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Economic importance of farm-level bruchid control in stored dry beans and cowpeas in Uganda

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Abstract

The damage bruchids cause to beans and cowpeas as major vegetable sources of protein is of considerable significance as protein shortage is acute in the diets of many Ugandans. Use of post-harvest techniques that would allow beans and cowpeas to be stored free of bruchids would reduce loss of these sources of protein, enhance their shelf life, improve food quality and seed viability and ultimately increase rural incomes and food security. This research explored financial consequences of effects of alternative farm-level bruchid control measures in stored dry beans and cowpeas in Iganga and Kumi districts of Uganda during the 1997-1999 period using partial budgeting and dominance analysis techniques. Results showed that actellic, wood ashes, solar heat and leaf powders of tobacco and tephrosia were economically viable post-harvest protectants of dry beans and /or cowpeas for at least 3 months in farm storage. Tobacco was the most profitable treatment on beans and tephrosia was the most profitable treatment on cowpeas. Additional economic benefits were realised either as a result of higher returns from increased marketable and sowable surplus or the low cost of grain protection. The analysis scheme outlined in this study that links partial budget and dominance evaluation techniques is a useful tool for future determination of the best post-harvest interventions to control bruchids.

Key words: Botanicals, bruchids, credits and debits, marginal rates of return, net benefit curve, post-harvest grain losses, grain legumes, Uganda

Introduction

A tragic, but all too common plight, of the small-scale farmer in Uganda is the irreversible seed and grain damage by weevils, which constitutes economic losses in nutritive value (vegetable protein) shortage in the Ugandan diet. The damaged product could also become a health hazard. Moreover, food grains that have been damaged by bruchids and weevils are undesirable in the market place causing surplus losses to both the producer and the consumer. In the case of seed grain, germination potential can be highly impaired (Taylor, 1972). As a consequence, inability to store beans and cowpeas safely forces small-scale farmers to sell off excess grain beyond their domestic requirements at harvest time at glut produce prices. Later traders sell needed grain back to farmers at high prices, increasing the farmers' debt burden.

Unfortunately, few data exist as to the actual quantitative and qualitative losses of beans and cowpeas in farm storage. Post-harvest losses caused by bruchids are difficult to quantity in Uganda because the semi-subsistence farmers do not keep relevant records. There is also a wide variety of storage methods in use. Given undefined periods over which grains are kept and the random trading practices used, the grain quantities in storage are continually changing. An earlier study in Uganda which collected data from actual sample farms showed that in some specific situations post-harvest grain legume losses exceeded 30 percent (Hall, 1970). In another farm storage survey in the central and western regions losses of beans attributed to insects in farmers' stores were estimated at 22.9 percent (Byaruhanga, 1971).

This study was conducted during the 1997-99 period in Iganga and Kumi districts under farmer-managed storage conditions. The economics component of the study explored financial consequences of effects of tested treatments on grain legume quantity and seed viability in storage with the following objectives: (a) to determine differences in post-harvest loss of quantity as a result of alternative treatments applied to control grain legume bruchid infestation, (b) to evaluate extra debits and credits involved in the proposed post-harvest bruchid control measures, and (c) to identify economically viable bean and cowpea bruchids management interventions to reduce loss of stored grain legumes on the farm.

Methodology

Two aspects of bean and cowpea bruchids management strategies were distinguished in this study: the product and process innovations and the economic terms on which the innovations have to be based. Evaluation from the product and process perspective involved ten farmers in Iganga district and six farmers in Kumi district. Seven treatments of dry large seeded beans (*Phaseolus vulgaris* L.) in Iganga district included leaf powders of three botanicals namely *Lantana camara* L., *Nicotiana tabacum* L. (tobacco) and *Tagetes minuta* L. (Mexican marigold); a solar dryer treatment; a wood ash treatment; a chemical treatment (actellic dust 1% a.i) and a control (no-treatment). Eight treatments of dry cowpea seeds (*Vigna unguiculata* L.Walp) in Kumi district included leaf powders of three botanicals namely *Tephrosia vogelli*, *Tagetes minuta* and tobacco and also a wood ash treatment, a solar dryer treatment, an actellic dust treatment, a vegetable oil treatment and a control.

The leaf powders of botanicals were processed from harvested leaves that were shade-dried. Leaves were used because of easy availability and shade-drying was to avoid rapid volatilisation of inherent active ingredients. The use of the powder form was to increase active surface area. The leaf powder was applied to grain at the rate of 2% w/w. Wood ash was obtained from the participating farmers' kilns irrespective of the tree species used. The application rate of wood ash was also 2% w/w. Solarisation of grains involved sun drying in a low cost dryer made of a shallow (1x3x0.3 m) pit lined with a black plastic sheet and the grain covered with a clear plastic sheet. Sun drying was done on a dry sunny day for two hours once a month. In the vegetable oil treatment dry cowpea grains were coated with an edible vegetable oil at the rate of 5 ml per kg of grain. In the chemical treatment, actellic dust 1% a.i was applied at the rate of 0.5 gm per kg of grain. Control treatments included grain which did not receive any form of treatment prior to or during experimental storage.

The grains were obtained from participating farmers' new season harvests at about 15-16% moisture content and were divided into one-kilogram working samples by the coning and quartering method (NRI, 1995). From each farmer, 7 kg of beans or 8 kg of cowpeas were obtained for the treatments. Treated and untreated grains were placed in muslin-cotton bags, stored on raised platforms to avoid moisture and arranged in a completely randomised pattern in the farmers' houses. Samples of each treatment were drawn monthly during the 3-month storage period to determine damage levels following the converted percentage damage method (NRI, 1995). Bruchid damaged grains were defined as those with distinct insect emergence holes. The effect of each treatment method on grain quantity and quality was then determined and compared with control trials.

Economic evaluation methods included partial budgeting and dominance analysis. Data on differences in bean and cowpea quantities, seed viability, input quantities and associated prices, grain farmgate and retail prices at harvest and 3 months later were collected. Seed viability was determined using blotter method (Neergard, 1979). Partial budgeting involved comparing the sum of added income (AI) and reduced costs (RC) equals credits with the sum of added costs (AC) and reduced income (RI) which is debits. Credits minus debits were the estimates of the differences in net cash benefits (NCB) as specified below:

NCB = (AI + RC) - (AC + RI) .... (1)

Dominance analysis was done by listing post-harvest bruchid control measures in the order of their increasing debits and matching them with their respective net cash benefits. The bruchid management methods with net cash benefits less than those of options with lower debits were dropped as dominated options (Mubanderi *et al.*, 1999). The remaining options which were not dominated were used to plot a net benefit curve along which farmers can expect to gain cash income as they shift between economically viable options. Marginal rates of return (MRR) gained by shifting along the net benefit curve were computed using the following formula:

MRR = (MB/MC) x 100 .... (2)

Where: MB = Marginal benefit or change in net benefits and MC = Marginal cost or change in debits.

According to Bereket and Asefu-Adjaye (1999), the marginal rates of return are the rates at which net benefits change as the investment changes.

Results and Discussion

From a biophysical perspective, the effectiveness of the different treatments applied to control bean bruchid infestation varied considerably. Bean damage levels built up depending on the type of treatment applied and storage duration. After 3 months of storage, solar heat, tobacco leaf powder and actellic dust provided effective disinfestation, registering bruchid bean injuries of 0.35%, 1.85% and 2.47%, respectively. Seed viability generally decreased as bruchid infestation increased. Solar heated beans were, however, least viable (50% germination) whilst beans admixed with actellic dust and tobacco leaf powder were most viable with 90.22% and 88% germination, respectively. Generally, the effectiveness of botanicals declined with protracted storage duration.

On cowpeas, bruchid damage levels and seed viability also varied according to the type of treatment applied and prolonged storage duration. The best treatments that reduced bruchid damage levels included mixing cowpeas with tephrosia and solarisation which registered 2.8% and 8.8% bruchid injury levels, respectively. Unlike the case of beans, solarisation did not impair cowpea seed viability. The most viable seeds were those mixed with tephrosia leaf-powder ashes and solar heated which had germination levels of 76%, 88% and 94%, respectively. According to CIAT (1986), the efficacy of wood ashes is dependent on mechanical filling of the spaces between the grains prohibiting bruchids from infestation. In the case of cowpeas, the efficacies of botanicals also declined with prolonged duration.

