The Sterile Insect Technique: can established technology beat malaria?

The Sterile Insect Technique (SIT) is the mass production, sterilisation and subsequent release of sterile insects into a target population in an area-wide integrated approach. The released sterile males mate with wild females; they thus no longer produce offspring and therefore the size of the target population is reduced. Over the years, SIT has proven to be a safe, effective and environmentally sound method to suppress, eliminate or contain pest populations. The International Atomic Energy Agency (IAEA) has a long history of supporting SIT programmes against key insect pests, including fruit flies, tsetse flies and moths. Recently, an integrated five year study to assess the feasibility of SIT to control African malaria mosquitoes has been initiated. In this article, we discuss the components and research requirements for such a feasibility study including sexing, mass production, sterilisation and release methodologies.

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Introduction

In 2004 the International Atomic Energy Agency (IAEA) initiated an integrated five year feasibility study to develop technologies for controlling malaria mosquitoes with the Sterile Insect Technique (SIT). The goal of the project is to develop and evaluate all relevant components needed for such an area-wide integrated approach to vector control. Some of the experimental work is performed at the Agency's laboratories in Seibersdorf, Austria, and a pilot project area is un- der development in the Northern State of Sudan, in collaboration with the Tropical Medicine Research Institute (TMRI) in Khartoum, Sudan. Moreover, collaborations with other research groups in developed and developing countries have been initiated to develop methods and share opinions. This paper provides an introduction to SIT and the project as a whole.

Background

SIT: 'The principle'

The SIT is based on the mass production, sterilisation and subsequent release of sterile insects into a target population (Knipling 1955, Dyck *et al*. 2005). The released sterile males mate with wild females, which produce no viable offspring. Repeated releases lead to population suppression and can, under certain circumstances, lead to local elimination of a population. Sterility can be induced through chemosterilants, irradiation, or modern biotechnological approaches. Other methods of inducing sterility in a population are the release of hybrids or insects with translocations or other chromosomal rearrangements (Knipling et al. 1968), but these fall outside the scope of this paper.

For the SIT to be a successful component of a control programme, certain prerequisites are needed (Vreysen 1995): 1) colonization (i.e. establishment of the species in the laboratory) should be feasible and mass production possible at a reasonable cost to provide the required number of sterile insects, 2) the competitiveness of the sterile male needs to be adequate and there should be no major behavioural differences between the sterile and wild population, 3) population density of the target species needs to be low or reduced prior to release to make it economically feasible to obtain the desired sterile-to-wild male ratio, 4) detailed information on the target population is required, such as spatial and temporal dynamics, mating behaviour, breeding sites, flight range, *et cetera*, 5) the method needs to be applied against the total population in the target area or part of the population that can be isolated by natural or artificial barriers to exclude immigration from neighbouring sites, 6) the target area should preferably contain only one species, and 7) the release of sterile females is not acceptable for those species where the females are vectors of disease and/or cause biting nuisance (Robinson & Franz 2000). Females therefore need to be removed from the release population. The removal of females is also advantageous for agricultural pests to reduce cost, avoid assortative mating (i.e. mating between released

males and females), avoid (limited) economic losses and increase the overall efficiency of the programme (Robinson 2002a).

Although it is generally believed that the released males need to be fully sterile, it has been suggested (Robinson 2002b) that complete sterility does not have to be induced and that more sterility can be introduced into the field population using lower radiation doses but with more competitive insects. Moreover, reduced competitiveness of the sterile males can be partly overcome by increasing the ratio of sterile-to-wild insects (Knipling 1955).

