CROP PROTECTION

Economic Damage Caused by Spittlebugs (Homoptera: Cercopidae) in Colombia: A First Approximation of Impact on Animal Production in *Brachiaria decumbens* Pastures

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Dano Econômico da Cigarrinha-das-Pastagens (Homoptera: Cercopidae) na Colômbia: Primeira Aproximação do Impacto na Produção Animal em Pastagens de *Brachiaria decumbens*

RESUMO - Usando um modelo de simulação como ferramenta de análise, quantificou-se o impacto econômico da cigarrinha-das-pastagens em termos de produção animal na Colômbia. Três níveis de infestação (10, 25, 50 adultos/m^2) e de área infestada (25, 50, 100%) foram avaliados usando dados obtidos no Brasil com *Notozulia entreriana* (Berg) em *Brachiaria decumbens* Stapf. O modelo considerou sistemas de produção de duplo propósito em dois ecossistemas contrastantes: (1) trópico-seco, caracterizado por seis meses bem definidos de estação chuvosa e (2) trópico-umido, caracterizado por distribuição uniforme de chuva durante o ano. Comparada com as pastagens não infestadas, a carga animal e a produtividade de leite e carne tiveram um decréscimo de 1-8, 8-34 e 38-54%, respectivamente, aos níveis de infestação baixo, intermediário e alto, dependendo da área da fazenda infestada. O custo de produção de leite e carne aumentou 0-4, 3-16 and 18-30% nos mesmos níveis de infestação, causando redução no lucro da ordem de 3-16, 17-69 e 67-100%. Em nível regional, o dano econômico nos 1.140.000 ha plantados com pastagens suscetíveis à cigarrinha-das-pastagens nos trópicos úmidos da Colômbia variou de US$7-25, 28-36 e 39-47 milhões/ano. Nos 4.720.000 ha de pastagens suscetíveis no trópico-seco, o prejuízo econômico foi de US$33-118, 132-175 e 228-273 milhões/ano. O investimento requerido para desenvolver variedades resistentes à cigarrinha-das-pastagens e adaptadas a solos de baixa a média fertilidade (US$6 milhões em 12 anos) é baixo quando comparado com o dano econômico causado pelas cigarrinhas-das-pastagens na Colômbia constituindo-se, assim, grande incentivo ao apoio as pesquisas em melhoramento de variedades e manejo da cigarrinha-das-pastagens.

PALAVRAS-CHAVE: Gramínea forrageira, impacto econômico, praga das pastagens.

ABSTRACT - Using a simulation model as an analysis tool, the economic impact of spittlebugs in pastures of Colombia was quantified in terms of animal production. Three levels of abundance (10, 25, 50 adults/m^2) and farm area affected (25, 50, 100%) were evaluated using data obtained in Brazil for *Notozulia entreriana* (Berg) on *Brachiaria decumbens* Stapf. The model considered dual-purpose production systems in two contrasting ecosystems: (1) the dry tropics, characterized by a well defined, 6-month rainy season and (2) the humid tropics, characterized by uniform rainfall distribution throughout the year. Compared to healthy pastures, stocking rate, milk and meat productivity decreased 1-8, 8-34 and 38-54%, respectively, at low, intermediate and high abundance levels, depending on farm area infested. The cost of producing milk and meat increased 0-4, 3-16 and 18-30% at the same infestation levels, causing net income to decrease 3-16, 17-69 and 67-100%. At the regional level, economic damage in the 1,140,000 ha sown to grasses susceptible to spittlebugs in the humid tropics of Colombia ranged from US$7-25, 28-36 and 39-47 million/yr. In the 4,720,000 ha of susceptible grasses in the dry tropics, economic damage was US$33-118, 132-175 and 228-273 million/yr. The investment required to develop grass varieties resistant to spittlebugs and adapted to soils with low to intermediate fertility (US$6 million over 12 yr) is low compared with the economic damage caused by spittlebugs in Colombia, and therefore presents a major economic incentive for support of research on varietal improvement and spittlebug management.

KEY WORDS: Economic impact, forage grass, pasture pests.

Cattle raising in tropical America is based on extensive production systems that depend on forage grasses for meat and milk production. Several species of the genus *Brachiaria* (Trin.) Griseb. are among the most important grasses, in particular *B. decumbens* Stapf cv. Basilisk. Its introduction, mainly in the Neotropical savannas, has dramatically increased the stocking rate in lands previously occupied by low-yielding native grasses (C. Lascano, CIAT, unpublished).

