An Economic Comparison of Biological and Conventional Control Strategies for Insect Pests in Cashew and Mango Plantations in Tanzania

William Juma George[1], Joseph Hella[2], Lars Esbjerg[3], Maulid Mwatawala[4]and Gration Rwegasira[4]
[1]Department of Economics, Dodoma University, Dodoma, Tanzania
[2]Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Tanzania
[3]Department of Business Administration, Aarhus University, Aarhus, Denmark
[4]Department of Crop Science and Production, Sokoine University of Agriculture, Morogoro, Tanzania
[*]E-mail of the corresponding author: williamgeorge74@yahoo.com

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Abstract

This study was undertaken to compare alternative methods of pest control for insect pests in order to determine which methods has the highest efficacy against insect pests and the least detrimental side effects, while maintaining production and profits. The analysis was based on the experimental trials for three treatments: weaver ants, chemical insecticides and control. Data on yields, quantities and prices of inputs and output were collected and analyzed using inferential statistics (t-test), partial budgetary technique and marginal analysis involving dominance analysis. The results of partial budget analysis shows that a change from chemical insecticides treatment to weaver ants returned net benefits greater than zero by Tsh. 692 923 and Tsh.1019665 in cashew and mango plantations respectively. Similarly, positive net benefits was obtained when growers change from control to weaver ants treatment by Tsh. 504 989 and Tsh. 891 297 in cashew and mango plantations. The dominance and MRRanalyses shows that if cashew and mango growers change from conventional agricultural practices to weaver ants, they would earn MRR of 1621% which is above minimum acceptable rate of return (MARR) of 100%. The t-test analyses show that weaver ant treatment is superior over conventional agricultural practices. The study concludes that weaver ant treatment was economically feasible and financially undertaking. Further field experimental trials will be repeated in the next two growing seasons to confirm results obtained in 2012.

Key words: Conventional, weaver ants, partial budgeting, yield, cashew and mango

1.0 Introduction

Cashew is an important export fruit crop in Tanzania, particularly in the Mtwara Region, while mango is the most important commercial fruit crop in the Coast Region (MDB, 2010). The quality and production yields of these crops areseriously affected bythe prevalence of various insect pests which farmers find difficult to control, making production risky (Dwomoh *et al*, 2009). The mirids (*Helopeltis anacardii*) and coreid bug (*Pseudotheraptus wayi*) are the major pests in cashew in Tanzania (NARI, 2010), whilefruit flies (particularly *Bactrocera invadens*)and the mango seed weevil (*Sternochetus mangiferae*) are the most serious pests in mango plantations (Mulungu *et al*., 2008; Mwatawala *et al*., 2009; Ekesi, 2010).

Growers rely on pesticides as an immediate solution to pest problems. Pesticides, however, are expensive due to repeated application, as well as potentially damaging to human health and environment (Christian *et al*., 2008). Thus, the use of pesticides can create problems such as environmental pollution, particularly of ground water and food supplies; the development of resistance in pest populations; adverse effects on the population of non-target organisms; secondary pest outbreaks and resurgence of target pests (Kos *et al*., 2009). These drawbacks to both producers and consumers have provided a strong impetus for the development of biological control agents in integrated pest management (IPM). Thus, to reduce dependency on chemical insecticides, a suitable integrated pest management model using weaver ants (*Oecophylla longinoda*) was tested in Tanzanian production environments during the 2012 growth season.