Results from partial budget analysis (Table 1) showed that, on average, tobacco leaf powder, if adopted by the farmer, can give an added net cash benefit of USD 1.27 per 100 kg of beans in storage. This comes from mainly grain loss reduction and improvement in seed viability. Another promising technology for bean bruchid control was actellic (1% a.i) dust which, on average, gave incremental net cash benefit of USD 1.23 per 100 kg of beans. It has to be noted that the additional procurement cost in the latter case was three times as high compared to the cost incurred in using tobacco leaf powder. The results also indicated that, on average, solarisation with an added net cash benefit of USD-4.31 per 100 kg of beans, was a viable option for bruchid control in the study area. The marginal revenue derived from the use of this technology was not enough to compensate for the additional cost of solarisation due to high rates of loss of seed viability and procurement cost of pit construction and plastics. Partial budgeting also indicated that farmers would be able to realise an additional net cash

Table 1. Partial budget analysis of effects of farm-level bruchid control measures 3 months after treatment of stored dry beans and cowpeas in Iganga and Kumi districts 1997-99

Differentials in USD/100 kg.	Beans (Iganga)							Cowpeas (Kumi)							
	Control	Tagetes	Tobacco	Lantana	Ashes	Solarisation	Actellic	Control	Tagetes	Tobacco	Tephrosia	Oil	Ashes	Solarisation	Actellic
1. Credits															
Mean loss reduction in grain[a]	-	0.15	0.42	0.13	0.22	1.57	1.42	-	0.94	0.51	3.79	1.07	2.03	3.19	0.53
Mean Improvement in Viable seed[b]	-	0.81	1.26	0.77	0.59	0.02	1.52	-	0.05	C.11	3.75	0.50	1.28	2.76	0.47
Sub totals	0	0.96	2.68	0.90	0.81	1.57	2.94	0	0.99	0.62	7.54	1.57	3.31	5.95	1.00
2. Debits															
Mean loss of bruchid damaged grain[a]	-	0.31	0.71	0.37	0.45	0.78	0.71	-	0.47	0.25	1.90	0.30	1.01	0.33	0.75
Mean loss of unviable seeds[b]	0.66	0.08	0.63	0.08	0.06	2.52	0.76	1.45	0.11	0.50	1.88	-	0.64	0.67	1.16
Mean procurement costs[c]	-	0.03	0.07	0.04	-	2.58	0.24	-	0.01	0.05	1.19	0.61	-	2.58	0.24
Sub totals	0.66	0.42	1.41	0.49	0.51	5.88	1.71	1.45	0.59	0.80	4.97	0.91	1.65	3.58	2.15
3. Added net cash Benefit (1-2)	-0.66	0.54	1.27	0.41	0.30	-4.31	1.23	-1.45	0.40	-0.18	2.57	0.66	1.66	2.37	-1.15

NOTES:
/a 1USD = UShs 1550 (1998); farmgate average price per kg at harvest: beans = 0.3, cowpeas = 0.25, average non glut price per kg, 3 months later for beans = 0.4, cowpeas = 0.3
/b Seed grain retail prices per kg at harvest, beans 0.9, cowpeas 0.7. Seed grain buy-back prices per kg from traders 3 months later bean 1.0, cowpeas 0.8
/c Input procurement prices per unit: Vegetable oil 1.2/l, clear and dark plastic 1.0/m Acetllic; (1% a.i) 4.8/kg. The cost of producing leaf powder of botanicals was estimated at 10% based on grain injury levels.

benefit of USD 2.57 per 100 kg of cowpeas, if they could adopt the tephrosia leaf powder technology due to mainly high rates of grain loss reduction and improvement in seed viability. Unlike in the case of beans, solarisation also, once adopted to control cowpea bruchids, can give an additional net cash benefit of USD 2.37 per 100 kg of grain stored. But the corresponding additional cost of using this technology was USD 3.58 per 100 kg of cowpeas which was incurred in constructing the pit and paying for the plastics.

The various bruchid management strategies were arranged in increasing order of debits and matched with their respective net cash benefits as presented in (Table 2). In the pattern of increasing debits and increasing net cash benefits, tobacco leaf powder followed by actellic (1% a.i) dust dominates all other bean bruchid control options because each of these two options has higher net cash benefits but generally less debits than the dominated control measures. Similarly in the case of cowpeas, use of ashes, solar heat or tephrosia leaf powder dominates the rest of the tested cowpea bruchid control measures. When dominating bruchid control options were ploted against a pattern of increasing net cash benefits, a net benefit curve was obtained (Figure 1). On the basis of the net cash benefit curve, marginal rates of return (MRR) were computed (Table 3) to indicate changes in net cash benefits from one treatment to another along the net benefit curve.

Results from MRR analysis showed that a one USD investment in shifting from the cheap and locally available tobacco leaf powder to use of actellic in bean bruchid control could result in a 15 percent reduction in returns. In the case of cowpeas, for a farmer using ashes and would like to shift to use of solar heat to control bruchids, a 27 percent increase in returns would be realised. And, a 13 percent

Table 2. Dominance analysis of bruchid control measures (USD per 100 kg of grain).

Treatment	Debits	Net cash benefit
Control (beans)	0	-0.66
Control (cowpeas)	0	-1.45
Tobacco (cowpeas)	0.62	-0.18
Ashes (beans)	0.81	0.30
Lantana (beans)	0.90	0.41
Tagetes (beans)	0.96	0.54
Tagetes (cowpeas)	0.99	0.40
Actellic (cowpeas)	1.00	-1.15
Solarisation (beans)	1.57	-4.31
Oil (peas)	1.57	0.66
Tobacco (beans)	2.68	1.27
Acetellic (beans)	2.94	1.23
Ashes (cowpeas)	3.31	1.66
Solarisation (cowpeas)	5.95	2.37
Tephrosia (cowpeas)	7.54	2.57

Table 3. Marginal rates of return (%) for adoption of alternative bruchid control measures.

Treatment USD/100 kg	Debits (MC)	Marginal Cost USD/100 kg	Net benefit benefit	Marginal (MB)	MRR = (MB/MC) 100
Tobacco (Beans)	2.68		1.27		
Actellic (Beans)	2.94	0.26	1.23	-0.04	-15.4
Ashes (cowpeas)	3.31	-	1.66	-	-
Solarisation (cowpeas)	5.95	2.64	2.37	0.71	26.9
Tephrosia (cowpeas)	7.54	1.59	2.57	0.20	12.6

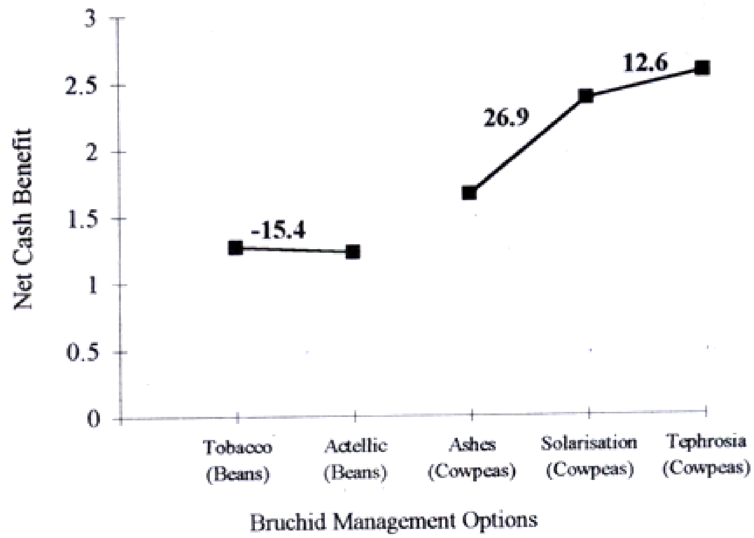

Figure 1. Grain bruchid control net cash benefit curve for adopting various management options.

increase in returns would be obtained by a farmer shifting from solarisation to use of tephrosia leaf powder in the control of cowpea bruchids in storage.

Conclusion

Economic losses attributed to bruchids in stored dry beans and cowpeas are substantial in Uganda where well-built storage facilities are not usually available at farm-level. While it is often possible for crops in the field to recover after an insect attack has been controlled, it is impossible for stored dry beans and cowpeas to recuperate after bruchid damage. Thus, a farmer participatory approach in the use of techniques that would allow beans and cowpeas to be kept in storage free of bruchids would clearly provide economic benefits to both bean and cowpea growers and consumers.

This research has demonstrated that wood ashes, solar heat and leaf powders of tobacco and tephrosia can be economically viable post-harvest protectants of dry and/or cowpeas for at least 3 months in farm storage despite the short-life repelling action of botanicals and the largely physical beneficial action of wood ashes. Since solar heat treatment has a negative effect on bean germination, this bruchid control method should be limited to cowpeas and to beans for food consumption only. The use of approved contact chemical pesticides such as actellic (1% a.i.) would be profitable for dry bean storage but the recommended dosage rates must strictly be adhered to and the food grains need to be washed thoroughly to remove the chemical from the seed coat. The consumer would probably prefer a safer protectant.