History of SIT for malaria

Substantial research was dedicated to genetic control of mosquitoes from 1950-1980, especially against *Anopheles albimanus* Wiedemann in the Americas and *A. pharoensis* Theobald and *A. stephensi* Liston in Asia. Benedict & Robinson (2003) provide a review of these earlier programmes. The largest SIT field programmes against an *Anopheles*-vector (*A. albimanus*) were performed in El Salvador and were initiated in 1972 (Lofgren *et al.* 1974). Over a five month period, 4.3 million sterile pupae were released around Lake Apastepeque. Results were promising and a substantial reduction in population size was observed (Lofgren et al. 1974, Dame et al. 1981). A second more extensive trial located on the Pacific coast of El Salvador took place between 1977-79 (Lowe *et al.* 1980, Dame et al. 1981), when up to 0.5 million sterile males or 1.25 million sterile male pupae were released daily. Complete control was not achieved due to the immigration of females from outside the target area, despite the introduction of a barrier zone (which consisted of a zone covered with indoor residual spraying) (Dame *et al.* 1981). Nevertheless, re-analysis of the data (Benedict & Robinson 2003) on *A. albimanus* densities in the release and a nearby control area emphasises how successful the sterile males were in preventing a normal seasonal rise in vector density (Curtis 2005). In both these trials, sterilisation was induced with chemosterilants.

Figure 1. The Sterile Insect Technique has successfully targeted various pest insects, but can it also be used against malaria mosquitoes? Clockwise: malaria mosquito (*Anopheles arabiensis*), New World screwworm (*Cochliomyia hominivorax*), tsetse fly (*Glossina* spp.) and Mediterranean fruit fly (*Ceratitis capitata*). *De steriele-mannetjestechniek is succesvol ingezet bij de bestrijding van verschillende plaaginsecten, maar kan het ook gebruikt worden tegen malariamuggen? Kloksgewijs: malariamug (*Anopheles arabiensis*), schroefwormvlieg (*Cochliomyia hominivorax*), tseetseevlieg (*Glossina *spp.) en Mediterrane fruitvlieg (*Ceratitis capitata*).*

SIT: 'A brief overview'

The SIT approach has been developed and successfully applied against several insect species (figure 1). The most successful and well-known project is the eradication of the New World screwworm *Cochliomyia hominivorax* (Coquerel) from the USA, Central America (Dame 1985, Snow 1988) and (during an outbreak in 1989) Libya (Lindquist *et al*. 1992). Another example is the eradication of the tsetse fly *Glossina austeni* Newstead from the island of Zanzibar (Vreysen *et al*. 2000). Ongoing SIT projects are taking place against the Mediterranean fruit fly (medfly) *Ceratitis capitata* Wiedemann in Central and South America, parts of southern Europe, South Africa and Australia (Robinson 2002a). The largest medfly production facility is in El Pino, Guatemala, and produces around two billion sterile male flies per week (IDIDAS 2005), primarily for use in California, Guatemala and Mexico. Other pests targeted with SIT include the Mexican fruit fly Anastrepha ludens (Loew) in southern USA and Mexico (Toledo *et al*. 2004), the melon fly *Dacus cucurbitae* Coquillett in Japan (Ito et al. 2003), the onion fly *Delia antiqua* (Meigen) in The Netherlands (Ticheler et al. 1974, Everaarts 2006), the codling moth *Cydia pomonella* (Linnaeus) in British Colombia (Bloem *et al*. 1997) and the pink bollworm Pectinophora gossypiella (Saunders) in California (Lindquist *et al.* 1990).

Malaria: 'the problem'

In 2005 the World Malaria Report by UNICEF, the World Health Organisation, and Roll Back Malaria (UNICEF & WHO/-RBM 2005) gives a clear picture of the current malaria situation. 350-500 million cases of clinical malaria occur annual- ly, of which 60% in sub-Saharan Africa. Moreover, 80% of all deaths attributed to malaria occur in this region.

In numbers, this means that each year one million Africans die of the disease, with the vast majority of deaths occurring in child-ren below five years of age. Pregnant women are another major risk group: malaria can cause low birth weight and premature delivery. The impact of malaria on the economic situation of endemic countries is high: an estimated annual reduction of 1.3% in economic growth is reported (UNICEF & WHO/RBM 2005).

