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AGRICULTURAL SYSTEM STRUCTURE AND THE EGYPTIAN COTTON LEAFWORM

W.B. Clapham, Jr.

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

W.B. Clapham, Jr., is presently with Environmental Perspectives, Inc., 2081 Lamberton Road, Cleveland, Ohio, 44118, USA.

PREFACE

The interactions between agriculture and the environment have emerged as important factors linking the concerns of the agriculturist, the economist, and the systems analyst. Recognition of their importance has led to the establishment of a task at IIASA to study the environmental problems of agriculture. During the first year of this task, it has looked at environmental problems at the field level and at the regional and national levels. In addition, it has attempted to provide a framework which can allow the insights made at one level to become meaningful at the others as well.

This paper provides a fairly detailed look at a particular environmental problem of agriculture in a developing country. The Egyptian cotton leafworm is a particularly good example of such a problem, as it is significant at both the field and national levels. Furthermore, one must take a rather broad view of the problem in order for it to make any sense. Concentrating on the regional economics of the pest without considering its biology opens no new avenues for solution of the leafworm problem, and the same is true of concentrating exclusively on the pest. Looking at the biology of the pest in the context of the overall farming system, however, provides some insights into potential new control strategies which could be introduced in the real world with a minimum of difficulty.

Acknowledgements

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ABSTRACT

Many problems of agricultural production systems can be understood and solved only by understanding the overall production systems of which they are parts. An example is the Egyptian cotton leafworm, which is one of the main pests on the cotton crop in the Arab Republic of Egypt. The main control measures now used against this insect are hand-picking of egg-masses and aerial spraying of pesticides. Both are intensive, and little increase in their efficiency is possible. But the structure of the cropping system is such that relatively minor alterations in the crop rotation may have a marked impact on leafworm population dynamics at relatively low cost. The technical issues involved in these alterations are well within the realm of possibility. But to implement them would require the development of a comprehensive view of the agricultural production system as a whole, a high sensitivity to the needs and decision-making frameworks of the Egyptian fellah, and an understanding of the biology of the cotton leafworm.

AGRICULTURAL SYSTEM STRUCTURE AND THE EGYPTIAN COTTON LEAFWORM

Agriculture is a highly structured system directed toward particular production goals. It is also a system beset by problems of many sorts: environmental, technological, and economic, to name only a few. Some features of agricultural systems can be examined satisfactorily as relatively isolated phenomena. But many are so much the consequence of the system which produces them that they cannot be adequately understood out of context. This paper looks at a critical environmental problem of agriculture which has been the subject of intense analytical study and shows how the structure of the system confers powerful constraints on managerial actions as well as possible avenues for creative solutions.

The Egyptian cotton leafworm, Spodoptera littoralis (Boisduval), is the most serious pest of the Egyptian cotton crop. The others (Table 1) are much less important. It constitutes a significant problem because Egyptian cotton occupies a unique position in the economy, and losses to the cotton leafworm are measured in tens of millions of Egyptian pounds (£E) per year. Cotton is Egypt's most important cash crop, and both raw and processed cotton form important parts of the country's agricultural exports. As a very high-quality long-staple fiber, it occupies a unique and significant position in the world market. In the early 1970's, raw cotton production accounted for 5.4% of the country's total gross domestic product. This is a relatively low number, but by no means insignificant. It is equivalent to 75.6 % of the country's total agricultural exports, and 46.2% of her total exports (El-Tobgy, 1976). This is a reduction from previous years (Figure 1), but cotton is preeminent in Egyptian exports and will continue to be so for the foreseeable future. Like many developing countries, Egypt has a chronic balance of payments deficit, and so dependable an export product is of critical economic importance to the country as a whole.

It is always difficult to assess the role of pests in crop production, as there is no agreement on how to measure it. The simplest measure conceptually would be to weigh the total losses to pests relative to production which would be realized if the pest simply were not there. This is extraordinarily difficult, however, because pests are present even under the best of conditions, and it might not

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be possible to determine how a crop would behave in the absense of predation. On the other hand, it is not uncommon to forecast crop production on the basis of a large number of factors, including geography, weather, current health of the crop, and average pest levels. But very high pest infestations can reduce production below even this expected yield.

Both of these measures have meaning, and attempts at both have been made. For example, Pimentel et al (1978) estimate that crop losses to pests, pathogens, and weeds account for roughly 1/3 of the average crop production for most crops in developed countries such as the United States. This is despite the use of pesticides and advanced technology. Crop losses of the same sort in developing countries are typically much higher than this. Of course to say that 1/3 of a crop is lost is an estimate relative to what production level would be achieved were pests absent from the system. Much of these losses are not felt by the farmer, because they represent the "background" losses which are always present in the system. But severe economic pests can cause depredations above background levels, and the Egyptian cotton leafworm is a significant economic pest. For example, in 1961, the infestation of this moth was so heavy that 1/3 of the expected cotton crop was lost. In human terms, these losses were sufficient to lead to a major revision of land ownership within the country (El-Tobgy, 1976). Economic losses were on the order of £E 100 million. In biological terms, if the "background" losses to pests were 33%, as suggested by Pimentel et al (1978), then a 1/3 loss in the expected cotton crop implies that the cotton leafworm and its fellow travelers actually consumed some 55% of total yield (if P is gross production, and if expected yield is .67P, then a 1/3 loss in expected yield represents an actual yield of 67 x .67P, or total losses of P - (.67P x .67) = .55P). These would be high losses for any crop in any country. But for a developing country characterized by an annual population growth rate of 2.5% and an average annual income of £E 150 per agricultural family (£E 25 per rural person), such losses in the key cash crop are extremely significant.

