Quarterly Journal of Econometrics Research
2015 Vol.1, No.2, pp.32-44
ISSN(e): 2411-0523
ISSN(p): 2518-2536
DOI: 10.18488/journal.88/2015.1.2/88.1.32.44

BENEFIT-COST ANALYSIS OF ALTERNATIVE INSECT PESTS MANAGEMENT IN CASHEW AND MANGO ORCHARDS IN TANZANIA

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ABSTRACT

This study was conducted to determine the financial feasibility of African weaver ants (Oecophylla longinoda) as biological control agents in cashew and mango orchards. It was compared to chemical insecticides and control based on the experimental data in 2012/13 and 2013/14 cropping seasons. Three important discounted financial indicators were used in the study; they are the Net Present Value (NPV), Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR). Three scenarios concerning the increase of costs and benefits were used. The results of the study showed that all indicators for financial feasibility analysis were positive and accepted in each treatment. In cashew, African weaver ant without feeding indicated highest NPV (TZS 32 640), BCR (2.5:1) and IRR (57%). In mango, conflicting results were observed in feasibility ranking. But African weaver ants without feeding gave highest acceptable NPV of TZS 66 926. The three scenarios showed that setting much higher costs and benefits at five percent the NPV for African weaver ant was highest than other treatments. The findings of this study suggest that African weaver ant without feeding are financially feasible to be adopted and was recommended.

Keywords: Anacardium occidentale, Biological control, Economic analysis, Mangifera indica, Oecophylla longinoda.

Contribution/Originality

This study is one of very few studies which have investigated the financial feasibility of using African weaver ants (*Oecophylla longinoda*) to provide information that help smallholder farmers making decision on appropriate alternative insect pest management in Tanzanian cashew and mango.

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1. INTRODUCTION

Cashew (*Anacardium occidentale*) and mango (*Mangifera indica* L.) are the most important tree crops widely grown in the Southern and Eastern Tanzania (NARI, 2010; Marketing Marker Associates, 2011). The most important cashew and mango growing regions are Mtwara and Coast. The crops are produced in Tanzania both for export and local markets and contribute as a source of income to smallholder farmers (USITC, 2007; United Republic of Tanzania (URT), 2012). However, the presence of numerous insect pest species causes low yields and quality at farm level.

Cashew is attacked by sucking insect pests such as cashew mosquito bugs (*Helopeltis anacardii*) and coconut bugs (*Pseudotheraptus wayi*) (NARI, 2010). Insect pests for mango are seed weevil (*Sternochetus mangiferae*) and fruit flies particularly *Bactrocera invadens* (Mwatawala et al., 2009). Control of these pests is crucial to sustainable production of cashew and mango.

Although there are several insecticides available that can control the various pests afflicting cashew and mango in Tanzania, they are often too expensive for poor resource farmers and can result in food contamination or environment pollution (Christian *et al.*, 2008). Integrated Pest Management (IPM) has been used in different regions around world to reduce both dependence on insecticides and yield reductions due to insect pests damage (Van Melle and Cuc, 2000; Peng *et al.*, 2010). The IPM model such as the use of Asian weaver ants (*Oecophylla smaragdina*) have mainly focused on South East Asia and Australia, and that it is so far limited research has addressed the financial feasibility of using African weaver ants (*Oecophylla longinoda*) for insect pest control in Tanzania.

Studies in the Northern territory of Australia indicated that substituting conventional insecticides with Asian weaver ant biocontrol in cashew orchards led to increased net benefits of 71% over three seasons due to improved nut yields and quality combined with lower costs (Peng *et al.*, 2004). Similarly in mango orchards net benefits increased by 73% over three seasons due to higher fruit quality and lower costs (Peng and Christian, 2005). In Thai and Vietnamese citrus plantations net benefits increased with 15% and 47%, respectively, when substituting chemical pesticides with Asian weaver ants, where as a 125% negative net gain were associated to the use of weaver ants in a Thai mango plantation (Offenberg *et al.*, 2013). McConnachie *et al.* (2003) revealed positive benefit-cost ratios of biocontrol ranging from 1.9:1 to 53:1 arising from saving in control costs in South Africa as whole. A study by Alene *et al.* (2007) estimated benefit-cost ratio for biocontrol for management of mango mealybug varied between 200:1 to 740:1 with the discounted value of benefits amounting to a NPV of USD 1.7 million for Nigeria, USD 3.8 million for Ghana and USD 7 Million for Benin as whole. Therefore, the objective of this study is to analyze the financial feasibility of adopting African weaver ants, *O. longinoda* as biocontrol against insect pests in cashew and mango orchards in Mtwara and Coast regions of Tanzania. Results of this study provides information to help smallholder farmers in other parts of the country who want to venture into weaver ants in understanding the real costs and return issues.