Malaria: 'control efforts'

Efforts to control malaria are currently focused on two main strategies: anti-malarial treatment and vector control. Due to widespread resistance of the main malaria parasite Plasmodium falciparum Welch to the affordable drugs chloroquine and sulfadoxine-pyrimethamine (FansidarÆ), other anti-malarial therapies are urgently needed. Currently, WHO recom- mends combination therapies in those countries where resistance is reported. The preferred combination contains artemisinin, derived from the plant *Artemisia annua*. Although artemisinin-based combination therapies (ACT's) are currently the best treatments available, they are ten times more expensive than the conventional monotherapies (Mutabingwa 2005). A number of malaria-endemic countries have now adopted ACT's as their first or second line drug treatment. However, actual implementation is still ongoing in most of these countries (UNICEF & WHO/RBM 2005).

Contemporary vector control methods include the use of Insecticide Treated bedNets (ITNs) and Indoor Residual Spraying (IRS). Other efforts focus on larval control mainly by *Bacillus sphaericus* Meyer & Neide and *B. thuringiensis* Berliner derivatives, which are bacterial compounds that are toxic to mosquito larvae (Fillinger *et al*. 2003). Coverage of ITN's is increasing in Africa, although major differences between countries are observed. A new generation of ITN's, the long-lasting insecticidal bednets (LLN's) are now recommended due to their highly extended life span. These nets stay effective for 4-5 years, while the conventional nets require re-impregnation every 6-12 months. However, the cost of an ITN remains a major constraint to ownership for a large proportion of Africans and voucher schemes are being introduced to improve uptake (Magesa *et al*. 2005). Disturbingly, in many countries resistance of mosquitoes against insecticides commonly used for IRS and bednets is increasing (Vulule *et al*. 1994, Hargreaves *et al*. 2000, Etang *et al*. 2003, Etang *et al*. 2004).

Mosquito SIT at the IAEA

Insecticide and drug resistance in recent years has led to an increased interest in other methods of malaria control. Promising results were obtained in the trials in El Salvador, and since the 1970's a variety of other insects have successfully been targeted with SIT. Increased knowledge of SIT, combined with great advances in the tools required to conduct such campaigns (*e.g*. remote sensing, geographic information systems and computer models) have resulted in a renewed interest in SIT for malaria vectors, particularly for potential application in urban 'island' settings and vector populations in geographically or ecologically isolated areas (Curtis 2002).

The target species

The project will initially focus on *A. arabiensis* Patton, which belongs to the *A. gambiae* species complex (White 1974), comprising seven sibling species of which *A. gambiae* Giles *sensu stricto* and *A. arabiensis* are the major malaria vectors. For SIT to be manageable, preferably one vector species should be present in the release area. Anopheles arabiensis is present in some areas where *A. gambiae s.s*. is not present, while *A. gambiae s.s*. occurs sympatrically with *A. arabiensis* throughout most of its distribution range. Moreover, the genetic make-up of the target population must be such that it can be regarded as a uniform, panmictic (*i.e*. freely mating) species. This appears to hold true for *A. arabiensis*, which is believed to be a rather uniform species. *Anopheles gambiae s.s*. on the other hand shows extreme genetic heterogeneity and substantial gene flow barriers between different chromosomal and molecular forms exist (Tripet *et al*. 2001, della Torre *et al*. 2002). *Anopheles funestus* Giles, the other major vector on the African continent, was not considered a suitable target, as crucial knowledge of the population genetic structure of this species and of its colonization procedures is lacking (Cohuet *et al*. 2004), although some observations have been made of substantial population heterogeneity in *A. funestus*, and so far two chromosomal forms have been described (Cohuet *et al*. 2004).

