Using carnivorous plants to control malaria-transmitting mosquitoes

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1 Introduction

Malaria remains one of the major vector-borne diseases in the world. It is responsible for approximately one million deaths per year, mainly of children below the age of five, particularly in Sub-Saharan Africa [1]. Mosquitoes of the genus *Anopheles* are the sole vectors of malaria in sub-Saharan Africa [2]. Current vector control methods are based on larvicide application in breeding sites, indoor residual spraying (IRS) and/or insecticide-treated bednets (ITNs). Larvivorous fish have also been used to control immature stages in breeding sites. However, insecticide resistance poses a serious threat to sustainable insecticide-based vector control in many African countries. Insecticides may also pose serious environmental and human health threats. These insecticide-based control methods are not sufficient on their own to reduce or even eliminate the malaria burden. There is therefore an increasing need to develop novel vector control methods that can complement or replace existing intervention tools.

Carnivorous plants trap and kill their prey, including mosquitoes and their larvae, by ingenious pitfalls and traps, and then use their prey as a source of nitrogen for protein synthesis. They have modified leaves that trap insects by pitfalls (Waterwheel), flypaper traps with sticky mucous and snap traps (Sundews) or bladder trays that suck the insects (Bladderworts). Waterwheels and Sundews also have brightly colored flowers that attract insects including mosquitoes. The shiny droplets of sticky fluid attract mosquitoes [3,4].

Twenty three species of carnivorous plants have been described in Uganda. They are classified into those that grow in water (aquatic) and those growing on land (terrestrial)[5]. The *Drosera spp.* (Sundews) grow on land whereas *Utricularia* (Bladderworts) and *Aldrovanda* L. (Waterwheel or waterbug plants) are found floating on water. There are three species of the genus *Drosera* distributed throughout Uganda. *Drosera madagascariensis* and *D. burkeana* are found in southwest Uganda while *D. indica* is found in the Northern District of Gulu. Nineteen species of *Utricularia* and one species of *Aldrovanda* (*vesiculosa*) have been found in various places in Uganda. *Drosera madagascariensis,* with its leafy stems, offers high chances of trapping mosquitoes that may not necessarily be attracted to the shiny sticky leaves but that would be flying around. At the same time, the leaves of *D. burkeana,* occurring in basal rosettes, would enhance the visibility of the sticky leaves hence increasing the chances of attracting mosquitoes. The aquatic *Aldrovanda* and *Utricularia* plants are suitable for mosquito larvae capture because they can be viewed as motile if the water is a little agitated, hence increasing their chances of finding prey. Those growing in water trap and eat small insects and may be able to trap *Anopheles* larvae while those on land may trap and eat adult mosquitoes [3]. These properties imply potential for them to be used as biological control agents against malaria-transmitting vectors.

We hypothesise that if propagated and deployed appropriately in and around houses and in mosquito breeding sites (like stagnant water), these plants may reduce the population of adult mosquitoes, thereby reducing transmission of malaria.

2 The idea

As part of round 4 (2010) of the Grand Challenge Exploration grants scheme we set out to develop a novel way of controlling malaria-transmitting mosquitoes by deploying live, insect-eating plants around houses and in mosquito breeding sites. We conducted field surveys to collect and identify carnivorous plants. *Aldrovanda vesiculosa* and *Utricularia reflexa* were collected from swamps in various locations in Uganda and brought to the laboratory where they were kept in distilled water. Water from the sites of collection of these plants was collected and analysed for mineral and heavy metal content. *Drosera madagascariensis* was collected from areas around the swamps and taken to a model house sited in the herbarium gardens at Makerere University. Soil from the collection sites was also collected and analysed chemically. Larvicidal bioassays were performed by exposing 4th instar *Anopheles gambiae s.l.* larvae to *Aldrovanda vesiculosa* and *Utricularia reflexa*, in shallow vessels. Surviving larvae were determined at intervals of 12 hrs. Control vessels were set up without the plants and the surviving larvae were also counted at 12 hr intervals. *Drosera madagascariensis* plants were transplanted into shallow pots and irrigated with distilled water or rain water. It was allowed to grow so as to gain enough biomass for mosquito trapping experiments.