2. MATERIALS AND METHODS

2.1. Descriptions of Study Areas

The study was conducted at two experimental sites in 2012/13 and 2013/14 cropping seasons. The two sites are predominantly cashew and mango growing areas in Tanzania with good population of weaver ants. The first experiment on cashew orchard was conducted at Naliendele Agricultural Research Institute (NARI) in Mtwara Region, Southern Zone of Tanzania. The experimental site is located at 10º22'S, 40º10'E and at an altitude of 120 m above sea level. The area receives a mean annual rainfall of about 1160mm (unimodal), which falls between November and April. The second experiment was on mango orchard based at Mlandizi village in Kibaha District, Eastern Zone of Tanzania. Its geographical coordinates are 6º46'0"S, 38º55'0"E and at an altitude of 73m above sea level. It receives average annual rainfall of 1023 mm between November and May.

2.2. Experimental Treatments

In the cashew and mango orchards, four different treatments were compared: (i) in the first treatment, a chemical pesticide was used to control pests (chemical), (ii) in the second treatment, weaver ants without feeding were used for biocontrol (WANF), (iii) in the third treatment, weaver ants supplied with food were used for biocontrol (WAF), and (iv) a control treatment where no control measures against insect pests were applied (control). A total of 72 trees of similar age and appearance were allocated to each treatment in both crops. Karate ® 5%EC was applied in the chemical treatment at a concentration of 0.005 litres per cashew tree four to five times per season. The motorized backpack sprayer (M 225-20 Motor-Rückensprühgerät) was used for spraying. The first round was applied at the beginning of leaf flush with additional rounds being applied during flowering and ending at about mid-nut development. Bayfidan, EC 250 g active ingredient was applied at a concentration of 0.015 litres per tree once in every three weeks making a total of four rounds as insecticide for control of powdery mildew diseases (PMD). Also five rounds of Sulphur dust against PMD at the concentration of 0.25Kg per tree were applied at 14-days intervals during panicle emergence and continuing throughout the flowering period making five rounds per season (NARI, 2010). Chemical insecticide treatment used to control sucking and chewing pests in mango orchards were used once every three weeks. Their application concentration was as follows: Powershot (200ml) was applied 10 ml/tree trees three rounds, Dudumida (30g packets) was applied 1g/tree trees three rounds. Fungicides were applied once every two weeks at a rate as follows: Vegimax (125ml packet) was applied one milliliters per tree trees four rounds, Potassium Nitrate (500g) was applied 15g per tree trees applied four rounds and Megasin (500g) was applied 10g/tree trees applied four rounds (AMAGRO 2011, un published report).

In the weaver ant treatments in both crops, weaver ant colonies were collected from neighboring villages and transplanted onto plantation trees so that each colony occupied nine trees with eight colonies per treatment. In the treatment where ants were provided food, weaver ants were fed eight times per season (two times per month in four months) with a 1kg of 30% sugar solution, 1 litre of water and 2kg of fish meat. The weaver ant feeding treatment was not included in the mango orchard during the first cropping season because competing *Pheidole megacephala* ants were abundant in the plantation this year. Feeding might have attracted these ants, which could have resulted in the eradication of the weaver ant colonies, as *P. megacephala* is able to kill weaver ant colonies (Seguni *et al.*, 2011). Sulphur spraying regimens identical to the chemical treatment were used in both weaver ant treatments to control PMD. To study the extra costs and returns associated to pest protection, no control measure was used against pests on the trees in the control treatment, except for sulfur sprayings that were applied as in the other treatments. Sulphur sprayings were needed, as PMD is believed to destroy the harvest if not controlled by Sulphur.