Mass production

Development of appropriate methods of mass production is critical for the success of SIT programmes. Experience in medfly rearing has shown that colonization and mass production itself accounts for considerable fitness loss and behavioural change due to the large selective pressure during colonization and the unnatural conditions of the rearing process (Cayol 2000) and these effects should be minimized as much as possible. In mosquitoes, it is well-known that larval rearing conditions, such as density and food availability, have an important effect on the size and energy reserves of the adults (Clements 1992). Recent experiments with A. gambiae s.s. have shown that males reared at lower densities as larvae were much more likely to succeed in acquiring the first female during mating, compared to males reared at higher densities (Ng'habi et al. 2005). The trade-off between a short development time and space restriction desired in a mass rearing facility, and the overall fitness and behaviour of the insects produced, needs to be understood to implement effective production management. Research is under- way on all aspects of rearing, including egg handling, larval rearing, pupal collection, adult holding, membrane blood feeding, as well as the development of quality control procedures.

Sterilisation

Insects can be sterilised by use of chemosterilants, irradiation (figure 2), or modern biotechnological approaches. Chemosterilants were used experimentally and in field trials in the 1960-70's (Dame et al. 1981). However, chemosterilising agents are mutagenic and present a potential hazard to humans during the treatment process. Their use was abandoned (Hayes 1968) after concerns were raised about the effects of the chemicals on the environment and non-target

organisms, particularly when large numbers of treated insects were released. These concerns were mainly based on the findings of one, so far unreplicated study (Bracken & Dondale 1972) that found that spiders fed on a diet of nothing but chemosterilised mosquitoes consequently became sterile. Although the amount of residue released in the environment was very low due to the careful rinsing of the pupae (LaBrecque *et al*. 1972), it is unlikely that current public opinion would be in favour of chemosterilisation. Ionising radiation has therefore become the principal technique for sterilisation, even though it has been reported to reduce competitiveness of the males more than chemosterilisation (El-Gazzar & Dame 1983, Dame 1985).

Figure 2. Cobalt-60 gamma source used for the irradiation of insects. *Cobalt-60 gammabron die gebruikt wordt voor de bestraling van insecten.*

The irradiation process is generally carried out using gamma rays, due to their high energy and penetrating capability. When biological matter is irradiated, molecular bonds are broken, ions created and free oxygen radicals are formed. Presence of free radicals results in DNA damage, leading to the formation of dominant lethality in the germ cells (LaChance 1967, Curtis 1971). Moreover, somatic damage can occur in cells undergoing mitosis. In general, damage induced by irradiation is greater with increasing dose and small- er as insect development progresses. The efficiency of SIT programmes is directly related to the ability of sterile males to successfully locate, mate and inseminate wild females. In general, the competitiveness of irradiated insects will be lower than the competitiveness of wild insects, however the goal is to reduce the negative effects of irradiation as much as possible but still maintain an adequate level of sterility.

In mosquitoes, both the pupal and the adult stages can be irradiated. Pupae are more robust than adults, which make them easier to handle for irradiation. Competitiveness loss due to irradiation is considered greater in the pupal stage than in the adult stage (Curtis 1976, Andreasen 2003), however there is little research into the use of lower doses. The effects of lower doses will be addressed in the current mosquito SIT programme.

As only limited data is available on the radio sensitivity of *A. arabiensis*, the first phase of the programme has focused on the development of dose-sterility curves for the pupae and adult stages. Once completed, a range of doses will be tested in competition experiments. Initial experiments in the laboratory will be performed to gain insight into the level of competitiveness present in the sterile males. A large cage will be used in which sterile males compete with non-irradiated laboratory-reared males for laboratory-reared females. However, in later stages of the programme, competition experiments will need to take place in a semi-field setting, such as a greenhouse, where irradiated males will be competing with (wild) males for (wild) females.

Moreover, there are ways to reduce irradiation damage. Irradiation in a low-oxygen environment can produce more competitive insects (Fisher 1996). For anophelines, the few studies with irradiation under low oxygen that have been performed (Curtis 1976, El-Gazzar & Smittle 1984) indicated no major benefits, but as the method proved worthwhile for other insect species, this might still be worth pursuing. Modern biotechnology has suggested that transgenic methods may be able to induce sterility (Thomas et al. 2000) although such methods are not yet available for anopheline mosquitoes. Moreover, the release of transgenic insects in the wild may be problematic.

