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Farmers' knowledge and perceptions of the stunting disease of Napier grass in Western Kenya

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Production of Napier grass, *Pennisetum purpureum*, the most important livestock fodder in Western Kenya, is severely constrained by Napier stunt (Ns) disease. Understanding farmers' knowledge, perceptions and practices is a prerequisite to establishing an effective disease management approach. Using a random sample of 150 farmers drawn from Bungoma, Busia and Teso districts of Western Kenya, this study sought to: (i) assess farmers' perceptions and knowledge of Ns disease, including its effects on the smallholder dairy industry; (ii) record farmers' current practices in managing Ns disease; and (iii) identify Ns disease management challenges and intervention opportunities in order to develop an efficient integrated disease management approach. The majority (86·7%) of the farmers were aware of Ns disease and observed that it was spreading rapidly in the region, which was perfectly predicted by farmers' access to agricultural information (marginal effect = 0·164), indicating a need for extension platforms for knowledge sharing among the industry stakeholders. The disease had affected Napier grass yields so most farmers could not feed their livestock on the amounts they produced, and they were buying Napier grass. Those who relied on income from selling Napier grass received less due to loss in productivity. Milk production had reduced by over 35%. The cause of the disease was unknown to the farmers, with no effective disease management strategy available to them. An integrated disease management approach needs to be developed to fit within the mixed farming systems, supported by simple decision aids.

Keywords: Napier stunt disease, smallholder dairying, Western Kenya

Introduction

Napier grass, *Pennisetum purpureum* (Poaceae), is an important crop that significantly contributes to livelihoods of small-scale farmers in Western Kenya by supporting the smallholder dairy and cereal production systems in the region. It is the main fodder for the dairy industry, in addition to its novel use as a trap plant for management of cereal stemborer pests in 'push–pull' technology (PPT). PPT involves planting Napier grass around a plot of maize (*Zea mays*) or sorghum (*Sorghum bicolor*) intercropped with a stemborer repellent intercrop such as cattle forage legumes of the genus *Desmodium*, commonly known as desmodium. Desmodium repels the pests (push) while Napier grass attracts them (pull), consequently leaving the cereal crop protected (Cook *et al.*, 2007). Napier grass also serves as a soil conservation crop that is planted for environmental protection to stabilize soils and act as windbreak, a building material, and as firewood (Jones *et al.*, 2004).

Cultivation of Napier grass has intensified recently as small-scale dairy farming shifted from extensive to zero-grazing systems in the areas of high agricultural potential in Western Kenya, which are densely populated and where farmholding sizes are small. These conditions limit natural grazing and therefore cattle are fed on crop residues, concentrates and cultivated fodder, mainly Napier grass. The number of farmers practising PPT in the region has also increased to over 50 000. This is not only helping to increase yields of cereal crops through the control of stemborers and striga weeds (Khan *et al.*, 2008, 2010), but also producing fodder for livestock in the cereal–livestock mixed farming systems practised in the region (Hassanali *et al.*, 2008). Farmers who either keep no livestock or have excess fodder sell bundles of Napier grass to other farmers in need of fodder, making the crop a valuable source of income to farm households in the region.

However, continued contribution of Napier grass to the livelihoods of the small-scale farmers in the region is threatened by Napier stunt (Ns) disease (or 'Napier grass stunt') whose effects only become visible in regrowth after cutting or grazing. In Western Kenya, the disease is associated with a phytoplasma belonging to the 16SrXI strain ('*Candidatus* Phytoplasma oryzae') group (Jones *et al.*, 2004, 2006). The affected plants show symptoms that include foliar yellowing, small leaves, proliferation of tillers and shortening of internodes to the extent that clumps appear severely stunted. Often the whole stool is affected, with complete loss in yield and eventual death

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of the plants. The disease is transmitted by *Maiestas* (= *Recilia*) *banda* (Hemiptera: Cicadellidae) (Obura *et al.*, 2009), and is spread through planting of infected material and by the insect vector. A similar stunting disease has also been reported in Uganda, Ethiopia and Tanzania where Napier grass is an important fodder (Orodho, 2006; Nielsen *et al.*, 2007), indicating the extent of the problem of Ns disease in eastern Africa.

The effect of Ns disease has been serious for the dairy sector in Western Kenya, an industry that plays an important role in the livelihoods of many farm households in generating income and employment (Mudavadi *et al.*, 2001). The disease thus indirectly affects agricultural growth, which is crucial to the overall socio-economic development of the region. The impact of the disease is such that the viability of the smallholder dairy industry in the region is seriously threatened (Jones *et al.*, 2004). This threat has increased in recent years because of liberalization in the dairy subsector and increased milk prices (Orodho, 2006), and is compounded by declining farm sizes and numbers of grazing fields.