Biology of the Cotton Leafworm

The Egyptian Cotton Leafworm is a member of the cutworm family, Noctuidae. It is found quite widely throughout the middle East and into the U.S.S.R. Within Egypt, it attacks more than 70 species of plants in addition to cotton (Bishara, 1934; Willcocks and Bahgat, 1937; Moussa et al., 1960). Three of the plants attacked by the leafworm are widely grown in Egypt (Table 2). The leafworm does not do much damage in maize, however, leaving it a significant pest only of cotton and berseem clover (Trifolium alexandrinum). As we shall see shortly, these two plants are quite different biologically, but they are so closely tied to each other in the cropping scheme that they provide a powerful mechanism for maximizing the problems caused by the cotton leafworm.

Depending on temperature, relative humidity, and similar factors, the developmental time of the leafworm varies from two to seven weeks (Harakly and Bishara, 1974; Nasr and Nassif, 1974). The breakdown of the life cycle into egg, larvae, pupae and adults, is shown in Figure 2.

Eggs are laid in rather prominent masses comprising about 20-1000 eggs apiece. They are commonly laid on the undersides of cotton leaves about 50 cm from the ground (El-Saadany and Abdel-Fattah, 1976), but oviposition can take place on practically any erect object 20-200 cm high, as well as on smaller weeds or even on damp soil near seedlings (Abul-Nasr et al, 1972). The egg masses are prominent enough that they can easily be picked by hand, and they are concentrated toward the center of fields and away from places in which hand-picking of egg masses has already taken place (Iss-Hak and Abdel-Megeed, 1975). Hand-picking is, in fact, a very effective way of control for the cotton leafworm, if sufficient manpower can be made available to go into the fields, find the egg masses and remove them. But it does damage the cotton plants to a degree, and it requires large numbers of pickers, who are commonly children. It is not as widely practiced as was once the case.

The larval stage is the longest-lasting and most destructive period in the life cycle of the cotton leafworm. It comprises roughly half of the life cycle, during which the moth feeds most actively on cotton. There are 6 instars. The larvae move considerably throughout the day as they feed on cotton leaves. During the heat of the day, the younger larvae are in the shade on the underside of leaves, commonly relatively close to the ground, while older larvae may actually hide in the soil itself (Gawaad and El-Gayar, 1974; Abdel-Megeed and Iss-Hak, 1975).

The pupa stage is one of low activity in which the animal lives about 3-5 cm below the soil surface. The adult, on the other hand, is an active flyer, capable of relatively long flight (Salama and Shoukry, 1972). Flight activity is concentrated in the hours shortly after sunset and shortly before sunrise (El-Saadany and Abd-El-Fattah, 1975b), although they are active throughout the night.

There are typically three population peaks of the cotton leafworm within each year. The first peak of egg-mass numbers appears around the beginning of June, with two others at the end of July and in September (Abul-Nasr *et al.*, 1973b). Adult moth peaks typically occur about mid-June, late July and early September (Abul-Nasr *et al.*, 1973c). The largest peak of egg masses is typically the late spring peak, although this generation often corresponds to the smallest peak of adult moths. Mortality from predators and from control measures seems to be highest for the first yearly generation. Nevertheless, the maximization of egg masses in the spring indicates that production of larvae is greatest in the first generation. Since the larvae comprise the most destructive stage this means that the key generation from the viewpoint of cotton destruction is the first, regardless of the effectiveness of insecticide or other control measures.

Control of the Cotton Leafworm

The biology of the cotton leafworm suggests several ways in which control might be carried out. Foliar insecticides can be directed against the eggs, as well as the early-instar larval stages. Soil insecticides, on the other hand, can be used against late-instar larvae and pupae. Mechanical soil treatment such as plowing and cultivation may be able to destroy or bury late-instar larvae and pupae. Hand-picking of egg masses has been practiced for many years, and the night-flying adults can be attracted to light traps. Several actual or potential parasites or predators might form the basis of a biological control scheme. Less conventional techniques such as sterile-male, bacterial or pathogenic control, pheromones, or integrated control, are also possible, at least in principle.

CHEMICAL CONTROL OF THE COTTON LEAFWORM. Large quantities of insecticides are consumed in Egypt each year, largely for the protection of cotton from its pests. The main weapon in the control of the cotton leafworm is aerial insecticide spraying or small-scale insecticide applications using backpack sprayers. Both represent a drain on foreign exchange stocks, as pesticides are not manufactured in Egypt, and the spraying firms are largely European.

A tremendous amount of research is going on in Egypt at the present time into the effectiveness of different pesticide formulations for control of the cotton leafworm in different places. They are too numerous to cite, but there are literally hundreds of articles on the relative effectiveness of different pesticide formulations for the cotton leafworm. These appear for the most part in four journals: Agricultural Research Review, the Economic series of the Bulletin of the Entomological Society of Egypt, the Bulletin de la Societe Entomologique d'Egypte. and the Zeitschrift fuer angewandte Entomologie.

Insecticide strategies which have been used and researched extensively in Egypt include all major insecticide groups, as well as foliar vs. soil application, application in irrigation water, and comparisons of different mechanical strategies for spraying. Most of the chemicals used against the cotton leafworm are insecticides; that is they are designed to kill the insect. But other chemical strategies are also being examined. These include anti-feedants, or materials designed to disrupt the feeding activities of the insect (e.g. Kamel et al, 1974). In field trials, these are capable of giving very high levels of protection for up to a week after treatment. Anti-moulting compounds are those designed to disrupt the moulting between instars of the larvae. Laboratory and field studies of these also have indicated a potential for high levels of control (Rizk and Radwan, 1975; El-Tantawi et al, 1976).