Sexing

The release of only males is a prerequisite for any mosquito SIT programme (Robinson & Franz 2000), thus an efficient sex separation system is required. Male mosquitoes are generally smaller than females, resulting in smaller pupae and a shorter development time (Clements 1992). However, in anophelines, mechanical sex separation of pupae based on size will not yield satisfactory separation, because the size distributions are overlapping. The effectiveness that was achieved with mechanical pupae separation of *A. albimanus* in the first El Salvador trial was only 85% (Lowe *et al*. 1980), which is too low for any operational SIT programme.

Male and female mosquitoes have a distinctly different spectrum of wing beat frequency and they can easily be differentiated and separated on the basis of this. However, upscaling a system in a way that it can automatically recognize and sort males and females with little stress remains a challenge. In such a system, females would be removed only at the very last stage of development, reducing the capacity of the facility and increasing the costs of mass rearing.

The main focus currently is on sexing methods based on genetic transformation. The classical genetic sexing strains (GSS's) have been developed for various insects including anophelines and they rely on the linkage of a dominant selectable marker to the male determining chromosome. Linkage is accomplished by radiation-induced translocations followed by crossing and screening of the offspring. Resistance genes, e.g. temperature-sensitive lethal genes and insecticide-resistance genes, have been used as selectable markers. The process of creating a GSS is very time consuming and the system must be accurate and stable under mass rearing conditions. Moreover, the method is species-specific. However, once established, these strains can be very valuable. For example a GSS of medfly is currently used in all SIT operational programmes (Robinson et al. 1999). A successful anopheline GSS was the MACHO strain of A. albimanus used in the second trial at the Pacific coast in El Salvador (Dame *et al*. 1981). This strain was created by linking an insecticide (propoxur) resistance gene to the male chromosome and an inversion was induced to suppress further recombination and thus stabilize the strain. Females were removed from the population by treatment of the eggs with a discriminating dose of insecticide. The effectiveness of this sexing strain was 99.9% and large numbers of male mosquitoes (one million per day) could be released (Lowe *et al*. 1980, Dame *et al*. 1981).

Another method to create a GSS is by genetic transformation whereby a specific segment of DNA is inserted into

the genome (transgenesis) creating a genetically modified organism (GMO). This will require the insertion of a conditionally lethal gene that would be expressed only in the females. Genetic transformation can also be used to engineer strains of mosquitoes that render the mosquito refractory to Plasmodium parasites (Ito et al. 2002), or generate a sterilising system that is based on dominant lethal genes expressed in females only, referred to as RIDL (release of insects carrying dominant lethals) (Alphey *et al*. 2002). In RIDL, no irradiation is required. So far, successful germline transformation has been accomplished in a number of insects (Robinson *et al*. 2004) using fluorescent markers to identify transformed individuals. However, for a sexing strain, the marker needs to be accompanied by a gene that is conditionally lethal to females and this has not yet been accomplished for Anopheles, though several of such strains have been developed in *Aedes aegypti* (Linnaeus) (Alphey pers. comm.). Another useful application of transgenesis is the ability to mark insects so that they can be recognized after release. Marking can also result in a sexing method. Recently, a transgenic sexing strain has been developed in *A. stephensi* that has male mosquitoes expressing a fluorescent protein in their gonads. Females do not express the protein and can be removed from the population by automated screening of third instar larvae (Catteruccia *et al*. 2005).

Our project will focus on the development of a genetic sexing strain based on a classical genetic approach. In the case of *A. arabiensis* this can be done using an insecticide (dieldrin) resistant strain that is currently under study. Parallel to this, the transgenic approach will also be developed. Both types of sexing strains would require irradiation to sterilise the males.