Despite the obvious damaging effects of Ns disease in Western Kenya, there remains no effective method for its control in the region. Efforts have been made by national research organizations to develop management approaches for the disease, including selection of resistant cultivars, but the selected cultivars have been found to be susceptible in various locations in Western Kenya. In addition, some of the selected cultivars are less productive than existing Napier grass varieties, and hence do not meet farmers' demands (Mulaa *et al.*, 2010). This has therefore negatively affected the adoption of the proposed stunt-resistant varieties in the region. This has further compounded the already poor adoption of technologies aimed at alleviating biotic constraints, including diseases, to smallholders' farming systems in developing countries (Nyankanga *et al.*, 2004). This is partly attributed to the process of technology development that does not allow adequate participation and/or consideration of farmers' knowledge, perception and practices (Bentley & Thiele, 1999). A few studies have highlighted the importance of Ns disease to farming households in East Africa (Boa *et al.*, 2005; Kabirizi *et al.*, 2007; Mulaa *et al.*, 2010). However, these studies lack details of the determinants of the stated outcomes that are of economic importance if adoption of the research outputs is to be achieved. This gap motivated this study to be conducted to understand farmers' perceptions and knowledge of Ns disease in Western Kenya and their determinants, and to identify potential points for intervention in the development of an integrated management strategy for the disease. Specifically, the study sought to address three objectives: (i) to assess farmers' perceptions and knowledge of Ns disease, including its effects on the smallholder dairy industry; (ii) to establish farmers' current practices in managing Ns disease; and (iii) to identify Ns disease management challenges and intervention opportunities, in order to develop an efficient integrated disease management approach.

Materials and methods

Study sites

A survey was conducted from November to December 2008 in three districts in Western Kenya, namely Bungoma (0°25′ to 0°53′S, 34°21′ to 35°04′E), and Busia and Teso (0°1′ to 0°46′S, 33°54′ to 34°26′E). Western Kenya is one of the most densely populated areas in sub-Saharan Africa, with populations of over 500 persons per km^2. It is characterized by high levels of extreme poverty (about 60%), which exceed the national average of 46% (Kabubo-Mariara & Ndeng'e, 2004). The study districts are among those in the region that produce most of the livestock products in Kenya (Orodho, 2006). They lie at an altitude of 1200 m a.s.l. in Teso to 2500 m a.s.l. in Bungoma, with an average annual rainfall of 630–1600 mm. Although smallholder dairying is one of the main economic activities in these districts, with Napier grass being the main fodder, milk output is low (Orodho, 2006).

Sampling procedures

A multistage sampling process was conducted to select farmers for the survey. As Ns disease was first reported in Western Kenya, the affected districts were sampled based on the severity of the disease spread. Because the target population was the smallholder dairy farmers who had Napier grass in their farms, a sampling frame was developed with the help of extension agents and village elders who had clear information about their region. This was done at the location administrative units. A total of 150 dairy farmers were chosen at random from the sampling frame, 50 from each of the three districts.

Data collection

Data were collected using a semistructured questionnaire (Appendix S1) administered through face-to-face interviews with the respondents. The questionnaire was developed to capture farmers' knowledge of, and experience with, Ns disease and to document how they were addressing the problem. This was captured as a series of binary responses by asking farmers if they knew about Ns disease, if they recognized it on their farms, and how they described the symptoms of the disease. The responses to this were recorded as 1 if the response was a 'yes' and 0 if the response was a 'no', as shown in Table 1. The perception on the disease severity was captured as a categorical variable using a 4-point Likert scale rating commonly used for such measurements (Khan *et al.*, 2008). For this, farmers were asked to rate the severity of the disease on a scale of 0 to 3, where 0 = no problem, 1 = moderate problem, 2 = severe problem and 3 = very severe problem (Table 1). Finally, farmers were asked about their willingness to replace Napier grass with alternative fodder grasses, with answers treated as binary variables where 1 = yes and 0 = no. Other aspects captured in the questionnaire interviews included farmers' socio-economic characteristics including age, gender, education level and household size; proportion of land affected by Ns disease; Ns disease-causing agents; rate of spread of Ns on their farms; and their estimation of disease effects on the dairy industry and fodder sufficiency. Data were also collected on respondents' efforts to control the disease. The questionnaire was pretested before being used in the main survey. Enumerators from the selected sites were recruited and trained for the purposes of data collection.

Data analysis

Both descriptive statistics and econometric models were used in data analysis. The data was summarized using cross tabulations and subjected to analysis of variance, F tests and χ^2 tests to compare differences in the various responses and districts. Further analysis of determinants of farmers' knowledge of Ns disease, their perceptions on the disease severity and their willingness to replace Napier grass with other resistant grasses was conducted using selected econometric models. Based on the objectives of the study, selected variables as shown in Table 1 were identified as dependent and independent variables for the specific models. Where the dependent variable was binary, as in the case of farmers' knowledge of the disease and their willingness to replace Napier grass with alternative grasses, a binary logit model was used to assess the factors determining the likelihood of the desired outcome (yes = 1); in the case of Likert scale responses, an ordinal regression with a logit link (ordered logit) was used (Gujrati, 2003). These models are founded in random utility (RU) theory and are built around a latent regression (McFadden, 2001):

$$Y^* = \beta X + \varepsilon_i$$

where Y^* is an underlying latent variable that indexes farmers' knowledge of Ns disease and their perception about its severity and willingness to replace Napier grass with alternative grasses as fodder, β is a column vector of unknown parameters to be estimated, X is a row vector of respondent characteristics, and ε_i is the stochastic error term (Green, 2000).

