop residues from the root and shoots increase soil organic carbon, water stable aggregation, and macro porosity thereby hastening the rate of water infiltration and soil water retention (Rasse *et al.,* 2000).

Besides supply of BNF-N, cover crops often provide excellent habitat for predatory and parasitic insects and spiders. Some good insectary plants, often used as cover crops, include alfalfa, sweet clover, vetch, red clover, white clover and cowpeas. Migration benefits from the cover crop to the main crop are sometimes associated with the post-bloom period of cover crop. Here, mowing the cover crops in alternate strips may facilitate their movement, while the remaining strips continue to provide refuge for other beneficial species. Long-term cotton cover crop studies have also been tried in Louisiana (Millhollon and Melville, 1991) and at Arkansas (Scott, 1990). The Arkansas study spanned over a period of 17 years (1973 to 1988) revealed that cotton grown after winter cover crops of rye+hairy vetch produced an average of 234 kg more seed cotton per hectare than a control (cotton-winter fallow). Cotton, following pure vetch, showed a 129 kg increase, while yields after rye+crimson clover had a 72 kg yield improvement per hectare. In the long-term Louisiana study, cotton yields declined for the first nine years when cover crops were used, but increased steadily thereafter. In the final four years of the study, cotton yields were 360 kg/ ha higher in following of cotton (without N fertilizer)-vetch rotation as compared to cotton (60 kg of fertilizer N/ha)-fallow. The average of 30-year study period revealed that the highest cotton yields followed in cotton-wheat (60 kg of fertilizer N), cotton-hairy vetch and cotton-common vetch systems.

## Smother Crops

One of the best approaches for reducing problems caused by weeds is increasing the crop density either of sole crop or intercrop. Shading the top soil and competition for water and nutrients will certainly suppress weed germination and growth (Altieri and Liebman, 1986). Highest crop yield and greatest weed suppression are often found with the highest densities of components in an intercropping system (Shetty and Rao,1981). Legumes are often used for cover because they are less competitive with cotton and have the capacity to yield N. Inclusion of forage legumes in cropping system can also be an effective approach to weed control (Entz *et al.,* 1995).

Since mechanism of weed control varies with the cropping system in practice, yet, crop diversification prevents the development of population of specific weeds adapted to cultural practices and resource competitiveness associated with a mono-culture of a single crop or row crops (Liebman and Dyck, 1993). Thus, use of crop specific herbicide- tillage practices results in the proliferation of specific weed species associated with continuous cropping system.

## Component of IPM

The agro-ecology approach in understanding insect population dynamics and pest management is proposed by Altieri (1983). The cropping system using agro-ecology principles of pest management could be developed by studying sustainable models existing in natural ecosystem. In mixed cropping system, out of total insect-pests, 53 per cent showed lower abundance, 18 per cent were more abundant, 9 per cent showed no difference and 20 per cent were variable in the response as compared to sole crop system.

Sometimes, multiple cropping systems are favoured as insects were less prevalent than in sole crops (Altieri and Liebman, 1986). Insects may have more difficulty in finding host plants in an intercrop due to presence of non-host plants, to camouflage of the preferred host, to changes in the texture or colour of the total background, to masking of a chemical attractant, or to presence of a repellent from a non-host plant. Even if insects successfully find the host, there may be interference with reproduction and survival. Mechanical barriers may be present in the form of non-host plants, insects may leave the field more quickly if it is not a pure crop stand, or there may be differences in either the

