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Introduction

This issue of *THE ICAC RECORDER* is comprised of three articles in addition to short notes. The first paper is on an environmental audit of the Australian cotton industry which was conducted by Gibb Environmental Sciences Limited and Arbour International Environmental Consultants Limited. The audit was conducted in 1991 at the initiative of the Australian Cotton Foundation with the objective to look into the allegations made by certain critics in Australia that cotton growing and its processing are causing serious damage to the environment. The audit team interviewed people and paid on-site visits to pesticide stores, gins and seed processing plants. In the report, the auditors have reviewed the performance of the cotton industry and have made a number of recommendations on pesticide storage and application, land use, water use, ginning and seed processing to minimize the environmental pollution in the long run. The Australian Cotton Foundation has prepared an action plan, in cooperation with the other cotton research and development organizations, to implement the recommendations of the report.

The second paper also relates to environment protection. There are a number of agronomic measures which help to keep pest populations low and reduce the use of pesticides. Sex pheromones and biological pesticides are an alternative to chemicals. The sex pheromones have already proved their worth. The next hope is microbial insecticides. In this paper the mode of action of viruses and bacteria, which are the only successful source of microbial insecticides, is discussed, as well as the causes of failure of early baculoviruses. Progress in the use of recombinant viruses and bacteria is also reviewed.

Cotton is grown as a rainfed crop in many countries, simply because water is in short supply or the soil conditions are such that inexpensive irrigation is not feasible. Water is required in the root zone for nutrient uptake and to meet evapotranspiration losses. Well levelled soil permits flood or furrow irrigation, but in both cases the water use efficiency is very low. Fertilizer nutrients leach down, accentuating waterlogging, or are taken away with the water run-off. Drip irrigation and sprinkler irrigation do economize on water use, yet there is another option: subsurface drip irrigation. In the third paper, results from some experiments on subsurface drip irrigation are discussed, which show that subsurface irrigation, in addition to economizing water use, also gives higher yield on sandy soils, and has shown to provide more efficient use of fertilizer.

Australian Cotton Industry Environmental Audit

The cotton industry in Australia has developed in a short span of time. Pesticide use increased, as in many other countries, but its manifold increase is also attributed to rising area. Some critics allege that heavy use of pesticides and other aspects of cotton production are causing serious damage to the environment. The Australian Cotton Foundation, realizing the importance of the environment, decided to commission an independent audit of the cotton production industry to ascertain which environmental problems are occurring and how they could be solved. In December 1990, Gibb Environmental Sciences and Arbour International of the United Kingdom were commissioned to conduct the audit and identify the major environmental issues, assess the overall performance of the industry and recommend measures to reduce environmental pollution. Production practices, ginning and seed processing were included in the evaluation.

Audit activities included interviews with key individuals within and outside the industry. The audit team visited farmers, gin personnel, research scientists, aerial operators, seed producers and various government and business personnel dealing with cotton. Site visits to fields, pesticide warehouses and cotton gins were also included in the survey.

From the data collected no convincing evidence could be found that aerial spraying caused unacceptable levels of environmental damage. It was observed that unpleasant smells drifting to villages or towns are not a result of pesticide drift but odors which are released as a result of decomposition of organophosphate pesticides. However, use of suitable clothing to avoid exposure, observance of re-entry periods, pesticide storage, unscientific mixing of pesticides and disposal of pesticide containers were identified as areas where the industry must improve its performance. Regarding fertilizer use, it was observed that fertilizer has the potential to cause damage to the environment through eutrophication of waterways and volatilization which causes nitrous oxide to be released into the atmosphere. Water use was found to be efficient, except for tail-water run-off in the case of furrow irrigation, which needs to be minimized and reused properly instead of diverting it into rivers. Dust control and monitoring, both at gins and seed processing plants, was also found to be an environmental concern which needs improvement. The principal recommendations made in the report to overcome the above mentioned dangers follow.

Recommendations Concerning Pesticide Use

Application of Pesticides

1. Poor performers among aerial operators and growers should be reformed or removed from the industry. This should be primarily achieved by industry (Australian Cotton Foundation, Aerial Agriculture Association of Australia and Agricultural and Veterinary Chemicals Association of Australia) education programs and peer pressure.

2. The Aerial Agriculture Association of Australia should continue to exert pressure on all operators to join the Association and become accredited.

3. The Australian Cotton Foundation should encourage its members to use Aerial Agricultural Association of Australia's accredited aerial operators.

4. Regulatory authorities should maintain tighter control of pesticide use as a disincentive against poor standards.

5. More monitoring of spray drift in populated areas is required. Air monitoring should be introduced in a small number of key sites (for example, Wee Waa, Moree). Methods used should be comparable with those currently used in Emerald.