The coefficients generated from these regression models through maximum likelihood estimates are not easily interpreted and thus marginal effects, the effect of a small change in the explanatory variables on the probability of a particular outcome (knowledge of Ns disease, perception of severity of the disease, and willingness to replace Napier grass with an alternative fodder grass), are commonly presented. Marginal effects are used to interpret the magnitude by which a one-unit change in an independent variable will change the probability outcomes, and are represented in an equation as follows (Green, 2000):

Table 1 Description of variables used in the regression analysis of factors influencing farmers' knowledge and perception on Napier stunt (Ns) disease, and willingness to replace the grass

Variable	Description	Variable type	Units
Dependent variable			
nsd_know	If the farmer knows or is able to properly identify Ns disease	Dummy	1 = yes, 0 = no
nsd_sevown	Severity of Ns disease on the farm	Categorical	0 = no problem, 1 = moderate problem, 2 = severe problem, 3 = very severe problem
nap_repla	Willingness of farmers to replace Napier with other grasses due to Ns disease	Dummy	1 = yes, 0 = no
Explanatory variables			
age	Age of the farmer	Years	Continuous
gender	Gender of the farmer	Dummy	1 = male, 0 = female
hh_size	Household size	Persons	Continuous
av_inco	Average income from sale of Napier grass and milk	Ksh	Continuous
martalst	Marital status	Categorical	1 = single, 2 = married, 3 = widowed, 4 = divorced
none	No education (reference)	Dummy	1 = yes, 0 = no
nonfom	Non-formal education	Dummy	1 = yes, 0 = no
pri_educ	Primary level education	Dummy	1 = yes, 0 = no
sec_educ	Secondary level education	Dummy	1 = yes, 0 = no
postsec	Post-secondary level education	Dummy	1 = yes, 0 = no
landsiz	Land area	Acres	Continuous
infoacc	Access to farming information	Dummy	1 = yes, 0 = no
farmexp	Farming experience	Years	Continuous
exper_nap	Experience in Napier grass farming	Years	Continuous
paddk	Source of fodder from own paddocks	Dummy	1 = yes, 0 = no
fod_own	Source of fodder from growing own	Dummy	1 = yes, 0 = no
fod_bou	Source of fodder from purchase (reference)	Dummy	1 = yes, 0 = no
Nap_rosid	Growing Napier on roadside plots (reference)	Dummy	1 = yes, 0 = no
nap_own	Growing Napier grass on own land	Dummy	1 = yes, 0 = no
nap_rent	Growing Napier grass on rented land	Dummy	1 = yes, 0 = no
nap_szacre	Land area under Napier grass	Acres	Continuous
nsd_onfam	If Ns disease has occurred on-farm	Dummy	1 = yes, 0 = no
nsd_sprd	If Ns disease has been spreading on the farm	Dummy	1 = yes, 0 = no
nsdpro_acre	Proportion of land with Ns disease in acres	Acres	Continuous
tlu	Tropical livestock units per farmer	Units	Continuous
Bungoma	Bungoma district	Dummy	1 = yes, 0 = no
Busia	Busia district	Dummy	1 = yes, 0 = no
Teso	Teso district (reference)	Dummy	1 = yes, 0 = no
grpmeb	If respondent belongs to organized groups	Dummy	1 = yes, 0 = no

$$\frac{\partial E(Y \mid X)}{\partial x_i} = f(\beta X)\beta_i$$

where $f(\cdot)$ is the density function corresponding to the distribution function $F(\cdot)$

Results

Socio-economic characteristics of the respondents

The majority (57%) of respondents interviewed were male, with these proportions significantly varying between districts, ranging from 40% in Busia to 72% in Bungoma. The farmers were of middle age category (mean age of 43·7 years), with about 50% of them being in the age bracket of 25–40 years (Table 2).

Overall, the farmers in the three districts were smallholders and kept modest numbers of livestock (Table 2), comprising 1·7 units of improved cattle on average, with Bungoma farmers keeping the highest number (3·1), followed by those in Busia (1·1) and Teso (0·8). Additionally, the farmers kept local breeds of cattle (overall mean 1·6), goats (mean 0·7) and sheep (mean 0·6). A few improved dairy goats (mean 0·2) were also kept, principally for milk production, an activity that is gaining popularity in the region as an alternative dairy animal owing to the limited sizes of farms. The number of improved dairy cattle, dairy goats, local goats and sheep varied significantly between districts. Farmers had a general shortage of fodder, with only 42% of them having enough fodder to feed their livestock. Sources of fodder varied but comprised own farm (>90% of the respondents) supplemented with fodder from purchase (40%), direct grazing on paddocks (19·3%) or free grazing (26·7%), with these proportions varying significantly between districts. On average, the majority (90·7%) of the farmers grew Napier grass on their own farms, which averaged 1·8 acres, but with significant differences between districts (Table 2). Only a small proportion of the farmers grew Napier grass on rented farms (7·3%) and on roadsides (6·7%) on plot sizes averaging 1·5 and 0·3 acres, respectively. In general, farms were significantly larger in Bungoma (with larger numbers of livestock) than in Busia and Teso districts (Table 2). This can partly be explained by the fact that the district is relatively sparsely populated, with land consolidation as a preferred method of land use and preservation.