2.3. Data Used in the Financial Analysis

2.3.1. Yields

In cashew the physiologically ripe raw nuts that had dropped to the orchard floor were collected every second day separately for each tree. Collection of the nuts started in late August and ended in November in each cropping season. After the harvest the mass of raw nuts collected from each tree was summed and converted into kernel mass before being compared between treatments. To convert raw nut mass into kernel mass, the raw nut mass was multiplied by 0.245. This conversion factor is the average of two different methods (high out turn and low out turn) (UNIDO, 2011). In mango the number of fruits per tree was obtained by counting all fruits on each tree on the day before the commercial mango harvesters were collecting all fruits in the plantation. Mango fruits were counted on 18/12 and 20/12 in 2012 and 2013, respectively.

2.3.2. Costs and Incomes

The costs associated to each treatment were based on the inputs needed to manage each treatment as detailed in Table 1. Wage rates, transport costs and prices on equipment were obtained from local markets. The total variable costs were estimated as the product of total quantity of inputs/labour used and market prices. To obtain the average costs per tree for each treatment, the total cost was divided by the number of trees (N=72 trees). Selling prices of cashew kernels and mango fruits were based on the price that smallholders could obtain by selling their produce to local farmer cooperatives. The average price used in the analysis was obtained by interviewing 12 representatives from five farmer cooperatives (Namkuku primary cooperative, Mtwara district; Nanganga and Mpowora primary cooperative, Masasi district; Umoja primary cooperative society, Tandahimba district; Jitegemee primary cooperative society, Mkuranga district; Mwendapole primary cooperative, Kibaha district). In cashew there was a realized premium price on organically produced nuts, which were used in the weaver ant and control treatments as these methods are compatible with organic certification. This premium price was given by the Masasi cooperative for organically grown nuts, which were subsequently exported to the Netherlands. For mango there was not yet established market for organic products. In this case the premium price for organic produce used in the analyses was based on what farmer cooperatives expected to be able to achieve via collective action. The gross benefit per tree was calculated by multiplying average yields per tree and price (organic vs. conventional prices).

2.4. Benefit Cost Analysis

A financial benefit cost analysis (BCA) was used to estimate the costs involved and benefits accrued in the management of insect pests in cashew and mango orchards. The BCA is a popular quantitative method used to discount the costs and benefits of alternative investments to a common time period. The two major ways of conducting a BCA are financial and economic analysis. A financial BCA is made from the perspective of the person; group or unit directly involved in the project, for example a farm (Gittinger, 1982). Only the expenses that will be made by the farm and the benefits that will accrue to the farm (externalities not included) are taken into account in a financial analysis (ICRA, 2009). An economic BCA takes the broader perspective of the society. In calculating prices, the main difference between a financial and economic BCA is that while the former uses market prices, the later uses shadow prices. A financial BCA was carried out from the farmers' perspective of the costs incurred and benefits accrued from managing the insect pests in both orchards.

There are different B-C methods such as net present value (NPV), benefit-cost ratio (BCR), internal rate of return (IRR), Pay Back Periods (PBP), etc. For the purposes of comparison, The NPV, BCR and IRR are the financial indicators used in the study. Future flows of costs and benefits were discounted at 10% for a period of two cropping seasons to obtain their present values. The discount rate was considered as the opportunity cost of capital in Tanzania as proposed by the World Bank.

The NPV was calculated from (Equation 1) adopted from Shively (2000).

$$NPV = \left[\frac{GB_1}{(1+r)^1} + \frac{GB_2}{(1+r)^2}\right] - \left[\frac{TVC_1}{(1+r)^1} + \frac{TVC_2}{(1+r)^2}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, GB =Gross benefit in each season, TVC = Total variable costs, 1 and 2 = Number of seasons and r =discount rate.The treatment is financially feasible if the calculated NPV is positive (greater than zero) and highest when discounted at the opportunity cost of capital (Gittinger, 1982; Poudel *et al.*, 2009).

