International Journal of Sustainable Agricultural Research
2015 Vol.2, No.4, pp.98-110
ISSN(e): 2312-6477
ISSN(p): 2313-0393
DOI: 10.18488/journal.70/2015.2.4/70.4.98.110

PARTIAL BUDGETING ANALYSIS OF DIFFERENT STRATEGIES FOR MANAGEMENT OF INSECT PESTS IN CASHEW AND MANGO ORCHARDS IN TANZANIA

J.G. William[1]† --- J. Hella[2] --- E. Lars[3] --- J. Offenberg[4] --- M. Mwatawala[5]--- G. Rwegasira[6]

[1,2]*Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture (SUA), Morogoro, Tanzania*

[3,4]*Aarhus University, Aarhus C, Denmark*

[5,6]*Department of Crop Science and Production, Morogoro, Tanzania*

ABSTRACT

Before changing from one production method to another, farmers need to consider costs and incomes resulting from the change. This study estimated the effects on net benefit of switching from conventional Tanzanian growing practices (spraying of chemical pesticides and non-pest control) to the use of African weaver ants (Oecophylla longinoda) to control pests in cashew and mango. Yield data from one cashew and one mango plantation covering two cropping seasons was used in an economic analysis. The use of chemical pesticides and the use of weaver ants resulted in higher yields compared to the non-control treatment. Lower input costs in weaver ant treatments, though, resulted in higher economic returns than the use of chemical insecticides in both seasons and crops. In all cases weaver ant treatments also produced higher returns than non-control treatments, despite their higher costs. Switching to African weaver ants without feeding was feasible due to positive net change in benefits in both crops. In cashew the average net benefit for the two seasons was 94% higher when using ants compared to non-control and 112% higher than in the chemical treatment. The corresponding values in mango were 117% and 63%, respectively. Marginal Rate of Return (MRR) was highest for African weaver ants without feeding in cashew at 235% in 2012/13 and 405% in 2013/14 seasons. Similarly, MRR was highest for weaver ant without feeding in mango at 509% in 2012/13 and 743% in 2013/14 seasons. In conclusion, the use of African weaver ants without feeding was consistently the most economically feasible management strategy to be used in Tanzanian cashew and mango pest management.

Keywords: Biological control, Net benefit, Marginal rate of return, Cashew, Mango.

† Corresponding author

Contribution/ Originality

This study documents the effects on net benefit when switching from conventional agricultural practices to African weaver ants against insect pests in cashew and mango orchards in Tanzania

1. INTRODUCTION

Cashew and mango represent an important source of income for smallholder farmers in Tanzania (Marketing Development Bureau (MDB), 2010). High yields and quality nuts/fruits are essential to ensure a price premium (Ekesi *et al.*, 2007; Marketing Marker Associates (MMA), 2011). Insect pests are one of the main factors responsible for low yield and quality Mulungu *et al.* (2008). Major insect pests in cashew orchards are cashew mosquito bugs (*Helopeltis anacardii*) and coconut bugs (*Pseudotheraptus wayi*) (NARI, 2010). In mango orchards, the major insect pests are mango seed weevil (*Sternochetus mangiferae*) and fruit flies, particularly *Bactrocera invadens* (Mwatawala et al., 2009). To combat these pests smallholder farmers often rely on chemical pesticides, but these are expensive and potentially damaging to human health and the environment (Christian *et al.*, 2008).

This challenging situation invites attention from entomologists to concentrate their attention on integrated pest management (IPM) for the production of cashew and mango, for example by using weaver ants (*Oecophylla spp*) as biological control agents (Peng *et al.*, 2010). Previous studies have mainly focused on South East Asia and Australia when using Asian weaver ants (*Oecophylla smaragdina*) for biocontrol; so far only limited research has addressed the feasibility of using African weaver ants (*Oecophylla longinoda*) for pest control in Tanzania.

Substituting conventional insecticides with Asian weaver ant biocontrolin cashew orchards in Northern Territory Australialed to increased net benefits of 71% over three seasons due to improved nut yields and qualitycombined 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, whereas a 125% negative net gain were associated to the use of weaver ants in a Thai mango plantation (Offenberg *et al.*, 2013).In the present study we analyzed the economic feasibility of adopting African weaver ants, *O. longinoda* as biocontrol agents in cashew and mango orchards in Tanzania.