Farmers' awareness and perceptions of Ns disease and its effects on their incomes

The majority (86·7%) of the respondents interviewed were aware of Ns disease, but with significant differences observed between districts, ranging from 62% of the respondents in Teso to all of those in Busia. Additionally, the majority (83·3%) of the respondents had witnessed the disease in their own farms, while 86% had seen it on neighbouring farms (Table 3), indicating that it is a general problem in the region. The majority (65·3%) of the farmers were able to identify the disease from the key symptoms of stunted growth whereas 54·7% could identify yellowing of leaves, with significant differences between districts. Much higher proportions of respondents in Busia and Bungoma, 98 and 72% respectively, mentioned stunted growth as a symptom of Ns disease than did those in Teso (26%). However, yellowing of leaves was mentioned by a higher proportion (100%) of respondents in Busia than in Bungoma (28%) and Teso (36%) (Table 3).

Ns disease was regarded as a serious constraint to income generation by the majority (66%) of the respondents in Bungoma and by 50% in Teso, and identified by 76% of respondents in Busia as a moderately serious problem (Table 3). When the respondents were asked to estimate what area of their Napier grass fields was affected by the disease, the majority (84%) in Busia district and 50% in Bungoma district indicated one-quarter and entire field respectively. Similarly, in Teso, 26% of the respondents mentioned that one-quarter of their fields was affected while 28% said the disease had attacked their entire field (Table 3). The majority (84%) of the respondents reported that they had seen the disease spread in their farms, with significant differences between districts, ranging from 56% in Teso to 98% in Busia and Bungoma districts (Table 3). The rate of spread of the disease was estimated by 60% of the respondents in Busia as slow, but by 58% of the respondents in Bungoma as fast (Table 3). These observations confirm that since the disease was first reported in Western Kenya (Bungoma district) in 2001 (Jones *et al.*, 2004) it has spread to most of the region, affecting 83% of respondents' farms.

Ns disease has had negative impacts on the smallholder dairy production in the region in terms of reduction in the amount of Napier grass yields and the number of livestock units supported by one's own fodder, consequently affecting the milk yield and incomes (Table 4). On average, the amount of Napier grass harvested monthly in the period preceding the study, during the short rains of 2007 and long rains of 2008, substantially reduced when Ns disease became present by about 46 and 37% respectively. This reduction occurred despite an increase in the area planted to Napier grass (by about 36%) as a response to the effects of the disease. The average number of dairy cows supported similarly dropped from three to two, whereas the number of dairy goats dropped from 1·3 to 1·2 per farmer. Respondents reported a substantial reduction (35%) in the amount of milk obtained per month, with reductions in the amount and quality of fodder being mentioned as a probable cause. Consequently, incomes obtained from monthly milk sales had reduced by about 37% (Table 4). These effects were most serious in Bungoma, where the amount of Napier grass harvested monthly reduced by about 1·7 and 1·4 tonnes in the short rains of 2007 and long rains of 2008 respectively ($P < 0{\cdot}001$).

In Busia, the amount of Napier grass harvested monthly reduced by about 0·2 tonnes per month over

Table 2 Socio-economic characteristics of the respondents

	District				Significance	
Variable	Busia (n = 50)	Bungoma (n = 50)	Teso (n = 50)	Mean (n = 150)	F value	χ^2 value
Gender (%): Male	40	72	58	56·7		10·48***
Age category (%)						
25–40	44	30	76	50	22·64***	
41–54	34	40	16	30		
55–70	22	22	8	17·3		
71–85	0	8	0	2·7		
Education level (%)						
None	2	10	8	6·7		33·45***
Non-formal	2	6	10	6		
Primary	64	62	20	48·7		
Secondary	28	22	44	31·3		
Post-secondary	4	0	18	7·3		
Mean no. of livestock owned/household						
Improved dairy cattle	1·14	3·12	0·84	1·7	27·12***	
Local cattle	1·56	1·36	1·98	1·63	0·899 ns	
Improved dairy goats	0·0	0·0	0·6	0·2	3·128**	
Local goats	0·88	0·26	0·88	0·67	3·361**	
Sheep	1·06	0·34	0·4	0·6	5·380***	
Farmers with sufficient fodder (%)	40	34	52	42		4·58 ns
Source of livestock feed (%)						
Own fodder	100	96	90	95·3		5·69*
Buy fodder	60	42	18	40·0		18·50***
Have grazing paddocks	4	44	10	19·3		29·838***
Free grazing fields	30	4	46	26·7		22·977***
Proportion of farmers growing Napier grass on own farm, rented farms or roadside (%)						
Own farm	100	94	78	90·7		15·28***
Rented farm	8	4	10	7·3		1·37 ns
Roadside	2	6	12	6·7		4·07 ns
Average size of land under Napier grass/household (acres)						
Own farm	1·9	2·8	0·4	1·8	4·45**	
Rented farm	0·4	10	0·7	1·5	172·94***	
Roadside	0·1	0·5	0·1	0·3	0·693 ns	