The additional economic benefits obtained from the tested bruchid control measures were realised mainly as either a result of higher returns from increased marketable and or sowable surplus or lower cost of grain protection. This revelation strongly suggest that post-harvest protectants must be evaluated from both a biophysical and an economic perspective. For example, solarisation of beans was viewed favourably from a biophysical perspective but this option was not found economically viable due to high rates of loss of seed viability and procurement cost of pit construction and plastics. Conversely, use of wood ashes to profitable cowpeas in storage did not apppear to be very efficacious from a biophysical view point but this protectant was preferred in an economic context because wood ashes are spare by-products from the farmer's kiln which would otherwise go to waste.

Given the opportunity to choose from the tested improved postharvest technologies farmers are expected to make rational decisions according to their real local agro-ecological and socio-economic situations. A farmer will try out the solution to the bruchid problem that does not involve too much risk taking in the social -economic context and that seems to be economically feasible.

The analysis scheme outlined in this study, that takes into consideration the actual cash costs and benefits involved in technological investments and ranks the improved technologies according to marginal rates of return, seems to be a rational way small-scale farmers would try out and adopt any technology, not to mention post-harvest technology.

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The cowpea production function in Uganda: A Cobb-Douglas approach

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Abstract

Cowpea (*Vigna unguiculata*)is one of the important legume crops grown in Uganda, especially in the northern and eastern parts of the country. Using farm data collected through a detailed diagnostic survey in four major cowpea producing districts of Uganda, a Cobb-Douglas model was used to estimate the cowpea production function, using ordinary least squares regression techniques. The returns to scale of cowpea production, marginal productivities and elasticities of the inputs used in cowpea production were estimated from the production function. From the estimated cowpea production function, land, labour and pesticides were the most significant production inputs in that order. The returns to scale of cowpea production were 1.6, 1.7, 2.2 and 1.5 for Arua, Lira, Soroti and Pallisa districts respectively and were significantly different ($P = 0.01$). The returns to scale showed increasing returns in all cases, significant at 1% probability level of significance. The value marginal produtivities of land and capital were greater than the unit costs of these inputs. The value marginal productivities of inputs used for pest control and labour were, however, lower than the unit costs of these inputs. The findings of this study therefore indicate that, increase in cowpea production, in the short run, will generally be achieved by bringing more land under cowpea production, and in the long run, by the use of labour saving technologies such as ox-cultivation and by improving productivity, through better agronomic practices, and better technologies of pest control. Estimation of the cowpea production function at the farm level gave an insight of the most critical factors to consider in increasing cowpea production. The estimation of the returns to scale enables the analysis of the relationship between the size of the cowpea enterprise and profitability, given the available farming technology. The policy recommendations on the improvement of cowpea production given in this paper are based on the above two concepts.

Key Words: Input elasticities, marginal productivity, production function, returns to scale

Introduction

For economic, social and technological reasons, the diet of a large section of the world's population especially in protein content is considered poor (FAO, 1992). Yet proteins of plant origin are relatively cheaper than animal originated proteins. Therefore, increasing supplies of grain legumes (the chief source of plant proteins) offers a potential solution to minimising protein deficiencies in low resource subsistence households. Cowpea (*Vigna unguiculata* (L.) Walp) has been proposed as one of the grain legumes whose inclusion in African cropping systems could substantially improve the nutritional levels of both human and livestock populations, as well as soil fertility (Mehta, 1971). The cowpea is the second most important pulse crop in tropical Africa, with common beans (*Phaseolus vulgaris)* being most important. But the latter is less tolerant to adverse conditions (Purseglove, 1988). In Uganda, cowpea is ranked as the most important legume crop in the northern and eastern regions of the country where beans are grown on a relatively lower scale compared to other regions of the country (Anonymous, 1993). Peak production in Uganda was realised in 1974 when 64,000 metric tonnes of cowpea were produced. After 1974 there was a general decline in production to as low as 20,000 metric tonnes, produced in 1982. The production of cowpeas in Uganda in 1992 was about 40,000 metric tonnes (Anonymous, 1993). This level of production is still very low considering the fact that the Ugandan population is increasing at an average annual rate of 2.5% (World Bank, 1993) and there has been decline in the production of other legume crops such as beans, groundnuts, soybeans, pigeon peas and field peas.

Following the Uganda Government's liberalisation policies in 1990's. there has been a steady increase in domestic demand of the major food crops. There has also been an increasing external demand for a number of food crops due to droughts in neighbouring countries. For instance, in 1994 food crop exports contributed about 40 percent of the total non-traditional exports earnings (BOU, 1994).

The need for strategic planning to take advantage of the regional markets while at the same time ensuring food security at both the farm and national level is critical. Therefore, the principal purpose of this study was to estimate a cowpea production function and measure the responsiveness of cowpea to changes in the quantities of inputs necessary to produce it in Uganda. The specific objectives were: (a) to estimate the input elasticities in cowpea production for selected districts in Uganda, (b) to determine the returns to scale and marginal productivities of the various inputs used in the production of cowpea with the current technology of production, for selected districts in Uganda; and (c) to make policy recommendations, based on the findings of (a) and (b) for the improvement of cowpea production in Uganda.

Methodology

The sample frame comprised of four districts of Uganda namely, Arua, Lira, Soroti and Pallisa that were purposively selected to represent a cross-section of the region where cowpea production is intense using the multiple stage sampling procedure (Poate and Daplyn, 1993). Thirty five households (farms) within the four districts were selected to participate in the diagnostic survey. Data obtained were used to estimate the cowpea production function and returns to scale for cowpea production.

Production Function

The Cobb-Douglas approach was used to estimate the cowpea production function. Agricultural production can be considered as a function of certain input factors such as land, labour and capital. The variation in the levels of these inputs directly affects the gross agricultural production and the cost of production (Halter *et al.*, 1959; Naik, 1965; Boris *et al.*, 1991). A production function can be expressed simply as follows:

$$Y = f(X_1, X_2, ..., X_n) \qquad (1)$$

Where Y is the quantity of agricultural output and X_i (i = 1, 2, ..., n) are the various inputs used in production.

According to Naik (1965), the productivity of various input factors is established using the concepts of elasticity of production and marginal productivity. This can be done by fitting a production function to a sample of farms. The Cobb-Douglas type of production function was used because of the advantages of being linear in logarithms and thus empirically simple. It also generates elasticities, permits the calculation of returns to scale and gave the best fit for the empirical data used in this study. It is based on the production function first proposed by Charles W. Cobb and Paul H. Douglas in an empirical study dealing with the productivity of labour and capital in the United States (Cobb and Douglas, 1928). The Cobb-Douglas production function may take the general form of:

$$Y = A X_1^{a1} X_2^{a2} \ldots X_n^{an} \qquad (2)$$

Where Y is the quantity of agricultural output and X_i (i = 1, 2, ..., n) are the various inputs used in production. A and a_i (i = 1, 2,...,n) are constants, a_i is the elasticity of production of factor X_i and $a_i Y/X_i$ is the marginal productivity of X_i.[1] A logarithm transformation of equation (2) gives a linear function

$$\text{Ln } Y = \text{Ln } A + a_1 \text{Ln } X_1 + a_2 \text{Ln } X_2 \dots + a_n \text{Ln } X_n + e \qquad (3)$$

A and a_i can be estimated from equation (3) using ordinary least squares regression analysis. The statistical significance of these parameters can therefore be established using the t-test, assuming normality of the residuals (Steel *et al.*, 1997). As already indicated in equation (2), the regression coefficients in equation (3), a_i (i = 1, 2, ..., n) are the elasticities for the individual factors of production X_i (i = 1,2, ...,n), respectively. They show approximately the average percentage change in total product which might be forthcoming if the input of any resource, X_i, is increased by one per cent (Heady, 1946). If the elasticity obtained for a particular production factor is more than one, it implies that there are increasing marginal returns for that individual production factor. If, on the other hand, the elasticity obtained for a particular production factor is less than one, it implies that there are diminishing marginal returns of the individual production factor. When negative elasticities are obtained from empirical data applied to equation (3), they are meaningless (Tintner, 1944). This is because it would imply that production would decrease when certain factors of production are increased. However, Alcantara and Prato (1973) suggest that in economic terms, a negative input elasticity implies that the input is being employed beyond the optimal level. In most studies when negative elasticities are obtained, they are usually not statistically significant. From the results of the diagnostic survey it was established that land, labour and pesticides were the most important factors used by farmers in the production of cowpeas (Sabiti *et al.*, 1994). Therefore, the cowpea production function was estimated by incorporating these factors in the following equation:

$$Y_j = A\, LAN^{a1}_j \,.\, LAB^{a2}_j \,.\, PEST^{a3}_j \,.\, CAP^{a4}_j \qquad (4)$$

where
Y_j = quantity of cowpea produced in district j in kg
LAN_j = land area devoted to cowpea production in hectares
LAB_j = mandays of labour devoted to cowpea production
$PEST_j$ = amount of money used for pest control in USh per hectare per season
CAP_j = capital invested in cowpea production, measured non-cash cost of depreciation of farm implements used in cowpea production[3]
j = 1, 2, 3 and 4 for Arua, Lira, Soroti and Pallisa districts, respectively

A, a_1, a_2, a_3, and a_4 are constant parameters which were estimated by taking a logarithm transformation of equation (4) to form a function linear in logarithms similar to equation (3), and then using ordinary least squares regression techniques:

$$\text{Ln } Y_{ij} = \text{Ln } A_j + a_{1j} \text{Ln } LAN_{ij} + a_{2j} \text{Ln } LAB_{ij} + a_{3j} \text{Ln } PEST_{ij} + a_{4j} \text{Ln } CAP_{ij} + e \qquad (5)$$

The subscript i denotes the i th observation in district j, while e is the random error term.