Weaver ants, the use of which is compatible with organic certification, have been successfully developed and implemented in Vietnam, Thailand and Northern Australia (Peng *et al*., 2009). Previous research has shown that substituting conventional chemical methods with weaver ant biocontrol led to increases in net incomes of more than 70% in both cashew and mango orchards(Peng *et al*., 2008). Further, Dwomoh *et al*. (2009) found that pest control with weaver ants increased Ghanaian cashew production 4-5 folds compared to no pest control-the common alternative.A key unresolved issue, however, is related to the economic consequences for growers of this conversion. Kishor *et al*. (2011) emphasized the importance of conducting economic analyses of various agricultural technologies to save farmer's meager resources and to enhance the competitiveness of agricultural activities. The feasibility, economic and otherwise, of using weaver ants has not been examined under the socio-economic conditions prevailing in Tanzania. The objective of this study is to compare alternative methods of pest control for insect pests in order to determine which methods has the highest efficacy against insect pests and the least detrimental side effects, while maintaining production and profits. To test whether this also holds for Tanzania, experiments were carried out for both cashew and mango during the 2012 growth season using indigenous weaver ants as a major component. These were compared with two other plots managed with conventional agricultural practices: chemical insecticides and control plots. Partial budgeting, dominance, MRR and t-test statistic results showed that farmers stand to gain better if they change and adopt weaver ants.

2.0 Methods

2.1 Data sources

The data for this analysis were obtained primarily through field trials conducted in Mtwara and Coast Regions of Tanzania where cashew and mango are important crops respectively. In each plantation, the experiment included treatments such as untreated trees (control), trees sprayed with chemical insecticides according to conventional insecticides regime and trees colonized by weaver ants which received 16 colonies per plantation and each colony was given access to 9 trees.

2.2 Data analysis

Two analytical tools were respectively used in the Excel Computer Program to identify the treatments that are not only profitable but also exhibit good margin. The partial budget analysis comes first followed by the marginal analysis (involving dominance analysis) that compares the net benefits from the partial budget. Follow up comparison using t-test of mean differenceswas performed in SPSS 16 for windows to select appropriate (superior) treatments.

2.2.1 Partial budget analysis

In determining the most economically acceptable treatment, partial budget analysis was carried to generate the net benefits of the treatments under studyusing yield at 2012 market price for the crops and inputs.

Estimation of costs that vary:The relevant costs to use in partial budgeting analysis (PBA) are costs that vary between alternative treatments: Costs that vary (total variable costs) for all inputs in each treatment in both plantations were calculated using the current market price as presented in Equation 1.

$$TVC = X_i P_{xi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: $TVC =$ Total Variable Cost per tree, $X_i =$ Quantity of the i^{th} variable input, $P_{xi} =$ Price of the i^{th} variable input.

Estimation of yields and benefits: The economic analysis is based on the average yields of each alternative. A quadrat method which is $1/4\,m^2$ was used to estimate production volumes of cashewnut per tree by counting the number of nuts on the branch area of tree canopies (NARI, 2010). Four quadrats were measured for each tree evenly positioned in four directions (Figure 1).

Figure 1: One meter square method for counting number of cashew nuts per tree

Yieldsof mango fruits were measured by counting all the number of fruits per tree during harvest in each treatment. The gross field benefits (GB) for each treatment in cashew and mango plantations were computed as the product of yields and the price per unit of output as presented in Equation 2.

$$GB = QP \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where: $GB =$ gross field benefit, $Q =$ Quantity of the output (weights of nuts per tree in cashews and number as used in mangoes), $P =$ Producer price.

Estimation of net benefit:This is the gross field benefit less the total costs that vary (management expenses) as presented in Equation 3.

$$NB = GB - TVC \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: $NB =$ Net benefit, $GB =$ gross field benefit, TVC =Total Variable Cost.

The net income effect of the proposed change was calculated by comparing the new benefits and cost saved to the benefits foregone and new costs. The producer will be able to make effective decisions resulting from the equations for Benefit-Detriment analyses as presented as suggested by Kay *et al*., (2008). For the change to be economically feasible and financially undertaking, the equation should be greater than zero to indicate positive change. A negative difference will indicate that the change is less profitable.

