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# Integrated Pest Management for Cotton with a focus on Whitefly and Aphids

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CFC / ICAC / 03 project was an international joint effort conducted by the Israel Cotton Board, involving Egypt, Ethiopia, and Zimbabwe. The project aimed at developing integrated methods for control of whitefly and cotton aphids, both of which cause stickiness to cotton. The broad objectives included the production of high quality non-sticky cotton; increased profitability for both raw cotton producers and processors; and reduction in damage to the environment.

The project developed new target-oriented, environmentally compatible pesticide formulations and their application methods; promoted biological pest control; developed guidelines for economic use of these methods; and disseminated the project findings to extension staff of participating and other countries.

The project comprised five main components:

## Development of novel target-oriented pesticides

Target-oriented insecticidal formulations, based on vegetable oils, were developed and tested under controlled conditions. This included: characterization of different species of Vegetable Oils (VO) according to their bioactivities vs. Bemisia and their phytotoxic tendencies; accumulating knowledge on the formulation-function relationship of VO as control agents; formulation and scaling up of prototype VO formulations for field application under semi-commercial conditions; development of a laboratory setup for adaptation and quality assurance of formulations based on VO of local origin; and production of experimental formulations of VO for field research by the cooperating groups.

The kind of tested VO, all of major commercial importance, showed a similar activity repertoire, which included toxicological and behavioral components. However, different oils varied in potency, speed of action and bio-persistence, in such parameters as: residual activity against adult and immature Bemisia, spray toxicity to larval stages, and modification of adult's behavior expressed by settling and oviposition deterrence. Among the eight tested VO, groundnut, castor and cottonseed oils showed the most prominent activities. Coconut oil was the most phytotoxic and castor oil was the safest to the crop.

Systematic study of the effects of formulation variables on control-related properties of VO resulted in several promising formulating procedures. Among these, two formulation lines, one based on cottonseed oil (No 4) and the other based on castor oil (No III), gave the most promising results for all the studied kinds of VO. Both experimental and field versions of "optimized" and "stabilized" formulations retained VO activity towards the target pest and had minimal phytotoxicity. The formulations made only of non-toxic and environmentally friendly ingredients, were proven to be consistent and stable, to exhibit good dilution stability and were easy to dispense and apply. In addition, a simple laboratory setup was developed and suggested as a model for development and preparation of similar formulations from local VOs in the target countries.

At the beginning of the project, the material based on cottonseed oil applied with a long drop-tube sprayer (2 treatments at 2-week intervals), caused a reduction of 71.5% on the average infestation level of whitefly immatures on the Acala variety and 50% reduction on the Pima variety. However the long drop-tube sprayer had to be withdrawn due to the damage it caused to the cotton plants, and it was replaced by the Tornado sprayer that was developed within the framework of the project.

66 novel materials were tested in 5 stages, along the course of the project. After each stage, the superior materials were sent for repeat tests to Egypt, Zimbabwe and Ethiopia.

## Stage 1

Phytotoxicity was tested and 21 materials were disqualified at this stage.

## Stage 2

The remaining 45 materials were tested for their effect on whitefly control, under ideal spray conditions with complete coverage of the underside of the leaves. In this series of tests it was determined that material III gave the best results.

## Stage 3

Materials No. III and No. 4 were compared using knapsack and tractor mounted sprayers under standard field conditions. In all of the cases, the results of material No. III were superior to those of No. 4.

## Stage 4

Application methods were tested. It was found possible to reduce spray volume from 500 l/ha to 200 l/ha with material No. 4 if the amount of active material remained constant. In addition, both materials, three tractor-mounted sprayers were compared: the long drop-tube sprayer, the air-sleeve sprayer and the Tornado sprayer. The long drop-tube sprayer had the best results, with no difference displayed between the air-sleeve and Tornado sprayers. Various knapsack sprayers, such as the knapsack drop-tube sprayer, the standard knapsack sprayer and the motorized knapsack sprayer also had good results.

Two applications of material No. III at 2-week intervals with the Tornado sprayer caused a reduction of average infestation by 55.7% compared with 13.3% obtained under similar spray applications with material No. 4. An additional improvement was obtained with material No. III by switching to 4 applications at weekly intervals between treatments. Of the three different sprayers (the air-sleeve, the Tornado and the knapsack drop-tube), a reduction of 74% in average whitefly population was obtained in comparison with the unsprayed control under similar conditions. The standard treatment, 2 applications of Diafenthiuron, reduced the population by 86%. There was no difference between the Pima and Acala cotton varieties sprayed by the air-sleeve or the Tornado sprayers.