6. Tank mixing of several chemicals to be simultaneously applied should not be carried out without firm guidance on the compatibility of the products concerned. Commonly required mixtures should be identified and research conducted to confirm their compatibility.

7. Chemical handlers should be provided with and required to use proper protective equipment including full overalls.

8. Field workers such as bug checkers and chippers should also wear appropriate clothing, including long trousers and shirt sleeves.

9. Employers should provide laundry facilities at the place of work for the washing of pesticide-contaminated work clothes.

10. Aerial spraying has many advantages over boom spraying, including the need for fewer operators and thus less occupational exposure to pesticides; easier control by regulatory authorities; and less soil compaction.

11. New farms should be designed with aerial spraying ill mind so that potential spray drift problems are avoided.

12. Rural communities surrounded by cotton farms should plant tree-lines as biological buffers. Species should be chosen to maximize effectiveness as barriers to spray drift.

13. Cotton farmers should plant tree lines around their own properties (with due allowance for the safety of crop spraying aircraft) to limit the drift of spray off the property.

14. Planning authorities should exert controls to ensure that new housing is sensibly zoned in relation to existing cotton farms to avoid potential spray drift problems. Zoning of new cotton farms should similarly take account of existing residential development.

15. Doctors/health workers should be encouraged to maintain long-term data bases on incidence of cancer, asthma and allergies in cotton growing areas.

16. Chemical companies should provide information on the minimum re-entry periods which should be observed after crops are sprayed for all products.

17. Pesticides likely to produce strong drifting odors should be avoided in areas where use could lead to public nuisance.

18. Research into integrated pest management techniques should be continued and encouraged, helping to avoid problems of pesticide resistance and contributing to a reduction in the quantities of pesticide used.

19. Continued observance of the Pyrethroid Strategy is essential in order to continue to avoid pesticide resistance undermining current ability to control pests with available products.

20. Research into all aspects of pesticide resistance should be maintained and encouraged.

21. Aerial operators should be encouraged to purchase turbine engine aircraft when current piston-engine aircraft are due for replacement. In areas where noise complaints are frequent, the immediate replacement of piston-engine aircraft should be considered.

Storage of Pesticides

22. All pesticides and herbicides should be stored under lock and key and preferably under cover.

23. Pesticide stores should have adequate space for the quantities of chemical to be kept, have proper bonding, segregation of different products and security control.

24. Chemical storage and handling needs improving. The Australian Cotton Foundation, the Agricultural and Veterinary Chemicals Association and the Aerial Agricultural Association of Australia should have a strong education policy to ensure that growers and aerial operators are aware of the correct procedures.

Disposal of Pesticide Containers

25. Proper facilities should be provided for the disposal of pesticide containers. The Australian Cotton Foundation should lobby government to achieve this.

26. The industry as a whole, including chemical manufacturers, aerial operators and growers, should work together to increase the proportion of chemicals supplied in bulk or in reusable containers.

27. The industry as a whole should also seek ways to increase the proportion of steel drums which are recycled instead of being buried.

28. The use of empty pesticide containers for secondary purposes, such as trash cans, should be completely avoided.

29. Where burial of pesticide containers on-site is the only option, growers and aerial operators should ensure that pits are managed to the highest possible standard. Detailed records should be kept of the location and contents of pits.

30. In case of liquid waste evaporation, pits should only be dug on sites where adequate testing has ensured that the ground is impermeable. Evaporation pits should be lined.

31. Evaporation pits should be securely fenced and signed to prevent people or animals accidentally entering them.

Recommendations Concerning Land Use

Acquisition of Land

32. The Australian Cotton Foundation should develop an environmental policy or code of good practice on land acquisition. This should not only detail where new cotton fanning developments should be encouraged (and where they should not), but should also cover aspects such as the layout and design of the newly established farms and their proximity to residential areas and sensitive wildlife habitats.

33. Land use changes involving the cotton industry should be documented in detail. A data base should be established to include details of previous land use (and, in cases where land ceases to be in use for cotton, sub-

sequent land uses), details of adjacent land uses and information on natural/semi-natural habitats present on the land before and after the change.

34. Growers who wish to develop large areas for growing cotton where there could be significant environmental impacts should be encouraged to undertake an independent environmental assessment of the proposals.

35. Where it is compatible with their overall farming operations, growers should be encouraged to retain areas of natural vegetation on their farms to encourage wildlife.

36. Growers should be encouraged to incorporate features to promote wildlife in water storage lagoons in so far as this is compatible with the primary function of the lagoons.

Treatment of Land

37. The practice of good agricultural methods to minimize problems of soil compaction and erosion should be encouraged.

38. Landcare groups should be promoted. This is an effective way of disseminating information, putting pressure on poor performers and liaising

with the local community. Both the number and status of cotton farming landcare groups should be increased and their activities promoted.