Brachiaria decumbens cv. Basilisk is the most widespread grass species in tropical America, cultivated on an estimated 40 million ha, mostly in Brazil, Colombia, and Venezuela (Pizarro *et al.* 1996). The generalized adoption of this cultivar can be attributed to its good adaptation to acid, infertile soils and because it forms an aggressive, high-yielding pasture that resists intensive grazing and trampling by animals (Keller-Grein *et al.* 1996). Also, the nutritive quality of this grass is good; animals find it palatable and those consuming it have good performance. Its susceptibility to grass-feeding spittlebugs (Homoptera: Cercopidae), however, reduces establishment and adoption of this cultivar in areas where the pest is important, such as the Neotropical savannas (Lapointe 1993).

Spittlebugs are considered the most damaging pests attacking pastures in tropical America because of their broad distribution and capacity to outbreak (Valério *et al.* 2001). This complex of native insects attacks wild and cultivated grasses from the southern United States to northern Argentina, and includes dozens of species, some of which are major pests of sugarcane (Fewkes 1969) and occasionally turfgrass and rice (Nilakhe 1985, Souza & Nilakhe 1985, Braman & Pendley 1993).

Spittlebug nymphs and adults feed primarily from the xylem of host plants (Thompson 1994). Adults, in particular, cause phytotoxemia in susceptible hosts because of certain components of their saliva (Byers & Wells 1966, Valério *et al.* 1988). As a result, plant photosynthetic activity is interrupted, causing necrotic lesions that spread longitudinally toward the leaf apex. If a severe attack occurs, the entire above ground sward dies back. As a consequence, dry matter production, digestibility, and quality of forage are significantly reduced, thereby decreasing stocking rate and milk and meat production (Valério & Nakano 1988,1989). In addition to the damage caused by adult spittlebugs, the feeding capacity of nymphs causes water stress and loss of biomass (Silva 1982, Barrientos *et al.* 1988). Therefore the aggregate impact of nymphs and adults reduces the persistence of improved grasses and contributes to environmental degradation (Taliaferro *et al.* 1967, Valério & Nakano 1987, Hewitt 1989).

The duration of the pest's life cycle and the number of generations per year depend on the spittlebug species and on local climatic conditions. In humid regions spittlebugs can be found year-round, whereas in seasonally dry regions the period of infestation coincides with the rainy season (Valério *et al.* 2001). *Aeneolamia reducta* (Lallemand) completes six generations per year in the dry tropics of Colombia's northern coast, despite almost 4 months of annual drought (CIAT 1999). In the moist tropics of Colombia's Amazon piedmont, which has no defined dry season, populations are not synchronized, and spittlebugs can be found throughout the year.

Although spittlebugs cause obviously severe damage to host plants, no information exists on the impact of this pest on animal production (Valério *et al.* 1998). To our knowledge, no studies based on real data have been conducted to estimate the economic damage caused by the spittlebug at the regional level. Most studies have been limited to evaluating the impact of the spittlebug on the host plant, which is fundamental to extrapolate the economic damage at the regional level.

Using a simulation model, this study aims to quantify the economic damage in terms of reduced milk and meat production in animals grazing *B. decumbens* under different levels of spittlebug infestation.

Material and Methods

Data on the nutritional quality and biomass production of *B. decumbens* under different spittlebug densities were obtained from Valério and Nakano (1988, 1989). Their studies quantified the impact of 0, 25, 50, and 100 adult *Notozulia entreriana* (Berg), kept at constant densities for 10 consecutive days in 1-m^2 cages (Table 1). To represent a more realistic low level of infestation, we extrapolated the impact of 10 adults/m^2 by regression analysis. Twenty-five adults were considered as moderate infestation, and 50 adults as high infestation. The level of 100 adults/m^2, evaluated by these authors, was not included to simplify the analyses and because it represents a pressure rarely achieved under natural field conditions. Because none of the Colombian combinations of pest/host species has been studied, impact estimates were approximated by these data obtained in the most complete studies to have assessed the quantitative impact of spittlebugs on forage grasses.

Table 1. Dry matter production (DM), in vitro dry matter digestibility (IVDMD) and crude protein (CP) of *B. decumbens* as affected by different densities of adult *N. entreriana* in Brazil.

Adults/m^2	DM (g/m^2)	IVDM (%)	CP (%)
0	66.5	65.9	10.3
10	61.9	64.9	9.8
25	44.1	59.5	8.3
50	33.7	51.2	7.2

Data were adapted from Valério & Nakano (1988, 1989).

The data corresponding to three measurements of quality and production compiled by Valério and Nakano (1988, 1989) were used: biomass production (DM), in vitro dry matter digestibility (IVDMD), and crude protein (CP). These data were used to calculate the reduction in forage biomass (i.e. stocking rate) and available nutrients (i.e.

digestible energy and protein) for cattle grazing *B. decumbens,* according to different levels of infestation. The decrease in milk and meat productivity was estimated on the basis of these results.