Benefit-cost ratio (BCR) is the ratio of discounted value of gross benefits (present value of benefit) to discounted value of variable costs (present value of costs). The Equation 2 adopted from Cellini and Kee (2010) and Shively (2000) was used.

$$\text{BCR} = \left[\frac{\text{GB}_1}{(1+\text{r})^1} + \frac{\text{GB}_2}{(1+\text{r})^2}\right] \div \left[\frac{\text{TVC}_1}{(1+\text{r})^1} + \frac{\text{TVC}_2}{(1+\text{r})^2}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, GB =Gross benefit in each cropping season, $TVC =$ Total variable costs in each season, $1\ and\ 2$ =Number of seasons and $r =$ discount rate. The investment is said to be financially feasible when the BCR is one or greater than one (Gittinger, 1982; Poudel *et al.*, 2009).

Internal Rate of Return (IRR) is the rate of return that sets the NPV of benefits minus costs to zero. It provides the answer in percentages (relative measure of investments). According to Shively (2000), IRR is that discount rate 'i' (Equation 3) such that:

$$\left[\frac{\text{GB}_1}{(1+\text{i})^1} + \frac{\text{GB}_2}{(1+\text{i})^2}\right] - \left[\frac{\text{TVC}_1}{(1+\text{i})^1} + \frac{\text{TVC}_2}{(1+\text{i})^2}\right] = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

That is, the $\text{NPV} = 0$ and $\text{BCR} = 1.0$. Where: GB =Gross benefit in each cropping season, $TVC =$ Total variable costs in each season, $1\ and\ 2$ =Number of seasons and i =interest (discount) rate. A treatment is financially feasible for investment when the IRR is higher than the opportunity cost of capital (Gittinger, 1982; Poudel *et al.*, 2009).

Sensitivity analysis (SA): The benefit cost analysis does not capture potential changes in factors that alter the feasibility of technologies (does not consider risks and uncertainties). Prices may change in the market and this affects the returns the farmers receive and costs may also change. What would happen given a certain percent increase in the benefit level and a certain percent increment in the cost. The financial feasibility of treatments under changed circumstances was ascertained through changes in NPV, BCR and IRR, assuming changes in total costs and gross benefits for three distinct scenarios: a 5% increase in costs without corresponding increase in benefits (SA1), a 5% increase in benefits without corresponding increase in costs (SA2) and a 5% increase in both costs and benefits (SA3).

2.5. Data Analysis

Microsoft Excel and John's Macintosh Program (JMP) version 10.0 computer packages were used to manage and analyze data. The BCA was used to compare the costs and benefits of managing insect pests for the four treatments studied.

3. RESULTS

3.1. Costs and Returns Analysis

Table1 shows a summary of variable costs and returns used in financial analysis for each treatment in cashew and mango orchards. In both season total variable costs for were highest in the chemical treatment followed by weaver ants with and without feeding and with the lowest costs in the control treatment. Yields in both cashew and mango were not significantly different between the chemical, WAF and WANF treatments but these treatments were all significantly higher than the control. Based on the interviews with farmer organizations the average selling price of a mango fruit would be expected to increase from TZS 880 to TZS 1100 if a market for organic mangos could be established.

The use of weaver ants (WANF) in cashew reduced total variable costs by 19% and 22% in the first and second season, respectively, compared to the use of chemical pesticides, and the use of ants increased costs by 37% and 24% in the two seasons, compared to the control group. Compared to the control treatment in mango, the use of ants (WANF) and chemicals increased costs by 23% and 206%, respectively, in the first season, and by 14% and 207% in the second season.

In cashew, the differences in costs between treatments and the lower selling price of nuts from the chemical treatment generated the highest net benefit in WAF, followed by WANF, control and chemical treatments in the first season, where as the net benefit in the second season was higher in the chemical compared to the control treatment and both of these treatments lower than the ant treatments. While in mango, the differences in costs and selling prices in the first season generated the highest net benefits in the WANF treatment, followed by the control treatment and lastly a very low benefit of only TZS 818 in the chemical treatment.

