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IMPACT OF FUNGICIDE APPLICATIONS FOR LATE BLIGHT MANAGEMENT ON HUCKLEBERRY YIELDS IN CAMEROON

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ABSTRACT

The influence of late blight infections, caused by *Phytophthora infestans*, was evaluated on thirteen huckleberry (*Solanum scabrum*) varieties during the 2000 and 2001 cropping seasons in Dschang, Cameroon. A randomised split block design was used. Plants were sprayed four times with Ridomil Plus® (12% metalaxyl + 60% cuprous oxide) at 2.5 kg ha^{-1} on a 21-day schedule while control plots were not sprayed. Late blight intensity was recorded weekly and fresh shoot yields were evaluated six times at 14-day intervals. Fungicide applications significantly reduced late blight intensity and consequently increased huckleberry yields. Cumulative shoot yields varied with the variety and fungicide treatment, from 54.14 to 238.33 t ha^{-1}. Yield losses due to late blight infection were estimated at up to 46%. Economic analyses indicated that fungicide sprays are necessary for a late blight protection programme in huckleberry. This spray regime based on fungicide application resulted in net profits of US$ 694 to $ 8,467 ha^{-1}, depending on the variety used and the trial period. The results show that late blight infections if not controlled, decrease huckleberry yields, and consequently net farm incomes. High yielding resistant varieties or foliar applications of Ridomil Plus® may be incorporated in integrated pathogen management schemes against late blight in huckleberries with a view to minimise use of fungicides.

Key Words: Integrated management, *Phytophthora infestans, Solanum scabrum,* yield loss

RÉSUMÉ

L'influence du mildiou, causé par *Phytophthora infestans*, était évalué sur treize variétés de la morelle noire *(Solanum scabrum)* pendant les saisons culturalles de l'an 2000 et 2001 à Dschang, Cameroun. Les éssais étaient réalisés en split-blocs pris au hazard. Les plantes étaient traitées quatre fois avec Ridomil Plus (12% de métalaxyl + 60% oxyde cuivreux) à 21 jours d'intervalle à la dose de 2.5 kg ha^{-1}. L'intensité du mildiou a été évalué hebdomadairement et les pousses fraiches ont été récoltées six fois à l'intervalle de 14 jours. Des traitements fongicides ont significativement réduit l'intensité du mildiou et par conséquent augmenté le rendement en pousses. Le rendement total en pousses fraiches a été variable. De 54, 14 à 238,33 t ha^{-1}, selon la variété et le traitement fongicide. Des pertes en rendements associées aux attaques du mildiou ont atteint 46%. Des analyses économiques indiquent que quatre traitements au Ridomil plus"sont nécessaires dans un bon programme de protection de la morelle noire contre le mildiou. Ce régime de traitement a poduit des augmentations en revenu net de USS 694 à 8.467 ha^{-1}, selon la variété utilisée et la période d'essai. Des résultats indiquent que le mildiou peut baisser le rendement de la morelle noire et par conséquent le bénéfice net des planteurs de la morelle noire si les actions appropriées ne sont pas menées pour rayer les effets néfastes de cette maladie. En outre, l'utilisation des variétés résistantes ou des traitements foliaires au Ridomil plus" peut etre incorporée dans des programmes de lutte intégrée contre le mildiou de la morelle noire.

Mots Clés: Gestion intégrée, *Phytophthora infestans*, *Solanum scabrum*, perte de rendement

INTRODUCTION

Solanum scabrum Miller, commonly called huckleberry or *jamajama* in Cameroon, is an important indigenous leafy vegetables in Africa (Schippers, 2000). The name *huckleberry*, may be confusing because the same name is also used for *Gaylussacia baccata* (Wangh.) K.Koch, a shrub with edible berries that belongs to the Ericaceae family (Schippers, 2002). Similarly, *Solanum scabrum* is often considered in literature as synonymous with other nightshades, such as *S. americanum* Miller and *S. nigrum* L. (Edmonds and Chweya, 1997; Schippers, 2002; Stevels, 1990).