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. The first experiment in a cashew orchard was conducted at Naliendele Agricultural Research Institute (NARI) (10°22'S and 40°10'E) in Mtwara Region, Southern Zone of Tanzania at an altitude of 120 m above sea level. The area receives a mean annual rainfall of about 1160mm (unimodal) which falls mainly between November and April. The mango orchard was based at Mlandizi village (6°46'0"S, 38°55'0"E) in Kibaha District, Eastern Tanzania and at an altitude of 73m above sea level. It receives an average annual rainfall of 1023 mm mainly between November and May.

2.2. Experimental Treatments

In the cashew and mango orchard four different treatments were compared: (i) a chemical treatment where chemical pesticides were used to control insect pests and diseases (chemical), (ii) an ant treatment were weaver ants were used for biocontrol (WANF), (iii) an ant treatment where weaver ants supplied with food were used for biocontrol (WAF), and (iv) a control treatment where no control measures against pests were applied (control).Seventy two trees of similar age and appearance were allocated to each treatment in both crops. In the chemical treatment in cashew, to control insect pests, Karate® 5% EC was applied at a rate of 0.005 litres per tree four to five times per seasonusing a motorized backpack sprayer (M 225-20 Motor-Rückensprühgerät). 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. To control for powdery mildew disease (PMD) Bayfidan, EC 250 g active ingredient was applied at a rate of 0.015 litres per tree once in every three weeks making a total of four rounds. To further prevent PMD to establish also five rounds of Sulphur dust were applied at a rate of 0.25 kg per tree at 14-days intervals during panicle emergence and continuing throughout the flowering period. The chemical spraying regime used in cashew was based on the recommendations given by Naliendele Agricultural Research Institute with mandate in cashew (NARI, 2010).

In the mango plantation Powershot (200ml; 10 ml/tree) and Dudumida (30g packets; 1 g/tree) were sprayed three times and once every three weeks, to control sucking and chewing pests. Fungicides were applied every second week, four times: Vegimax (125ml packet) was applied at a rate of 1 ml/tree, Potassium Nitrate (500g) at15g/tree and Megasin (500g) at 10g/tree. This spraying regimen was based on the recommendations given by the Association of Mango Growers in Tanzania (AMAGRO).

In the weaver ant treatments in both crops weaver ant colonies collected from neighboring villages were 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 may attract these ants which may result in the eradication of the weaver ant colonies as *P. megacephala* is able to kill weaver ants and destroy their 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 measures was used against insect pests on the trees in the control treatment, however, fungicides were applied as in the other treatments. Sulfur sprayings were needed as PMD is believed to destroy the harvest if not controlled.

2.3. Data

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. Fruits were counted on 18/12 and 20/12 in 2012 and 2013, respectively. The methods used for the field work in the cashew and mango plantations and the yields used in the present study derives from Nassor *et al* (submitted manuscript), where additional details can be found.

Costs and incomes: the costs associated to each treatment were based on the inputs needed to manage each treatment. In the weaver ant treatments, transplantation of weaver ant colonies covers the labor involved in identifying ant colonies and transporting them into the plantation. Plastic bags refer to the bags that were used to carry the ant nests that were transplanted into the plantation. Nylon rope was used to connect trees within ant colonies to ease their migration between trees. Plastic bottles were used to feed the ants with water and test tubes used as sugar solution feeders. Transport costs cover all the transport in relation to the management of the treatment. Wage rates, transport costs and prices on equipment were obtained from local markets. To obtain the average costs per tree for each treatment the total cost was calculated and divided by the number of trees($N = 72$ trees per treatment).

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. In mango there was not yet an 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.

2.4. Statistical and Economics Analyses

Analysis of variance was used to test the effect of treatments on yields for each season and for each crop. The partial budgeting technique was used to analyze the net change in benefits when switching from conventional practices to African weaver ant treatments. The decision to adopt African weaver ants was based on the Benefit-Cost equation. A positive difference indicates the change is profitable (Kay *et al.*, 2008).