3.2. Feasibility Analysis

A perusal of Table 2 shows the results of data analysis for the three financial indicators. The NPV, BCR and IRR worked out to be greater than zero, greater than one and greater than the discount rate (10%) for all treatments in both orchards.

In cashew orchard, all the decision criteria used was highest for African weaver ants without feeding than other treatments. On per tree basis, NPV African weaver ant without feeding was TZS 32 640 while African weaver ants with feeding was the second with NPV of TZS 32 114 and control third with NPV of TZS16 858.The NPV for chemical insecticides was lowest at TZS 15 380. The BCR was found to be highest for African weaver ants without feeding at 2.5:1, followed by 2.3:1 for African weaver ants with feeding, 2.0:1 for untreated control and 1.5:1 for chemical insecticides.

The IRR was highest for African weaver ants without feeding untreated control (57%), followed by weaver ant with feeding (49%) and untreated control (41%). Chemical insecticides recorded the lowest IRR at 24%. NPV for African weaver ants without feeding recorded highest at TZS 66 926 per tree, African weaver ants with feeding recorded the second highest at TZS 59 931third for chemical insecticides at TZS 44 773. Untreated control recorded the lowest NPV at TZS 33 981. The conflicting results (opposite order) between NPV, CBR and IRR were noted when ranking feasibility of the treatments. The BCR for African weaver ants with feeding was highest at 14.0:1 despite the lowest NPV when compared to African weaver ants without feeding, which ranked second with BCR at 11.7:1. Control ranked third with BCR of 6.8:1 and fourth for chemical insecticides with BCR of 3.5:1. Similar trend was observed when ranking based on IRR

(274% for African weaver ants with feeding, 174% for African weaver ants without feeding 132% for control and 72% for chemical insecticides.

3.3. Sensitivity Analysis Results

Table 3 shows the results of data analysis according to the assumed scenarios, SA-1, SA-2 and SA-3 in cashew and mango orchards. The analysis showed that all the financial indicators used in the study were slightly lower than those in the existing scenario if there is an increase of five per cent in the costs and the benefits remaining the same (SA-1). All the treatments enjoy astonishingly higher level of NPV, BCR and IRR when costs remained the same and there is an increase of five per cent in benefits (SA-2). The NPVs were found to be slightly higher than the existing values where five percent increase was made in both costs and benefits (SA-3) but the BCR and IRR remained the same as those were found in the existing scenario.

4. DISCUSSIONS

4.1. Costs and Returns Analysis

This study showed that the two methods based on weaver ant biocontrol were superior to chemical and control treatments in terms of net benefits. Ant treatments consistently showed higher net benefits than the two other treatments as they both benefitted from a fruitful combination of high yields and selling prizes and at the same time showed lower costs than the chemical treatments. On the other hand, the extra investment in the feeding of ants compared to unfed ants did not translate into significantly higher yields and net benefits. Therefore, the use of ants without feeding is recommended as a best practise to increase farmer´s net gains. Also the net benefits in the control treatments, despite low yields in these treatments, in some cases, exceed the chemical treatments, again due to lower costs and higher selling prices. This was especially pronounced in mango in the first season where the net benefit in the chemical treatment was very low. This low benefit was the result of the high investment in chemicals in combination with low yields that year, which drastically reduced the margin between income and costs. This result illustrates that treatments with high costs are economically risky in crops with variable yields. In the following year with several-fold higher yields, the net benefit in the chemical treatment increased considerably and to an extent where it exceeded the control treatment.

The higher yields in weaver ant and chemical treatments compared to the control treatments shows that both ant and chemical pesticides efficiently protected both crops. This positive effect was attributed to efficient control of several insect pests in the two crops. The non-significant difference in yields between the ant and chemical treatments showed that these two techniques were equally effective in their control of prevalent pests. These issues are discussed further by Nassor *et al.* (submitted manuscript) in the study that provided the yield estimates used in the current economic analyses.

