Intensified Maize Cultivation Enhances Malaria Transmission in Western Ethiopia

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Introduction

By the year 2020, maize is expected to become the dominant food crop in Africa. The burden of malaria, in parallel, has progressively increased throughout much of that continent. Maize pollen has been shown to provide an important source of nutriment for developing mosquito larvae. Larvae feeding on maize pollen develop more rapidly and are larger than larvae feeding on other food sources. This potentially results in an increased mosquito abundance and longer-lived females, thus increasing the risk for malaria transmission. In addition, malaria transmission is highest in areas of intense maize cultivation in western Ethiopia. Current trends in maize food production in sub-Saharan Africa, therefore, suggest that people living and working on or near smallholder farms of maize production may increasingly be burdened by malaria.

Aim

To test the hypothesis that maize cultivation contributes to the increasing burden of malaria in sub-Saharan Africa, we prevented maize plants from shedding pollen during the malaria-transmission season in a village with intense endemicity. We seek to determine whether the force of transmission thereby is reduced.

Methods

We de-tasseled and hand-pollinated maize in seven sites with stable mosquito habitats located in Omo-Nada Woreda, Jimma Zone (Oromia Region) in western Ethiopia. In parallel, maize grown on seven additional sites in the same district were allowed to shed pollen naturally. We recorded the force of malaria transmission and mosquito development continuously in each site during the rainy season (July to October 2006).

Adult, pupae, and larvae were monitored bi-weekly. The following measurements were recorded to determine habitat productivity:

Adult Captures by CDC light trap

- No. and identity of female anophelines per trap
- No. blood fed/gravid/parity (age)
- wing length (body size)

Larvae/Pupae

- Ratio of larvae/pupae for each site
- Pupae were brought back to the lab and allowed to emerge to adults for further analysis.

All female anophelines were preserved in 100% ethanol for PCR analysis to assess mosquito species and *Plasmodium* infection.

Sites were monitored on a bi-weekly basis throughout the growing season of maize.

Map of Ethiopia showing the location of the study sites in the Oromia region (Jimma Zone) of western Ethiopia.

Results

The apparent maize-malaria link is a surprising and unanticipated consequence of the agro-ecological dynamics of a dramatic expansion of maize production in eastern and southern Africa during the past two decades. The expansion of maize in Africa is a function of concerted efforts by national and multilateral policy emphasizing high yielding improved maize varieties for human food supply.

Mosquito larvae that feed on maize develop to the pupal stage more rapidly, more frequently, and produce larger adults where maize pollen is abundant than do those that have little access to this food. In addition, an epidemiological link has been demonstrated between intensification of maize cultivation and an increase in malaria incidence. These data strongly suggest a relationship between the agro-ecology of maize cultivation and malaria by creating enhanced conditions for malaria transmission in regions with high maize productivity.

In the Oromia region of western Ethiopia, we de-tasseled maize in a 50 m radius around each of seven productive mosquito breeding habitats, while seven additional sites were left to pollinate naturally. We monitored mosquito abundance and habitat productivity in all fourteen sites from July to October 2006. The intervention (i.e. de-teaseling) will be reversed between the two groups in 2007.

TABLE 1
Maize cultivation in the Bure District of northwestern Ethiopia, 1993–2002

Year	Total area (hectares) planted with maize	Total cereal area planted, hectares (maize % of total)
1993	11,331	63,795 (17.7)
1994	11,933	59,114 (20.1)
1995	12,882	61,012 (21.1)
1996	13,268	62,921 (21.0)
1997	13,727	66,217 (20.7)
1998	17,642	73,834 (23.8)
1999	19,460	77,078 (25.2)
2000	26,902	79,143 (33.9)
2001	26,758	78,140 (35.9)
2002	19,929	74,505 (26.7)*

* 2002 had a major decrease in the main rains; farmers shifted from maize fields to short-season wheat and maize yields decreased by half.

In the early 1980's, Ethiopia's socialist government saw maize as a high yielding field crop to replace labor-intensive teff and poor yielding sorghum. Maize surpassed teff, barley, and sorghum as the major crop by the mid-1980's. In 1995, maize cultivation was further expanded by the use of inorganic fertilizers, improved maize seeds, and agronomic techniques.

The intensity of maize cultivation was positively and significantly correlated with malaria incidence. The cumulative incidence of malaria in high maize cultivation areas was 9.5 times higher than in areas with less maize.

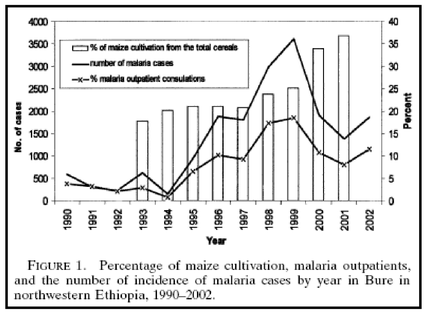
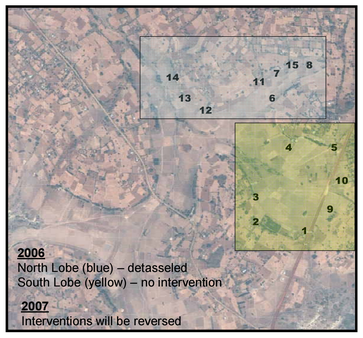


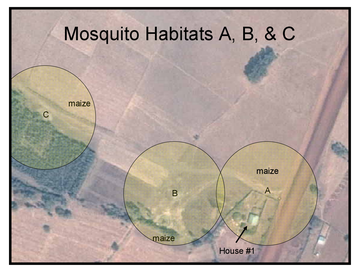
FIGURE 1. Percentage of maize cultivation, malaria outpatients, and the number of incidence of malaria cases by year in Bure in northwestern Ethiopia, 1990–2002.

Example of maize being cultivated in areas with stable mosquito breeding habitats. The adjacent home provides a place for adult mosquitoes to seek blood.

Satellite image of Omo-Nada Woreda (Oromia region) in Western Ethiopia. Fourteen sites were chosen to be included in this study based on the presence of stable mosquito breeding habitat(s) in close proximity to maize. In the northern lobe, tassels were removed from maize just prior to pollen shedding (2006). No intervention took place in the seven sites in the southern lobe.

Interventions will be reversed in 2007.





Enlarged image of study site #1. Mosquito breeding habitats are indicated by the letters A, B, and C. Notice the close proximity of the maize to the mosquito habitat and the location of the house where adult captures took place. Pollen was removed from maize located within a 50 m radius of the mosquito habitat, shown here by highlighted circles.

A team of Ethiopians removed tassels from maize just prior to pollen shedding in the seven intervention sites. Maize was then hand-pollinated to ensure a productive crop for the farmers.

Larvae and pupae were counted from each breeding site to determine productivity. Pupae were taken back to the lab and allowed to emerged to adults for further analysis. CDC light traps were used to monitor mosquitoes in nearby homes bi-weekly.

Conclusion

The force of transmission of malaria in sub-Saharan Africa might be reduced if maize plantings were excluded from the immediate vicinity of the homes, or if an early variety of maize was planted such that pollen shedding would occur prior to peek mosquito development. Alternatively, local malaria transmission could be markedly reduced by cultivating a GMO maize that sheds specific anti-mosquito toxins in its pollen. Sample analysis is currently underway. We anticipate that the de-tasselled sites will have reduced vector abundance, size, and infection rates.

Acknowledgements

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