2.2.2 Marginal analysis

The accruing net benefit and the cost that vary were then compared across treatments in dominance analysis based on the criterion that any treatment that had net benefit equal or lower than that of another treatment with lower cost is dominated and as such would not be considered for investment by the farmer. The Marginal analysis was carried out on the undominated treatments in a stepwise manner passing from one treatment with the lowest cost that vary to the next. This is to reveal how the net benefit from a decision to change from one treatment to another increaseswith cost. For each pair of ranked undominated treatments, a percentage marginal rate of return between treatment 1 and 2was calculated which is the ratio of marginal net benefit (increase of net benefits) to the marginal cost (increase of cost that vary) as presented in Equation 4.

$$MRR = \frac{Change\ in\ NB\ (NB_2 - NB_1)}{Change\ in\ TVC\ (TVC_2 - TVC_1)} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Marginal analysis was based on the assumptions that, fixed costs were not included and a treatment is considered worthy investment by farmers if MRR is higher than minimum acceptable rate of return (MARR) at 100% (CIMMYT, 1998; Asumadu *et al*., 2004).

2.2.3 Statistical analysis

Inferential statistics of t-test of differences between weaver ants and conventional agricultural practices was used to establish significant difference in the mean benefits of the treatments in cashew and mango plantations.

In comparing the mean benefits for treatments, the null hypothesis(H_o), that the mean benefits of using weaver ants is equal to that of conventional agricultural practices (Equation 5) was tested against the alternative hypothesis (H_a)that the mean benefits of weaver ant is not equal to that of conventional methods (Equation 6) using the t-statistic stated in Equation 7 and at 5% probability for significance. This is with the intention of determining if using weaver ants brings about benefits different (superior) from conventional agricultural practices(chemical insecticides and control), respectively.

$$H_o: \mu_1 = \mu_2 \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$H_a: \mu_1 \neq \mu_2 \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$t_c = \frac{(\bar{X}_1 - \bar{X}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Such that$\bar{X}_1$, S_1, μ_1 and $n_1$are the sample mean, sample variance, population mean and sample size of weaver ants, respectively; and $\bar{X}_2$, S_2, μ_2 and n_2 are the sample mean, sample variance, population mean and sample size of conventional agricultural practices.

3.0 Results

3.1 Budgeting

The crop budget (Table 1) contains details of yield components and associated costs that were used to construct partial budgets under *with* and *without* framework of technology assessments. Weaver ant treatment gave higher yields in cashew and mango plantations followed by chemical insecticides treatment. Plots with control treatments in both plantations recorded the lowest yields.Similarly, the cashew nuts and mango fruits protected by weaver ants fetches higherprices in the international markets compared to conventionally produced that use chemicals to control fruit flies and other pests.

Table 1: Crop budget of weaver ants versus conventional agricultural practices in cashew and mango plantations based on 2012 data in Tanzanian shillings

Operations	Cashew			Mango		
	Weaver ants	**insecticides**	**Control**	**Weaver ants**	**insecticides**	**Control**
Costs that vary						
▪ Transplanting of weaver ants	68200	0	0	55000	0	0
▪ Chemical insecticides		128160		-	131000	
▪ Sulphur dust	45000	187000	187200	-	-	-
▪ Motorized machine	0	100000	0	0	45000	0
▪ Labour for spraying	0	108000	0	0	15000	0
▪ Fuels(petrol)	2000	25000	0	0	5000	0
Total costs	**115200**	**548160**	**187200**	**55000**	**196000**	**0**
Benefits						
Yields	256.6	131.9	23.3	1697.0	865.0	589.0
Prices	1823.56	1576.67	1576.67	704.3	422.58	422.58
Gross field benefits	467925.49	207962.8	36736.41	1195197.1	365531.7	248899.62
Net benefits	**352725.49**	**-340197.23**	**-150464.59**	**1140197.1**	**169531.7**	**248899.62**

3.2 Evaluating the differences in benefits and costs

The partial budgeting analyses (Table 2) indicated that the shift or change from chemical insecticides to weaver ants returned net benefits greater than zero (positive) by Tsh. 692 923 and Tsh. 1 019 665 in cashew and mango plantation respectively.