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[1] Cobb, C.W. and Douglas, P.H. (1928). in their article show that a_i equals the elasticity of production x_i.

[1,2] Since there was no standard factor to measure the variability in fertility it is assumed that all the land in a given district is uniformly fertile

[2,3] This is calculated as follows:

$$CAP = \text{Total depreciation} \times \frac{\text{land area of cowpea}}{\text{total crop land}}$$

Characteristics of the estimated production function

(a) Returns to Scale: Returns to scale refers to the behaviour of the change of total returns when all the factors of production are changed simultaneously in the same proportion (Singh and Patel, 1973). It is however not possible for an entrepreneur to have control over all the resources. Therefore in empirical studies only economic returns to scale are generally worked out, including only those factors which are under the control of the entrepreneurs and contribute significantly towards returns. The sum of the regression coefficients (elasticities) of the log-linear Cobb-Douglas production function expressed in equation (3) indicates the returns to scale (Stigler, 1941). If the sum is less than one, it indicates decreasing returns to scale. If the sum is one, it indicates constant returns to scale and if it is greater than one, there are increasing returns to scale. In their study on returns to scale and the productivity of small scale farms in Meerut District in India, Singh and Patel (1973) tested the statistical significance of the returns to scale derived from the elasticities obtained by regression analysis, by an *a priori* assumption of constant returns to scale. They then calculated the t-value of the difference of the returns to scale from unity. The t-value was used to accept or reject the null hypothesis of constant returns to scale. This procedure gives a convenient way of testing the significance of farm data in estimating the returns to scale. In this study, the returns to scale of cowpea production (r_j) under the given technology of production in a given district j were estimated using the equation below and were also subjected to t-tests to establish the significance of the estimated parameters:

$$r_j = a_{1j} + a_{2j} + a_{3j} + a_{4j} \qquad (6)$$

In this way the returns to scale of the production of cowpea was estimated for each specific district.

(b) Marginal Productivity: The marginal productivity indicates approximately the returns which might be expected from the addition of one Uganda shilling (Uganda currency) worth of the various productive inputs. The Marginal productivities of the various input factors were calculated as follows:

$$MP_{LANj} = a_{1j} \cdot Y/LAN_j \qquad (7)$$
$$MP_{LABj} = a_{2j} \cdot Y/LAB_j \qquad (8)$$
$$MP_{PESTj} = a_{3j} \cdot Y/PEST_j \qquad (9)$$
$$MP_{CAPj} = a_{4j} \cdot Y/CAP_j \qquad (10)$$

where MP_{LANj}, MP_{LABj}, MP_{PESTj} and MP_{CAPj} are the marginal products of land, labour, pesticides and capital, respectively, in the production of cowpea in district j and Y, LAN_j, LAB_j, $PEST_j$ and CAP_j are the geometric means of production, land, labour, pesticides and capital variables in district j, respectively. In calculating the marginal productivity of x_i the geometric means of the sample values of x_i are used (Tintner, 1944; Heady, 1946; Naik, 1965). Data used for national level analysis were obtained from (Anon., 1993)

Results and Discussion

Table 1 shows the coefficients of a_i (i = 1,2,3,4) and constants A_j (j = 1,2,3,4) estimated by applying ordinarily least squares regression techniques applied on equation (5), using the farm data collected from the diagnostic survey. Table 1 also shows the results of the t-tests used to establish the significance of the estimated parameters. At the national level, land (significant at 1% level), labour (significant at 10%) and pest control costs (significant at 10% level) were significant factors in production of cowpea. The estimated elasticities were 1.07, 0.42 and 0.036 for land, labour and pest control costs, respectively. The coefficient of capital (CAP) was negative, contrary to *a priori* expectations and was not significant even at 20% level of significance. The negative coefficient of capital is meaningless since production can not be expected to fall as more capital is invested in production. This strange scenario could perhaps be due to the fact that in most cowpea producing districts, production is at subsistance level and is characterised by use of rudimentary tools such as handhoes with labour saving technologies such as ox-ploughs being limited to only a few areas (Sabiti *et al.*, 1994). Thus extra investiment would not necesarily result into increased productivity because of various production limitation which would require large capital investiments. From these results it is concluded that, in general, land is the most important input in cowpea production (it has the highest elasticity of production and is most significant compared to the other inputs), followed by labour and pest control costs, in that order.

The data from Arua district revealed that land and labour are the only significant (at 10% and 20% level, respectively) inputs in cowpea production. The estimated elasticities for land and labour in Arua

Table 1. Estimated cowpea production function for selected districts of Uganda.

Variable[1]	Unit[2]	Coefficient(a_i) (elasticities) and constants	Standard error of a_i	t-value
National level (pooled data)				
Constant (A)		4.9014***	1.3803	3.5510
Land (LAN)	ha	1.0679***	0.2008	5.3180
Labour (LAB)	MD/ha	0.4182**	0.2006	2.0850
Capital (CAP)	USh	-0.1451	0.1344	-1.0801
Pest control	USh/ha	0.0356**	0.0205	1.7347
Arua District				
Constant (A_1)		6.4891***	0.9757	6.6508
Land (LAN_1)	ha	0.9687**	0.5057	1.9156
Labour (LAB_1)	MD/ha	0.6500*	0.6997	0.9290
Capital (CAP_1)	USh	-0.1303	0.5440	-0.2395
Pest control	USh/ha	-0.0175	0.0748	-0.2341
Lira District				
Constant (A_2)		7.8765***	0.9999	7.8882
Land (LAN_2)	ha	1.0808**	0.6570	1.6451
Labour (LAB_2)	MD/ha	0.6208*	0.6167	1.0065
Capital (CAP_2)	USh	-0.5914	0.3428	-1.7254
Soroti District				
Constant (A_3)		3.3901***	0.9318	3.6382
Land (LAN_3)	ha	1.1102***	0.3215	3.4534
Labour (LAB_3)	MD/ha	0.5047**	0.3481	1.4500
Capital (CAP_3)	USh	0.3991**	0.2585	1.5628
Pest control	USh/ha	0.0606**	0.0460	1.3194
Pallisa District				
Constant (A_4)		2.3313**	1.0470	2.2265
Land (LAN_4)	ha	1.2723**	0.6597	1.9287
Labour (LAB_4)	MD/ha	0.5001*	0.5552	0.9008
Capital (CAP_4)	USh	0.3012*	0.3055	0.8599
Pest control	USh/ha	0.1160**	0.0715	1.6210

*** Significant at 1% level

** Significant at 10% level

* Significant at 20% level

1 see equation (4) for the definition of the variables

2 ha = hactare, MD/ha = Mondays/ hactare, USh.= Uganda shillings, USh/ha = Uganda shillings/hactare.

district were 0.97 and 0.65, respectively. Capital and pest control costs were not significant even at 20% level of significance.

In case of Lira district land and labour were again the only significant inputs (at 10% and 20% level, respectively) in cowpea production. The estimated elasticities were 1.08 and 0.62 for land and labour, respectively. Capital was again not significant even at 20% probability level. Pesticides were not used for cowpea production by the sample of farmers taken from Lira district and therefore pest control costs were not considered in this analysis.

Data from Soroti district revealed that land (significant at 1% level), labour (significant at 10% level), capital (significant at 10% level) and pest control costs (significant at 10% level), are all significant factors in cowpea production. The estimated elasticities were 1.11, 0.50, 0.40 and 0.06 for land, labour, capital and pest control costs, respectively. Basing on the size of the input elasticities, land is the most important input in cowpea production in Soroti district.

Results for Pallisa district were similar to those obtained in Soroti District. Land (significant at 10% level), labour (significant at 20% level), capital (significant at 20% level) and pest control costs (significant at 10%) were all significant in cowpea production in Pallisa. The estimated elasticities were 1.27, 0.50, 0.30 and 0.12 for land, labour, capital and pest control costs, respectively. As in Soroti district, land is the most important input in cowpea production in Pallisa District, basing on the size of the input elasticities, followed by labour, capital and pest control costs in that order.