Release methodology

Depending on the time of irradiation, mosquitoes can be released at either the pupal (pupal irradiation) or the adult stage (pupae/adult irradiation). Releases of pupae were performed in the El Salvador trials. The pupae were released in cups or pans and left to emerge in the field (Dame *et al*. 1974, Bailey *et al*. 1979, Lowe *et al*. 1980); a cup could hold around 1500 pupae. Cups were either put in floating containers that were released on water surfaces of breeding sites or on land when placed in release shelters. The latter method proved to be more effective (Lowe et al. 1980). How- ever, some predation (mostly by ants) was observed, but this was easily managed by placing baits around the release site (Bailey *et al*. 1979, Lowe *et al*. 1980). The release of pupae is feasible, but requires good access to the release sites by land and a large number of personnel to perform the daily releases. Irradiation of pupae has to be performed preferably on older pupae, thus irradiation and release will need to be done on the same day, which requires that the field sites should be in the vicinity of rearing and irradiation facilities. However, cooling of pupae delays their development and this may be a useful way to increase the time between irradiation and release.

Adults can be released by ground or by aerial release. In El Salvador, some experiments with adult ground releases were performed; a special 'flat cage' was developed that could hold up to 2000 adults and cages could easily be stacked for transport (Bailey *et al*. 1979). Mortality was acceptable, however handling was intensive and caused considerable stress to the mosquitoes. Releases were difficult and, due to weather conditions, adults had to be released after sunset. Aerial releases, although never tried with mosquit-