Recommendations Concerning Water Use

Water Abstraction

39. The water requirements of important wetlands should be recognized by the water authorities in their allocation of quotas.

40. Research into methods of cotton growing which could reduce water requirements (for example, use of short season varieties, better scheduling of irrigations, improvement of soil management) should be encouraged.

41. The rate of depletion of groundwater reserves should be monitored.

Water Management

42. All tail-water should be recycled. Both peer pressure amongst farmers and government inspections should be used to encourage the worst performers to improve their performance.

43. At least the first storm water run-off should be withheld and the water storage capacity on cotton farms should include allowance for this.

44. Studies should be conducted to provide realistic guidelines as to how to calculate the size of this first flush. The cotton industry should commission appropriate studies.

45. In areas such as Emerald, where the entire irrigation scheme was set up without provision of tail-water recycling, growers should set and work towards a realistic date for complete reticulation of tail-waters.

46. Research into the impact of pesticide contamination on population levels of fish and other aquatic wildlife would be useful.

47. Fish kill incidence should be promptly investigated by the responsible authorities to a set of specific criteria, providing a disincentive against illicit tail-water releases and helping to identify any other causes of catastrophic mortality.

48. Ground water supplies should be monitored for signs of contamination by pesticides or nitrate.

49. The use of billabongs for water storage should be discouraged.

Recommendations Concerning Cotton Processing

Ginning Operations

50. Dust abatement systems (fabric filters) should be fitted to all ginning sites. Obscuration meters should be fitted to the fabric filter outlets with visual and audible alarms and recording charts. The system will require a regular maintenance schedule. Monitoring records should be kept for at least 30 years.

51. Annual lung function tests should be carried out on all permanent staff. The records should be kept by the company for at least 30 years.

52. Plant layout should be such that air entering the gin building should be from a clean area, and suction points/doors/exit ports should be located near areas of high dust levels. Also, the layout should allow employees to

proceed from the outside to the rest and lunch areas without having to go through the ginning area.

53. Floors and equipment surfaces should be vacuumed down frequently during a shift; use of compressed air for clearing dust from surfaces should be discontinued.

54. Doors of enclosed console rooms should be kept shut.

55.All indoor personnel should use respiratory protection (class L disposable masks). Note that the masks offer adequate protection only if used correctly.

56. A program of employee education should be undertaken to emphasize the risks of dust inhalation and to demonstrate the best practicable means for reducing dust levels and avoiding excessive particle inhalation.

57. Employee exposure to noise in gins should be reduced.

58. Regular monitoring of noise levels should be undertaken.

59. Annual hearing tests should be carried out on all permanent staff.

60. In-house health and safety audits should be undertaken at all cotton processing facilities, including a review of previous accidents and of current safety procedures.

61. Accident Books should be maintained at all processing facilities. Information such as the nature of injury, part of body involved, where accident occurred, date, time, person to whom the accident was reported, lost time, activity undertaken when accident occurred, other people or vehicles involved etc. should be recorded.

62. More appropriate methods of reducing road dust at gins such as damping down with water or laying down a permanent road surface should be considered. The spreading of waste oil for this purpose should cease.

63. All solid waste should be sent to a competent waste disposal contractor who is licensed to accept and/or treat the specified waste stream. Waste treatment and disposal must be undertaken in a controlled manner.

64. The uncontrolled burning of trash should be avoided.

Cotton Seed Processing

65. An appropriate program of dust reduction, dust monitoring and employee testing should be implemented.

66. Routine monitoring of the noise and audiometry tests should be undertaken. If the process or the machinery is changed significantly, a new survey on noise should be undertaken.

67. A routine monitoring program for HCl, ammonia and ammonium chloride should be implemented at the seed processing plant. Future monitoring should assess personal exposure limits (short and long-term) and should compare these to existing statutory limits and international guidelines.

68. The "Sentinel" waste treatment system for the handling of pesticide wastes generated by seed treatment should be regularly maintained and the filters replaced to ensure satisfactory performance.

69. The water in the evaporation pond receiving effluent from the treatment plant should be subjected to occasional monitoring to verify that high

levels of pesticide residues are not budding up. Proper fencing and signing of the evaporation pond is also required.

70. The on-site burial of sludge produced by the system is an undesirable practice. Ideally this waste, along with spent filters, should be disposed of by a competent licensed contractor.

71. Where on-site disposal of sludge is unavoidable, investigations should be undertaken to ensure the suitability of the disposal site, and the location and quantities of buried sludge should be recorded.