Huckleberry is widely grown in more than 20 African countries, especially in the high rainfall areas of the humid forest zone of West and Central Africa and to a lesser extent in East Africa and is also found in southern Asia

(Schippers, 1997; Schippers, 2000). It is the most commonly grown indigenous vegetable in Cameroon, and commercial fields are found mostly in the western and northwestern provinces of the country (Stevels, 1990; Westphal *et al.,* 1981). In Cameroon, huckleberry is exported to neighbouring countries, such as Gabon and Nigeria (Schippers and Fereday, 1998).

Leaves and fresh shoots are used widely as a cooked vegetable and are often referred to as spinach. The spinach can be served with corn *fufu*, plantains, sweetpotatoes, potatoes, yams, maize or pounded cocoyams (Ngundam, 1997). Huckleberry also has some medicinal value in certain parts of Africa and the juice extracts of the leaves are used to treat diarrhoea in children, certain eye infections, jaundice, sores and stomach-aches (Dupriez and De Leener 1989; Edmonds and Chweya 1977; Kokwaro 1976, Maundu *et al*.,1999; Watt and Breyer-Brandwijk, 1962).

A major constraint to increased huckleberry cultivation in Cameroon is the susceptibility of the crop to diseases (Fontem, 1991a; Nkengakah, 2000; Schippers, 2000) among which is late blight, caused by *Phytophthora infestans* (Mont.) de Bary. A germplasm collection programme was carried out during 1998 and 1999 to characterise the major accessions found in Cameroon (Berinyuy *et al*., 2002). The collection established about 13 morphologically distinct varieties. The response of these varieties to late blight infection is largely unknown. The present study was conducted to assess the effect of late blight on fresh shoot yields of various varieties of this vegetable and to evaluate the economic efficiency of fungicidal management of the disease with fortnightly applications of Ridomil Plus® (12% metalaxyl + 60% cuprous oxide).

MATERIALS AND METHODS

Cultural procedure. Field experiments were conducted during the 2000 and 2001 growing seasons in Dschang (1400 m), Cameroon. The land used in each cropping season had not been grown with any Solanaceous crop for the past four years. In each season, a randomised split block design was used with three replicates. Varieties were assigned to main plots while fungicide treatments occupied sub-plots. Each sub-plot, measuring 3.6 x 2.5 m, was separated by a crop-free zone 2 m wide to limit interplot interference.

Thirteen morphologically distinct huckleberry varieties were used in both seasons (Table 1). A nursery bed, measuring 16 x 1.5 m, was fertilised with 300 kg ha^{-1} of urea to accelerate plant growth. The nursery was set 19 March 2000 and 9 April 2001 and seeds were drilled 5 cm apart in rows spaced 10 cm. After sowing, the beds were shaded with fresh grass mulch until germination was completed. Nursery plants received two foliar sprays of maneb (Trimangol 80 72 WP) at 1.6 kg a.i. ha^{-1} before transplanting.

Seedlings were transplanted when nursery plants were 20 – 30 cm high and had developed at least 5 – 6 true leaves. They were planted in rows spaced 0.40 m apart with 0.25 m between plants within the row. In both seasons, field plots were fertilised with 120 kg ha^{-1} of 20-10-10 (N-P-K) 7 and 49 days after transplanting (DAT). In the following year, plants received a supplementary application of manure (10 t ha^{-1}) before transplanting and a foliar fertiliser (Manvert 8-8-6 NPK, 4 L ha^{-1}) at 38 DAT. In both seasons, plants were sprayed with deltamethrin (Decis 25 EC) at 0.7 L ha^{-1} to control foliar insects, such as black aphids (*Aphis fabae* Scop.) and flea beetles (*Epilachna hirta*). The field was hand weeded and tilled as needed.

Fungicide protection. In both trials, half of each main plot received four foliar sprays of Ridomil Plus® (72 WP) at 2.5 kg ha^{-1} to control late blight infections, while the other half was not sprayed. A 3 x 2.5 m bamboo sheet was held between each sprayed and unsprayed sub-plot during spraying to prevent drift of the fungicide onto unsprayed plants. The fungicide protection was applied using a Solo knapsack sprayer (Solo Kleinmotoren GmbH, Sindelfingen, Germany) with a single flat fan nozzle that delivers about 700 L ha^{-1} at a maximum pressure of 4 kg cm^{-2}. The first treatment was applied at first sign of foliar late blight symptoms (14 DAT in 2000 and 20 DAT in 2001) and a 21-day spray schedule was observed for subsequent sprays.