Perhaps the most severe problems with the use of chemicals to control insect infestations in Egypt, as in most countries, is the development of resistance within the target population as well as the significant impacts on non-target populations. Resistance to the common organochlorine insecticides was noticed in the 1960's (Ali and Ayad, 1976), forcing a switch to organophosphate compounds. Even seasonal development of resistance has been noticed to certain insecticides (Hassan et al, 1970).

There are some more unusual chemical methods of control, of which one of the more interesting is the pheromones. These are chemicals created by one sex of adult animals (generally females, at least in the arthropods). Very small quantities of these chemicals are highly attractive to the other sex, so that adult males can locate available females by moving up the pheromone gradient. Pheromones have been synthesized for several species of economically important insects and used either to bait traps which are laced with potent insecticides or sprayed into the air to swamp the natural pheromone gradient and thereby make it extremely difficult for adult males and females to locate each other. Hall et al (1975) report a method of production of large quantities of the main component of the sex hormone of the cotton leafworm. It would appear, however, that this pheromone is not in widespread use at the present time.

NON-CHEMICAL METHODS OF LEAFWORM CONTROL. The best known methods of non-chemical control of economically important insects is so-called biological control. In this approach, there are several insects which are capable of parasitizing the cotton leafworm. They are summarized in Table 3. This is not a large number of organisms, and none of them provide very high levels of control similar to those of the successful biological control experiences described throughout the world by de Bach (1974). Peak levels of parasitism and predation now occur in August, in which only 35-41% of the leafworm population is removed (Hegazi *et al*, 1973). Nevertheless, observations by Abul-Nasr *et al*., (1973a) indicate that predation was sufficiently high in Giza, just outside Cairo, that the percentage of cotton-leafworm eggs to hatch is roughly 1/2 that of another station (Sakha) in the northern Delta. During the three-year period of observation, the hatching rate was 29.5% at Giza, compared with 66.2% at Sakha.

Deliberate use of pathogenic bacteria and viruses has been used with considerable success against some insects in some parts of the world. This is especially true of *Bacillus thuringensis* and nuclear polyhedrosis viruses. These have also been tried in Egypt against the Egyptian cotton leafworm, but they are not in widespread use. In fact, the bacterium that appears to have been most studied, *Serratia marcescens*, appears relatively ineffective as a control agent, although it does cause both reduction in feeding, reduction in weight, and some mortality (Khalil *et al*., 1975; Ali *et al*., 1975). Nuclear polyhedrosis viruses also seem much less effective under field conditions than in the laboratory (El-Ibrashy and Sadek, 1973), although a large field test of viral control is now being established in the Fayoum (Collins, 1979).

Agricultural techniques can have rather far-reaching impacts on growth of the leafworm. A review of older techniques by Bishara (1969) points out that cotton losses to pests can be reduced by numerous techniques, including early planting, control of spacing the cotton plants, cone-dibble sowing, and proper timing of irrigation. Madkour and Hosny (1973) point out that frequency of oviposition by the leafworm is a function of cotton variety, irrigation frequency, and fertilization. Timely plowing is also a rather effective way of killing or burying late-instar larvae and pupae. Nasr (1975) documents up to 97% destruction of immature leafworms through a single plowing of leafworm-infested clover. One of the best ways of reducing numbers of egg-masses is by hand-picking. This has been practiced as long as the leafworm has been present in Egypt, but it has become somewhat less common now that chemical controls have become so widespread.

One rather interesting approach to control of the leafworm is the use of light traps. A typical light trap is built around an ultraviolet light of about 80-125 Watts. It is set out in the field to attract the night-flying adults. Once attracted to the lights, they may be killed through physical trapping, pesticides, or electric shock (El-Saadany, 1974). When populations are relatively low, the light trap has a collection efficiency of roughly 90%, and egg masses are quite uncommon near traps (Khattab, 1975). Unfortunately, light traps, like pesticides, are relatively broad- spectrum in their actions. Beneficial insects as well as pests are attracted by the light trap, and their populations are correspondingly reduced (El-Borollosy and Awadallah, 1973). In addition, the electricity that would be required for broad-scale control by light traps is relatively high.

The Cotton Leafworm Problem in Context

The cotton leafworm continues to be a major economic pest. The methods of control discussed so far (and discussed overwhelmingly in the Egyptian entomological literature) are oriented toward the leafworm itself and not toward the system of which the leafworm is a part. If we look at this system in detail, we quickly see that the leafworm problem is far deeper than simply the biology of one insect would indicate and that its solution should involve all parts of the production system.

Perhaps the simplest place to begin would be with the cropping system used in most of Egypt. In the cotton-growing areas of the country, cotton is grown in a two- or three-year rotation with berseem clover (*Trifolium alexandrinum*), wheat, and coarse grain. The three-year cycle, which is the more common, is illustrated diagrammatically in Figure 3. Cotton is a summer crop which is planted in February or March, following a catch crop of berseem clover from which one or two cuttings should normally be taken before the field is ploughed for cotton. There are several reasons for this, not the least of which is that cotton is a highly soil-exhausting crop and berseem clover is an excellent way of replenishing the soil. The other two years of the cycle feature a full-season clover crop or wheat in the winter and coarse grains in the summer. There are two crops each year; The summer and winter crops follow each other immediately, separated only by the time required to prepare the soil. Indeed some crops are "relay-planted," with seedlings of one crop planted amid the mature individuals of the previous crop.