Table 2: Partial budget for calculating net change of substituting weaver ants for insecticides in cashew and mango plantations in Tanzanian shillings

Cashew				**Mango**			
Benefits		**Detriments**		**Benefits**		**Detrimnets**	
(a) Additional benefits		*(c)Reduced benefits*		*(a) Additional benefits*		*(c) Reduced benefits*	
▪ Increased benefits	259963		0	▪ Increased benefits	829665		0
(b) Reduced costs		*(d) Additional costs*		*(b) Reduced costs*		*(d) Additional costs*	
▪ Chemical insecticides	128160	▪ transplant colonies	68200	▪ chemical insecticides	131000	▪ Transplant colonies	55000
Sulphur dust (powder)	142000			▪ Motorized machine	45000		
▪ Motorized machine	100000			▪ Fuel (petrol)	5000		
▪ Labour cost for spraying	108000			▪ Labour for application	15000		
▪ Fuel (petrol)	23000						
Total benefits	**761123**	**Total detriments**	**68200**	**Total benefits**	**1074665**	**Total detriments**	**55000**
Net change of benefit in cashew plantation: $\boldsymbol{Benefits - Detriments = 692923}$				**Net change in benefit in mango plantation:** $\boldsymbol{Benefits - Detriments = 1019665}$			

Similar results (Table 3) shows that the shift or change from control treatment to weaver ants returned net benefits greater than zero (positive) by Tsh. 504 989 and Tsh. 891 298 in cashew and mango plantation respectively.

Table 3: Partial budget for calculating net change of substituting weaver ants for control treatments in cashew and mango plantations in Tanzanian shillings

Cashew				**Mango**			
Benefits		**Detriments**		**Benefits**		**Detrimnets**	
(a) Additional benefits		*(c)Reduced benefits*		*(a)Additional benefits*		*(c)Reduced benefits*	
▪ Increased benefits	431189		0	▪ Increased benefits	946298		0
(b) Reduced costs		*(d) Additional costs*		*(b)Reduced costs*		*(d) Additional costs*	
▪ Sulphur dust	142000	▪ transplant colonies	68200	-	0	▪ transplant ant colonies	55000
Total benefits	573189	Total detriments	68200	Total benefits	946298	Total detriments	55 000
Net change in benefit in cashew plantation: $\boldsymbol{Benefits - Detriments = 504989}$				**Net change in benefit in mango plantation:** $\boldsymbol{Benefits - Detriments = 891298}$			

In the partial budget analysis, costs that vary and net benefits for each treatment was calculated but did not compare the costs that varied with the net benefits. To generate more information for effective decision making marginal analysis involving dominance analysis was performed to gives details on interaction between total variable costs and net benefits and the return to additional investment as a farmer changes from conventional agricultural practices to weaver ant technology.

3.3Comparing the costs that vary with the net benefits

Table 4 presents the results for marginal analyses involving dominance and marginal rate of return in cashew and mango plantations. In cashew plantation, the dominance analysis shows that control and chemical insecticides treatments were dominated ('D') by weaver ant treatment indicating that control and chemical insecticides treatments were less profitable than weaver ant treatment. Since only one treatment remained, marginal rate of return (MRR) cannot be calculated.

Table 4: Partial budgeting with dominance and marginal analysis to establish profitability of treatments in cashew and mango plantations

	Cashew			**Mango**		
	Weaver ants	**Control**	**Insecticides**	**Control**	**Weaver ants**	**Insecticides**
Yield	256.6	23.3	131.9	589	1697	865
GB	467925.5	36736.41	207962.77	248899.62	1195197.1	365531.7
TVC	115200	187200	548160	0	55000	196000
NB	352725.5	-150463.59	-340197.23	248899.62	1140197.1	169531.7
MRR	**--**	**D**	**D**	**--**	**1621%**	**D**

GFB = gross field benefit, TVC = total variable cost, NB = net benefit, MRR = marginal rate of return and D = dominated treatment.

In mango plantation, the dominance analysis results showed that control and weaver ant treatments were dominated by chemical insecticides treatment. Hence the decision on the best technology to adopt cannot be decided at this stage. This lead to analysis of MRR which threw more light on the relationship among the undominated treatment in terms of increasing costs and benefits. The net change in net benefits between weaver ant treatment and control treatment was Tsh. 891297.48, and change in total cost that vary was Tsh. 55 000 which resulted in MRR of 16.21 (1621%).