The economic damage caused by spittlebugs was calculated for two hypothetical farms with 100 ha of *B. decumbens* under dual-purpose production systems. The farms were located in two contrasting ecosystems: (a) the dry tropics, characterized by a well defined, 6-month rainy season and representative of Colombia's northern coast (i.e. departments of Atlántico, Bolivar, Cesar, Córdoba, Guajira, Magdalena and Sucre), and (b) the humid tropics, characterized by a relatively uniform rainfall distribution throughout the year and representative of the forest margins ecosystem (i.e. departments of Caquetá, Putumayo and Chocó). Table 2 summarizes the technical parameters of the dual-purpose herd at both sites, while Table 3 shows the average productivity of *B. decumbens* under typical management conditions of both ecosystems.

Because spittlebug attacks occur during the rainy season, the impact of this pest in the humid tropics is relatively constant year-round. In the dry tropics, however, the insect survives the dry period as diapausing eggs. Therefore the presence of nymphs and adults is restricted to the humid months. Accordingly, the analyses conducted in this study considered that the economic damage caused by spittlebugs was uniform throughout the year in the humid tropics, but restricted to 6 months in the dry tropics.

The third dimension evaluated was the farm area affected by the insect. The impact was calculated with three proportions of the farm under permanent spittlebug infestation: 25, 50 and 100% of pastures infested.

The Simulation Model. To calculate economic damage, information on the three variables was introduced into a simulation model: (1) insect abundance: low, intermediate, high; (2) farm area infested: 0, 25, 50, 100%; and (3) ecosystem: dry tropics (infestation during 6 months) and humid tropics (infestation during 12 months).

The model was initially developed in 1995 by the Center for Research and Training in Tropical Agriculture (CATIE, its Spanish acronym) and the International Animal Production Systems Network for Latin America (RISPAL, its Spanish acronym), which was later adjusted and calibrated by CIAT. The model uses spreadsheets to conduct an *ex ante* analysis of the costs and income-returns of current and potential land uses and the interactions between technological components and biological productivity (Holmann & Estrada 1997, Holmann 1999).

The model's *ex ante* prediction of expected loss in milk and meat productivity depends on the level of infestation found in a given pasture over a given period of time. The reduction in milk and meat production is expressed not only in terms of kg meat and milk, but also in terms of net income and production costs.

The model's flexible structure allows users to make partial or global modifications based on their specific interests and analytical capacities. The model's structure consists of six spreadsheets. Spreadsheet A contains the basic information required to run the model; spreadsheet B, the data to calculate animal production; spreadsheet C, the information to calculate the production of pastures and timber-yielding trees; spreadsheet D, the data to calculate crop production; spreadsheet E, the information to estimate amortization costs and investment in infrastructure and

Table 2. Productive parameters of *B. decumbens* under management conditions characteristic of Colombia's humid and dry tropics.

Attribute	Humid tropics[1]	Dry tropics (season)[2]
Biomass production (kg DM/ha)[3]	5300–8000	2600–4000 (rainy)
		260–400[4](dry)
Digestibility (%)[3]	60 - 66	60–66 (rainy)
		45 (dry)
Crude protein (%)[3]	8–10	8–10 (rainy)
		3 (dry)
Biomass transfer from rainy to dry season (kg DM)[5]		650–1000
Losses because of trampling (%)	30	30 (rainy)
		20 (dry)
Use of labor (wages/ha/yr)	7	7
Establishment costs (US$/ha)	294	294
Voluntary animal intake (%LW)	2.5	2.5 (rainy)
		2.0 (dry)

[1]Rivas and Holmann (1999); [2]Torres *et al.* (2001).
[3]Taken from Table 1 according to different degrees of infestation.
[4]Equivalent to 10% biomass production during rainy season
[5]Equivalent to 25% biomass production during rainy season

Table 3. Animal productivity parameters in dual-purpose herds under typical management conditions of Colombia's humid and dry tropics.

Attribute	Humid tropics[1]	Dry tropics[2]
Parturition rate (%)	65	70
Annual replacement (%)	15	15
Stocking rate (AU/ha)	1.16	0.93
Milk production (kg/lactation)	760	1200
Duration of lactation (days)	240	240
Price of milk (US$/kg)	0.16	0.16
Use of labor (work days/cow/yr)	5	5
Adult weight (kg)	400	450
Price per work day (US$/day)	8.85	8.85
Commercial value (US$) milking cow (400 kg)	320	320
Commercial value (US$) culled cow (350 kg)	240	240
Commercial value (US$) weaned calf (110 kg)	95	95

[1]Rivas and Holmann (1999); [2]Torres *et al.* (2001).

equipment; and spreadsheet F, the linear programming correlation matrix.