Comparing the results obtained from the different districts, it is apparent that land is the most important input in cowpea production. In all the four districts land had the highest elasticity of production which in all cases was the most significant, compared to the other inputs. It was also noted that the elasticities of land in Soroti and Pallisa districts, where there is extensive use of oxen for land preparation, were relatively higher than the elasticities of land in Arua and Lira districts, where there is less use of ox-cultivation. The policy implication of these findings about land, is that the most critical issue in increasing cowpea production would be how to bring more land under the crop. Studies in the major cowpea producing areas have shown that cowpea production has high profitability comparable to that of groundnut production, which is the most important competing enterprise (Sabiti, 1995). The net income of groundnut production (293,000 USh per hectare) is higher than that of cowpea (205,800 UShs per hectare), but the returns to labour in cowpea production (2,580 UShs per Man day) is higher than that of groundnut production (1,502 UShs per Man-day). Cotton which is the most important traditional cash crop in the area has a negative net income and returns to labour of only 385 UShs per Man day (Sabiti, 1995). Farmers have not taken advantage of the potential of cowpea as a commercial crop. Labour saving technologies such as ox-cultivation would be appropriate in enabling farmers bring more land under cowpea production.

Labour, like land, was a significant input in cowpea production in all the four districts. However, the elasticities of labour were higher in Arua and Lira districts, where there is less use of ox-cultivation (which is a labour saving technology) compared to Soroti and Pallisa districts where there is more use of ox-cultivation. This indicates that labour input is more critical in Arua and Lira districts and that if Man-days in cowpea production are increased in these districts production is likely to increase by a higher percentage compared to Soroti and Pallisa districts.

Capital is only significant in Soroti and Pallisa districts. This can be explained by the fact that cowpea is largely grown by small scale farmers and apart from ox-ploughs (used mainly in Soroti and Pallisa districts), the hand hoe is the basic implement used in agricultural production. Hence capital is significant only in Soroti and Pallisa districts where there is extensive use of ox-cultivation. Consequently, the level of agricultural production in Pallisa and Soroti districts will depend on whether the farmer possesses ox-ploughs or not. Purchase of ox-ploughs accounted for the largest proportion of capital inputs. The policy implication of this is that since capital, largely accounted for by the cost of the ox-plough, has positive elasticities of production in Soroti and Pallisa districts where ox-cultivation is extensively used, encouraging farmers in Arua and Lira districts to use ox-cultivation, would have a positive impact on cowpea production in these districts when coupled with other technologies. Pest control costs were only significant in Soroti and Pallisa districts where there is relatively more use of pesticides compared to Arua and Lira districts.

In estimating the cowpea production functions (Table 1), the variables which did not turn out to be significant at 20% level of significance were dropped from the equations. Therefore the production fuctions varied depending on districts. The estimated production functions for both national and district level were as follows:

Naional level (Pooled data)

$$Y = 4.9014\ LAN^{1.068***}\ LAB^{0.4182**}\ PEST^{0.0356**} \quad R^2 = 0.474 \quad N = 64 \tag{11}$$

Arua District:

$$Y_1 = 6.4891\ LAN_1^{0.9687**}\ LAB_1^{0.6500*} \quad R^2 = 0.485 \quad N = 13 \tag{12}$$

Lira District

$$Y_2 = 7.8765\ LAN_2^{1.0808**}\ LAB_2^{0.6208*} \quad R^2 = 0.678 \quad N = 10 \tag{13}$$

Soroti District

$$Y_3 = 3.3901\ LAN_3^{1.1102***}\ LAB_3^{0.5047**}\ CAP_3^{0.3991**}\ PEST_3^{0.0606**} \quad R_2 = 0.628 \quad N = 24 \tag{14}$$

Pallisa District

$$Y_4 = 2.3313\ LAN_4^{1.2723**}\ LAB_4^{0.5001*}\ CAP_4^{0.3012*}\ PEST_4^{0.1160**} \quad R^2 = 0.446 \quad N = 16 \tag{15}$$

The returns to scale at national level (r) and in selected districts(r_j) are calculated using the coefficients in equations (11-15) and are given in Table 2. The statistical significance of the calculated returns to scale was tested by making an *a priori* assumption of constant returns to scale (*ie.*, r = 1) and then testing the significance of the difference of the calculated returns to scale from unity, by using the t-test. The results of this analysis are also shown in Table 2. The calculated returns to scale were, 1.62, 1.70, 1.62, and 2.19 for Arua, Lira, Soroti and Pallisa districts, respectively. The combined national data gave 1.52 returns to scale. In all cases the returns to scale were increasing and significant at 1% level of significance. The increasing returns to scale signify that, if all the relevant input factors are increased by a given percentage, then production (Y) will increase by a percentage greater than the percentage increase in the input factors. Therefore, in all the four districts there are advantages of increasing the

Table 2. Estimation of returns to scale of cowpea production in selected districts of Uganda.

Item	Arua (Eq 12)	Lira (Eq 13)	Soroti (Eq 14)	Pallisa) (Eq 15)	National (Eq 11)
Returns to scale (r_j)[a]	1.6187	1.7016	1.6149	2.1896	1.5218
Difference between r & unity	0.6187	0.7016	0.6149	1.1896	0.5218
Degrees of freedom	8	6	19	11	64
Standard error of difference	0.2781	0.1169	0.0324	0.0172	0.0082
t-value	2.2247***	6.0017***	18.9783***	69.1628***	63.6341***
Returns to scale as by t-test	Increasing	Increasing	Increasing	Increasing	Increasing

*** significant at 1% level

[a] Calculated using coefficients in equations (11-15)

relevant input factors, used in the production of cowpeas, assuming that the purely competitive model holds with constant input and output prices. Therefore, farmers should be encouraged to take advantage of higher profits obtained by producing on a larger scale..

Table 3 shows the calculated marginal productivities. The marginal productivities were calculated for only the relevant inputs which turned out to be significant in the estimation of the various production functions. In order to deduce accurately the implications of the calculated marginal productivities, the value marginal productivity (VMP) of each of the relevant inputs in the various districts was calculated. The value marginal productivities were calculated by multiplying the respective marginal productivities with the market price of cowpea. An average rural market price of USh 400 (US$ 0.30) was used for this analysis.

Considering the VMP of land, the results in Table 3 indicate that, an increase of 1 hectare of land in the production of cowpea, increases the farmers returns by USh 219,200, 145,400, 93,560 and 269,440 in Arua, Lira, Soroti and Pallisa districts, respectively. The VMP of labour were USh 272, 564, 272 and 648 for every man day/ha increase in labour for cowpea production in Arua, Lira, Soroti and Pallisa districts, respectively. The VMP of labour for all the districts except Pallisa district was, however, lower than the average rural wage rate (US 600). The VMP of capital was USh 1.6 and 3.6 per USh increase in the money invested in implements used in cowpea production in Soroti and Pallisa

Table 3. Estimation of the marginal productivities of various inputs in cowpea production of selected districts of Uganda.

Variable	Unit	Geometric mean	Elasticity (a_i)[a]	MP[b]	VMP[c] (USh)
Naional level (Pooled data)					
Land (LAN)	ha	0.471	1.068	385.5	154,300
Labour (LAB)	MD/ha	98.8	0.4182	0.72	288
Pest control	USh/ha	16,690	0.0356	0.0004	0.16
Output (Y)	Kg	170			
Arua					
Land (LAN_1)	Ha	0.311	0.9687	548	219,200
Labour (LAB_1)	MD/ha	168.8	0.6500	0.68	272
Output (Y_1)	Kg	176			
Lira					
Land (LAN_2)	Ha	0.425	1.0808	363.7	145,400
Labour (LAB_2)	MD/ha	63.1	0.6208	1.41	564
Output (Y_2)	Kg	143			
Soroti					
Land (LAN_3)	Ha	0.560	1.1102	233.9	93,560
Labour (LAB_3)	MD/ha	87.9	0.5047	0.68	272
Capital (CAP_3)	USh	12,565	0.3991	0.004	1.6
Pest control	USh/ha	19,714	0.0606	0.0004	0.16
Output (Y_3)	Kg	118			
Pallisa					
Land (LAN_4)	ha	0.493	1.2723	673.6	269,440
Labour (LAB_4)	MD/ha	80.7	0.5001	1.62	648
Capital (CAP_4)	USh	8,885	0.3012	0.009	3.6
Pest control	USh/ha	13,645	0.1160	0.002	0.8
Output (Y_4)	Kg	261			

[a] From Table 1

[b] MP = Marginal productivity calculated using equations (8)-(11)

[c] VMP = Value marginal productivity, calculated by multiplying the MP by average rural market price for cowpea (USh 400)

districts, respectively. Since the returns per Shilling invested in implements is more than one in both districts, it is profitable for farmers to increase investment in implements such as ox-ploughs.