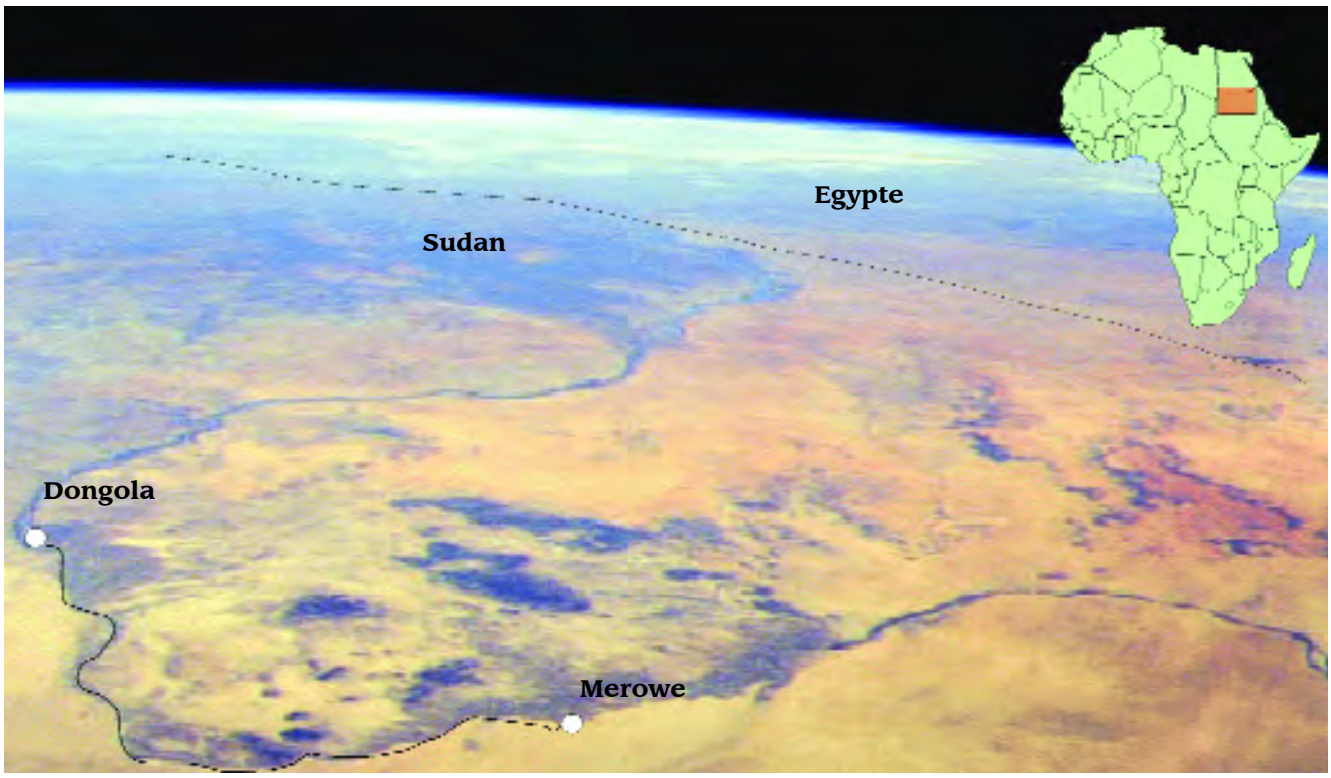

Figure 3. Satellite image of the project area along the Nile, situated between Dongola and Merowe, in Northern State, Sudan. Photo: unknown
Satellietbeeld van het onderzoeksgebied langs de Nijl, gelegen tussen Dongola and Merowe, in de Noordelijke Staat van Soedan.

oes, have a number of potential benefits over ground releases. The release sites can be further away from the facilities, extending the geographical scope of the operation greatly. The need for good ground access to the field sites is no longer valid for daily releases, although for monitoring purposes it would still be desired. In addition, the number of staff required for aerial releases is lower and aerial releases can benefit from existing on-board navigation equipment to accurately release the mosquitoes in the designated areas. However, costs associated with aerial releases are higher and landing strips/platforms et cetera need to be in place. Aerial releases are performed in the large medfly programmes where flies are kept immobile during packing and transport by chilling and are released through the bottom of the aircraft. However, unlike the robust medfly, mosquitoes are rather fragile creatures. Handling, packing and release methods for mosquitoes need to be developed and tested to assess the impact of aerial release on male behaviour and longevity (Dame & Curtis 1996). Moreover, age of release is important, in El Salvador it was found that the release of older adults (2-3 days) caused less population reduction than the release of pupae or young adults (Dame et al. 1981).

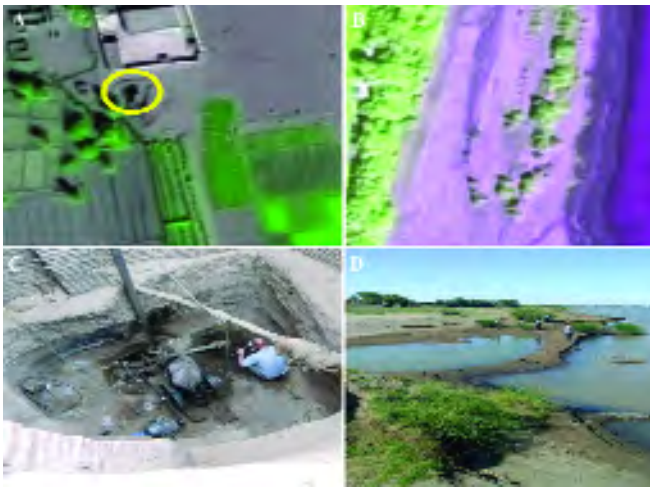

Figure 4. High-resolution satellite images (a, b) from the project area in Northern State, Sudan. **a** Leaking underground pump, **b** riverside. Pictures below (**c, d**) show what was observed during ground inspection. *Hoge-resolutiesatellietbeelden (a, b) van de onderzoeksgebieden in Noordelijke Staat, Soedan.* ***a*** *Lekkende ondergrondse pomp,* ***b*** *rivieroever. Foto's onder (**c, d**) laten de situatie zien vanaf de grond.*

Field evaluation

Historically, the majority of research on mosquito behaviour and ecology has focused on females, as these are the vectors of disease. Male biology and behaviour has largely been ignored (Ferguson *et al*. 2005), but it is a crucial component for any SIT programme. Therefore, the project focuses on improving field evaluation of released males: this will entail developing methods for assessing male behaviour and competitiveness, dispersal and monitoring of released male mosquitoes.