The model assumes that the target function of cattle raisers is to increase their annual net income. It therefore performs all calculations on an annual basis and assumes that the agricultural enterprise is stable and therefore does not increase its stock throughout the year.

The model calculates animal productivity based on mathematical equations of nutrient requirements of dairy cattle obtained from the National Research Council of the National Academy of Sciences of the United States (NRC 1989). The user gives the model information on forage biomass production according to season of the year and its corresponding nutritive quality, depending on spittlebug damage. The model then matches animal nutrient requirements with nutrient offer and predicts animal productivity.

Results

Tables 4 and 5 show the effect of different levels of spittlebug infestation in the humid and dry tropics of Colombia on four parameters of economic importance: (1) stocking rate (AU/ha), (2) milk and meat productivity (kg/ha/yr), (3) cost of milk and meat production (US$/kg), and (4) net income (US$/ha/yr). To facilitate interpretation, the data given in Tables 4 and 5 have been converted to figure form (Figs. 1-2).

Stocking Rate. The stocking rate drastically decreased in both ecosystems with increasing levels of spittlebug infestation (Fig. 1). The final stocking rate resulted from the significant reduction of available biomass in the pasture (Table 1) and the loss of quality of *B. decumbens* in terms of protein and energy. Both effects are associated with the level of spittlebug infestation. The stocking rate in non-infested pastures in the humid tropics ecosystem is higher than that of the dry tropics (1.16 versus 0.93 AU/ha) because precipitation is higher and more evenly distributed throughout the year; as a result, the biomass production of any pasture is higher.

The pasture's carrying capacity decreased 2-8% as it changed from a healthy pasture (no infestation) to one with a low infestation (10 adults/m^2), depending on the proportion of farm area infested (i.e. from 1.16 to 1.14-1.08 AU/ha for the humid tropics and from 0.93 to 0.91-0.86 AU/ha for the dry tropics, Tables 4 and 5). The difference in stocking rates between healthy and infested pastures in both ecosystems can be attributed to higher precipitation and improved distribution of rains throughout the year in the humid tropics, which allows a higher stocking rate.

Similarly, the stocking rate was further decreased 7-28% when infestation level increased from low to intermediate (from 10 to 25 individuals/m^2), depending on the proportion of farm area infested. When infestation increased from intermediate to high (from 25 to 50 adults/m^2), the stocking rate decreased another 26-33%. In other words, when the same healthy pasture was compared with one presenting a high level of spittlebug infestation, the stocking rate decreased by 39-54% (i.e. 1.16 versus 0.59-0.72 AU/ha in the humid tropics and 0.93 versus 0.46-0.57 AU/ha in the dry tropics).

Milk and Meat Production. Because of the reduced stocking rate and nutritive quality of the pasture, milk production decreased 2-8% in both ecosystems when cows grazing a healthy pasture were moved to one with a low infestation level (Fig. 1; Tables 4 and 5).

Although proportional reduction in milk production was similar in both ecosystems, in absolute terms the reduction was higher in the dry tropics of Colombia because the animal genotype found in this ecosystem produces more milk (i.e. 1200 versus 760 kg/lactation) and weighs more as an adult (i.e. 450 versus 400 kg) than the genotype commonly found

Table 4. Impact of different levels of spittlebug infestation (abundance and proportion of farm area infested) in a dual-purpose production system in Colombia's humid tropics.

Infestation level		Stocking rate (AU/ha)	Production (kg/ha/yr)[1]		Milk production cost (US$/kg)	Meat production cost (US$/kg)	Net income (US$/ha/yr)
Abundance (adults/m^2)	Affected area (%)		Milk	Meat			
0	0	1.16	390	95	0.123	0.61	32
10	25	1.14	382	94	0.124	0.62	31
	50	1.12	375	92	0.125	0.62	30
	100	1.08	360	88	0.126	0.63	27
25	25	1.06	357	87	0.128	0.63	26
	50	0.96	324	79	0.133	0.66	21
	100	0.76	258	63	0.142	0.70	10
50	25	0.72	243	59	0.146	0.72	7
	50	0.67	228	55	0.150	0.75	5
	100	0.59	197	48	0.159	0.79	0

[1]Kilograms of liquid milk and live weight

Table 5. Impact of different levels of spittlebug infestation (abundance and proportion of farm area infested) in a dual-purpose production in Colombia's dry tropics.