The VMP of pest control was USh 0.16 and 0.8 per USh increase in investment in pest control, in Soroti and Pallisa districts, respectively. This shows that in both districts, although the elasticity of production of inputs used for pest control is positive, the increase of investment in pest control by UShs 1 results in a less than UShs 1 increase in the returns to the farmer. This might be related to our observation during the diagnostic survey,that misuse of pesticide by the farmers was common (data not shown). In many cases farmers used low dosages, applied insecticides irregularly or untimely and used improper application methods such as sprinkling the pesticide instead of using sprayers. Besides, most farmers were not aware of the recommended application rates. This resulted in much wastage. Therefore the full potential of increased returns from the use of pesticides is not realised by most of the farmers, although some invest considerably in pest control.

Conclusions and Recomendations

In this analysis a Cobb-Douglas type of model was used to estimate the cowpea production functions in Ugandan agriculture using ordinary least squares regression. A number of parameter estimates which were generally consistent with the observed behaviour on farms in the study area, were derived for the cowpea production function model.

The returns to scale calculated in this study indicated increasing returns in cowpea production in Uganda especially in Pallisa district. Land and labour inputs had significantly positive elasticities in all the districts considered in this study, while capital and pest control inputs had significant elasticities only in Soroti and Pallisas districts where ox-cultivation and pesticides are extensively used. Also, land, labour and capital had favourable marginal productivities in cowpea production. Pest control inputs, however, had diminishing marginal productivity. This was attributed to the improper use of pesticides, due to wrong dosage applications coupled with poor application methods.

Based on the findings of this study it is recommeded that:

(a) The government should endeavour to restock the areas where there have been high losses of oxen due to civil turmoil, especially in the eastern region. The critical shortage of oxen is a major constraint to the crop development programme in the study area. Results of this study have shown that it is profitable (VMP > marginal input cost) for farmers to invest in ox-cultivation. Apart from increasing cropped land, the oxen can increase farm income from direct livestock and livestock by-products sales.

(b) Since crop production in the study area is done under low-input farming system which uses land and labour as the principal inputs and where land, labour and capital have favourable marginal productivities in cowpea production, farmers should allocate more land to cowpea and also use improved management practies. In the short run, increase in the area planted with cowpea will increase cowpea production, since land has the highest production elasticity compared to the other inputs and is not a limiting factor in most of the study area. Improvement of production technology through the use of ox-cultivation and the proper use of pesticides, will also in the long run increase cowpea production in the study area. The increasing returns to scale imply that, increased production of cowpea will increase farmers' incomes.

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Analysis of factors influencing loan repayment under the "Entandikwa" credit scheme in Mpigi district

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Abstract

The Government of Uganda introduced the "Entandikwa"(Start up capital) credit scheme in the 1994/95 budget as a revolving fund with the objective of improving the incomes of the rural and urban poor. The repayment period was one year. However, by the end of the first round of loan disbursement in 1996, only 21.5% of the total disbursement had been recovered. This study sought to understand the reasons at the borrower level that had influenced loan repayment. Data collected from a systematic sample of 80 beneficiaries was used to determine the key factors responsible for this loan recovery performance. A chi square test and logistic regression models were used to analyse the data. Results indicated a weak relationship (insignificant) between loan repayment and the economic activities financed. The regression results indicated that lack of experience in the financed economic activity, tertiary level education, sex of borrower, brick and tile making, bakery, knitting, tailoring and transport as sources of income had negatively influenced loan repayment. The vigilance of the intermediary agencies positively influenced loan repayment while the fungibility of credit and political preference of the borrowers were statistically insignificant. The poor repayment performance could also be attributed to the way the scheme was implemented: hurriedly and mainly through the political organs of the government. Loans were thus viewed as political handouts and taken by many without any intention of paying back. The need to operate the credit scheme through private micro-finance institutions with expertise in rural credit and Government's continued provision of a conducive economic policy environment for economic growth appear as key to operate any such credit schemes.

Key words: loan servicing, micro-finance, revolving fund, rural and urban income, Uganda

Introduction

Credit has been defined by Adegeye and Dittoh (1985) as a situation where someone obtains control over the use of money, goods or services in the present in exchange for a promise to repay at a future date. Credit plays an important role in improving production by either helping to acquire improved technology or by supporting increased production activities and consequently improving the income of the beneficiaries (Adams and Pischke, 1980). However, loan delinquency and defaults have plagued many credit programmes in developing countries (Adams and Vogel, 1986). The "Entandikwa credit scheme" which was started in 1994 in Uganda was no exception to this phenomenon.

The credit scheme was the latest in a series of government attempts to deliver credit, particularly in the rural areas, for income generating micro-enterprises. It was supposed to be a revolving start-up fund to help micro-projects and small-scale economic ventures that are income and employment generating. It started in the 1994/95 financial year with an initial fund of six billion shillings, and covered all the districts of Uganda, with a promise from government to inject the same amount of money every financial year, over and above what had been recovered in loan repayment. This was supposed to make money available to more borrowers every year. The fund was administered through the administrative structures of government, with the assistance of selected intermediary agencies (IAs).

In the case of Mpigi district, all the money borrowed under the "Entandikwa" credit scheme was supposed to be repaid by december 1996 (Anonymous, 1996). However, only a small percentage (21.5%) of the total loans disbursed had been repaid by the deadline. This clearly indicated a low rate of loan recovery. Borrowed funds were being retained by the first beneficiaries instead of being put back into the revolving fund. Failure to repay made sustainability of the scheme very uncertain, and the majority of the people were likely to be denied the opportunity to access the credit.

This study was borne out of a need to understand the factors that had influenced the observed poor performance of "Entandikwa" credit scheme in order to improve the performance of this and future credit schemes. The primary objective of the study was to ascertain the factors responsible for the poor loan recovery and recommend remedial measures. The following hypotheses were used to guide the analysis of the above objectives: (a) The economic activities of borrowers are not significant determinants of loan repayment, (b)the socio-demographic characteristics of the borrowers are not significant determinants of loan repayment, (c) attitudinal effects do not have a significant bearing on loan repayment and (d) fungibility of loans is not a significant factor of loan repayment.

Methodology

The study was conducted in Mpigi district in central Uganda. It was limited to the first phase of the scheme in which 1092 beneficiaries received loans. Eighty (80) of the beneficiaries were randomly selected from a list of all beneficiaries from the district for interview. A sampling ratio of 1:13 was used. In order to select the first name on the list, the first 13 names were each written on a separate piece of paper and subjected to a random draw from a bowl. The name on the first paper picked was listed number one on the sample list. Thereafter, every 13th name on the general list was sampled.

Data types and sources

Both primary and secondary data were collected. Primary data were collected on socio-demographic characteristics, economic activities, main sources of income, marketing, business management ability, use of the borrowed funds, attitudes towards the scheme, political preferences, and problems encountered in repayment. These data were obtained from loan beneficiaries using a semi-structured, largely pre-coded questionnaire. The questionnaire was administered by the researchers. Other primary data were obtained from intermediary agencies. Secondary data consisted of; (i) lists and numbers of the beneficiaries for the district, (ii) total amount of money loaned and repayment for the district, (iii) amount of loan repaid and balances of the sampled beneficiaries, and (iv) working guidelines of the scheme.

Data analysis

The Sanderatne (1978) analytical framework was adopted for the analysis. The dependent variable was repayment. It was determined in terms of the percentage of what was repaid to the total loan as at the time of conducting the interview. The independent variables were the following characteristics of the borrowers:

(i) Economic Activity. This included all categories of funded projects grouped as below such as for crop production, livestock production, trade and commerce and others,

(ii) attitude, including political inclination and the vigilance of the intermediary agencies in collecting repayment.

(iii) demography, including sex, age, family size and level of education.

(iv) Fungibility i.e. the diversion and substitution of loans.

Descriptive statistics, chi-square and the logit model were the tools of analysis used in the study. Under the descriptive statistics, totals and percentages were used for comparative purposes. In chi-square test, the dependent variable, which was repayment, was measured in terms of the percentages of the total loan repaid. Repayments were categorised into only two: 1= < 30%, and 2 =≥ 30%. The two categories were compared with the categories of the economic activity as the independent variables, namely crop production, livestock production, trade and commerce and "others" (brick and tile making, tailoring, and knitting, bakery and transport).