To compare the costs that varied with the net benefits, marginal analysis involving dominance analysis was used. The Marginal Rate of Return (MRR) for each cost undominated treatments were calculated as the marginal net benefits (i.e. the change in net benefits between treatments) divided by the marginal costs (i.e. change in costs), expressed in percentage. Recommendations were made based on the comparisons of the rates of return between treatments to the minimum rate of return acceptable to farmers from 50% to 100% (CIMMYT, 1998). Hence, any treatment that returns MRR above 100% is considered worthy investment by farmers.

3. RESULTS

3.1. Costs and Return Analysis in Cashew

The total variable costs, cashew yields, gross and net benefits for each treatment are presented in Table 1. In both seasons total variable costs were highest in the chemical treatment followed by weaver ants with and without feeding and with the lowest costs in the control treatment. The use of weaver ants (WANF) 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.

Yields were not significantly different between the chemical, WAF and WANF treatments but these treatments were all significantly higher than the control. 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, whereas 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.

3.2. Costs and Returns Analysis in Mango

Table 2 presents the total variable cost, number of mango fruits per tree, gross and net benefits for each treatment. Similar to cashew, total variable cost was highest in the chemical treatment in both seasons followed by the use of weaver ants and with lowest costs in the control treatment. Compared to the control treatment, 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 both years the average number of mango fruits was not significantly different between the chemical, WAF and WANF treatments but these treatments all produced higher yields than the control treatment. Based on the interviews with farmer organizations the average selling price of a mango fruit would be expected to increase from 880 TZS to 1100 if a market for organic mangos could be established. In the first season the differences in costs and selling prices generated the highest net benefits in the WANF treatment, followed by the control treatment and lastly a very low benefit of only 818 TZS in the chemical treatment. In the second year, higher yields increased the net benefit in the chemical treatment where it exceeded the control treatment but still with higher benefits in the ant treatments.

The use of ants (WANF) increased the net benefit with 66% compared to the control treatment in the first season and with 103% in the second. Due to low yields in the first season in combination with high costs in the chemical treatment the net benefit in WANF was more than 11 times higher than in the chemical treatment, whereas, in the second year with much higher yields, WANF produced a 33% increased net benefit.

If average net benefits for the two seasons are compared between treatments the use of ants in cashew increased the net benefit by 94% compared to the control whereas it increased by 112% compared to the chemical treatment. In mango, ants increased the benefit by 117% compared to the control and by 63% compared to the chemical treatment. It follows that the use of chemical pesticides compared to the control decreased net incomes with 8% in cashew, whereas it lead to an increase of 33% in mango.

In the second year the net benefits for both crops were slightly higher in the treatments where ants were fed compared to the unfed ants. However, it should be noted that this difference was based on a non-significant difference in yields between the two treatments. Therefore, the observed differences in net benefits should not be considered statistically significant.

3.3. Partial Budgeting

For cashew, partial budgeting analyses show that switching from insecticides to African weaver ants led to a positive net change in benefits of 8 731 TZS/tree in the 2012/13 season and 13 903 TZS/tree in the 2013/14 season. Similarly, a positive net change in benefits by 9 991 TZS/tree in the 2012/13 season and 16 622 TZS/tree in the 2013/14 season was obtained when switching from untreated control treatment to African weaver ants (Table 3).

Partial budgeting analyses for mango show that switching from insecticides to African weaver ant without feeding gave positive net change in benefits by 8 957 TZS/tree in the 2012/13 season and 20 736 TZS/tree in the 2013/14 season. Also, a positive net change in benefits by 3 918 TZS/tree in the 2012/13 season and 39 118 TZS/tree in the 2013/14 season was obtained when switching from untreated control treatment to African weaver ants (Table 4).

3.4. Marginal Analysis

Chemical insecticides and African weaver ants with feeding were cost dominated treatment in cashew orchard (Table 5) and therefore not subjected to marginal analysis. Switching from the baseline (untreated control) to African weaver ants without feeding gave the MRR values at 235% in the 2012/13 season and was highest in 2013/14 season at 405%. The lowest MRR values were recorded when switching from untreated control to African weaver ants with feeding at 290% in the 2013/14 cropping season.