Statistically significant levels at *P < 0·10, **P < 0·05, ***P < 0·01; ns, not significant.

the same period. This resulted in reductions in the incomes from sale of Napier grass by about 517 Kenya shillings (Kshs) ($1 = 82 Kshs) in Busia during the long rains of 2008. However, the reverse occurred in Bungoma where the price of Napier grass increased almost three-fold, from about Kshs 426 to Kshs 1144 per tonne. This resulted in increases in monthly incomes from the sale of Napier grass, by about Kshs 925, despite the reduced yields of the grass. This can be attributed to the high demand for the fodder that was accompanied by large increases (of about Kshs 2270 per month) in the amounts of money spent to purchase Napier grass in the district (Table 4). In Teso, where the community culturally practised communal grazing, the farmers indicated that they reduced the acreage under Napier grass (by about 1640 m^2) as a result of the disease. This consequently resulted in reduced amounts of harvested fodder, milk yields and income from Napier grass sales. However, as a result of significant increases in the price per litre of milk, from about Kshs 35 to Kshs 46, the farmers realized a net increase in monthly incomes from milk sales (of about Kshs 216) (P < 0·001).

Factors influencing farmers' knowledge of Ns disease

Understanding the factors that determine farmers' knowledge and perception of Ns disease is critical in designing appropriate intervention programmes. Table 5 presents the logit coefficients and marginal effects of the factors influencing farmers' knowledge of Ns disease in the study districts. The model was significant at 1% (Prob > χ^2 = 0·024) with four significant predictors for farmers' knowledge and their ability to identify Ns disease on their farms: gender of the respondent (*gender*), and age of the respondents (*age*), both of which were negative; agricultural information access (*infoacc*) and average income from sale of Napier grass and milk (*av_inco*), which were both positive.

Farmers' perceptions on the causes, severity and control of Ns disease

Although the majority of the farmers expressed knowledge of Ns disease, over half of them (57·9%) did not know its cause. However, an insect, which they were

Table 3 Farmers' knowledge and perceptions on Napier stunt (Ns) disease on their own and neighbouring farms

Variable	District				
	Busia (n = 50)	Bungoma (n = 50)	Teso (n = 50)	Mean (n = 150)	χ^2 value
Knowledge of Ns disease (%)					
Farmers with knowledge of Ns disease	100	98	62	86·7	39·58***
Farmers with Ns disease on their farms	98	96	56	83·3	40·12***
Symptoms of Ns disease reported on other farms	100	98	60	86·0	42·19***
How farmers recognize Ns disease (%)					
Stunted growth	98	72	26	65·3	59·17***
Yellowing of leaves	100	28	36	54·7	61·55***
Observed other signs	4	2	0	2·0	2·04 ns
Perceptions of Ns disease severity (%)					
No problem	2	2	44	16·0	98·47***
Moderate problem	76	32	6	38·0	
Severe problem	20	38	40	32·7	
Very severe problem	2	28	10	13·3	
Proportion of Napier grass affected by Ns disease (%)					
None	2	2	44	16·0	108·15***
One quarter	84	12	26	40·7	
One half	8	16	2	8·7	
Three quarters	6	20	0	8·7	
Entire field	0	50	28	26·0	
Ns disease spreading on the farm (%)	98	98	56	84·0	43·75***
Spread of Ns on farmers' Napier grass (%)					
Slow	60	4	2	22·0	103·84***
Fast	34	58	38	43·3	
Very fast	4	36	16	18·7	
Not observed	2	2	44	16·0	
Perception on the causes of Ns disease (%)					
Unknown insects/worms	18	4	12	11·3	
Soil infertility	20	6	2	9·3	
Don't know the cause	54	84	36	58·0	
Soil erosion	–	2	–	0·7	
Planting young canes	–	2	2	1·3	
Transplanting of canes	2	–	–	0·7	
Animals	2	–	10	4·0	
Fresh cow dung	4	–	–	1·3	

***Statistically significant at $P < 0{\cdot}01$; ns, not significant.

unable to identify, was implicated as the main cause of the disease by 11·4% of the respondents (Table 3). The respondents were largely unaware of any management approach for the disease (data not shown). About a third (30%) of the farmers indicated uprooting and burning the diseased plants as a way of managing the disease, while <5% of the respondents mentioned a range of measures including planting of disease resistant Napier grass cultivars, use of fertilizers and crop rotation. Notably, some respondents (about 3%) mentioned a need for scientists to carry out research on the disease to come up with high yielding Napier grass varieties that also are resistant to the Ns disease (data not shown).

The ordered logit coefficients and marginal effects of factors influencing farmers' perception on the severity of Ns disease are presented in Table 6. The positive and significant predictors in this model were level of education (*pri_educ* and *sec_educ*), experience in Napier grass farming (*exper_nap*), knowledge of the disease (*nsd_know*) and the dummy variable representing Bungoma district (*bungoma*) with Teso district as the base. The dummy variable for Busia district (*busia*) was also significant but negative. The model was significant at 1% and cut-off points (*/cut*), which show the likelihood or probability of perceiving the disease spread as either high or low, satisfy the conditions $\mu_0 < \mu_1 < \mu_2$ implying that the categories are ordered (Knight *et al.*, 2005). The first cut-off point (0 = no problem) was used as reference for comparison purposes, therefore is usually dropped in the analysis.