In a series of four trials in Zimbabwe under various coverage conditions, it was found that a set of novel materials had good aphid control if the underside coverage of the leaves was complete. Under standard field conditions using the knapsack sprayer with a tail-boom there were no satisfactory results concerning aphids.

Stage 5

Examining the effects of the materials on beneficial insect populations under field condition will discuss later (in this page).

# Design of criteria for cotton sprayers and design of new spray techniques

Three manual sprayers and one tractor-mounted were developed and tested by the engineering groups from Egypt, Zimbabwe and Israel. The sprayers were developed in an effort to achieve very high uniformity of spray deposition, as required for whitefly control with the nontoxic pesticides developed in the present project.

Two motorized knapsack sprayers were modified for application of the nontoxic pesticides in small farms, one by the group from Egypt and one by the group from Zimbabwe. The group from Israel developed an electrically powered sprayer for the same purpose. Field tests of the manual sprayers showed higher uniformity of spray deposition for all of the newly developed sprayers as compared with commercially available machines.

The tractor-mounted sprayer was developed with a high ground clearance in order to provide high uniformity of spray deposition, while still enabling operation in fields where branches cross from one row to the next. The application tests gave better results than any commercial sprayer known to the researchers, but also gave lower uniformity and lower quantities of pesticides on the targets as compared to an earlier model with very small ground clearance.

# Biological control

Our main goal here was to understand the dynamics of the pest and its natural enemies in order to facilitate optimal pest management. This was achieved by determining:

1. The pest biology and population dynamics;

2. The natural enemies' (parasitoids and predators) identity, biology, dynamics and impact - how important are they, and when are they important?

3. The effects of insecticidal (commercially used materials and new preparations) treatments on natural enemies - does it cause damage to control efforts and how can such damage be decreased?

4. The impact of neighboring crops – how do they influence the levels of B. tabaci populations?

Whiteflies were found in all countries throughout the warm seasons. In most cases populations were lowest when cotton was young and rose with the season; a sharp rise in Egypt and Israel occurred in late July or August. Maximal levels in untreated fields were as low as 2.5/leaf [1997 report, p.194] but also reached as high as 68/leaf [1998 report, p.162 5]. In Ethiopia, high populations were observed early in the season due to their development on alternative hosts from which they had moved on to cotton [1997 report, p.221]. In Zimbabwe, both Trialeurodes vaporariorum and Bemisia tabaci were active, but did not cause damage in most cases.

In Egypt and Israel Encarsia lutea Masi and Eretmocerus mundus (Mercet) were the predominant whitefly parasitoids [1995 report, p. 101]. In Ethiopia and Zimbabwe Encarsia transvena and Eretmocerus mundus or a very similar species, were found. Rates of parasitization often rose with the season and reached levels up to 90% [1992 report, p.95; 1998 report, p.199]. The 5-year averages for Israel and Egypt were between 65-70%, while for Ethiopia, the one reported year averaged 47% parasitism. No correlation was found between % parasitism and whitefly population. The use of insecticides did not affect % parasitism in1998 but it reduced parasitism significantly in 1997. The high percentages of parasitism indicate that parasitism alone prevents a significant increase in whitefly populations. This is especially significant in the light of quick resistance build-up in whiteflies resulting from successive treatments with insecticides.

Many predator species were found. Most coincided among the countries and locations but some did not. The more generally occurring ones were Chrysoperla carnea, Orius spp. Deraeocoris pallens (In Israel), Campilomma spp., Coccinella spp., Hippodamia variegata, Scymnus spp., spiders of various kinds and predaceous mites, esp. Amblyseius swirskii (studied only in Egypt). Since none of these are either specific to, nor regular predators of whitefly, we established methods to evaluate their value in our context, drawing correlation between predator abundance and that of whitefly populations, and conducting specific behavioral observations. The only predators showing overall correlation with the whiteflies were species of Orius. Studies conducted with A. swirskii in Egypt also indicate that the abundance of this species may be linked with that of the whiteflies. Direct observation of predators on plants in relation to whiteflies showed that predators frequent whitefly infested plants. Although this relationship does not always give a clear picture of their activity, the Heteroptera, and probably also the mites, do seem to be important controlling factors of whitefly populations.