Disease and yield evaluations. Crops were exposed to naturally occurring inocula in the field. In both seasons, disease severity (percent of leaf area diseased) was scored weekly on five randomly selected plants in the centre rows of each sub-plot with the aid of a modified Horsfall-Barratt (Berger, 1980) rating scale. In each season, thirteen weekly ratings, initiated from first foliar late blight symptoms, were scored for each sub-plot. Values for Standardised Area Under Disease-Progress Curves (SAUDPC) were calculated from the severity data according to the formula used by Campbell and Madden (1990).

Plots were harvested six times on a 14-day schedule, starting from 35 DAT in 2000 and 27 DAT in 2001. Fresh shoots were handpicked from the inner rows of each plot. After discarding diseased leaves and foreign bodies, such as weeds and slugs, clean shoots were weighed and marketable yields were expressed for each subplot in metric tonnes fresh wt ha^{-1}. Cumulative yields were obtained from the six harvests in each season.

Economic appraisal of fungicide protection. Economic analyses were conducted for costs and returns to the fungicidal treatments on each variety. Total returns were the value of the marketable yields obtained in each sub-plot. A unit farm gate price of US$ 0.10 kg^{-1} of fresh huckleberry was applied on marketable yields to estimate the total returns. The cost of the fungicide used per hectare was US$ 50 ha^{-1} for each treatment and the cost of spraying the fungicide was estimated at US$ 7 ha^{-1}. The total cost of fungicide application for one hectare of huckleberry was US$ 228 per season.

The increase in leaf yield over unprotected (control) treatments was assumed to be solely due to the fungicide treatments. Therefore, partial budgeting was used to estimate profit per hectare for each huckleberry variety. Profit was estimated by deducting total fungicide control cost from income derived from yield increase above unsprayed treatments for each variety. Costs of land preparation, nursery maintenance, transplantation, weeding, insects control and harvesting were not included in the partial budgeting. Benefit-cost ratio, defined as the number of times the fungicide control cost was recouped from the value for the increased yield, was calculated as:

$$\text{Benefit – cost ratio} = \frac{\text{Value of increased yield}}{\text{Cost of fungicide control}}$$

Statistical analyses. Differences in SAUDPC as well as fresh shoot yields between the spray treatments were examined by analysis of variance (ANOVA) of a split block design. Data for SAUDPC (in percentages) were arcsine transformed before analysis. Treatment means were separated using the Fisher's protected LSD at $P = 0.05$. All computations were carried out using an MSTAT-C statistical package (Michigan State University).

RESULTS

Late blight severity in sprayed and unsprayed sub-plots. Analysis of variance (ANOVA) revealed highly significant ($P < 0.001$) differences between varieties and fungicide treatments for SAUDPC in both years. Consequently, late blight severity varied with varieties and fungicide usage. In both seasons, the most susceptible variety to late blight was the medium leaf-type SS15 (6.7 % in 2000 and 18.2 % in 2001), followed by the medium leaf-type SS08 (5.3 % in 2000 and 5.6 % in 2001), and the large leaf type SS18 (2.4 % in 2000 and 3.8 % in 2001) (Table 2). Susceptibility of varieties to late blight did not appear to be related to leaf size. Susceptible (> 1% SAUDPC) varieties were observed among the small (SS06), medium (SS08, SS15, SS19) and large (SS05.1, SS18) leaf-types. Moreover, resistant (< 1% SAUDPC) varieties were also found among the small (SS01, SS02.1, SS13), medium (SS22, SS25.1) and large (SS09) leaf-types.

In either season, late blight was more severe in unsprayed plots than in sprayed plots. Fungicide applications significantly reduced SAUDPCs in susceptible varieties in both trials (Table 2). At harvest all the unsprayed plots had higher late blight infections than the sprayed plots.

Shoot yields of huckleberry in sprayed and unsprayed sub-plots. Analysis of variance (ANOVA) revealed highly significant ($P < 0.001$) effects of varieties and fungicide treatments on fresh shoot yields. During the six harvests, mean fresh shoot yields for the 13 varieties varied between 5.07 and 47.13t ha^{-1} (Table 3). The yields increased from the first to the third harvest in 2000 and the fourth harvest in 2001. Except for the first harvest of 2001, all the yield estimates recorded in sprayed plots were significantly higher than those in unsprayed plots. Mean percent yield reduction varied between 8 and 44%, depending on the harvest period and season. The highest yield loss was recorded during the third harvest period in both years (Table 3).