3.4 The t-statistics

The results of t-test analysis of mean benefits showed significant differences $(p < 0.05)$between weaver ants and chemical insecticidesin cashew and mango plantations (Table 5).

Table 5: Comparison of mean benefits between weaver ant and chemical insecticides in cashew and mango plantations using t–tests

	Cashew			Mango		
Treatments	**mean**	**Standard deviation**	**tc**	**mean**	**Standard deviation**	**tc**
Weaver ants	4240.0	337.81	41.1*	14300.0	7648.7	8.8*
Insecticides	2198.3	208.16		6006.9	5588.3	

*Significant at 95% confidence interval

A similar result was found when weaver ants were compared with control treatment in both plantations (Table 6).

Table 6: Comparison of mean benefits between weaver ant control treatment in cashew and mango plantations using t–tests

	Cashew			Mango		
Treatments	**mean**	**Standard deviation**	**tc**	**mean**	**Standard deviation**	**tc**
Weaver ants	4240.0	341.79	82.8*	14300.0	7648.7	10.8*
Control	388.3	179.57		4090.3	4570.5	

*Significant at 95% confidence interval

3.5 Quality of nuts and fruits

With respect to the quality, it was observed that trees colonized by weaver ants producedclean and shining cashewnut and mango fruits (Figure 2).

Figure 2: Nuts and fruits protected by weaver ants in cashew and mango plantations looked clean and shining

However, with insecticide spray and control treatments, the nectar was noted to accumulate on the inside curve of nuts, which encouraged sooty development, resulting in black residue/sooty mould on the nuts due to fungus invasion and damages (Figure 3).

Figure 3: Nuts and fruits protected by conventional agricultural practiceslooked black or dull and damaged skin

Further quality assessments show that weaver ant treatment in cashew and mango plantations produced an average of 20.8% grade-1 and 17.3% of first class fruit respectively compared to trees protected by chemical insecticides and control treatments.

4.0 Discussion

4.1 Crop budgeting

From the yield component results it is evidence that the weaver ant treatment increased the yields two-folds compared to chemical insecticides. This was attributed to a reduction of the infestation due to protection of nuts in the trees colonized by weaver ants. These results agree with the findings of Dwomoh *et al*. (2009) who found that pest control with weaver ants increased Ghanaian cashew production four to five-foldscompared to chemical spray. The highest cost that vary in insecticides in cashew and mango plantations was caused by repeated applications which small scale growers cannot afford to buy these insecticides and their equipment. In making farming considerations, a farmer may think in terms of net benefit (savings) of alternative treatments. It is from this that weaver ant treatment gave maximum net benefitat 78% associated with reduction of cost that vary in both plantations. From this it is easier to see the benefits the producers stand to gain from using a less costly and an environmentally friendly production method. These findings conform to Peng *et al*. (2008) who revealed that substituting conventional chemical method with weaver ant biocontrol led to increases net incomes of more than 70% in cashew and mango orchards. Thefindings is also supported by Perrin *et al*. (2005), who revealed that a farmer will not choose a production system unless the rate of return on capital is more than the direct costs of the variable inputs.

4.2 Evaluating the differences in benefits and costs

The benefit-detriments analyses (partial budgeting) revealed that a change from either chemical insecticides or control treatments to weaver ants is profitable. This is shown by net benefits greater than zero (positive) in both plantations. A positive difference indicates that the net benefits in farming with weaver ant treatment exceed the net benefits of farming with conventional agricultural practices suggesting that the change treatments to weaver ants is economically feasible to farmers in both plantations. CIMMYT (1998) argues that partial budgeting analysis alone cannot give effective decision, hence the need to carry out further analysis leading to marginal analyses.