The cropping system is a sophisticated one which is fairly well adapted to the crops and technology available to the Egyptian farmer. Crops are matched to the seasons in which they can be grown, and the timing of planting and harvesting is directed toward maximizing production. The optimal time for cotton-planting ranges from early February to mid-March, depending on the part of the country; For this reason, the clover crop preceding it is only a catch crop with 1-2 cuttings supposedly permitted.

The fellah is a responsive farmer who can make major changes when it is in his interest to do so. And he is very aware of the relationship between his economic and food needs to the timing of planting. Until the year-round availability of water from the High Dam at Aswan, for example, corn was planted in July - September as a so-called Nili crop immediately following the annual Nile river floods and harvested in November. Year-round irrigation water allowed it to take its place as a summer crop, with planting in May and June. Yields are significantly higher due to better climatic conditions available during the summer, and the earlier planting date also allows it largely to escape the depredations of corn borers. Virtually all farmers throughout the country have changed over to summer planting of corn.

These details of the cropping system are important for our purposes, since the dynamics of cotton leafworm population growth are most meaningful when seen against the timing of planting and harvesting of those crops with which the insect is associated. These, in turn, are strongly affected by the decision processes of the farmer as constrained by the government and by the cooperative structure within which he operates. About 90% of the spring generation of cotton leafworms ovipositing on cotton emerge from pupae which have matured in the soil of adjacent clover fields (Abul-Nasr and Naguib, 1968; El-Tobgy, 1976). These are the full-season clover fields which precede the summer crop of coarse grains. Irrigating these fields after 10 May is prohibited in order to dry out the soil and raise its temperature. This very simple expedient, which has not been enforced strongly in the past, impairs maturation of the leafworm pupae, and can exterminate up to 40% of the population (Webb, 1978).

As El-Tobgy (1976, p. 185) points out, there is adequate fodder for livestock feeding during the winter, but there are still shortages at critical times of the summer. So it is not uncommon for producers to take one or two extra cuttings of clover before planting cotton. (Colorado State University, 1977). The result is that cotton is planted at somewhat later than the optimal date and it has less time in the ground. In 1978, for example, only 2% of the targeted cotton acreage was planted by 11 March, and only 50% by 24 March. The Ministry of Agriculture then attempted to encourage farmers to plant cotton by granting 475 kg. of fodder to all cotton producers in upper Egypt for each hectare of clover plowed within one week (Webb, 1978). The cotton crop is relatively sensitive to timeliness of planting, however, so that this delay can result in significant reductions in yields (Brown, 1955), and correspondingly lower income to the farmer from cotton. But the fodder production on the same land is increased.

In the same way, the full-season clover crop is a critical source of fodder for the animal herds. Each successive cutting is equivalent to between 12-20 tons per hectare (green weight) of high-grade hay, and the full-season clover fields are responsible for over 3/4 of the total fodder produced in the country (El-Tobgy, 1976). The importance of this crop is illustrated by the fact that the area in full-season clover increased by over 60% in the 25 years following 1950, and this increase was at the expense of cotton and sustenance food crops such as wheat. In addition, farmers often defoliate their corn to feed their livestock during the summer when fodder is most scarce. This defoliation leads to yield reductions of up to 35%, even though corn is the main bread grain of the rural poor, and virtually all is consumed in the countryside. Farmers have even been known to feed bread to their animals when stocks of more usual fodder were depleted.

There is thus a strong implicit tradeoff between production of fodder and cotton. Clover is animal feed that is translated into either draft energy or meat and dairy products that can be sold at unregulated producer prices. The cotton is sold through the cooperatives at prices considerably lower than the market levels. Despite econometric studies which show cotton to be the most profitable crop in Egypt (e.g. Zaki, 1976), the perception of the farmer clearly ranks the production of clover higher.

In principle, many measures might be able to reduce losses to the leafworm. The chemical strategies described above represent only one, and their disadvantages as far as drain of foreign exchange, resistance, and effect on non-target organisms are well known. Hand-picking of leafworm eggs is less common today than it used to be before the advent of chemical pesticides. The children who used to be the main pickers are now more likely to be in school. Young people are more likely to migrate to the perceived "greener grass" of the towns and cities, or they may go to oil-producing countries where they can make many times the salary they could in Egypt. It is often said that rural unemployment is high in countries such as Egypt. This is true during parts of the year, but the need for labor is so high during the peak season for leafworm egg-mass picking in June that the government must sometimes forbid all agricultural workers from taking vacations so that the egg-mass picking teams can work at full strength (Webb, 1978). They are still not always able to keep up with the moth population. Once the moths have gotten out of hand, aerial spraying with insecticides is now the only feasibile recourse.

The problems of the cotton production system in Egypt, as well as some of its opportunities, are shown diagramatically in Figure 4. The general question at hand is what to do within the context of the cotton-production system in Egypt to increase production of cotton and to reduce cotton losses to the cotton leafworm. The figure clearly shows the role of pesticide application on reduction of the leafworm and concomitant increases in final yield. It also shows the negative implications of pesticide resistance and pesticide impact on non-target organisms. It is difficult to assess the killing potential of different pesticides in the field, but the experimental literature suggests that mortality from in-field applications is on the order of 70-80%.

The vegetation in the fields not planted to cotton is critically important to leafworm dynamics. Particularly important are those fields planted to berseem clover. These, in turn, are a function of demand for fodder. Additional mechanical methods of leafworm control are limited by the agricultural labor force which, in turn, is strongly affected by the workings of the labor market both within the rural and urban areas of Egypt and in other potential labor markets around the Middle East. If more people were available, or if those that were available were better motivated or better workers, then it would be easier to control the leafworm without resorting to the use of large amounts of pesticides. But the necessary labor force is not available.