Cumulative yields were significantly higher in 2001 than in the preceding year, presumably due to the extra fertilization applied on the crop during the latter year. In 2000, the yields varied between 54.14 and 173.20 t ha^{-1} for unsprayed plots and between 64.59 and 225.62 t ha^{-1} for sprayed sub-plots. In the following year, the yields were higher, ranging from 95.83 to 191.33 t ha^{-1} for unsprayed sub-plots and from 114.44 to 238.33 t ha^{-1} for sprayed plots (Table 4).

Varieties varied in their response to the fungicide treatments. All the sprayed plots recorded increases in fresh shoot yields compared to the unsprayed plots. However, the yield increases were not significant ($P > 0.05$) for late blight resistant varieties SS01, SS02.1, SS09, SS13 and SS19 in 2000 and SS01, SS09, SS13 and SS19 in 2001 (Table 3). In 2000, the highest yielding variety in unsprayed sub-plots was the large leaf-type SS09 (173.20 t ha^{-1}), followed by the large leaf-type SS18 (161.03 t ha^{-1}). In the following year, the highest yielding variety in unsprayed sub-plots was the medium leaf-type SS25.1 (191.33 t ha^{-1}), followed by the small leaf-type SS02.1 (149.17 t ha^{-1}) (Table 4). Percent yield reduction varied between 5 and 45% in 2000 and 16 to 46% in 2001. A mean yield loss recorded for the 13 varieties was 26% in 2000 and 30 % in 2001. The highest yield loss was recorded on the most susceptible variety SS15 (45% in 2000 and 46% in 2001) (Table 4).

Economic feasibility of fungicide management. Results of economic feasibility of fungicide management are presented in Table 5. Mean returns for unsprayed plots were US$ 9,761 in 2000 and US$12,558 in 2001. The returns derived from late blight protection were higher in sprayed than in the unsprayed plots. The mean values for sprayed plots were US$ 13,252 in 2000 and US$ 17,855 in 2001. Total returns were higher for 2001 than for 2000 because of the higher yields recorded for the former that were presumably due to the application of more fertilisation. In 2000, net profits were highest for the large leaf-type SS18 (US$ 6,231), while in the following year, they were highest for the medium leaf-type SS15 (US$ 8,467). Profits derived from fungicide protection varied from US$ 694 to 6,231 in 2000 and from US$ 1,549 to US$ 8,467 in 2001. The mean profit for the 13 varieties was US$ 3,263 in 2000 and US$ 5,069 in 2001 (Table 5).

Benefit-cost ratios calculated for the 13 varieties generally ranged from 3.0 to 27.3 in 2000 and 6.8 to 37.1 in 2001. The ratios were generally higher for late blight-susceptible varieties (SS04.2, SS05.1, SS06, SS08, SS15 and SS18) than for resistant varieties (SS01, SS02.1, SS09, SS13, SS19 and SS22, and SS25.1). The highest benefit-cost ratio was recorded for SS18 (27.3) in 2000 and SS15 (37.1) in 2001 (Table 5).

DISCUSSION

Contrary to a popular belief that large leaf-type varieties of huckleberry are more susceptible to late blight than the small leaf-types (Nkengaka, 2000), we did not observe any correlation between late blight susceptibility and leaf size. Late blight-resistant and -susceptible varieties were found among the three leaf types.

In our previous investigations, late blight had been reported as the most important production constraint in major Solanaceous vegetables, such as potato (Fontem, 1991b; Fontem, 1998; Fontem *et al.,* 1998) and tomato (Fontem, 1993; Fontem *et al.,* 1998) in Cameroon. Huckleberries have been produced for centuries in Cameroon without any threat from late blight. This disease was first reported on potato in Cameroon in 1954 (Russel, 1954) and on huckleberry in 1991 (Fontem, 1991a). Although this study reveals that late blight is an important disease of susceptible huckleberry varieties, its severity in the field was not as high as that observed for potato or tomato in Cameroon. Moreover, yield losses of up to 46% were also low compared to 71% for potato (Fontem *et al*, 1998; Fontem, 1998) and 100% for tomato (Fontem *et al.,* 1998).