4.3 Comparing the costs that vary with the net benefits

To compare the costs that varied with the net benefits, marginal analysis was done. In this study, the marginal analysis involved dominance analysis, and calculating the marginal rate of return (MRR) for the non-dominated treatment (CIMMYT, 1988). The dominance analysis results showed that only weaver ant treatment was profitable in cashew plantation hence it was not possible to look at the effects on returns from changing from one treatment to another. In mango plantation, results of the dominance analysis indicate that insecticides treatment dominates the other hence it is prudent to look at the effects on returns from changing from one variety to another. Considering that net benefits from control treatment was the least, growers gain more if they change to weaver ants with high net benefit. CIMMYT (1998) noted that the minimum marginal rate of return acceptable to farmers before making a decision to change from an old practice to a new practice is between 50 and 100%. In this study, the MRR from control treatment to weaver ant treatment was 1621%, which is far beyond 100%. This implied that for each Tsh. 1 invested in weaver ant treatment, mango growers recover their Tsh. 1, plus an additional Tsh. 16.21 as profit. Since the resulting MRR is greater than the minimum acceptable rate of return (MARR =100%), the change from conventional agricultural practices to weaver ant technology in cashew and mango plantations are profitable. This suggests that weaver ant use in both plantations at the present yields, and prices of inputs and outputs is superior. This finding is also supported by Evans (2005) who pointed out that if a technology is relatively new, requiring some new skills, a higher bound MARR may be appropriate to a farmer to shift from his/her usual investments.

4.4 Qualities of nuts and fruits

Trees colonized by weaver ants produced nuts and fruits of higher quality than trees in the insecticides and control treatments. During nut development stage, young nuts secreted extra floral nectar that was observed to attract weaver ants. The nectar was removed by weaver ants which eliminated the development of sooty mould and improves the nut appearance. Peng *et al*. (1997, 2004) showed that cashew trees protected by weaver ants produced cleaner and shiner nuts than trees protected by insecticides in cashew and mango orchards.In addition to the higher quality of external appearance in the chemical insecticides treatment in both plantations, the nuts and fruits contain insecticide residues compared to those in the weaver ant treatment because no insecticides were used. Thus, Tanzanian cashew and mango may be sold as organic, which fetches a higher price in the international markets compared to conventionally produced nuts and fruits that use chemicals to control insect pests. This is an additional marketing advantage that further thatinflates the economic benefits to farmers. From this it is easier to see the benefits organic producers stand to gain from using a less costly and an environmentally friendly production method. Koekoek (2002) reported that the price premium for biologically produced cashews was 25% - 50% higher than the conventional nuts and fruit price and increase about 15% annually.

4.5 Comparison of mean benefits

In testing the null hypothesis of no significant difference in the mean benefits of weaver ants and conventional agricultural practices (Equation 5), and applying the test statistic in Equation 7, the null hypothesis is rejected for the acceptance of the alternative hypothesis. This shows that weaver ant treatment obtained larger mean benefits than the conventional agricultural practices and that weaver ant protection and the associated high price for nuts and fruits produced by weaver ants assisted in increasing respectively the and benefits significantly. This indicating that weaver ant treatment was superior and effective compared to conventional treatments.

5.0 Conclusion

This study has shown that weaver ant treatment in cashew and mango plantations has enormous potential in terms of improving yields, quality and consequently economic returns. Growers in both plantations would be better off if they change from conventional agricultural practices to weaver ants as biological controldue to the positive net benefit and high marginal rate of return (MRR) associated with the change. The MRRwas above 100% minimum acceptable rate ofreturn (MARR) which is a requirement for farmers to change from one technology to another. Investment on weaver ant treatment in both plantations appears to be an economically feasible and financially undertaking. In addition, a price premium based on nut and fruit quality will be an important incentive for farmers to shift to the weaver ants. Based on the results it is clear that, farmers in cashew and mango growing areas in Tanzania should be encouraged to adopt weaver ant technology to address poverty reduction, sustainability and environmental concerns. It allows growers to significantly cut chemical insecticide use who cannot afford to buy these insecticides and their equipment and produce insecticide-free or organic nuts/fruits. Further field experimental trials will be repeated in the next two growing seasons to confirm results obtained in 2012.

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