The system as it now exists is very tightly constrained. But it is not static, and it is capable of major changes with the proper stimuli. The shift in the corn season cited above is only one example. What is clear is that the current reliance on pesticides and hand-picking represents a set of approaches which have reached a limit of their effectiveness. Additional intensity in either or both might lead to an improvement, but it would be relatively small and at great cost. Major improvements would require the identification of points within the system to which the leafworm population was especially sensitive.

Figure 4 suggests at least one of these points. Certain feasible developments might enable the farmer to make certain minor changes in the cropping patterns which might, in turn, allow a powerful attack on the cotton leafworm at very low cost. If there were not such a shortfall of fodder, then the triennial cropping cycle could be altered slightly, as suggested in Figure 5, to shorten the time of the full-season clover crop by about 10%. Earlier planting of corn might improve corn yields somewhat, although it would do so at the cost of some of the presently realized clover crop. But the result would be that the farmer could plow his fields in early May, at which time the key spring generation of cotton leafworms is at its most vulnerable stage.

This vulnerability is not inherent in the biology of the cotton leafworm; It is generated by the structure of the system. The density of suitable hosts for the leafworm is lower at this time than at any other. The clover season is nearing its end, and the newly planted cotton crop is but seedlings. Indeed the late-instar larvae may move en masse from clover to adjacent cotton fields at this time. A particularly vivid description of this movement is given by Brown (1955). But this is not all. The farmer must plow his clover fields in any case in order to plant his corn. This can result in massive leafworm mortality, if the timing is right. Roughly 90% of the eggs laid by the spring generation of the cotton leafworm are oviposited by adults derived from the adjacent full-season clover fields. If judicious and timely plowing could destroy even 90% of the late-instar larvae and pupae of this generation, then the level of control of the cotton leafworm which would be obtained simply by advancing the planting date of corn a few weeks would be over 80% before the application of a single gram of insecticide or the expenditure of any additional effort by the farmer. This is a significant level of control by any calculation, and it depends on a lower level of leafworm destruction than that observed by Nasr (1975). Higher levels of control would be possible using soil insecticides in conjunction with cultivation. These measures followed by hand-picking of egg-masses would surely lower the spring leafworm peak by a marked amount and would most likely allow the widespread implementation of an inexpensive integrated control system analogous in some ways to the successful U.S. experiments in integrated control of the boll weevil.

The fly in the ointment, of course, is that the opportunity costs of shifting the corn-planting date even by a couple of weeks is extremely high, in that it might require forgoing one cutting of clover. Given that fodder is already in such short supply in the summer that farmers are willing to defoliate one of their own personal subsistence food crops to feed their animals, it is obvious that moving the corn-planting date forward even a little would be simply inconceivable unless demand for fodder were somehow decreased or fodder supply increased.

As discussed by El-Tobgy (1976), animals serve two major functions in Egypt: the production of meat and dairy products, as well as draft energy to pull carts and plows, and to operate pumps. It has been seriously proposed by numerous agencies, from the World Bank to the Egyptian Ministry of Agriculture (El-Gamassy, 1979; Hindy, Hoofnagle et al., 1976), that at least some of the functions of draft animals are highly inefficient and they could easily be replaced by electric or diesel pumps or motors. This substitution of mechanical power for animal power would in no way displace human labor and thereby increase the urban unemployment problem. But it would, at least in principle, allow the retirement of some of the animal population, which would thereby reduce demand for fodder, or at least the substitution of meat or dairy animals which would allow a direct improvement of the food supply. It would certainly reduce demand from very small farmers, whose use of animals is oriented more towards animals as motive power than as sources of meat or milk.

On the supply side, virtually nothing has been done to the present time to increase the yields of berseem clover, despite the well-established plant-breeding work now going on in Egypt. Egyptian-developed cotton varieties are world-famous, and Ministry of Agriculture plant-breeders have produced all of the commercial varieties of wheat, rice, corn, sorghum, barley, broadbean, lentil, onion, flax, sesame, and peanut (El-Tobgy, 1976). It is not impossible that major research on berseem clover would allow sufficiently improved growth that the final cutting could be taken in time to plow the field by the critical date of leafworm emergence and still provide at least as much fodder as at the present time.

For the moment, we must simply accept that the cropping scheme is as it is, and that the rational behavior of the Egyptian fellah is to give clover production the emphasis he does. As a result, the Egyptian cotton leafworm is an integral part of the cropping system, and more effective direct control is not possible. Control is possible only by mobilizing very large numbers of people for the egg-mass picking duties during the summer and aerial spraying with insecticides over most of the crop. But the leafworm is potentially sensitive to indirect measures which exploit the features of the production system to which it is most vulnerable. The changes required in farmers' activities are not very great. But they would depend on a major commitment by the government to a balanced evolution of the system and a careful understanding of the way farmers make decisions so that they could afford to support this evolution and feel that it represented their own self-interest.

The technical issues are not insuperable. Improving the yield of berseem clover to allow current yield levels (or higher) in a 10% shorter growing season is certainly within the competence of the plant breeder. There are other good reasons to replace draft animals with electric pumps besides lowering the demand for fodder, and many parts of the country have an adequate low-cost energy source from electricity generated at Aswan. Indeed there may be other measures which could complement these to move the system to a state inimical to leafworm growth. The hard job will be to develop a sufficiently comprehensive view of the production system as a whole to define the most effective policy instruments to make the necessary changes and then to carry them out in the real world. It is certainly not likely to happen in the near future. But it may not be totally impossible.