Action Plan

The Australian Cotton Foundation, in cooperation with the Cotton Research and Development Corporation, the Australian Cotton Growers Research Association, the Aerial Agricultural Association of Australia, the Agricultural and Veterinary Chemicals Association, the Cotton Consultants Association, the Irrigators Association of Australia and cotton seed distributors, has prepared an action plan to implement the recommendations. Regarding pesticide use, which is of direct concern to growers, the Australian

Cotton Foundation will provide specialized education programs to disseminate information on misuse of mixtures, re-entry periods, evaporation pits and justified use of pesticides, The Cotton Research and Development Corporation will commission a project to address the pesticide resistance problem. Wherever required, the concerned institutions will maintain a data base of necessary information. The ginners will include the recommendations of the audit in their programs to upgrade and maintain their gins. The ginners and cotton seed distributors will also improve their occupational and health standards. The action plan spells out the role of various components of the Australian cotton industry to implement the recommendations.

Microbial Insecticides

Pesticides have now become undoubtedly the most important input in agriculture. They have contributed significantly in the last 40 years to improved productivity of crops by safeguarding against heavy losses due to pests. If applied in good time and properly, they ensure minimum wastage of other inputs, including the operator’s technical know-how and economic resources. On the other hand, insecticides being highly toxic, have always been unsafe to handle without proper care. But now, two major disadvantages of pesticides are becoming Of more concern to society: first, the ill-effects of insecticides on the environment are now being realized; secondly, the resistance reported in target species has posed a serious challenge to researchers. Additionally, heavy use of insecticides can be associated with the outbreak of secondary pests, rapid resurgence of target pests and destruction of non-target organisms, especially the beneficial natural enemies. Under such circumstances it is natural to look for alternatives which could at least decrease the use of pesticides, if not eliminate them. One option could be the use of microbes for pest control. They are safe to non-target pests and do not leave residues which may be harmful to beneficial insects, mammals, fish, birds and other non-target organisms. Bacteria, fungi, nematodes, protozoa and viruses have shown their potential as microbial insecticides. The entomopathogenic nematodes are effective against sucking and chewing insects, but their effect is dependent on high humidity for transmission, making them more suitable for soil-borne pests rather than aerial use. Viruses and bacteria have been used more extensively on cotton in a number of countries.

Viruses

Viruses were identified to be a source of insect control even before the pesticides were developed and marketed. Among the naturally occurring insect pathogenic viruses, baculoviruses have shown the greatest potential for pest control from the point of view of safety and effectiveness. The baculovirus insecticides are benign to non-target insects, leave no environmental residues, can initiate infection from a single cell and are sometimes cheap to produce. However, they are not a good replacement for insecticides due to their slow rate of effect, conditions for their ingestion by the target host, rapid inactivation by ultraviolet light, long-term storage disadvantages and sometimes higher cost of production. Unexpected circumstances have also led to non-expansion of certain biological insecticides. One example is the use of the baculovirus "Elcar" manufactured by Sandoz in the early 1980s. It showed effective control of *Heliothis* species on cotton in many countries, which favored its registration as a commercial product. But unfortunately, the release of Elcar coincided with the introduction of synthetic pyrethroid insecticides which seemed to solve many of the poor control problems associated with older chemical insecticides. As a result, Elcar could not gain a market and had to be withdrawn. A slow rate of kill (4-6 days) during which the larva will continue feeding and cause damage to the crop, a weak effect on medium to large-sized larvae and the half-life of the virus under field conditions were undesirable characteristics of Elcar. These problems will have to be overcome if such entomopathogens are to be used on a commercial scale.

Interest in controlling cotton pests with entomopathogens has grown in the past few years on the account of the undesirable aspects of pyrethroids and environmental issues. The pathogenic viruses have been found to affect more than 12 major cotton pests. These viruses are mainly from the *Baculoviridae.* Three recognized families of *Baculoviridae* are the nuclear polyhidrosis viruses (NPV), the granulosis viruses (GV) and the non-occluded baculoviruses. Among viruses, NPV and GV have the unique characteristic of producing a large pseudo-crystalline protein matrix known as the inclusion body. The mature viruses are embedded in the inclusion body, which provides shelter and stabilizes the virus particles in the environment (usually on the plant surface and soil) until they are ingested by the host and initiate another life cycle. The only mode of infection is by host ingestion, followed by incorporation in mid-gut cells and later by other susceptible cells, causing lysis, liberation of viral products and eventual organ disruption, leading to death of the insects. The virus-affected larvae continue feeding and movement until they die.

The baculoviruses have been tried in more than 19 countries, mainly against lepidoptera. In many cases they were found to be more effective against *Heliothis* species, and control equivalent to the chemical insecticides has been reported. In the USA, successful control of *H. zea and H. virescens* has been reported with this virus. In 1990, the USDA applied *Heliothis* species NPV to 100 square miles so as to control the insect on alternate host plants. In Australia *H. armigera* has been controlled successfully. China has been using this virus on a large scale to control *Heliothis.* NPV has also been successfully used in a number of other countries, but the most successful use of a baculovirus has been reported in Colombia, where the application of *T. ni* NPV is so effective in controlling *T ni* larvae that it has replaced all other control measures for this pest.