The high costs associated to the chemical treatments were partly a result of the simultaneous use of several pesticides in both crops and four to five sprayings per season. If these recommended extensive sprayings are needed to obtain adequate pest control, the results of the present study suggest that this investment is not matched with adequate incomes and therefore should be avoided. It may be considered if fewer chemicals or spraying applications would suffice.

Increased yields and net incomes associated to the weaver ant technology compared to alternative control methods comply with previous studies. Peng *et al.* (2004) and Peng and Christian (2005) found that the use of *O. smaragdina* increased net incomes with 71% and 73% compared to chemical pesticide treatments in cashew and mango, respectively, over a three year period. These increases were based on lower costs and higher quality of the harvest in both cases as well as a higher yield in the case of cashew. Higher cashew yields associated to the use of *O. Longinoda* has also been observed by Dwomoh *et al.* (2009) in Ghana, where weaver ants increased yields more than four-fold compared to control treatments but showed no significant difference compared to chemical treatments. In this case no analyses were conducted on net benefits. Lastly, Offenberg *et al.* (2013) found that *O. smaragdina* was able to increase net incomes with 47% in Vietnamese citrus plantations compared to chemical treatments. In this case because of high costs associated to the use of chemicals, as there was no significant difference in yields. In contrast, the same study found that *O. smaragdina* was unable to protect Thai mango adequately as net benefits in this case was 125% lower in the ant treatment compared to trees protected with chemical pesticides due to failed fruit set in the ant trees.

4.2. Financial Analysis

Benefits and costs and do not serve as true yardsticks for making a decision to go for investing in cashew and mango production. This is due to the fact that costs incurred and returns are not comparable without discounting such costs and returns. For this purpose, three techniques i.e. Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR) were used for comparisons. There were differences in feasibility ranking of the treatments in cashew and mango orchards.

In the cashew orchard, all the decision criteria were highest for African weaver ants without feeding. The NPV was positive and highest for African weaver ants without feeding indicating that that the discounted worth of benefits was greater than discounted worth of cost steams. This suggests African without feeding was feasible for adoption. The results are in inline with that of Bokonon-Ganta *et al.* (2002) in Benin reported the discounted value of benefits of biological control of mango mealybug generated higher net benefits which demonstrated the success of the option. Similar results have also been reported by McConnachie *et al.* (2003) in South Africa. Less variable cost for African weaver ants without feeding compared to chemical insecticides proved advantageous to give the highest BCR. These results compare well to Zeddies *et al.* (2000) and Norgaard (1988) recorded benefit-cost ratio of 199:1 and 149:1respectively when biological control was applied against cassava mealybug. Bokonon-Ganta *et al.* (2002) in Benin found biological control effective against mango mealy bug with benefit-cost ratio estimated at 145:1. Van den Berg (2010) found highly cost effective biological control of the spiny blackfly in Switzerland with a benefit-cost ratio of 199:1. The highest IRR for African weaver ant without feeding in cashew and for African weaver ant with feeding compared to conventional practices indicating the worthiness of investments. In the mango orchard, none of the four treatments studied was observed to hold the best position for all decision criteria used (opposite order). The conflicting resultsmight be due to differing cash inflow. Farmers need to decide one treatment to adopt and invest in. This was resolved by considering NPV indicator (absolute values) and ignoring the values of BCR and IRR. African weaver ants without feeding returned highest acceptable NPV implying that weaver ants without feeding is financially feasible due to high value added from its implementation. Jacobs (2007) reported that for conflicting results between NPV, BCR and IRR should rely on NPV to take decisions on the basis of ranking more than one technology.

4.3. Sensitivity Analysis (SA)

Sensitivity analysis indicated that the treatments can improve their positions if benefits are increased at five percent. In addition, increase only in benefits and not in the costs, would lead the treatments to astonishing returns.