Fungicide applications significantly reduced late blight intensity and consequently increased fresh shoot yields in susceptible varieties. Ridomil Plus® or Ridomil MZ (12% metalaxyl + 60% mancozeb) has been reported to control late blight effectively in potatoes and tomatoes in Cameroon (Fontem and Aighewi, 1993; Fontem *et al.,*1996; Fontem *et al.,* 1998; Fontem, 1998). Economic analyses revealed that four sprays of this fungicide at 2.5 kg ha^{-1} on a 21-day schedule are necessary for an adequate late blight protection programme in huckleberry. This spray programme resulted in profits of US$ 694 to 8,359, depending on the variety and trial period. Benefit-cost ratios were higher for susceptible huckleberry varieties than for resistant varieties, suggesting that fungicide applications were more profitable in susceptible varieties than in resistant ones. The study also revealed that high-yielding resistant varieties, such as SS09 and SS25.1, might be adopted by farmers to reduce any dependence on chemical fungicides.

These results show that huckleberry late blight infections may decrease fresh leaf yields and consequently net farm incomes if not checked by an appropriate management method. Besides, resistant varieties or foliar sprays of Ridomil Plus® may be incorporated into integrated pathogen management schemes against huckleberry late blight.

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TABLE 1. Morphological characteristics of the varieties used in the study

Variety	Leaf blade characteristics		Stem wings*	Stem and branch colour	Corolla colour
	Mean size (cm)	Type			
SS01	5.1 x 6.6	Small	-	Purple	White
SS02.1	4.2 x 5.5	Small	-	Green	Violet stripe
SS04.2	14.0 x 22.0	Large	+	Green	Violet stripe
SS05.1	11.0 x 13.0	Large	+	Green	White

SS06	4.3 x 5.3	Small	-	Green	Purple
SS08	9.1 x 14.0	Medium	+	Green	White
SS09	10.0 x 13.0	Large	+	Purple	Purple
SS13	5.1 x 5.9	Small	+	Green	Purple
SS15	6.7 x 10.0	Medium	-	Green	Violet stripe
SS18	16.0 x 18.0	Large	+	Green	Purple
SS19	7.2 x 12.0	Medium	+	Purplish green	Purple stripe
SS22	11.0 x 15.0	Medium	+	Green	Violet strip
SS25.1	8.6 x 13.0	Medium	+	Purple	White stripe

*Stem wings are inconspicuous (-) or conspicuous (+); Source: Berinyuy *et al.* (2002)

TABLE 2. Standardised (%) areas under late blight progress curves as influenced by fungicide treatments against huckleberry late blight during two seasons in Dschang, Cameroon

Variety	Leaf type	2000		2001	
		Unsprayed	Sprayed	Unsprayed	Sprayed
SS01	Small	0.3a[z]	0.0a	0.6a	0.1a
SS02.1	Small	0.4a	0.0a	0.8a	0.0a
SS04.2	Large	3.1a	0.5b	3.5a	0.2b
SS05.1	Large	1.8a	0.3a	1.2a	0.1a
SS06	Small	3.0a	0.1b	1.3a	0.2a
SS08	Medium	5.3a	0.8b	5.6a	0.2b
SS09	Large	0.3a	0.1a	0.5a	0.0a
SS13	Small	0.6a	0.1a	0.3a	0.1a
SS15	Medium	6.7a	0.6b	18.2a	0.8b
SS18	Large	2.7a	0.4b	3.8a	0.2b
SS19	Medium	1.6a	0.2a	1.5a	0.1a
SS22	Medium	0.8a	0.1a	0.6a	0.0a
SS25.1	Medium	0.8a	0.2a	0.1a	0.0a
Mean		2.1b	0.3a	2.9a	0.2b
LSD (0.05)		1.7		2.6	
CV (%)		28.1		31.9	

[z]Means within a row for each year followed by different letters are significantly different according to Fisher's LSD (P = 0.05)

TABLE 3. Mean fresh shoot yields (t ha^{-1}) for six harvests of huckleberry as influenced by fungicide treatments against late blight during two seasons in Dschang, Cameroon