Recombinant Baculoviruses

Foreign genes can be introduced into baculoviruses alongside a duplicate copy of the polyhedron promoter, therefore permitting the construction of recombinant baculoviruses that express high levels of foreign proteins but which still produce mature polyhedra no less stable in the environment than normal viruses. In Australia, the CSIRO Division of Entomology, -in cooperation with ICI (Australia) and ICI Agrochemicals of the UK, is undertaking studies to develop a baculovirus insecticide against *Heliothis.* The virus selected for studies was NPV isolated from *Heliothis armigera* which has similar properties to the one used in Elcar. The studies were undertaken with the objective to insert a foreign gene having an insecticidal effect into the viral genome, thereby producing an engineered virus that has insecticidal activity against *Heliothis* species. In August 1991, it was demonstrated that by introducing foreign genes into the genome of NPV, a faster acting virus could be produced. It was observed that the larvae infested with resultant recombinant virus ceased feeding and became paralysed before they would if infected with the normal virus. This gives the hope that, in the not too distant future, a faster acting *Heliothis* virus can be generated and used commercially as a biological insecticide.

Bacteria

Microbial control of cotton pests, other than baculoviruses, has been tried extensively with entomopathogenic bacilli. Within this group the main species tried is *Bacillus thuringiensis (Bt).* Most of the research has been carried out with the Bt variety *kurstaki,* the HD-1 strain. The bacterium contains a protein crystal within the bacterial spores. In most cases it is this crystal, the endotoxin, that provides the insecticidal properties of this microbe. When the spores of Bt are ingested by the target insect, toxin is released in the mid-gut causing loss of the integrity of the mid-gut epithelium, resulting in paralysis of the host. Bt has the advantage (over baculoviruses) that the insects stop feeding soon after ingestion of the bacterium. This advantage is the reason why Bt now forms one of the important components of integrated pest management in many crops, accounting for 90% of the total use of microbial insecticides.

Use of Bt for the control of *Heliothis* and many other species of lepidoptera in cotton has been reported in 16 countries. In the US, the early trials conducted in the 1970s, showed that Bt failed to provide satisfactory commercial control under heavy populations of the insect. This result may be attributed to the fact that *Heliothis* does not feed on foliage for a long time and finds its way to fruiting parts rapidly. Large scale use of Bt for experimental purposes has been reported in the USA and the former USSR. Several years of experiments in the USA have shown that strains better than Bt HD- I are available. Currently, intensive research efforts are underway in private and public sector institutions to develop improved strains of Bt. The possible approaches are as follows:

- Non recombinant means of constructing more potent toxin gene combinations
- Recombinant methods to engineer transgenic plants which express the Bt toxin
- Insertion of Bt endotoxin into endophyte cells inhibiting the vascular system

Any of these approaches may give rise to products which can be successfully employed as an alternative to pesticides.

Lately, genetic engineers have increased the insecticidal expression of Bt strain HD- I in cotton plant tissues by altering the coding sequence for proteins so as to be more plant-like. In 1990, transgenic cotton plants carrying a gene construction coded HD-1 were compared under sprayed and unsprayed conditions with non-engineered cotton by Texas A&M researchers at College Station, Texas, USA. Transgenic plants, both under sprayed and unsprayed conditions, showed fewer larvae of budworm and bollworm as well as a lower percentage of fruit infection, which could cut insecticide application by about 50%. In other studies, different species of *Heliothis have* shown different levels of sensitivity to the pathogen. It has been found that *H. virescens* is almost 50 times more sensitive to engineered toxin than *H. zea.* Chembred, which is a subsidiary of Calgene in the USA, plans to test Bt strains during 1992 in some Latin American countries (personal communication).

It roughly costs US$ 3-4 million and a period of about three years to develop a microbial pest control agent, as against US$ 40-80 million and 8-

12 years in the case of a new chemical control agent, thus the utility and promise of microbial control of cotton pests, particularly *Heliothis.* Research efforts usually proceed from *in vitro* to field evaluation and then to commercial adoption. In the case of the Bt gene, research has reached the stage of field evaluation, but it will still take some time before microbes replace chemical insecticides.

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Subsurface Drip Irrigation Experiments in the United States

The cotton plant is not a water loving plant, yet it needs more than 150 hectare centimeters of water to mature under flood irrigation. Nature has rewarded some regions/countries with a high wealth of water for agricultural purposes, either through rainfall or irrigation. In those countries with abundant storable water resources, soil is the key factor determining the irrigation method as well as schedule. Flood irrigation and furrow irrigation are cheap, but some soils are not suited to these methods because of their texture, low water holding capacity, poor infiltration rate and steep topography. In other countries, scarcity of water compels the exploration of ways and means to reduce water use per unit area.