Given the susceptibility of Napier grass to Ns disease, the respondents were asked if they would be willing to replace Napier grass with any other fodder grasses. A majority (54%) of the respondents indicated willingness to replace the Napier grass with other grass varieties that are resistant to Ns disease. However, they could not suggest any particular candidate grasses they would prefer planting. Results in Table 7 show that the likelihood of

Table 4 Perceptions of the effect of Napier stunt (Ns) disease on farmers' earnings in Western Kenya

		Before Ns disease				Situation now with Ns infection				Overall change		
Variable	*n*	Busia	Bungoma	Teso	Mean	Busia	Bungoma	Teso	Mean	+ve/−ve	%	*t*-test
Area planted with Napier grass (m^2)	124	6992	8482	4580	7093	7217	16213	2937	10075	2883	35·7	−1·382 ns
Napier grass harvested/month (tonnes)												
Short rains 2007	120	1·65	3·03	1·12	1·93	1·44	1·29	0·39	1·04	−0·89	46·1	3·541***
Long rains 2008	122	1·73	3·52	1·26	2·17	1·49	2·12	0·47	1·36	−0·81	37·3	6·513***
Number of livestock supported by own Napier grass												
Dairy cows	90	1·7	4·2	1·9	3·1	1·7	2·1	2·1	2·0	−1·1	35·6	4·751***
Dairy goats	90	0·0	1·5	1·0	1·3	0·0	1·5	1·0	1·2	−0·1	7·6	NA
Income from the sale of Napier grass (Kshs/month)	22	1882·4	1500·0	2400·0	1796·0	1364·7	2425·0	1800·0	1577·0	−219·0	12·2	1·14 ns
Amount spent to purchase Napier grass (Kshs/month)	41	1489·3	1445·8	740·0	1441·0	1555·4	3715·0	600·0	2523·0	1082·0	75·1	−2·765***
Amount of milk produced/month (litres)	82	365·2	360·1	169·8	338·4	313·9	202·7	134·4	220·1	−118·3	34·9	5·783***
Income from the sale of milk per month (Kshs)	83	11100·0	11319·8	5961·0	10613·3	8582·6	5969·6	6176·7	6687·8	−3925·5	37·0	5·902***

***Statistically significant at $P < 0{\cdot}001$; ns, not significant.
Exchange rate at the time of the study: \$1 = 82 Kenya shillings (Kshs).

Table 5 Logit results on factors influencing farmers' knowledge of Napier stunt disease in Western Kenya

	Logit coefficient		Marginal effect	
Variable[a]	Coef.	SE	dy/dx	SE
gender	−1·029*	0·622	−0·048*	0·035
age	−0·004**	0·002	0·000**	0·000
martalst	−0·368	0·681	−0·018	0·034
farmexp	0·022	0·040	0·001	0·002
nonfom	−1·823	1·534	−0·184	0·249
pri_educ	−0·982	1·427	−0·050	0·077
sec_educ	−1·534	1·500	−0·103	0·137
postsec	−2·536	1·634	−0·318	0·349
hh_size	−0·054	0·104	−0·003	0·005
landsiz	−0·015	0·083	−0·001	0·004
tlu	0·051	0·166	0·002	0·008
grpmeb	0·333	0·880	0·018	0·053
infoacc	1·685*	1·017	0·164*	0·170
exper_nap	−0·048	0·055	−0·002	0·003
av_inco	0·001***	0·000	0·000***	0·000
_cons[b]	2·562	3·164		

[a]Description of the variable names and their measurements is shown in Table 1.
[b]*_cons*, the constant (also called the intercept) is the predicted log odds when all of the explanatory variables in the model are held equal to 0.
*10% significance, **5% significance, ***1% significance.
$n = 149$, log likelihood = −44·905, LR χ^2 (15) = 27·71, Prob > χ^2 = 0·024, pseudo-R^2 = 0·236.

farmers' willingness to replace Napier grass with alternative grasses was positively and significantly predicted by farmer's level of education (*nonfom* and *sec_educ*), knowledge of Ns disease (*nsd_know*) and average income (*av_inco*), while it was negatively predicted by the farmer being male compared to female (*gender*) and farmer's perception on severity of Ns disease (*nsd_sevown*). The positive signs for education and Ns disease knowledge suggest their importance in the ability of the farmers to make informed decisions. The negative sign for gender on the other hand indicates that male farmers were less likely to replace Napier grass with alternative grasses, as opposed to their female counterparts. Farmers' perception on Ns disease severity was put in the model to evaluate whether this had any effect on their willingness to replace Napier grass with other alternative grasses. Surprisingly, the results showed that farmers who perceived Ns disease spread to be rapid were not willing to replace Napier grass with alternative grasses, as depicted by the negative sign of the variable *nsd_sevown*.