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Table 1
Significant pests of the Egyptian cotton crop

Spodoptera littoralis (Boisd.)	Egyptian Cotton Leafworm
Pectinophora gossypiella (Sand.)	Pink Bollworm
Earias insulana (Boisd.)	Spiny cotton Bollworm
Spodoptera exigua (Hb.)	Lesser Cotton Leafworm
Agrotis ipsilon (Hfn.)	Black cutworm
Heliothis armigera (Hfn.)	Corn earworm
Bemisia tabaci (Gennadius)	Whitefly
Aphis gossypii Glov.	Cotton Aphid
Empoasca lybica (de Berg.)	Leafhopper
Tetranychus sp.	Spider Mite
Thrips sp.	Thrips

List compiled from Hassan *et al*, 1974; Harakly and Bishara, 1974; El-Saadany and Abd-El-Fattah, 1975a.

Table 2
Plants attacked by the Egyptian cotton leafworm

Crop	Average Cultivated Area, 1970-1974 1,000 feddans	Season (s=summer, w=winter)
Cotton	1,551	s
Berseem Clover	2,801	w
Corn	1,245	s
Cabbage	<1>	
Cowpea	<1>	
Castor Bean	<1>	
Sweet Potato	<1>	
Lettuce	<1>	
Artichoke	<1>	
Tomato	<1>	
Pepper	<1>	
Okra	<1>	
Jew's Mallow	<1>	
Hemp mallow	<1>	
Mulberry	<1>	
Soybeans	<1>	

List compiled from Abdel-Fattah et al, 1977; El-Tobgy, 1976; Harakly, 1974;, and Nasr and Nassif, 1970.

<1> These crops are minor crops in Egypt. All vegetables grown in Egypt account for about 5% of the total cropped land. About 2/3 of the vegetable production is in the summer, but many vegetable crops are grown throughout the year.

Table 3
Predators and parasites on the Egyptian cotton leafworm

Parasites	
Chelonus inanitus (L)	Eggs/Larvae
Microplitis rufiventris Kok.	Early Larvae
Zele chlorophthalma (Noes.)	Larvae
Euplectrus laphygmae Ferriere	Larvae
Peribea orbata (Wied.)	Larvae
Predators	
Paederus alfierii Koch	
Labidura riparia Pallas	Eggs/Larvae
Calosoma chloristichtum Dej.	Larvae/Pupae
Orius albidipennis (Reut.)	Eggs
Blaptostethus piceus Fieber	Eggs/Larvae
Coccinella undecimpunctata	Egg

List compiled from Altahtawy et al, 1976a,b; Altatawhy et al, 1972; Afify and Farghaly, 1970; Hasseinen and Khalil, 1968; Tawfik and El- Husseini, 1971; Hegazi et al, 1977; Tawfik et al, 1976; Hegazi et al, 1974; El-Borollosy and Awadallah, 1973; Tawfik and Ata, 1973; Tawfik et al, 1972; and Ammar and Farrag, 1974.