In the USA, the most common method of field crop irrigation, in terms of area, is furrow irrigation, followed by sprinkler. Subsurface drip irrigation has generally been confined to high valued vegetables and orchards. Wherever the irrigation supply is limited, it is vital to minimize evapotranspiration losses. The results of some experiments undertaken in the USA on water conservation through subsurface drip irrigation are discussed below. Subsurface drip irrigation has been compared with furrow irrigation in good and poor soil to see the effect on yield. Subsurface irrigation has also been studied at various levels of fertilizer use and quantity of water released per day.

Subsurface Irrigation Compared to Furrow Irrigation

Furrow irrigation is easy to use and may not require heavy initial investment. But, in furrow and flood irrigation, the soil intake rate, soil homogeneity, slope and management skills make precise control of the irrigation water more difficult. The evapotranspiration rate is very high in areas where the cotton growing season is characterized by dry and hot climatic conditions. Under such circumstances, there is very low irrigation application efficiency. The following data on subsurface versus furrow irrigation relate to experiments conducted at the USDA-ARS Cotton Research Station, Shafter, California, for two years. Subsurface irrigation was compared with furrow irrigation on good soil and poor soil. Good soil means vertically and horizontally uniform soil with about 40% silt. Poor soil is very sandy, about 90% sand particles, with large buried pockets of pure coarse sand scattered about the field and approximately 30.5 cm of usable soil above them. There was also a clay layer at 1.2 to 1.5 meters in depth. The drip tubes, with a 20 mm diameter, were buried 38 cm deep under alternate furrows of cotton, grown with 75 cm row spacing. The tubes had emitters every two feet discharging one gallon of water/hour/emitter. The emitters were a treflan-impregnated, labyrinth type, placed inside the tubings before they are extruded so that there are no joints. They operated at a pressure of 20 lbs/sq inch. The results obtained on average over the two years are as follows:

	Lint Yield (kgs/ha)	
Soil type	**Subsurface Irrigation**	**Furrow Irrigation**
Good soil	1859	1875
Poor soil	1768	1552
	Net Water Applied (ha/centimeters)	
Good soil	158	252
Poor soil	153	273

The net water applied on furrows is the total water applied to field less the runoff to a tail-water return system. From the above data it may be observed that there are no differences in lint yield in the case of drip irrigation and furrow irrigation in good soil, although the quantity of water used in the case of drip irrigation was 94 ha centimeters less than in compared to furrow irrigation. In terms of percentage, drip irrigation gave the same lint yield with only 63% of the total water used. However, the real benefit of drip irrigation can be seen on poor soil where there was an additional benefit of 216 kgs lint/ha. The water savings were even higher, i.e. 120 ha centimeters. The results apply to a variety of sandy soils.

Subsurface Drip Irrigation With Varying Levels of Water and Fertilizer

Various levels of nitrogen and quantities of water were tried on silty clay loam soil in West Texas. The soil profile had a very thick and less permeable layer at 0.9 m deep. Nitrogen was applied at the rate of 64, 99, 144, 183 and 224 kgs N/ha. Out of the total, 64 kgs/ha was applied before sowing, while the rest was injected via the trickle tape in the form of a urea-ammonia nitrate solution. The drip system was installed prior to planting approximately 36 cm deep in the soil. The field was irrigated with trickles before sowing at the rate of 28 ha centimeters. The quantity of water applied during the season varied from 0.46 to 4.45 ha centimeters/week. The crop was grown with one meter row spacing, but the trickle tapes were installed so that each tape would supply water to two rows. The data recorded on lint yield are as follows:

Water Rate	**Nitrogen Rates (kgs/ha)**					
(ha centimeters/day)	**64**	**99**	**144**	**183**	**224**	**Average**
0.06	708	548	492	478	640	573.2
0.13	768	676	566	547	662	643.8
0.32	936	1013	797	908	943	919.4
0.38	1222	1286	1109	1144	1221	1196.4
0.53	1132	1278	1272	1244	1085	1202.2
0.64	1271	1268	1282	1308	1337	1293.2
Average	1006.2	1011.5	919.7	938.2	981.3	971.4

It is apparent from the data that the water levels certainly increased the lint yield under all fertilizer treatments. Maximum yield was generally achieved at the highest water level of 0.64 ha centimeters/day, although there does not seem to be much gain over rates of 0.38 and 0.53 centimeters/day. The nitrogen levels did not affect the lint yield. Even no addition of nitrogen in the trickles resulted in an equally good lint yield.