Infestation level		Stocking rate (AU/ha)	Production (kg/ha/yr)[1]		Milk production cost (US$/kg)	Meat production cost (US$/kg)	Net income (US$/ha/yr)
Abundance (adults/m^2)	Affected area (%)		Milk	Meat			
0	0	0.93	529	84	0.116	0.57	42
10	25	0.91	519	82	0.116	0.57	40
	50	0.90	509	81	0.117	0.58	39
	100	0.86	489	78	0.119	0.59	36
25	25	0.85	484	77	0.120	0.59	35
	50	0.76	439	70	0.125	0.62	29
	100	0.62	350	55	0.133	0.66	17
50	25	0.57	328	52	0.137	0.68	14
	50	0.53	307	49	0.142	0.70	11
	100	0.46	265	42	0.150	0.74	5

[1]Kilograms of liquid milk and live weight

in the forest margins of the country's humid tropics (Torres *et al.* 2001, Rivas & Holmann 1999).

Similarly, milk production decreased another 7-28% when cows were moved from a low to intermediate level of infestation and another 24-32% when moved from an intermediate to high level of infestation, depending on the proportion of farm area infested. Comparing the healthy pasture with the highly infested one, both milk and meat production decreased by 38-50% (i.e. 390 versus 197-243 kg milk/ha in the humid tropics and 529 versus 265-328 kg milk/ha in the dry tropics).

A similar trend was observed in meat production. That is, the reduction in meat productivity per ha was proportional to that of milk in both ecosystems. Contrary to milk, however, meat production per ha in absolute terms was higher in the humid tropics than in the dry tropics due to greater availability of nutrients and voluntary consumption throughout the year. The strategy of cattle raisers in the dry tropics has consisted in concentrating milk production during the rainy season. However, animals lose weight during the dry season and, as a result, meat production is lower compared with the humid tropics, based on the parameters reported in this study (Tables 2 and 3).

Costs of Milk and Meat Production. The reduction in stocking rate and milk and meat production attributable to spittlebugs has a direct effect on production costs. With a low level of infestation, the production costs of both milk and meat increased 0-4%, depending on the proportion of farm area infested (Fig. 2; Tables 4 and 5).

Likewise, the unitary cost of milk and meat production increased an additional 3-13% when cows were moved from

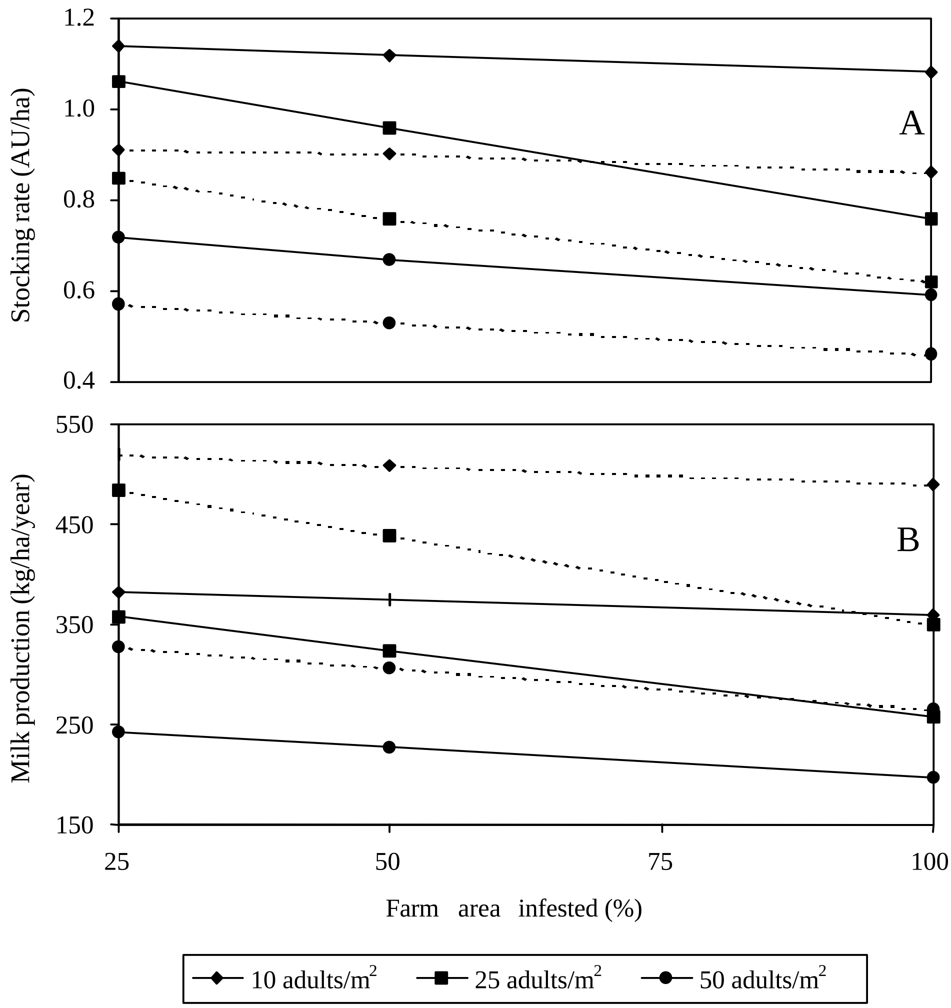

Figure 1. Effect of different levels of spittlebug infestation on animal stocking rate (A) and milk production (B) in pastures of *B. decumbens* in the humid (solid line) and dry (dashed line) tropics of Colombia.