Similarly, chemical insecticides generated low net benefits at higher costs in the mango orchard in both cropping seasons (Table 6) and were not considered in marginal analysis. The MRR value at 509% was recorded in the 2012/13 cropping season when switching from the baseline (untreated control) to African weaver ants without feeding. The highest MRR value at 743% was recorded in the 2013/14 season when switching from the baseline (untreated control) to African weaver ants without feeding. Lowest MRR value at 186% in the 2013/14 cropping season was recorded when switching from untreated control to African weaver ants with feeding.

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 prizes. 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 illustrate 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 then 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. Partial Budgeting

The benefit-cost equation yielded positive net changes in benefits when switching from either chemical insecticides or control to African weaver ants. This implies that the incremental benefits in farming with African weaver ants exceed the incremental costs and suggests that using African weaver ants is an economically feasible management practice. However, Evans (2005) pointed out that if a technology is relatively new, requiring some new skills, higher benefits associated with less costs may be appropriate to a farmer to change or shift from his/her old technology.

4.3. Marginal Analysis

Switching from untreated control (baseline) to African weaver ant with and without feeding increased farmers' returns. Both gave MRR above 100% which is typically considered a minimum rate of return acceptable to smallholder farmers to change from one technology to another. This implies that for every Tanzanian shilling invested in African weaver ant with and without feeding, farmers recover their one Tanzanian shilling plus an additional shilling as benefit thus making the use of African weaver ants an attractive option. Farmers who are keen on high profit margin are recommended to adopt African weaver ant without feeding as this gave highest MRR in the analysis. This finding is in line to Das *et al.* (2010) who claimed that rational farmers adopt a new innovation that has a comparatively higher MRR.

5. CONCLUSIONS AND IMPLICATIONS

Agricultural growth requires continuous improvement of crop production technology at the farm level. The objective of partial budget was to recommend insect pests management practice that is economically superior and socially acceptable to smallholder farmers. The proposed technological change in this study was from conventional practices to African weaver ants as biological control agent in cashew and mango orchards. Partial budget results indicated positive net change in benefit when switching from conventional practices to African weaver ants. Switching from untreated control to African weaver ant without feeding resulted into highest and above 100% MRR, and was recommended.

6. ACKNOWLEDGEMENTS

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

REFERENCES

Christian, D.G., A.B. Richie and N.E. Yates, 2008. Growth, yield and mineral content of miscantusinganteus growth as a biofuel for 14 successive harvests. Industrial Crops and Products, 28: 320-327.

CIMMYT, 1998. From agronomic data to farmer recommendations: An economics training manual. Completely Revised Edition. Mexico D.F: 9-38.

Das, A.M., Biswas and M. Mandal, 2010. An economic analysis of Stevia (Stevia Rebaudiana) cultivation through stem cutting and tissue culture propague in India trends. Journal of Agric Econ, 3: 216-222.

Dwomoh, E.A., J.V.K. Afun, J.B. Ackonor and V.N. Agene, 2009. Investigations on oecophyllalonginoda(Latreille) (Hymenoptera: 116 Formicidae) as a biocontrol agent in the protection of cashew plantations. Pest Management Science, 65: 41 – 46.

Ekesi, S., P.W. Nderitu and C.L. Chang, 2007. Adaptation to and small-scale rearing of invasive fruit fly bactrocera invadens (Diptera: Tephritidae) on artificial diet. Annals of the Entomological Society of America, 100: 562 – 567.

Evans, E., 2005. Marginal analysis: An economic procedure for selecting alternative technologies/practices, department of food and resource economics, university.

Kay, R.D., W.M. Edwards and P.A. Duffy, 2008. Farm management. 6th Edn., New York: McGraw-Hill Companies.

Marketing Development Bureau (MDB), 2010. Annual review of cashewnut. Ministry of agriculture, food security and cooperatives. Annual Review of Cashewnut. Ministry of Agriculture, Food Security and Cooperatives. Tanzania: Dar es Salaam. pp: 41.