Water Applied in Subsurface Irrigation and its Effects on Yield

The most important advantage of trickle irrigation seems to be its economy in water use. Experiments have been conducted for more than ten years to establish the water requirement in the case of subsurface drip irrigation. A team of research scientists at USDA-ARS, Water Management Research Laboratory in Fresno, California, conducted experiments on *G. hirsutum* (Variety *Acala* SJ-2) from 1979 to 1991. The results achieved are as follows:

Year	**Water Applied (centimeters/ha)**	**Lint Yield (kgs/ha)**
1979	145	1560
1980	164	1399
1981	175	1668
1982	163	2044
1983	161	1614
1987	150	1614
1987	164	2098
1988	170	1453
1990	151	1937
1991	165	1829

From the above data it is observed that on average 158 ha centimeters of irrigation water was applied in the above mentioned experiments to achieve near maximal yield. Under the circumstances, where agricultural water supplies are unlikely to improve in the near future, subsurface drip irrigation can be a good alternative to save irrigation water.

Subsurface Drip Irrigation and Water Use Efficiency

It is important to reduce soil water drainage particularly in areas where the water table is high and saline. The addition of unnecessarily high amounts of irrigation water, more than the requirement of the plant, enhances deep percolation. Subsurface drip irrigation provides optimum soil moisture for the plant to grow, bear fruit and mature. The least drainage minimizes salinity and waterlogging, especially in areas where such a threat already exists. The water use efficiency of subsurface irrigation was compared with Low Energy Precision Application (LEPA) irrigation, improved furrow and historical furrow irrigation for two years. LEPA is a system of irrigation developed by the researchers of the Texas Agriculture Experiment Station in the early 1980s as an alternative to center-pivot irrigation. The center-pivot system has an advantage over row irrigation in areas where water is in short supply, because it can irrigate more efficiently. LEPA can irrigate even more efficiently than the center-pivot system. The results of the experiment are as follows:

Treatment	Year	Lint Yield (kgs/ha)	Water Applied (centimeters)	Water Use Efficiency (kgs/ton)
Subsurface	1989	1172	144	1.28
	1990	1447	151	1.06
LEPA	1989	1139	126	0.97
	1990	816	170	0.53
Improved Furrow	1989	1193	188	0.70
	1990	1188	126	1.19
Historical Furrow	1989	1212	195	0.70
	1990	1429	182	0.88

Water use efficiency was calculated by taking the mass ratio of lint yield to water applied (kgs/ton of water). The results were mixed. In 1989, subsurface drip irrigation gave the maximum water use efficiency. This result was not repeated in 1990.

It has also been noted that a low water supply forces the plant to use water from the shallow water table, particularly at the end of the growing season, ultimately lowering the water table and helping to prevent salinity problems. Phene et al (1991) have recommended this practice as a short-term means of reducing and controlling drainage outflow.

Economics of Subsurface Drip Irrigation

It appears from the reports so far that subsurface irrigation saves water use and utilizes fertilizer more efficiently, but is it economical to install the system compared with conventional or improved furrow irrigation and sprinklers? Smith et al (1991) reported the economics of various systems using grower records. While calculating the economics of each system, capital recovery was assumed to be 10 years at 10% interest. The data showed that trickle irrigation gave a net return of US$ 663.66 per hectare as compared to US$ 315.42 and US$ 321.30 per hectare in the case of improved furrow and historic furrow respectively, and a loss of US$ 201.71 per hectare in the case of low energy precision application. Smith et a] (I 99 1) concluded that increased yield and thus net returns are needed to compensate for the increased installation cost of subsurface drip irrigation. Additional advantages will be a reduction in the subsurface drainage water disposal costs and an increase in the ability to sustain long-term irrigation/agriculture in specific conditions. Subsurface drip irrigation has the disadvantage, in addition to costs, of disturbance in interculturing and deep plowing. From the results reported it can be concluded that

- It is economical to use subsurface irrigation on sandy Soils to achieve increased yield.
- Subsurface irrigation gives higher water use efficiency.
- Cotton will use more water than actually required to produce a good yield if it is applied.
- Subsurface irrigation helps to provide a solution to control waterlogging.
- Under water shortage conditions, subsurface irrigation can help to maintain or expand area.
- Subsurface irrigation provides more efficient use of fertilizers.