Harvest period	2000			2001		
	Unsprayed	Sprayed	% yield reduction	Unsprayed	Sprayed	% yield reduction
1	12.59 b[z]	18.07a	30	9.53a	10.35a	8
2	17.28 b	22.36 a	23	13.69 b	24.27 a	44
3	30.68 b	44.89 a	32	18.62 b	31.93 a	42
4	22.10 b	27.62 a	20	34.24 b	47.13 a	27
5	9.89 b	12.42 a	20	24.91 b	32.81 a	24
6	5.07 b	7.16 a	29	24.59 b	32.06 a	23
Mean	16.27 b	22.09 a	26	20.93 b	29.76 a	30

Mean yields for 13 varieties

[z]Means within a row for each year followed by different letters are significantly different according to Fisher's LSD (P = 0.05)

TABLE 4. Cumulative fresh shoot yields (t ha^{-1}) of huckleberry as influenced by fungicide treatments against late blight during two seasons in Dschang, Cameroon

Variety	2000			2001		
	Unsprayed	Sprayed	% yield reduction	Unsprayed	Sprayed	% yield reduction
SS01	54.14 a[z]	64.59 a	16	108.33a	142.28a	24
SS02.1	88.35 a	99.92 a	12	149.17b	212.83a	30
SS04.2	121.25 b	148.62 a	18	145.09b	230.56a	37
SS05.1	104.61 b	129.85 a	19	105.28b	182.08a	42
SS06	94.20 b	155.17 a	39	135.17b	193.33a	30

SS08	96.28 b	133.89 a	28	98.61b	144.44a	32
SS09	173.20 a	182.95 a	5	132.78a	168.89a	21
SS13	62.01 a	71.35 a	13	95.83a	131.28a	27
SS15	75.31 b	136.25 a	45	100.83b	187.78a	46
SS18	161.03 b	225.62 a	29	143.22b	193.06a	26
SS19	64.07 a	73.29 a	13	96.67a	114.44a	16
SS22	91.16 b	130.64 a	30	130.28b	181.81a	28
SS25.1	143.35 b	170.67 a	16	191.33b	238.33a	20
Mean	97.61	132.52	26	125.58	178.55	30
LSD(0.05)	13.25		-	36.44		-
CV (%)	6.7			12.7		

Yields for six 14-day harvests

ZMeans within a row for each year followed by different letters are significantly different according to Fisher's LSD (P = 0.05)

TABLE 5. Economic analyses for one hectare of huckleberry production under fungicide protection against late blight during two seasons in Dschang, Cameroon

Variety	2000				2001			
	TR for unsprayed subplots (a)	TR for sprayed subplots (b)	Profit(b-(a+228))	Benefit – Cost ratio*	TR for unsprayed subplots (a)	TR for sprayed subplots (b)	Profit(b-(a+228))	Benefit – Cost ratio
SS01	5,414	6,459	817	3.6	10,833	14,228	3,167	13.9
SS02.1	8,835	9,992	929	4.1	14,917	21,283	6,138	26.9
SS04.2	12,125	14,862	2,509	11.0	14,509	23,056	8,319	36.5
SS05.1	10,461	12,985	2,296	10.1	10,528	18,208	7,452	32.7
SS06	9,420	15,517	5,869	25.7	13,517	19,333	5,588	24.5
SS08	9,628	13,389	3,533	15.5	9,861	14,444	4,355	19.1
SS09	17,320	18,295	975	4.3	13,278	16,889	3,383	14.8
SS13	6,201	7,135	706	3.1	9,583	13,128	3,317	14.5
SS15	7,531	13,625	5,866	25.7	10,083	18,778	8,467	37.1
SS18	16,103	22,562	6,231	27.3	14,322	19,306	4,756	20.9
SS19	6,407	7,329	694	3.0	9,667	11,444	1,549	6.8
SS22	9,116	13,064	3,720	16.3	13,028	18,181	4,925	21.6
SS25.1	14,335	17,067	2,504	11.0	19,133	23,833	4,472	19.6
Mean	9,761	13,252	3263	14.3	12,558	17,855	5,069	22.3

Economic returns for six 14-day harvests

All figures are in US$ ha^{-1} (US$1 = 750 FCFA)

Total return (TR) is the value of yield (kg ha^{-1} x US$0.10 kg^{-1})

*Benefit-cost ratio was calculated as profit/cost