A logistic regression model was used to analyse the probability of a borrower repaying the loan given a set of socio-economic variables. Repayment was used as the dependent variable with the following categories 1= ≥ 30% repayment, and 2 = ≤ 30%. The model for the logit regression was specified as follows:

$$Ln = \left[\frac{Pi}{1-Pi}\right] \alpha_0 + \alpha_1 LUT1 + \alpha_2 SINC5 + \alpha_3 EDUC3 + \alpha a_4 \, Sex + \alpha_5 VIA + \alpha_6 EDUC2 + \alpha_7 DEP + U_i$$

Where

P_i	=	Probability of repayment
LUT1	=	Loan used to begin a project (beginners)
SINC5	=	Brick making, knitting, bakery, transport and tailoring as income sources
EDUC3	=	Tertiary level education
Sex	=	(1 = male; 0 = female)
VIA	=	Vigilance of Intermediary Agencies
EDUC2	=	Secondary level education
DEP	=	Number of dependants owned by the borrower
α_1 -α7	=	Coefficients
U_i	=	Error term

Two limitations to the study were considered. Firstly, the Uganda National Farmers Association (UNFA) and secondly the intermediary agency (IA) that distributed the biggest amount of loans were not co-operative. The association in Mpigi district appeared to be disorganised and tracing the officials proved impossible. Secondly, the borrowers with poor repayment records were suspicious of the purpose of study. They suspected that certain measures were going to be instituted against them. This may have led to some respondents giving some wrong information on the amount of loan repaid and also exaggerating their problems. The SPSS statistical software (Marija, 1994) was used for data analysis.

Results and discussion

Table 1 shows that a total of Ushs 311,850,000 was disbursed to the beneficiaries by intermediary agencies (IAs). The IAs in descending order of the amount of loan funds handled were: The Uganda National Farmers Association (UNFA), 45.4%; Balyesiima co-operative saving and credit society Limited (LTD), 18.2%; Butambala united growers with 9.2%, and Nkumba growers, Medecos Savings and credit co-operative society Ltd., and Nadangira Agali-awamu savings and credit society, each with 9.1%. Each of the IAs had a specified geographical area of operation.

Surprisingly, out of the 80 beneficiaries sampled, (5%) stated that they never received "Entandikwa" money although their names were included on the list of beneficiaries. This category represented a group of automatic defaulters, as they could not be expected to repay what they never borrowed. This category was excluded from analysis.

Distribution of loan by socio-demographic characteristics of borrowers

(1) Sex: Male beneficiaries were 55% while women were 45% of the sample. The amount of loan received by male beneficiaries was 12,746,000 Ushs. (55.6%) of the total loans while female beneficiaries received 10,190,000 Ushs (44.4%).

(2) Civic status of the beneficiaries: Local council executive members (LC) constituted 50% of the total respondents while non executive members were 43.8%. Local council executive members received 44.5% of the total loan, while non-executive members got 51.8%.

(3) Political inclination of the beneficiaries: Out of the total respondents, 88.7% expressed support of the current political situation while those who were non-committal or non-supporters were 6.3%. Supporters of the current political situation received 88.2% of the total loan, while the non-committal or non-supporters received 8.2%.

(4)Education: Beneficiaries with primary education were 28.8% of the sample and they recieved 26.9% of the total loans while those with secondary education were 46,3% of the sample and recieved 47.69% of the loans. Those with tertiary education were 16.3 of the sample and recieved 20% of the loans.

Loan recovery performance

Generally, loan recovery was poor. Out of 311,850,000 UShs out, only 67,034,250 Ushs had been recovered at the time of the survey. This amounted to only 21.5% of the total that had been recovered by the end of the loan period. This was obviously poor loan recovery performance. The respondents recieved a total of UgShs. 22,936,000 out of which only 42.9% had been repaid.

Loan recovery performance by intermediary agency

The intermediary agencies received a commission of 4% from each loan application approved. However, all the agencies complained that this commission was insufficient to cover their operations and facilitate efficient running of the scheme. Consequently, the IAs could not adequately monitor and sensitise the borrowers to repay, a situation which likely contributed to the poor loan recovery in the district.

Medecos Ltd. of Entebbe municipal council had the highest loan recovery of up to 90% of the money it disbursed (Table 1). Balyesiima of Mawokota north and south, and Nadangira Agali-awamu of Busiro north had recovered 38.1% and 33.4%, respectively. Butambala United of Butambala, and Nkumba growers of Busiro south recovered 19.1% and 17.6% of their disbursement, respectively.

Table 1. Loan disbursment by intermediaries in Mpigi.

Intermediary agency	Shs disbursed	Percentage	Shs recovered	Percentage
Uganda National Farmers Association (UNFA)	141,600,000	45.4	NA	NA
Balyesiima co-operative savings and credit society	56,700,000	18.1	21,611,350	38.1
Butambala United growers	28,500,000	9.2	5,435,300	19.1
Nadangira Agali-awamu savings and credit society	28,350,000	9.1	9,470,000	33.4
Medecos Ltd.	28,350,000	9.1	25,519,600	90
Nkumba growers	28,350,00	9.1	4.9.78,000	17.6
Total	311,850,000	100	67,034,250	21.5

Loan recovery performance of borrowers by economic activity and socio-demographic characteristics of borrowers

Borrowers engaged in trade and commerce as a group had repaid 64.2% of the total funds loaned by the end of the loan period. Those categorised as "others" had repaid 48.9% while those in crop and livestock production had 40.4% and 34.3% of the loan repaid respectively. Out of the total money disbursed to the respondents, 42.9% had been repaid.

Analysis of factors influencing loan repayment

The borrowers reported a number of problems they thought were responsible for the low rate of repayment. The problems are summarised in Table 2. Unfavorable weather conditions and pests and diseases hit crop and livestock production activities. Borrowers who invested in tomato growing for example suffered severe late blight attack. The high numbers of poultry farmers in some areas led to an oversupply of the poultry products and this caused a fall in prices and, consequently, reduction in ability to repay the loans. Trade and commerce investments had no noticeable problems and this explains their high rate of repayment of over 60%.

The chi-square analysis was used to establish whether there was a relationship between the categories of the financed project or the economic activity, and the rate of loan repayment. The financed projects were categorised as: i) crop production ii) livestock production, iii) trade and commerce iv) and others (Brick and tile making, tailoring, knitting, transport). The results of the analysis are presented in table 3.

The calculated chi-square (7.8789) was greater than the tabulated (critical) value (7.815) at a significant level of 0.05. Therefore, the null hypothesis was rejected. So the economic activities of the borrowers influenced loan repayment. However, although the contingency coefficient was statistically significant at 95%, the value of 0.29948 (30%) suggested that a weak relationship between loan repayment and the economic activities financed. In terms of effect of socio-demographic characteristics of borrowers on loan repayment, several variables were regressed against the repayment categories (Table 4).

The results of the logistic regression as shown in table 4 above and the Wald statistic with a chi – square distribution were used to test the significance of each coefficient. The results show that the vigilance of intermediary agencies, sources of income of respondents, sex, tertiary level education and project beginners significantly influenced loan repayment.

The vigilance of intermediary agencies (IAs) had the most influence on loan repayment. It was highly significant at 1%, and was positively related to loan repayment.

Sex was coded as 1 for males and 0 for females; therefore, the negative sign of the coefficient implies

Table 2. Borrowers perception of problems affecting their loan repayments

Nature of problem	%Borrowers reporting	Most affected economic activity
Failure of projects due to natural hazards	30 (24)	Crop and livestock production
Illness of family members	15 (12)	All
Laxity of intermidiary agency's	11.3 (9)	All
Lack of market for products	10 (8)	Poultry keeping
Thefts	8.8 (7)	Poultry keeping
High cost ,poor quality feeds		Poultry keeping
None	15 (12)	Trade and Commerce

*Figures in parentheses are actual counts that males negatively influenced loan repayment. The log of odds of repayment decreases by 0.7411when the borrower is male. This implied that in this case with the Exp (B) of 0.48, males were 0.48 times less likely to repay than their female counterparts.

Possession of a tertiary education had a significant and negative influence on loan repayment at 10%. The exp of 0.44 implies that a unit increase in borrowers under this group reduced the odds of repayment by 0.44 units. In other words, the higher the number of borrowers with tertiary education, the less the probability of repayment.

The source of income of the borrower was another socio-economic factor that influenced loan repayment. Brick and tile making, tailoring, bakery, bicycle transport (boda-boda), and knitting as the main sources of income had a significant (at 95%) and negative influence on loan repayment. These respondents complained of lack of market for their products. Tiles and bricks were not selling; the bicycle transport service was no longer paying because of the increased use of motorcycle transport. Respondents who invested in bicycle transport could not therefore pay back in time due to loss of business. Bakery owners could not easily sell off their products because of the stiff competition and perishability of their products. The results indicate that a unit increase of borrowers under this category reduced the odds of loan repayment by 0.37 units. In other words, the higher the number of borrowers under this category, the less the probability of repayment.

The respondents who borrowed money to begin developmental projects (beginners) were less likely to pay as compared to their counterparts who borrowed to finish the projects. The results indicate that a unit increase of borrowers under this group reduced the odds of repayment by 0.31 units. This means that the higher the number of borrowers under this group, the less the probability of repayment. The negative relationship could have been caused by lack of experience in the project management. Fungibility and political inclination were not significant in influencing loan repayment. Therefore, the null hypotheses were accepted: that fungibility did not significantly influence loan repayment.

Table 3. Chi-square test results.