Predators were more sensitive to insecticides than the parasitoids. acetamiprid appears to be one of the more harmful insecticides to both parasitoids and predators, with the exception of the predacious mite A. swirskii in Egypt. Non-conventional insecticides (e.g. jojoba and mineral oils), and the IGRs: diafenthiuron, pymetrozine and pyriproxyfen usually did very little damage to enemy populations while killing high proportions of the pest. Similar results were obtained with flufinoxiron, kemesol (summer mineral oil) and National (winter mineral oil). The same trend was noticed when using natural (vegetable) oils, bemistop and buprofezin. Of the insecticides usually used in the cotton field, we found monocrotophos to be more harmful than endosulfan. These tests should be continued for more materials and under more varied field conditions.

Materials number 4 and III (developed during the course of the project) were tested by treating selected fields that abounded in natural enemies. Material 4 was relatively innocuous to predators. Material III showed detrimental activity to some of the enemies in the lab and in the field. In the latter case, the damage to natural enemies seemed short lived. The fact that the various materials were found less harmful to natural enemies while still able to control the whiteflies can suggests them as important tools for the control of the pest, especially early in the season.

We did not find any advantage in growing corn near the cotton. The main predators therein, Orius spp. did not seem to migrate into the cotton. Sunflowers were found to harbor few natural enemies and at times, a lot of whiteflies. Thus at best, the proximity of sunflowers will not cause a whitefly outbreak, but we should not rely on this crop to be a refuge for natural enemies.

# Establishment of economic thresholds

Seven field trials were conducted in which a total of 30 populations of whitefly were examined. Each population was counted twice weekly during the 60-day period before 80% boll opening (defoliating day) in the field. Finally, each population was characterized according to the average number of larvae (stage 2 or more, including pupae) per maximum leaf for the entire period. There was a follow-up of the effect of each population on the final yields, yield components, lint quality, sugar level and stickiness. From these populations it was found that the damage threshold for yield and quality averaged between 15 to 20 immatures per leaf (1999 report, p. 105 Table 15).

Gerling et al found migration into the field early in the season, but the main increase in population later in the season results from build-up within the field.

Reproduction within the field is dependent on 3 factors:

– initial population size;
– oviposition and survival of the various stages;
– number of generations.

Within the framework of the project, the effect of initial treatment timing which determines the initial population, and the effect of various chemical treatments on survival were studied in relation to very large whitefly populations.

It was found that a series of various treatments reduced the average population throughout the entire counting period at different percentage (Table 2).

Advancing the time of the first treatment, even if the population was very small at that stage, (average of 1.8 immatures/leaf) reduced the population level throughout the entire counting period and average reduction was about 45% for the whole season (1999 report, p. 112 Table 18).

From these results the following conclusions may be drawn:

– In fields in which whitefly build-up (migration and development within the field) is slow and can be controlled by 1-2 treatments, a threshold level of 15-20 larvae and pupae may be used.

– In fields in which the rate of whitefly build-up is high, one should speak in terms of "control strategy" and not in terms of a fixed threshold. The aim of this strategy is to ensure that the average population will not rise above 15-20 nymphs/maximal leaf as an average for the entire season. The strategy would include a series of treatments (date and chemical) at varying thresholds (from low at the beginning to a higher threshold later on) in order to achieve these results at a minimal cost, while adhering to the correct policy for preventing future pest resistance to the various chemicals. In order to improve preparation of these strategies, this particular study should be continued.

# Knowledge dissemination

Knowledge dissemination efforts took place throughout the project and its finalization.

a) Two out of the four PCC meetings that took place in Egypt and Israel in the summers of 1996 and 1977, included demonstrations of field trials conducted in the two countries. Extension staff and growers from the two countries attended those demonstrations in addition to the research staff from Zimbabwe and Ethiopia. Field demonstrations of the developed sprayers took place in Israel Egypt and Zimbabwe during the PCC meetings.

b) Two workshops for extension staff and growers were conducted: one in 1998 in Ethiopia (1998 report, p. 263-272) and the second in 1999 in Egypt (1999 report, p. 141-144, abstract booklet).

c) Two courses for participants from Egypt and Ethiopia were conducted in Israel during the summers of 1997 & 1998.

d) The project and its achievements were presented at two International Conferences: The 2$^{nd}$ International Workshop on Bemisia, San Juan, Puerto Rico, June 1998 (1998 report, p.273), and the World Cotton Research Conference-2, Athens, Greece, September 1998 (1998 report, p.275).

e) Five annual professional reports and a final project report were published, including technical appendixes describing the preparation methods for the new insecticides as well as descriptions and assembly instructions for the new sprayers.

f) A guideline manual of the methodology developed was prepared.