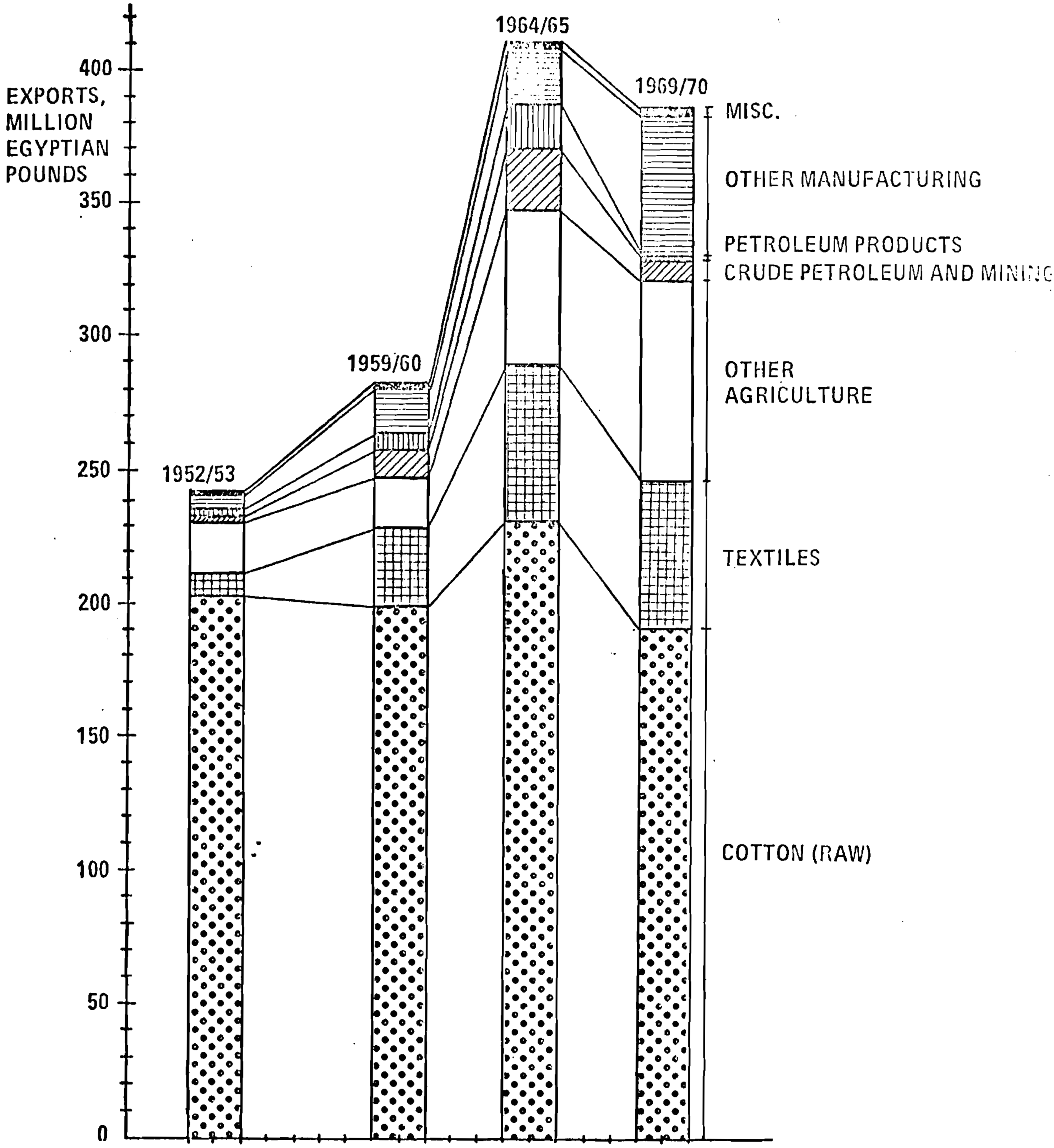

Figure 1. Breakdown of Egyptian exports, 1950-1970, by shares of major products.
Official statistics presented in Mabro, 1974.

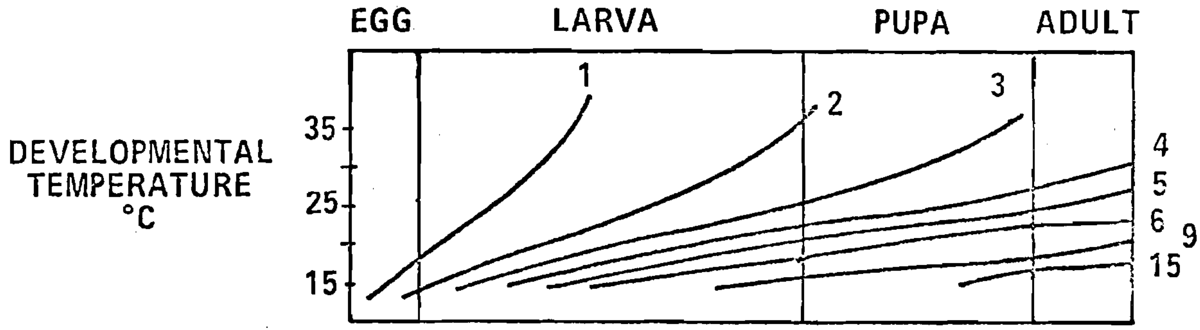

Figure 2. Life cycle of the Egyptian cotton leafworm. Contours indicate weeks within life cycle at different constant developmental temperatures.
Derived from data in Nasr and Nassif, 1974.

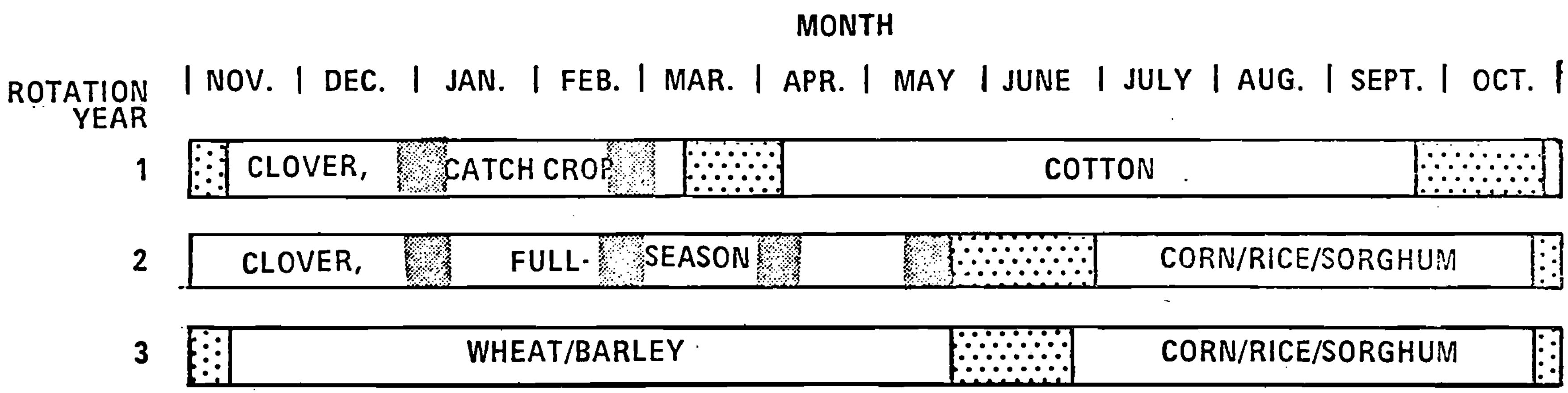

Figure 3. Schema for a triennial cotton-based cropping rotation in most of Egypt. Shaded areas indicate periods of changing from one crop to another; cross-hatched areas indicate periods of cutting clover. Compiled from El-Tobgy (1976) and Mabro (1974).

