13.3 Assessment of the Economic and Poverty Impacts of Biological Control of Cereal Stemborers in Kenya using the Economic Surplus Modelling Approach

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In response to the severe stemborers invasion in cereal farming regions of Kenya, a biological control (BC) program was initiated by icipe scientists. This program has released four natural enemies: *Cotesia flavipes* (Cameron), *C. sesamiae* (Cameron) (Hymenoptera: Braconidae), *Telenomus isis* (Polaszek) (Hymenoptera: Scelionidae) and *Xanthopimpla stemmator* (Thunberg) (Hymenoptera: Ichneumonidae) to suppress economically important stemborer pests; *Busseola fusca* (Fuller), *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) and *Chilo partelus* (Swinhoe) (Lepidoptera: Crambidae) . An economic surplus model was developed, based on time-series data on production, market and GIS, to evaluate the economic impact of the BC program in Kenya. Findings show that the BC intervention contributed to an aggregate monetary surplus of $US 0.74 billion to the economy of Kenya. The net present benefit of $US 141.52 million, the Internal Rate of Return of 113.08% and the Benefit Cost Ratio of 276:1 justify that the program was worthwhile. An estimated average of 57,400 persons were yearly lifted out of poverty due to the BC program. Wide promotion and up-scaling of the BC program should thus be considered.

Background and Objectives: In Eastern and Southern Africa, cereals, especially maize, *Zea mays* L., and sorghum, *Sorghum bicolor* (L.) Moench (Poacaea), are among the most important and widely grown field crops but their production is constrained by biotic and abiotic problems. Among biotic constraints, insect pests represent an important challenge and stemborers are by far the major injurious pests in maize and sorghum production (Omwega *et al.*, 2006). Biological control (BC) or use of natural enemies of the pests offers an alternative economically, socially, and environmentally friendly strategy to the frequently used expensive and harmful pesticides (Naranjo *et al.*, 2015). The International Centre of Insect Physiology and Ecology (icipe) undertook a BC program that involved mass-rearing and release of natural enemies to regulate stemborers pest populations. While the acceptable level of parasitism, stemborer densities and yield loss effects are well documented (Omwega *et al.*, 2006 and references therein), economic benefits and poverty reduction impacts of the BC program has not been established. This study analyzed the welfare effects of the release of natural enemies of maize and sorghum stemborers through different BC programs initiated by icipe from the early 1990s to 2007, and the return to investments in research on icipe implemented biological control programs in Kenya.

Methodology and data: The study adopted the Economic Surplus Modeling approach, commonly used for the evaluation of commodity-related technological progress in agriculture (Alston *et al.*, 1995). The economic surplus model estimates the aggregate total monetary benefits for socio-economic agents involved in the introduction of a research innovation of development intervention in a targeted social environment (Maredia *et al.*, 2000). The approach was developed following the framework presented by Alston *et al.* (1995) and others under the assumptions of close economy, linear curves of supply and demand and parallel shift of the supply due to the introduction of BC. Producer and consumer annual surplus changes were calculated using the supply-shift parameter and times series-data of production, prices, and price elasticity supply and demand of maize and sorghum. The supply-shift parameter was calculated using the yield gain from the BC, the annual area covered by the BC, the maize and sorghum price elasticity of supply. Yield gain data was obtained from exclusion experiments while the annual covered area was obtained through a GIS model based on the dispersal rate of the released natural enemies and the coordinates of the release locations, assuming a concentric circle spread from the release points. The Net Present Value (NPV) was calculated by comparing the present total surplus to the present cost of the program using a discount rate of 10%. The Internal Rate of Return (IRR) and the Benefit-Cost Ratio (BCR) were then computed to appreciate the BC program efficiency. The equivalent poverty reduction was assessed following Alene *et al.*, (2009) using data on annual agricultural gross domestic product (AgDP), the annual poverty incidence and poverty elasticity.

Results: Findings of the welfare gain from the economic surplus model show that icipe BC intervention has contributed to an aggregate value of $US 0.74 billion over 20 years (1993 to 2013), with 76.7% ($US 568.06 million) from maize and the remaining 23.29% ($US 172.45 million) from sorghum, implying that the program has induced a highly positive impact on welfare in Kenya. Distribution of the welfare results on the same period provide evidence of higher surplus gain for producers ($US 424.80 million; 57.36%) compared to consumers ($US 315.70 million; 42.63%), the former mainly gain from yield loss reduction and then productivity-effect while the later gain from reduction in price due to the supply-shift. The total NPV over the analysis period was estimated at $US 108.80 million for maize, $US 45.63 million for sorghum cumulating at $US 141.52 for both crops. These estimates indicated that the total discounted benefits from the BC implementation far outweighed the total discounted cost of the program, thus justifying the higher profitability of investing in BC against stemborer attacks. One important step in this evaluation was to appreciate the efficiency of investment in the BC-research by calculating the internal rate to return on the investments. The overall IRR of 113.08% obtained for the aggregate crop is attractive because the return is above the prevailing discount rate considered of 10%. This result justifies that the investment in icipe's biological control research was a highly worthwhile investments. Efficiency analysis provide a BCR of 276:1 meaning that each dollar invested in the biological control program generates an additional higher value of 276 dollars for both crops. These benefits were higher than those obtained in other BC program evaluations in Africa, including De Groote *et al.* (2003) who estimated a BCR of 124:1 for the biological control program of water hyacinth in Southern Benin. Poverty impact expressed here as the proportion of poor people lifted out of poverty ranged from

0.01% in 1996 to 0.56% in 2013, averaging 0.35% per year and representing 57.40 thousands of poor moved from poverty annually with the implementation of BC (Midingoyi *et al.*, 2016).

Conclusion and Policy Implications: Using the economic surplus model, the resulting welfare change in terms of monetary surplus for both producers and consumers confirmed the positive impact of the BC program on social welfare. The estimation of the internal rate of return and the BCRs revealed the high efficiency of funds invested in BC research. The NPV also confirmed the high profitability of this investment. Moreover, the results showed yearly increases in the number of persons lifted out of poverty. This reveals that the BC intervention remains an important policy tool that can promote poverty reduction. Investment in promotion and up-scaling of the biological program against stemborers pests for sustained cereal production and poverty reduction in East and Southern Africa is recommended.

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