Marketing Marker Associates (MMA), 2011. Fresh fruits and vegetables sub-sector value chain analysis in Tanzania. Small and Medium Entrprises Competiteve Facility: 33.

Mulungu, L.S., M. Makala and M.W. Mwatawala, 2008. Effect of mango weevil (Coleoptera: Curculionidae) damage on mango seed viability in Tanzania. Journal of Economic Entomology, 101(1): 114 – 117.

Mwatawala, M.W., S. Loth and M.M. Mulungu, 2009. Effect of mango weevil (Coleoptera Curculionidae) damage on mango seed viability in Tanzania. Journal of Economic Entomology, 101(1): 114 – 117.

NARI, 2010. Annual cashew research report. Naliendele agricultural research institute, ministry of agriculture. Tanzania: Food Security and Cooperatives. pp: 23.

Offenberg, J., T.B. Nguyen and D. Wiwatwitaya, 2013. The effectiveness of using weaver ant biocontrol in Southern Asian citrus and mango. Journal of Asian Myrmecology, 5: 139-149.

Peng, R.K. and K. Christian, 2005. Integrated pest management in mango orchards in the Northern territory Australia, using the weaver ant, oecophylla smaragdina, (Hymenoptera: Formicidae) as a key element. Journal of Pest Management, 51: 149 – 155.

Peng, R.K., K. Christian and K. Gibb, 2004. Implementing weaver ant technology in commercial cashew plantations. RIRDC Publication No. W04/088.

Peng, R.K., K. Christian, L.P. Lan and N.T. Binh, 2010. Integrated cashew improvement program using weaver ants as a major component - photo book for cashew growers in Vietnam. Ho Chi Minh City, Vietnam: Agriculture Publisher. pp: 69.

Seguni, Z.S.K., M.J. Ways and P. Van Melle, 2011. The effect of ground vegetations on competition between the ants oecophyllalonginoda and pheidolemegacephala and implications for conservations biological control. Crop Protection, 30: 713-717.

UNIDO, 2011. Tanzania's cashew value chain: A diagnostic. United nations industrial development organization (UNIDO). Vienna, Austria. pp: 235.

BIBLIOGRAPHY

Peng, R.K., K. Christian and K. Gibb, 1997. Control threshold analysis for the tea mosquito bug, helopeltispernicialis (Hemiptera: Miridae) and preliminary results of the control efficiency by the green ant, oecophylla smaragdina (Hymenoptera: Formicidae) in Northern Australia. International Journal of Pest Management, 43: 233:237.

Table-1. Cost (TZS/tree) and Revenues (TZS/tree) comparison between treatments in cashew orchards

	Year 2012/13				Year 2013/14			
Costs and yield components	WANF	WAF	Chem.	Control	WANF	WAF	Chem.	Control
Identify, harvest, transplant ant nests	556	556	0	0	397	397	0	0
Plastic bags	2000	2000	0	0	2000	2000	0	0
Nylon rope	600	600	0	0	0	0	0	0
Fish meat for ants	0	83	0	0	0	83	0	0
Bottles	0	400	0	0	0	50	0	0
Sugar to feed ants	0	14	0	0	0	14	0	0
Test tubes	0	300	0	0	0	100	0	0
Labour for feeding ants	0	1333	0	0	0	1333	0	0
Sulphur powder	2600	2600	2600	2600	4013	4013	4013	4013
Karate	0	0	1075	0	0	0	1138	0
Bayfidan	0	0	2730	0	0	0	2880	0
Sprayer for Sulphur	250	250	250	250	333	333	333	333
Sprayer for chemicals	0	0	500	0	0	0	320	0
Fuel for Sulphur	1390	1390	1390	1390	1519	1519	1519	1519
Fuel for chemical	0	0	1400	0	0	0	1530	0
Labour during Sulphur application	250	250	250	250	333	333	333	333
Labour during insecticides application	0	0	400	0	0	0	400	0
Labour for ring weeding	2000	2000	2000	2000	2500	2500	2500	2500
Labour for harvesting	1823	1823	1823	1823	1823	1823	1823	1823
Transport costs	563	614	590	484	717	794	717	461
Certificationcosts	60	60	0	60	60	60	0	60
Total variable costs (TZS tree^{-1})	12092	14273	15008	8857	13695	15352	17505	11042
Average yield (Kg/tree)	1.03^{a}	1.03^{a}	0.98^{a}	0.65^{b}	1.20^{a}	1.32^{a}	1.21^{a}	0.73^{b}
Average export prices (TZS/Kg)	28500	28500	23000	28500	28500	28500	23000	28500
Gross benefit (TZS/tree)	29355	29355	22540	18525	34200	37620	27830	20805
Net benefit (TZS/tree)	17263	15082	7532	9668	20505	22268	10325	9763