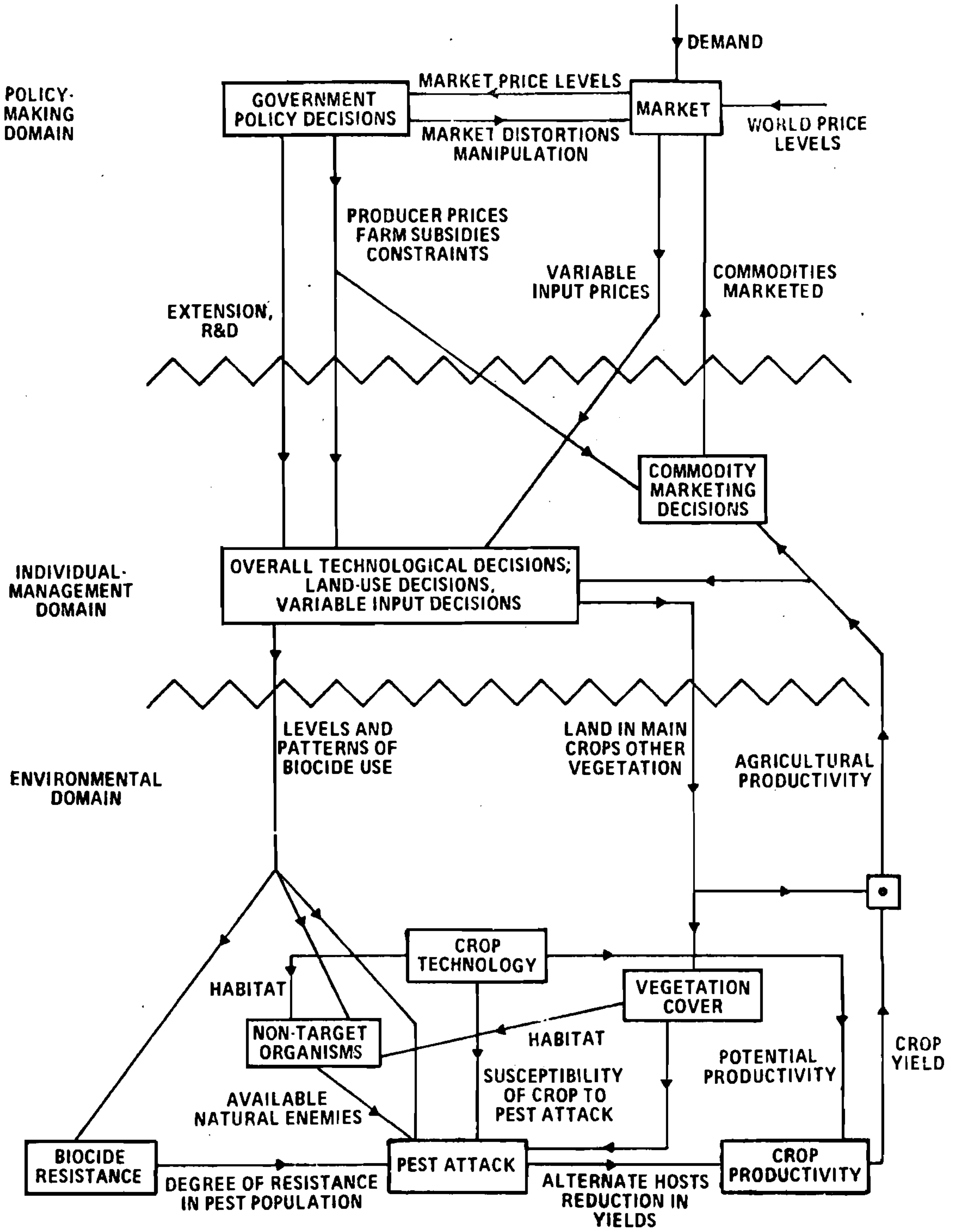

Figure 4. Overall systems view of the cotton leafworm problem. Items in boxes represent processes; labels on lines represent information signals connecting processes.

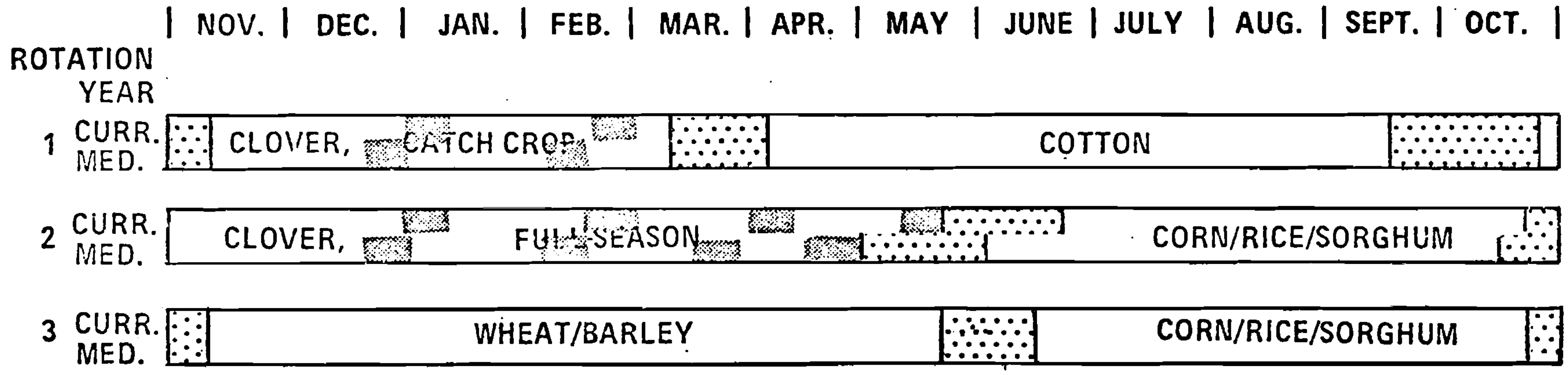

Figure 5. Schema for modification of basic triennial cotton-based rotation in most of Egypt to allow for a 10% reduction in the period for full-season clover. Shaded areas indicate periods of changing from one crop to the other; cross-hatched areas indicate periods of clover cutting. Within each year of the rotation, the upper part of the bar indicates current practice; the lower bar indicates the modification. See text for details.