a low to intermediate level of infestation, and 12-15% when moved from an intermediate to high level of infestation. In conclusion, the cost of producing milk and meat in a pasture highly infested with spittlebug is 18-30% higher than that of the same pasture without spittlebug infestation.

Net Income. The parameter that summarizes the economic damage caused by spittlebugs on pasture and herd productivity is "net income per ha." For both ecosystems, net income decreased 3-16% when the economic benefits of a healthy pasture were compared with those of a pasture presenting a low level of infestation, depending on the proportion of farm area infested (Fig. 2; Tables 4 and 5). The difference was US$32 to US$31–27/ha/yr for the humid tropics and US$42 to US$40–36/ha/yr for the dry tropics.

Furthermore, when grazing cows were moved from pastures with a low to intermediate level of infestation, the net income was additionally decreased 16-63%, depending on the proportion of farm area infested (i.e. from US$27 to US$26-10/ha/yr for the humid tropics and from US$36 to US$35-17/ha/yr in the dry tropics). Under high levels of spittlebug infestation, net income was further decreased 71-100% (i.e. from US$10 to US$7-0/ha/yr for the humid tropics and from US$17 to US$14-5/ha/yr in the dry tropics). The net income of US$0/ha/yr in the case of the humid tropics means that the production system is no longer economically viable with 100% of the farm under high spittlebug infestation (Table 4). When a healthy pasture was compared with a highly infested pasture, net income was reduced 67-100% (i.e. from US$32 to 0/ha/yr in the humid tropics and from US$42 to US$5/ha in the dry tropics).

An alternative to control spittlebug populations in pastures is to apply chemical products such as chlorpyrifos (e.g. Lorsban). However, the product's cost (US$16/ha) and the additional cost of labor to apply it (US$8.85/ha) would reduce net income by US$24.85/ha, which is not economically viable because the net income per ha in these production systems ranges between US$32 and US$42/ha/yr. Also, there is no guarantee that the pasture will not be re-infested during the rainy season.