The field site of the pilot project is situated in Northern State, Sudan, where pockets of breeding sites occur on the banks of the Nile in an area otherwise surrounded by irrigated land and desert (figure 3). *Anopheles arabiensis* is the only malaria vector present. Two localities, each at the edge of the anticipated release area, have been selected and state-of-the-art larval surveillance has been set in place. Around the project areas, on a monthly basis, larval surveys are performed in random and static sites. All breeding sites found are characterized according to fixed criteria (for instance larval density, water depth et cetera) and the data are fed into a hand-held computer linked to a Global Positioning System (GPS). Moreover, with aid of high-resolution satellite images of the project areas, potential breeding sites are easily identified (figure 4). Collection of meteorological data occur with automated weather stations on site. Population genetic studies on the various A. arabiensis populations present across the project area are performed. So far no chromosomal or molecular differences have been found between populations.

Conclusions

The objective of the programme is to see whether it is feasible, from a technical, economical and a biological perspective, to use sterile male mosquitoes to control mosquito populations in designated areas in the African context. It is a challenging project. However, considering the successes of SIT with other insect pests and the fact that current technology can facilitate many aspects of a SIT programme, the effort is justified. Substantial progress has been made in developing field sites and establishing research collaborations. Current research focuses on mass production, sexing and sterilisation. The success of a SIT campaign, besides proper management, largely depends on the quality and behaviour of the released insects. Where as in the past SIT might have been perceived as a stand-alone technology, the current thinking is to consider it as part of an integrated anopheline control programme, where SIT has the potential to suppress and at a later stage eliminate a local pest population.

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Samenvatting
De Steriele-Insecten-Techniek: kan een bestaande methode malaria verslaan?

In 2004 is het Internationaal Atoomagentschap (IAEA) begonnen aan een vijfjarige haalbaarheidsstudie naar het gebruik van de steriele-mannetjestechniek ter bestrijding van Afrikaanse malariamuggen. De steriele-mannetjestechniek behelst het in grote aantallen produceren, steriliseren en vervolgens loslaten van steriele mannetjes. De vrijgelaten mannetjes paren met wilde vrouwtjes in het veld; omdat ze steriel zijn komen er geen nakomelingen. Op deze manier kan een plaagpopulatie gereduceerd en uiteindelijk geëlimineerd worden. De steriele-mannetjestechniek is succesvol toegepast voor de eliminatie van diverse plaaginsecten, bijvoorbeeld de schroefwormvlieg in Noord- en Midden-Amerika en Libië en de tseetseevlieg in Zanzibar.

Het project zal zich in eerste instantie richten op de muggensoort *Anopheles arabiensis,* een belangrijke vector van malaria in Afrika. Er wordt onderzoek uitgevoerd naar de voorwaarden waaraan bij massaproductie moet worden voldaan om op grote schaal kwalitatief goede steriele mannetjes te produceren. Verder wordt er gewerkt aan een systeem om mannetjes en vrouwtjes te scheiden door middel van genetische methoden. Dit is nodig omdat vrouwtjes de ziekte overdragen en dus niet losgelaten mogen worden. Mannetjes worden steriel gemaakt door middel van gammastraling. Er zal onderzoek worden verricht naar de optimale dosis en ontwikkelingsstadium voor het bestralingsproces. Er wordt gezocht naar een dosis waarbij de muggen een hoog niveau van steriliteit hebben (gestreefd wordt naar minstens 80% steriliteit per mannetje), maar niet te veel inleveren aan competitievermogen. Er zal ook onderzocht worden hoe de muggen losgelaten kunnen worden en in welk ontwikkelingsstadium dit dient te gebeuren. Het veldonderzoek zal plaatsvinden in een gebied in het noorden van Soedan. *Anopheles arabiensis* is in dit gebied de enige malariavector. Met behulp van geavanceeerde technieken zoals global positioning systemen (GPS) en satellietbeelden worden de larvale broedplaatsen gelokaliseerd.