Source: Experimental data, 2012/13 & 2013/14 cropping seasons

Notes: Levels not connected by the same letter are significantly different at P<0.05

Table-2. Cost (TZS/tree) and Revenue comparison between treatments in mango orchards

	Year 2012/13			Year 2013/14			
Costs and yield components	WANF	Chem.	Control	WANF	WAF	Chem.	Control
Identify, harvest, transplant ant nests	174	0	0	174	174	0	0
Plastic bags	100	0	0	100	100	0	0
Nylon rope	208	0	0	208	208	0	0
Fish meat for ants	0	0	0	0	42	0	0
Bottles	0	0	0	0	50	0	0
Sugar to feed ants	0	0	0	0	14	0	0
Test tubes	0	0	0	0	100	0	0
Labour for feeding ants	0	0	0	0	1333	0	0
Apply insecticides (Dudumida)	0	2468	0	0	0	2600	0
Apply insecticides (Powershot)	0	4000	0	0	0	4320	0
Apply fungicides (KNO3)	1020	1020	1020	1140	1140	1140	1140
Apply fungicides (Megasin)	960	960	960	1080	1080	1080	1080
Apply fungicides (Vegimax)	432	432	432	480	480	480	480
Fuel for fungicides application	111	111	111	122	122	122	122
Fuel for insecticides application	0	111	0	0	0	122	0
Hire machine for fungicides application	200	200	200	240	240	240	240
Hire machine for insecticide application	0	240	0	0	0	288	0
Labour for spraying fungicides	200	200	200	240	240	240	240
Labour for spraying insecticides	240	0	0	0	0	288	0
Certification costs	260	0	260	260	260	0	260
Total variable costs (TZS tree-1)	3905	9742	3183	4044	5583	10920	3562
Average yield (fruits/tree)	12^{a}	12^{a}	8^{b}	68^{a}	71^{a}	73^{a}	35^{b}
Average prices (TZS/fruit)	1100	880	1100	1100	1100	880	1100
Gross benefit (TZS/tree)	13200	10560	8800	74800	78100	64240	38500
Net benefit (TZS/tree)	9295	818	5617	70756	72517	53320	34938

Source: Experimental data, 2012/13 & 2013/14 cropping seasons

Notes: Levels not connected by the same letter are significantly different at P<0.05

Table-3. Partial budget (TZS/tree) of weaver ants on cashew budget in 2012/213 and 2013/14 seasons

Cropping seasons	**2012/13**		**2013/14**	
Proposed change	Switch from chemical to ants	Switch from control to ants	Switch from chemical to ants	Switch from control to ants
I. INCREMENTAL BENEFITS FROM ANTS				
A. Added benefits	6815	10830	9790	16815
B. REDUCED COSTS				
(a) Karate application four rounds	640	0	710	0
(b) Bayfidan application three round	1575	0	1733	0
(c) Hiring sprayer for chemical	240	0	320	0
(d) Fuel for chemical application	1120	0	1223	0
(e) Labour for chemical applications	240	0	320	0
(f) Total reduced costs (a+b+c+d+e)	3815	0	4306	0
(g) Total incremental Benefits (A+f) = B	9630	10830	14096	16815
II. INCREMENTAL DETRIMENTS FROM				