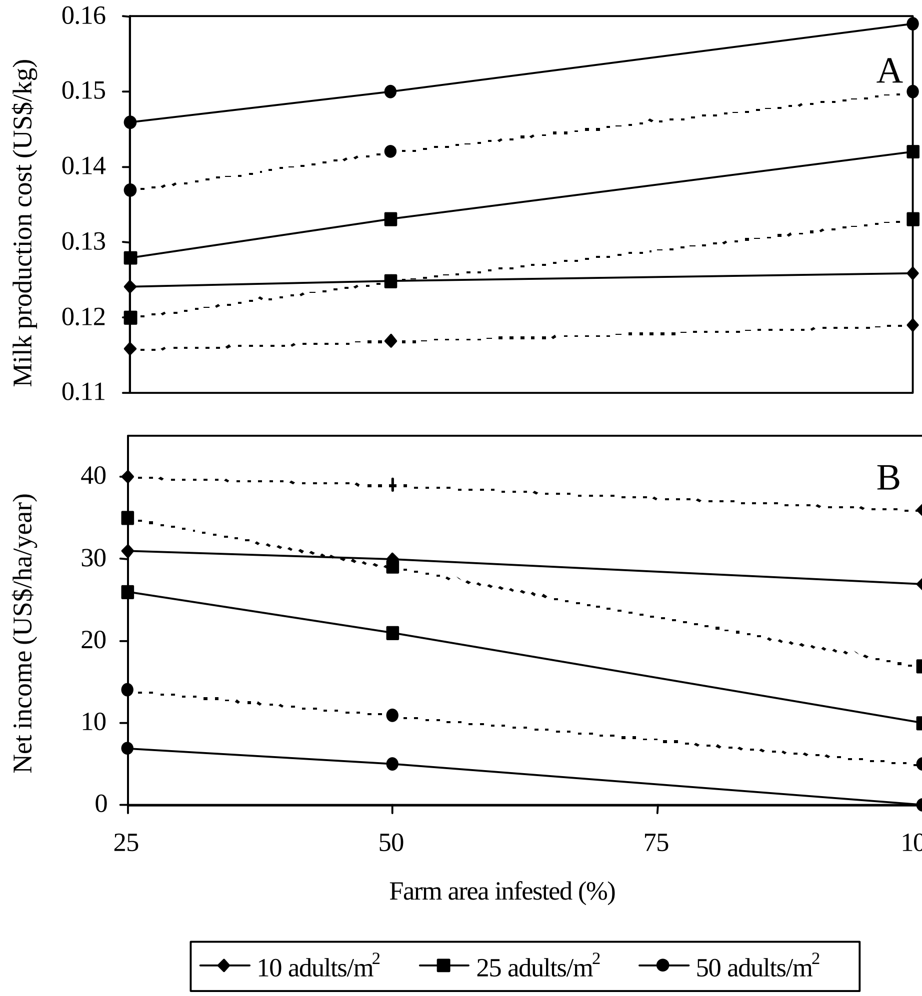

Figure 2. Effect of different levels of spittlebug infestation on milk production costs (A) and net income (B) in pastures of *B. decumbens* in the humid (solid line) and dry (dashed line) tropics of Colombia.

Production and Economic Damage at the Ecosystems Level. On-farm results generated by the simulation model must be extrapolated to the target ecosystems to estimate the impact of the spittlebug on animal production and its corresponding economic damage.

According to DANE (1996), there are approximately 1.6 million heads of beef cattle in Colombia's humid tropics (i.e. departments of Caquetá, Putumayo, and Chocó), which account for 6.1% of the national herd. The area under pastures in this ecosystem is approximately 1.2 million ha and an estimated 95% of this area is established with *B. decumbens* and *Homolepsis aturensis* Kunth (Chase) ("guaduilla"); both of these species are susceptible to spittlebug attacks (personal communication, John Miles, CIAT forage breeder). Therefore, 1.14 million ha of pastures are under grasses in constant danger of infestation.

In Colombia's dry tropics (i.e. departments of Atlántico, Bolivar, Cesar, Córdoba, Guajira, Magdalena and Sucre), the estimated bovine population is 8.0 million heads, accounting for 31.3% of the national herd; the area under pastures is approximately 5.9 million ha (DANE 1996). Estimates are that 80% of this area is established with *B. decumbens* and *Bothriochloa pertusa* (L.) A. Camus ("colosuana"), also susceptible to spittlebug attacks. As a result, approximately 4.72 million ha of this ecosystem could be infested by this pest during 6 months a year.

The economic damage of spittlebug impact on milk and meat production, expressed in kilograms of product and in dollars, was estimated for each ecosystem on the basis of these figures (Table 6). At a low level of infestation, and depending on the proportion of infested area in the region, the annual loss in milk production was 8-34 million liters milk in the humid tropics and 47-189 million liters in the dry tropics. The annual loss in meat production was 2-8 million kg for the humid tropics and 7-28 million kg for the dry tropics. The sum of the loss of meat and milk, translated into dollars, implied a net reduction in producer income of US$1.4-5.7 million/yr in the humid tropics and US$7.1-28.3 million/yr in the dry tropics. As a result, the annual economic damage for both regions together, using as scenario the low

Table 6. Regional economic impact of different levels of spittlebug infestation (abundance and proportion of farm area infested) in the humid and dry tropics of Colombia.

Infestation level		Production loss (millions kg/yr)				Economic loss (millions US$/yr)	
		Milk		Meat			
Abundance (adults/m^2)	Affected area (%)	Humid tropics	Dry tropics	Humid tropics	Dry tropics	Humid tropics	Dry tropics
10	25	8.5	47.2	2.0	7.1	1.4	7.1
	50	17.1	94.4	4.0	14.2	2.9	14.2
	100	34.2	188.8	8.0	28.3	5.7	28.3
25	25	37.6	212.4	9.1	33.0	6.8	33.0
	50	75.2	424.8	18.2	66.1	12.5	61.4
	100	150.5	844.9	36.5	136.9	25.1	118.0
50	25	167.6	948.7	41.0	151.0	28.5	132.2
	50	184.7	1,047.8	45.6	165.2	30.8	146.3
	100	220.0	1,246.1	53.6	198.2	36.5	174.6

infestation level, amounted to US$8.5-34.0 million/yr.

The economic loss is even greater with the intermediate level of infestation. Under this scenario, the annual loss in milk production was 37-150 and 212-845 million liters in the humid and dry tropics, respectively. Similarly, the loss in meat production increased to 9-36 and 33-137 million kg in the humid and dry tropics. Translated into monetary value, this impact implied a direct loss in cash flow of producers of US$7-25 and US$33-118 million/yr in the humid and dry tropics. These figures suggest that the potential economic damage with an intermediate level of infestation for both regions together is US$40-143 million/yr.