Discussion

The current study confirmed that Ns disease is a serious threat to smallholder dairy farming in Western Kenya, contributing to losses of income. The farmers were able to identify the disease by its symptoms, not only on their farms but also on neighbouring farms, confirming that the disease was spreading in the region. These disease identifications were confirmed through nested PCR by a study aimed at determining the range of phytoplasma strains associated with Ns disease in the three districts (L. O. Agutu, unpublished data). From a sample of 255 plants with symptoms, 239 were confirmed to be positive for phytoplama by nested PCR, indicating about 94%

Table 6 Ordered logit results of factors influencing farmers' perception about severity of Napier stunt disease in Western Kenya

Variable[a]	Logit coefficient		Marginal effects (ME) for moderate		Marginal effects (ME) for severe		Marginal effects (ME) for very severe	
	Coef.	SE	ME	SE	Coef.	SE	ME	SE
gender	0·105	0·384	−0·002	0·008	0·015	0·054	0·002	0·007
age	0·001	0·001	0·000	0·000	0·000	0·000	0·000	0·000
nonfom	−0·039	1·072	0·001	0·013	−0·005	0·150	−0·001	0·019
pri_educ	1·235*	0·750	−0·028	0·061	0·178*	0·110	0·025	0·018
sec_educ	1·358*	0·798	−0·087	0·101	0·216*	0·137	0·035	0·029
postsec	1·330	1·099	−0·148	0·207	0·233	0·208	0·044	0·061
hh_size	0·028	0·063	−0·001	0·002	0·004	0·009	0·001	0·001
landsiz	0·000	0·038	0·000	0·001	0·000	0·005	0·000	0·001
grpmeb	−0·203	0·583	0·006	0·027	−0·030	0·089	−0·004	0·012
exper_nap	0·079**	0·039	−0·001	0·004	0·011**	0·006	0·001**	0·001
nsd_know	6·787***	0·929	0·327***	0·057	0·502***	0·057	0·106***	0·029
infoacc	−0·668	1·049	0·049	0·131	−0·110	0·192	−0·017	0·035
av_inco	0·000	0·000	0·000	0·000	0·000	0·000	0·000	0·000
Busia	−1·453***	0·623	−0·036	0·075	−0·181**	0·075	−0·023**	0·011
Bungoma	1·156*	0·666	−0·060	0·075	0·179	0·113	0·027	0·021
nap_szacre	−0·057	0·147	0·001	0·004	−0·008	0·021	−0·001	0·003
fod_own	1·148	0·879	0·086	0·143	0·119	0·067	0·013	0·008
paddk	−0·688	0·609	−0·015	0·050	−0·087	0·069	−0·011	0·008
nap_own	−0·369	0·772	0·017	0·060	−0·057	0·128	−0·008	0·019
nap_rent	0·604	0·836	−0·040	0·098	0·097	0·150	0·014	0·026
/cut1[b]	5·189	1·896						
/cut2[b]	8·136	1·993						
/cut3[b]	10·716	2·055						

[a]Description of the variable names and their measurements is shown in Table 1.

[b]/cut1, /cut2 and /cut3 are cut-off points in the ordered probit analysis confirming the variables were ordered.

*10% significance, **5% significance, ***1% significance.

n = 149, log likelihood = −118·89, LR χ^2 (20) = 157·84, Prob > χ^2 = 0·000, pseudo-R^2 = 0·399.

accuracy in Ns disease symptom identification by the farmers. The results also corroborate the findings of Kabirizi *et al.* (2007) who observed that the disease had become more prevalent and severe since it was first observed in Uganda in 2000. It is hypothesized that part of the reason for the fast spread of the disease is because of the increased intensity of Napier grass cultivation to support the intensive zero-grazing and semi-intensive dairy production systems as a response to the increasing demand for milk in the region. Farmers' knowledge of Ns disease was positively predicted by their access to agricultural information and average income from Napier grass. Access to agricultural information has been emphasized in many studies as one of the key ways to build farmers' confidence in decision-making, whereas a lack of it limits farmers' innovation (Genius *et al.*, 2006). By exposing farmers to different information sources, they are able to improve their decision-making processes in evaluating factors that constrain their farming activities such as the presence of a disease. Indeed, information can best be considered as a productive resource, with a potential to condition and influence efficiency of production. Moreover, farmers who derive high incomes from Napier grass and dairy farming tend to have a greater interest in the quality and quantity of the Napier grass they are producing, either for sale or to feed their livestock. These farmers are thus likely to notice any changes in quality and amounts of the grass and, motivated by the income they earn, are likely to seek information on the problem, including identification of the symptoms of Ns disease.

Farmers' knowledge of Ns disease was negatively predicted by gender and age. The prediction that male respondents were less likely to understand and positively identify Ns disease compared to their female counterparts was unexpected, given that more men than women participated in the study. It is common in sub-Saharan Africa that women are predominantly involved in farming, even though men act as the household heads and are in most cases the respondents to surveys such as this. The experience that women acquire from continual farming makes them more familiar with occurrences on the farm, while their male counterparts are generally out in search of off-farm employment. Age, on the other hand, is often negatively correlated with literacy levels, and elderly farmers are rated as illiterate compared to younger farmers, and thus are unlikely to discern the symptoms associated with a disease, such as Ns disease, on the farm. In general, the farmers were unaware of the causes and spread of the disease.