**Table 5.** Effect of intercropping against cotton leafhopper and bollworms

| Treatment | Leafhopper (No./5 plants) | | | | Bollworm incidence (%) | | | | Yield (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | 30 | 45 | 60 | 75 | 45 | 60 | 75 | 90 | |
| | Days after sowing | | | | | | | | |
| Intercrop | | | | | | | | | |
| Blackgram | 3.3 | 10.1 | 17.3 | 20.9 | 24.0 | 21.3 | 21.1 | 21.4 | 455 |
| Greengram | 3.6 | 12.3 | 18.1 | 25.8 | 24.6 | 24.2 | 21.1 | 23.6 | 440 |
| Clusterbean | 2.9 | 8.9 | 14.4 | 20.4 | 21.8 | 14.7 | 18.4 | 20.9 | 662 |
| Mustard | 5.4 | 17.6 | 25.3 | 26.4 | 32.8 | 25.6 | 23.9 | 23.6 | 349 |
| Pure cotton | 7.2 | 20.0 | 30.3 | 29.4 | 36.1 | 27.8 | 27.2 | 26.2 | 343 |
| S. Ed | 0.7 | 1.3 | 2.02 | 3.7 | 4.7 | 2.7 | 3.4 | 1.9 | 21.6 |
| C. D. (P=0.05) | 1.5 | 2.6 | 4.13 | 7.6 | 9.5 | 5.6 | 6.8 | 3.9 | 44.4 |

Adopted from Suresh and Dasan (1996).

microclimate or the natural enemy population in the intercrop compared to a sole crop environment. There existed a complex interaction of biological, physical and climatic conditions of the intercrop system to provide an "associational resistance" to insects, compared to sole crops of component species (Tahvanainen and Root, 1972).

Among the various causes responsible for the low yield, the losses caused by the insect-pests are of prime importance in cotton. Lowest pink bollworm (*Pectinophora gossypiella)* incidence was observed with cotton intercropped with soybean (Vennila, 2002). Intercropping also influenced the growth, development and maturity of cotton that, in turn, affected *P. gossypiella* damage. Redgram served as an attractant crop for population of *H. armigera* emerging from cotton implying the impact of chronology of cropping system determining host availability and population dynamics of the pest. Cotton+cowpea was most effective in reducing bollworm infestation and comparable with cotton intercropped with soybean system (Rajput and Daware, 2002). The lowest populations of leafhopper (2.89 to 20.44/5 plants) and bollworm (14.66 and 20.94%) were observed in cotton intercropped with clusterbean over different periods and this was at par with blackgram intercropped with cotton, when compared to 7.22 to 36.05/5 plants and 26.22 and 36.05 per cent of leafhopper and bollworm incidence, respectively, in pure cotton crop (Suresh and Dasan, 1996). Leafhopper and bollworm management under intercropping is given in Table 5.

Similarly, a trap crop is planted specifically to attract certain insects. It is then sprayed with some type of insecticide, in conventional management, or left to detain the pests from the cotton crop, or the entire trap crop is tilled under to kill the pest insects. Early-sown cotton has been used as a boll weevil trap crop. Using fall-planted-cotton trap crops to reduce the number of over-wintering boll weevils was proposed (Javaid and Joshi, 1995). In a Mississippi study, Laster and Furr (1972) showed sesame (*Sesamum indicum)* to be more attractive than cotton to the cotton bollworm. More predators on sorghum than on cotton were observed in his Oklahoma strip cropping by Robinson *et al.* (1972). Lygus bug may also be kept out of cotton by using nearby alfalfa as a trap crop. Unmowed or strip-mowed alfalfa is preferred by that pest over cotton (Grossman,1988). Strip cropping of alfalfa prevents the immigration of pest at harvest time and keeps one of the main cotton pests, *Lygus hesperus* under control.

Strip cropping takes place when harvest-width strips of two or three crops are planted in the same field, thereby creating space biodiversity. Strip cropped cotton fields with alfalfa increase beneficial arthropod populations. Among the most notable are carabid beetles that prey on cutworms and armyworms (Grossman, 1989). Planting cotton into strip-killed crimson clover allows growth of cotton without any insecticide.

Thus, in terms of productivity, profitability, maintenance of soil health and fertility, pest reduction and organic cotton production, legumes are suitable as a best companion crop for cotton.

## FUTURE LINES OF WORK

- Breeding of short duration, early, determinate, compact and high yielding legumes with suitability to intercropping in cotton.
- Appropriate implements and machinery for working with legume intercropping need to be developed.
- Post-emergence herbicides selective to cotton based cropping systems are to be identified.
- Awareness in non-adopted areas to popularize the manifold advantages of legumes in cotton production system.
- Identification of location specific cotton based legume cropping system for further fine tuning to meet the multiple needs of the farmers.

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