5. CONCLUSIONS AND IMPLICATIONS

The study analyzed the financial feasibility of African weaver ants (*Oecophylla longinoda*) as biological control agents in cashew and mango orchards compared to conventional practices. The experimental data supported the research questions indicating that African weaver ant without feeding is financially feasible technology to be adopted. The results also agree with previous studies as indicated in this study. It is in this backdrop that the comparative analysis of the costs and benefits of the insect pest management used and the dissemination of the findings are of great importance to the farmers, researchers and policy makers for better yields and high quality nuts and fruits. There are some limitations in this study where the data is limited to two crops. Ideas for future experiment would be to implement in other tree crops to increase the validity of the study.

6. ACKNOWLEDGEMENTS

This research was supported by Danish International Development Assistance (DANIDA) project no: DFC no. 10-025 AU.

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Table-1. Comparisons of variable costs (TZS/tree) and returns (TZS/tree) used in the financial analysis in both orchards

Treatment	Seasons	Cashew kernels				Mango fresh fruits			
		Costs	Yields (Kg/tree)	Price	Return	Costs	Yields (pcs/tree)	Price (TZS/pc)	Return
WAF	2012/13	14273	1.03	28500	29355	-	-	-	-
	2013/14	15352	1.32	28500	37620	5583	71	1100	78100
WANF	2012/13	12092	1.03	28500	29355	3905	12	1100	13200
	2013/14	13695	1.20	28500	34200	4044	68	1100	74800
CHE	2012/13	15008	0.98	23000	22540	9782	12	880	10560
	2013/14	17505	1.21	23000	27830	10920	73	880	64240
Untreated	2012/13	8857	0.65	28500	18525	3183	8	1100	8800
	2013/14	11042	0.73	28500	20805	3562	35	1100	38500

Source: Experimental data

Table-2. NPV (TZS/tree), BCR and IRR (%) analyses of treatments in cashew and mango production

Orchards	Particulars	Treatments			
		WAF	WANF	CHE	Untreated
Cashew	Present Value of Benefits	57777	54951	43491	34035
	Present Value of Cost	25663	22311	28111	17177
	Net present value	32114	32640	15380	16858
	Benefit-Cost Ratio	2.3:1	2.5:1	1.5:1	2.0:1
	Internal rate of return	49	57	24	41
	Raking based on NPV	2	1	4	3
	Raking based on BCR	2	1	4	3
	Ranking based on IRR	2	1	4	3
Mango	Present Value of Benefits	64546	73818	62691	39818
	Present Value of Cost	5583	6892	17918	5837
	Net present value	59931	66926	44773	33981
	Benefit-Cost Ratio	14.0:1	10.7:1	3.5:1	6.8:1
	Internal rate of return	274	174	72	132
	Raking based on NPV	2	1	3	4
	Raking based on BCR	1	2	4	3
	Ranking based on IRR	1	2	4	3

Source: Experimental data
Notes: Discount rate = 10%

Table-3. Summary of financial indicators under sensitivity analysis for each treatment

Treatments	Sensitivity analysis (SA)	Cashew orchard NPV (TZS)	Cashew orchard BCR	Cashew orchard IRR (%)	Mango orchard NPV (TZS)	Mango orchard BCR	Mango orchard IRR (%)
Weaver ants with feeding	SA-1	30831	2.1:1	46	59701	13.3:1	265
	SA-2	35003	2.4:1	53	63159	14.7:1	283
	SA-3	33720	2.3:1	49	62928	14.0:1	274
Weaver ants without feeding	SA-1	31524	2.3:1	54	66581	10.2:1	169
	SA-2	35387	2.6:1	61	70617	11.2:1	180
	SA-3	34272	2.5:1	57	70272	10.7:1	174
Chemical insecticides	SA-1	13975	1.4:1	21	43878	3.3:1	69
	SA-2	17555	1.6:1	27	47012	3.5:1	72
	SA-3	16149	1.5:1	24	47012	3.5:1	72
Control	SA-1	15999	1.9:1	38	33689	6.5:1	127
	SA-2	18559	2.1:1	45	35972	7.2:1	132
	SA-3	17701	2.0:1	41	35680	6.8:1	132

Source: Experimental data
Notes: SA-1: Five percentage increases in cost, benefit unchanged
SA-2: Five percentage increase in benefits, cost unchanged
SA-3: Five percentage increase in both cost and benefit