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Short Notes

- Africa produces about 25% of the world phosphatic fertilizers but it might increase its share in the years to come. Morocco is the biggest producer in North Africa, but its production has been falling. Tunisia has improved its industry to produce 6,620 tons per annum of phosphate, making it the fifth largest producer in the world. Its production mainly comes from the superphosphate plant at Sfax constructed in 1952. However, the industry made significant improvements in infrastructure after 1970. Tunisia's phosphate rock mining industry is managed by the state-owned Compagnie des Phosphates de Gafsa. Processing is carried out by Le Groupe Chimique Tunisien. The third biggest producer in Africa is Togo which has the largest mine reserves. In the recent past, its production was disrupted by industrial turmoil but is expected to improve shortly. South Africa also produces a sizeable amount of phosphatic fertilizers to meet the requirements of its well developed agricultural industry and also for export. It has the additional advantage of a low content of heavy-metal contaminants in the material coming from Phalaborwa, located in the Northeastern Transvaal. The state-run company, Foskor, is actively expanding its production capacity. According to data as of mid-1991, its capacity had increased to four million tons per annum. The fertilizer industry in Zimbabwe is also well developed. In fact, Zimbabwe has one of the oldest plants in the region, where superphosphate production started in 1928 using raw bones as the source of phosphate. In 1958, another superphosphate factory was opened at Msasa with facilities for the production of sulfuric acid and phosphoric acid, using imported Moroccan phosphate rock. The present raw material source is local, from Dorowa. The phosphatic fertilizer demands in Zimbabwe have been almost constant at 5 1 0 thousand tons per annum for the last ten years, thus leaving a surplus for export. (Source: *African Business, No.* 162, February 1992)

- Potash is a major element of plant nutrition, but not much emphasis has been given to maintaining it in the soil, with most efforts devoted to meeting nitrogen requirements. Now that cotton in many countries gets sufficient nitrogen for plant growth and yield expectations have become high, potassium deficiencies are becoming realized. At the U.S. Beltwide Cotton Conferences, held in Nashville, Tennessee, from February 6-10, 1992, a special session was held on potassium. Papers were presented by ten university professors and two researchers from the Potash and Phosphate

Institute in Starkville, Mississippi, on various aspects of potash uptake, movement in the soil, utilization by the plant, methods of potash application and varietal responses to potash. Potash deficiency symptoms appear as a light green to golden mottling between the veins which turns the leaf margins brown. Severe soil deficiencies may make the plant leaves shed, thus affecting quantity as well. The symptoms can be corrected with timely application of soil-applied potash. In adverse situations, the speakers even supported foliar application. An interesting aspect of the presentations was the effect of potash on quality characteristics of cotton. It was noted that without the required quantities of potassium, the plant cannot produce an adequate amount of carbohydrates, i.e. sugars and starches, which are the main components of lint. K_2O deficient soils also produce less leaf area, chlorophyll concentration, CO_2 assimilation and produce low micronaire cotton which is usually noted after ginning. The data reported indicated that potash sufficiency led to an increase in ginning outturn, on average, by 0.8%, but varietal differences were noted. Resistance to verticillium wilt was also reported by more than one speaker on the basis of work done at Stoneville and Starkville, Mississippi.

- The International Commission on Occupational Health (ICOH) has a Committee on Organic Dust which deals with the effects of inhalation of organic dust and research and teaching on matters related to respiratory and non-respiratory diseases caused by organic dust. The Committee on Organic Dust organized the Sixteenth Cotton Dust Research Conference in Nashville, Tennessee, on January 9-10, 1992, in conjunction with the U.S. Beltwide Cotton Conferences. At the Cotton Dust Research Conference, papers were presented on changes in lung function, bronchial reactivity and cellular influx in people working in spinning mills. Some studies conducted on guinea pigs of pulmonary response to inhalation of cotton dust and changes in the airway reactivity were also presented. It was reported that inhalation of cotton dust by animals elevated their breathing rate, caused infiltration of neutrophils and lymphocytes into the air spaces, enhancement of zymosan-stimulated superoxide release from alveolar macrophages and airway closure. Young animals were found to be more sensitive to cotton dust than larger animals. Studies conducted on tannin extracted from cotton bracts, which is a potent agonist and intracellular calcium inhibitor, were also reported. It was remarked that endotoxin levels did not change in cotton samples stored for a period of six years, but there was a small decrease in endotoxin levels in samples from cardrooms. Speakers were mainly from the USA, United Kingdom and Sweden. The Committee on Organic Dust has published a number of scientific reports from its meetings, which can be obtained from the Chairman's office at the Department of Environmental Medicine, University of Gothenburg, P.O. Box 33031, S-400 33 Gothenburg, Sweden.

- A new book on "Weeds of Cotton: Characterization and Control" has been published by The Cotton Foundation in the US. The book has been written by 30 leading scientists, and it has been edited by two outstanding scientists, Drs. John R. Abernathy and Chester G. McWhorter, who have also contributed material for the book. The publication has fifteen chapters containing a taxonomic key for identification of major cotton weeds, their interference with cotton, control trends, herbicide use and herbicide and weed indexes. The publication, which is priced US$45 (postage and handling charges for mailing in the USA inclusive), will be available from April 1, 1992 from The Cotton Foundation, P.O. Box 12284, Memphis, Tennessee 38182-0284.