ANTS				
C. Reduced benefits	0	0	0	0
D. Added costs				
(h) Identify and transplant ant	139	139	93	93
(i) Plastic bags for carrying ants	100	100	100	100
(j) Nylon rope	600	600	0	0
(k) Certification costs	60	0	60	0
(k) Total added costs (h+i+j)	899	839	193	193
(l) Total incremental Detriments (C+k) = D	899	839	193	193
(r) Net change in benefits $(B - D)$	8731	9991	13903	16622

Source: Experimental data, 2012/13 & 2013/14 cropping seasons

Table-4. Partial budget (TZS/tree) of weaver ants on mango budget in 2012/213 and 2013/14 seasons

Years/seasons	2012/13		2013/14	
Proposed change	Switch from chemical to ants	Switch from control to ants	Switch from chemical to ants	Switch from control to ants
I. INCREMENTAL BENEFITS FROM ANTS				
A. Added benefits	2640	4400	13860	39600
B. REDUCED COSTS				
(a) Dudumida(chemical) applications	2468	0	2600	0
(b) Powershot (chemical) applications	4000	0	4320	0
(c) Hiring sprayer for chemical applications	111	0	122	0
(d) Fuel for chemical application	240	0	288	0
(e) Labour for chemical applications	240	0	288	0
(f) Total reduced costs (a+b+c+d+e)	7059	0	7618	0
(g) Total incremental Benefits (A+f) = B	9699	4400	21478	39600
II. INCREMENTAL DETRIMENTS FROM ANTS				
C. Reduced benefits	0	0	0	0
D. Added costs				
(h) Identify and transplant ant	174	174	174	174
(i) Plastic bags for carrying ants	100	100	100	100
(j) Nylon rope	208	208	208	208
(k) Certification costs	260	0	260	0
(k) Total added costs (h+i+j)	742	482	742	482
(l) Total incremental Detriments (C+k) = D	742	482	742	482
(r) Net change in benefits $(B - D)$	8957	3918	20736	39118

Source: Experimental data, 2012/13 & 2013/14 cropping seasons

Table-5. Dominance and marginal rate of return analysis in cashew orchards in years/seasons

Years/seasons	Dominance analysis					
	Treatments		**Costs**	**Net benefits**		**Dominance**
2012/13	Control		8857	9668		Undominated
	WANF		12092	17263		Undominated
	WAF		14273	15082		Dominated
	Insecticides		15008	7532		Dominated
	Marginal analysis					
		Costs	Net benefits	Incremental costs	Incremental net benefits	MRR (%)
	Control	8857	9668			
	WANF	12092	17263	3235	7595	235 > 100 recommeded
2013/14	Dominance analysis					
	Treatments		Costs	Net benefits		Dominance
	Control		11042	9763		Undominated
	WANF		13695	20505		Undominated
	WAF		15352	22268		Undominated
	Insecticides		17506	10325		Dominated
	Marginal analysis					
		Costs	Net benefits	Incremental costs	Incremental net benefits	MRR (%)
	Control	11042	9763			
	WANF	13695	20505	2653	10742	405 > 100 recommeded
	WAF	15352	22268	4310	12505	290 > 100 recommeded

Source: Experimental data, 2012/13 & 2013/14 cropping seasons

Table-6. Dominance and marginal rate of return analysis in mango orchards in two years/seasons

Years/ seasons	Dominance analysis					
	Treatments		**Costs**	**Net benefits**		**Dominance**
2012/13	Control		3183	5617		Undominated
	WANF		3905	9295		Undominated
	Insecticides		9742	818		Dominated
	Marginal analysis					
		Costs	Net benefits	Incremental costs	Incremental net benefits	MRR (%)
	Control	3183	5617			
	WANF	3905	9295	722	3678	509 > 100 recommeded
2013/`14			Dominance analysis			
			Costs	Net benefits		
	Control		3562	34938		Undominated
	WANF		4044	70756		Undominated
	WAF		5583	72517		Undominated
	Insecticides		10920	53319		Dominated
	Marginal analysis					
		Costs	Net benefits	Incremental costs	Incremental benefits	MRR (%)
	Control	3562	34938			
	WANF	4044	70756	482	3581	743 > 100 recommeded
	WAF	5583	72517	2021	3757	186 > 100 recommeded

Source: Experimental data, 2012/13 & 2013/14 cropping seasons