3 Results

The results of the larvicidal efficacy of *Aldrovanda vesiculosa* and *Utricularia reflexa* have been published and here we present the summary [6]. Chemical analysis revealed that the soil and water were acidic (pH<7), with low nitrogen and low levels of potassium, calcium and magnesium. The results of the larvicidal efficacy of the aquatic carnivorous plants are shown in Fig. 1. They show rapid elimination of the larvae from the test vessels. The mosquito trapping experiments were not completed. *Drosera madgascariensis* took long to achieve sufficient biomass for deployment in the model houses.

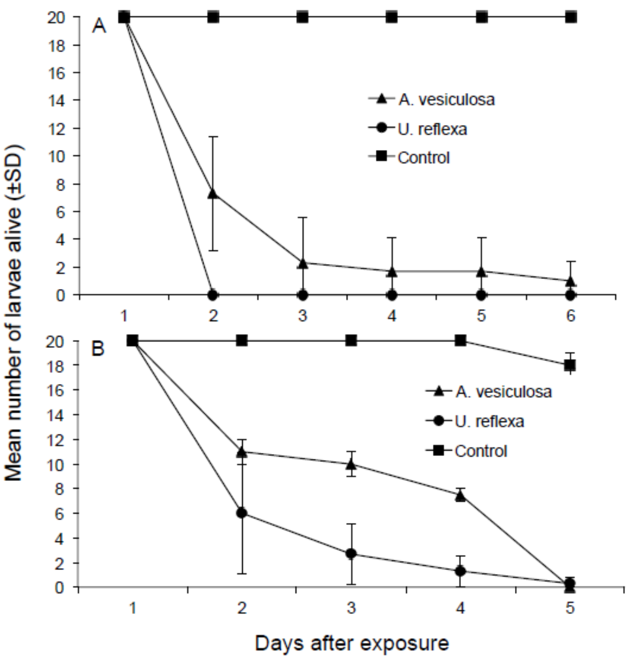

Figure 1. Larvicidal activity of fresh (A) and 7-day old (B) *Aldrovanda vesiculosa* and *Utricularia reflexa* on *Anopheles* larvae.

4 Discussion

Our results suggest that the aquatic carnivorous plants *A.vesiculosa* and *U. reflexa* may eliminate *Anopheles* mosquito larvae from breeding sites. The larvicidal property of these plants could be useful in reducing the populations of *Anopheles* mosquitoes around human dwellings, thereby reducing malaria transmission. While this study demonstrated the efficacy of the plants to control the population of *Anopheles* larvae under laboratory conditions it is still not known if the plants can survive in the natural mosquito breeding sites. The composition of the breeding site water may differ from the swamp water or distilled water that was used to rear larvae and perform the bioassays. We therefore planned to determine the larvicidal effects of these plants in different ecological sites where *Anopheles* mosquitoes breed using the method of Zairi and Lee [7]. This study was planned for the second phase of the grant.

Larval control of anopheline mosquitoes is a well-proven preventive method that deserves renewed consideration for malaria control, particularly in sub-Saharan Africa [8]. The Malaria Control Policy in Uganda is now based on indoor residual spraying, insecticide treated nets or early case detection and treatment [9]. But increasing resistance of malaria parasites to antimalarial drugs and vector resistance to insecticides, inadequate health care systems, population displacements, widespread poverty and declining community acceptance have reduced the effectiveness of these approaches. At the same time, ecological changes driven by deforestation [10], human migration and unmanaged urbanisation have increased the densities of human hosts and vector breeding sites in the country. Given the variability of malaria parasites, the vector and the vulnerability of human populations in Uganda, there is need for a range of malaria control approaches, including selective and sustainable vector control. Although unlikely to replace insecticide-based adult mosquito control, improved non-chemical larval control methods could offer sustainable supplements to other malaria vector and disease control efforts [11].

5 Future perspectives

This study demonstrated that aquatic carnivorous plants significantly reduced the population of *Anopheles* larvae under laboratory conditions. These plants may have a potential in the integrated management of malaria by controlling the density of malaria vectors around human dwellings. The study recommends further work on this biological strategy for controlling malaria by setting up open field trials to establish the efficacy of these plants in reducing the population of mosquitoes in a defined area and the pilot would investigate the effectiveness of the plants in reducing indoor mosquito population and incidence of malaria in small defined urban centres.

Our future studies will further expand laboratory studies on the larvicidal efficacy *Aldrovanda* and *Utricularia* and seek ways to cultivate and propagate these carnivorous plants. We will then also initiate small-scale field trials in different ecological settings in Uganda. A critical element of these studies will be to determine the impact of these plants on indoor and outdoor mosquito densities to gauge their true possible impact on malaria transmission.

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