The situation becomes even more dramatic when the scenario of high level of infestation is analyzed. In this environment, the annual milk production loss was 167-220 and 948-1246 million liters for the humid and dry tropics, respectively. In the case of meat, losses were 41-54 and 151-198 million kg. As a result, the economic damage in the most unfavorable scenario was US$28-36 and 132-175 million/yr for the humid and dry tropics. The overall balance of both regions indicates that the economic damage caused by the spittlebug, under a high level of infestation, is US$161-211 million/yr, depending on the proportion of area in the region permanently infested during the rainy season. This damage does not include other regions of the country, such as the extensive Llanos Orientales or the upland and interandean regions where pastures have been sown to varieties susceptible to spittlebugs. Accordingly, the potential damage reported herein for Colombia is considered highly conservative.

Discussion

A more precise estimation of economic damage will depend on (a) information on the biology and behavior of unstudied spittlebug species, (b) quantitative impact data on the particular spittlebug/forage species combinations found in the study region, nymphs as well as adults, and (c) detailed studies of population dynamics to compare real field circumstances with results of simulation models.

Studies to generate bioecological information and quantify damage are very important to precisely estimate impact and to improve spittlebug management. Fifteen spittlebug species from eight genera are found in association with graminoids in Colombia, and the complex varies according to region (Peck 2001). No specific data on the biology and behavior of most economically important species are available. Although this taxonomic diversity will probably affect impact, the degree of variation is still unknown; the damage caused by the most common species in the humid and dry tropics of Colombia has not yet been quantified. Estimates of impact will depend on detailed studies, such as those conducted by Valério & Nakano (1988, 1989), on the various species combinations of spittlebug and forage grass. For example, the most important association in Colombia's northern coast is *A. reducta* in *B. pertusa*; in the Amazon piedmont it is *Aeneolamia varia* (F.) and *Zulia pubescens* (F.) in *Brachiaria*; and in the Llanos Orientales it is *A. varia* in *B. decumbens.*

An important assumption of these results is the origin of impact data on plant quality and biomass production. To date, the studies conducted by Valério & Nakano (1988, 1989) are the most comprehensive, but they only deal with the effect of the spittlebug *N. entreriana* on *B. decumbens.* These data were used in our study to estimate the impact of other spittlebug species on other forage grasses in Colombia. Moreover, no data are available on the impact of nymphs that can be extrapolated to the field level. Although the damage caused by spittlebug nymphs most probably does not surpass that caused by adults, it is still significant and should be included.

Besides considering the biology and impact of the specific spittlebug/forage associations found in different regions, estimating economic damage will depend on insect ecology. This study did not attempt to relate the simulation model to real insect populations in the field. A next step would be to compare these results, based on infestation levels, with real levels of insect incidence in the field, especially to specify spatial, seasonal, and annual variations in pest infestation. Studies of population dynamics offering high resolution (frequent samplings of all life stages) are therefore needed as well as information on on-farm, ecosystem (different regions) and temporal (surveys over several years) variability (Peck 1999).

Despite the above limitations, the results obtained in this study on the economic impact of spittlebugs in Colombia are considered highly conservative because they did not include (a) other major animal production regions such as the extensive Llanos Orientales or the high elevation and interandean areas, and (b) the economic and production damage caused by spittlebug nymphs.

Grass species and varieties showing certain resistance to spittlebugs are currently available on the market, although their level of resistance depends on the spittlebug species. Although *Panicum maximum* Jacq., *Andropogon gayanus* Kunth, *B. brizantha* (Hochst. Ex A. Rich.) Stapf*,* and *B. dictyoneura* (Fig. & De Not.) Stapf can offer germplasm alternatives under certain circumstances, they require soils with intermediate to high fertility and adequate management (including nitrogen fertilization or association with legumes) to avoid pasture degradation. These characteristics greatly limit the ecological niches of these grasses. Accordingly, grass varieties that are not only resistant to the spittlebug but also adapted to soils of low-to-intermediate fertility should be developed.

The estimated investment necessary to finance a breeding program for new grass varieties resistant to spittlebugs and adapted to these soil conditions is about US$500,000/yr, over a 12-yr period (personal communication, John Miles, CIAT forage breeder). In other words, the total estimated cost of varietal improvement of grass species, tested and released to cattle raisers, is US$6 million. This amount is equivalent to 70% of the economic cost for producers over one year, at a low level of spittlebug infestation on 25% of the area under susceptible varieties, in the dry and humid tropics of Colombia. Based on this figure, producer associations are highly motivated to invest in research institutes that have the technological capacities to develop grass varieties resistant to spittlebugs.

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