Among the predictors of farmers' perceptions on the severity of Ns disease were the farmers' experience in

Table 7 Logit results on farmers' willingness to replace Napier grass with other alternative fodder grasses in Western Kenya

Variable[a]	Logit coefficient		Marginal effect	
	Coef.	SE	dy/dx	SE
gender	−1·194***	0·471	−0·289***	0·107
nonfom	2·539***	1·440	0·445***	0·133
pri_educ	0·194	0·877	0·048	0·219
sec_educ	1·581*	0·946	0·365*	0·189
postsec	−0·022	1·198	−0·006	0·299
hh_size	0·061	0·077	0·015	0·019
landsiz	0·068	0·076	0·017	0·019
tlu	0·070	0·116	0·017	0·029
infoacc	1·240	1·411	0·283	0·263
fod_own	0·566	0·945	0·139	0·224
nap_own	−1·071	0·945	−0·248	0·190
nap_rent	−0·872	0·931	−0·209	0·206
av_inco	0·000***	0·000	0·000***	0·000
nsd_know	4·731***	1·536	0·648***	0·085
nsd_onfam	1·632	1·452	0·367	0·264
nsd_sevown	−1·021***	0·312	−0·255***	0·078
nsd_sprd	−0·471	1·367	−0·118	0·342
nsdpro_acre	−0·121	0·313	−0·030	0·078
exper_nap	0·045	0·051	0·011	0·013
age	−0·006	0·005	−0·002	0·001
_cons[b]	−3·611	3·316		

[a]Description of the variable names and their measurements is shown in Table 1.

[b]_cons, the constant (also called the intercept) is the predicted log odds when all of the explanatory variables in the model are held equal to 0.

*10% significance, ***1% significance.

$n = 149$, log likelihood = −65·087, LR χ^2 (20) = 75·250, Prob > χ^2 = 0·000, pseudo-R^2 = 0·366.

Napier grass farming, their level of education and knowledge of the disease. The results indicated that farmers who had more experience in Napier grass farming and those who positively identified and understood Ns disease ranked its severity higher than those farmers with less experience, or those who did not understand much about the disease. Equally, the farmers with some level of education ranked the severity of Ns disease higher when compared to those with less or no education. Moreover, the location variables represented by the district dummies imply that, compared to Teso district which was used as a reference, farmers in Bungoma district ranked the severity of Ns disease highest while those in Busia ranked the severity of Ns disease lowest. This is probably because Ns disease was first observed in Bungoma in 2001 (Jones *et al.*, 2004), hence it is possible the disease had become more severe, with the respondents from the district having had relatively longer experience with it. On the other hand, the diversity in different districts in terms of sociocultural and agroclimatic factors could be possible attributions to the positive and negative signs exhibited by the coefficients. These results confirm that knowledge and experience enable farmers to recognize the trend of Ns disease on their farms and hence they are able to correctly rank its severity. Previous studies have also observed educational level and years of farming experience to positively and significantly influence farmers' perceptions. For example, Ayanwuyi *et al.* (2010) found education and farming experience positively related to farmers' perception on climate change in Nigeria.

The farmers surveyed in this study did not have an effective management approach for the disease but mentioned a range of measures that could potentially form part of an integrated management approach of the disease. The majority of them were also willing to adopt use of alternative fodder grasses, which was positively and significantly predicted by a farmer's level of education, knowledge of Ns disease and average income and was negatively predicted by the farmer being male compared to female and by the farmer's perception on severity of the disease. While the factors that positively predicted the responses above are well documented, the negative sign for gender indicates that male farmers were less likely to replace Napier grass with alternative grasses, as opposed to their female counterparts. As stated above, women play a more active role in the smallholder dairy industry in sub-Saharan Africa than men and would thus be able to understand the constraints affecting the productivity of the venture. They would therefore be more willing to adopt strategies aimed at alleviating the constraints, such as trying new or alternative fodder grasses to beat Ns disease. The negative sign associated with farmer's perception on severity of the Ns disease was not expected, but could be attributed to the fact that farmers' perceptions are often very subjective and prone to bias (Adesina & Baidu-Forson, 1995). In addition, Napier grass is regarded as the main fodder for most smallholder farmers who keep livestock, and therefore a solution to Ns disease would be seen as a preferable option than replacing the entire Napier grass cultivation.

The results of the current survey indicate the need for concerted and multifaceted research in order to develop an integrated management approach for Ns disease that would fit within the farmers' socio-economic situations, including gender aspects, as well as their mixed farming systems. Additionally, there is a need to develop simple decision aids in disease management within an integrated approach that allows integration of all available options. Access to information was found to have a positive influence on farmers' understanding of Ns disease, indicating that the farmers need information that would improve their understanding of the disease and enable them control it. Thus, there is a need to develop platforms for knowledge sharing and extension support systems among the stakeholders involved in dairy production in the region, including farmers and extension delivery players.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site.

Appendix S1 Questionnaire on perceptions of Napier grass farmers on Napier stunt disease in Bungoma, Busia and Teso districts of Western Kenya.