Economic activity	%<30	% ≥30	Row total
Crop production	12	11	23
Livestock production	15	11	26
Trade and commerce	3	14	17
Others	8	6	14
Column Total	38	42	80

Chi-Square value= 7.8789: degrees of freedom =3, contingency coefficient = 0.29948

Table 4. Results of the logistic regression.

Variable	Coefficient B	Standard Error	Exp (B)
Secondary education	0.4389^NS (1.4556)	0.3638	1.55
Tertiary education	-0.816_NS (29983)	0.4693	0.44
Number of dependants	0.154^NS (2.2009)	0.0710	1.11
Beginning project (Beginners)	-1.1574***(7.5514)	0.3416	0.31
Sex	-0.7411***(4.7073)	0.3416	0.48
Sources of income (brick and tile making, bakery, knitting, tailoring and transport)	-1.0052** (6.0899)	0.4073	0.37
Vigilance of intermediary agencies	1.055*** (7.2536)	0.3918	2.87

Notes: (a)*, **, *** coefficient significant at 10%, 5%, 1% level, respectively. (b) Figures in parentheses are Wald statistics

Goodness of fit assessment

The goodness of fit for the model used was assessed basing on observed and predicted outcomes as shown in the classification (Table 5). In effect, 30 of the observed outcomes are correctly predicted by the model, out of the 36 who had repaid more than 30% of their loans. Out of the 32 whose repayments were less than 30%, the model correctly predicts 75%. The model's overall prediction is 79.41% as correctly classified. The significance of all the coefficients, which is equivalent to the F statistic, is given by the model chi – square of 27.95 with 7 degrees of Freedom. This is statistically significant at 1 %. The null hypothesis was thus rejected.

Conclusions and Recomendation

Loan repayment performance of the beneficiaries under the "Entandikwa" credit scheme was generally poor. The scheme was started hurriedly before properly assessing its viability and implemented through the political organs of the government mainly local councils in the initial selection of beneficiaries. Furthermore, since the scheme was implemented towards the elections, many members of the public regarded it as an effort of the government to bribe the electorate to vote for candidates who were her supporters. Many borrowers therefore took it as their reward for the political support. Therefore, it is the political interference, rather than political preference that seemed to have influenced loan repayment.

Borrowers used the money to finance various economic activities. Although 30% of the respondents in crop and livestock production attributed failures of their projects due to natural hazards, the results of the chi-square test revealed that the relationship between loan repayment and the economic activities financed was weak. Therefore, the poor loan recovery performance could not have been due to certain economic activities.

If the respondents had borrowed money to start a project, this had a negative relationship with loan repayment. The negative relationship could have been caused by lack of experience in the management of the project. Therefore experience is important in the success of any economic activity and should not be overlooked especially where borrowed funds are involved.

Sex of the borrower significantly influenced loan repayment. Female borrowers exhibited a higher probability to repay than their male counterparts. Females were therefore better borrowers than males.

An examination of the influence of attitudes showed that loan supervision significantly influenced loan repayment. Increased supervision of the borrowers by intermediary agencies (IAS) was very important in influencing loan repayment, which is instrumental in the sustainability of the credit scheme.

Arising from the above, the following are remmended;

- In order to increase efficiency in the management of the scheme, participating priority and micro-

Table 5. Classification table for the dependant variable repayment.

	PREDICTED 1	PREDICTED 2	% CORRECT
Observed 1	30	6	83.33
Observed 2	8	24	75.00
-2 Log Likelihood	66.083		
Goodness of Fit	60.496		
Model Chi-Square	27.950		
Model Prediction	79.41%		

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Effect of processing on nutritional quality of finger millet - cowpea formulations

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Abstract

Fingermillet (*Eleusine coracana*) and cowpea (*Vigna unguiculata*) were blended in proportions of 100:0, 70:30, 60:40 and 50:50, millet to cowpea, respectively. Incorporation of cowpea to millet flour increased the protein, phosphorus and sodium content of the flour. Malting of the millet and roasting of cowpea prior to blending led to reduction in paste viscosity and improvement in gruel acceptability. It was concluded that a process consisting of malting of cereals followed by blending with an appropriately processed legume could serve as a simple, low cost technology for improving the protein and energy density of cereal based gruels.

Key words: Cereal utilisation, *Eleusine coracana*, nutrient density, *Vigna unguiculata*, weaning food

Introduction

The Uganda demographic and health survey of 1995 showed that 38% of children below the age of three years are stunted, 26% underweight and 5% wasted (UNFNC, 1996). The widespread occurrence of protein energy malnutrition (PEM) in developing countries has been linked to low nutrient and energy density of cereal gruels given to children (Uwaegbute, 1991). These gruels are also very low in protein and lack the essential amino acids lysine and tryptophan. Children are therefore unable to consume adequate quantities of such gruels to meet their energy and nutrient requirements, especially after their sixth month of birth.

Available commercial weaning foods such as Cerelac are expensive and are out of the reach of most families. As such many children are likely to continue relying on cereal based gruels for their nourishment. In order to address the problem of malnutrition, there is need to address the problems of high paste bulk, low protein and unbalanced amino acid profile of cereal gruels. There is also need to develop low cost formulations using locally available foods and simple and low cost technologies that are applicable within homes or at small commercial scale. Malting (Chandrasekhar *et al.*, 1988; Livingstone *et al*, 1993; Weaver, 1994), blending with high energy or/and protein food materials (Dahiya and Kapoor, 1993; Kikafunda *et al.*, 1998), and heat pregelatinisation (Okaka and Potter, 1979; Chandrasekhar *et al.*, 1988; Livingstone *et al.*, 1993) have been applied to reduce paste bulk and improve nutritional quality of starchy gruels.

Roasting leads to reduction in antinutritional factors (Igbedioh *et al.*, 1995; Chitra *et al.*, 1996; Apata and Ologhobo, 1997). Soaking prior to heat treatment has a positive effect in elimination of these factors (Gustafsson and Sandberg, 1995; Igbedioh *et al.*, 1995). During malting, starch is hydrolysed by amylases, producing sugars. Since increase in viscosity during cooking of starchy gruels is due to starch gelatinisation, starch hydrolysis results in reduction in gruel viscosity. Weaning formulations made from malted millet (Chandrasekhar *et al.*, 1988) and wheat (Livingstone *et al.*, 1993) for example exhibit lower viscosity than formulations made without malting. Malting has been reported to increase protein digestibility in wheat. This can be attributed to reduction in antinutritional factors during germination. Malting of legumes increases carbohydrate (Kelkar *et al.*, 1996) and protein digestibility (Chitra *et al.*, 1996; Griffith *et al.*, 1998), reduces antinutritional compounds (Igbedioh *et al.*, 1995; Chitra *et al.*, 1996), total dietary fiber (Chitra *et al.*, 1996) and dietary bulk (Livingstone *et al.*, 1993; Griffith *et al.*, 1998).

Blending of cereals with other food materials boosts the protein and/or energy content of weaning formulations. Because of their high protein and energy content, pulses and oil seeds are suited for use as supplements in cereal based weaning foods. Groundnuts (Griffith *et al.*, 1998; Dahiya and Kapoor, 1993), Greengram (Dahiya and Kapoor, 1993), Cowpea (Griffith *et al.*, 1998), soybeans (Mensah *et al.*, 1995) and chickpea (Livingstone *et al.*, 1993) have been used to boost the nutrient density of cereal based weaning foods.

The objective of the study was to develop a weaning formulation from finger millet (*Eleusine coracana* L. Gaerta) and cowpeas (*Vigna unguiculata* L Walp) and to determine the effect of a treatment consisting of malting of millet and soaking, dehulling and roasting of cowpeas on the nutritional, sensory and physicochemical properties of gruels made from the developed formulation.

Materials and Methods

Preparation of formulations

Cowpea and finger millet were winnowed and sorted to remove the mouldy, shriveled, broken seeds, chuff and other impurities. The seeds were then washed 3 times in distilled water. The cowpeas were further processed by steeping for 12 hours with water just covering the seeds in a bucket. This allowed enough imbibition of water. The seed coats were then removed by rubbing the seeds between the palms. The dehulled seeds were dried at 60°C for 12 hours, and were roasted for 15 minutes while stirring with a wooden stirrer.

The washed millet grains were steeped in enough water to cover them completely and then kept in the dark for 12 hours. The water was then drained and the grains thinly spread between wet cotton cloth and left to germinate for 48 hours at room temperature (24°C). The sprouted seeds were dried overnight in hot air oven (size 2, SG 93/B6/95 Gallenkamp, UK) at 60°C. The vegetative portions were detached from the dry grains by rubbing between hands and separated out by winnowing. The millet and cowpea were then blended in proportions of 70:30, 60:40 and 50:50, millet:cowpea. The millet and cowpea blends were milled (whole grain) using a laboratory mill (type 4142, 041 Braun, Germany). Some of the millet and cowpea prepared as described above were retained for analysis. Flour was also made by directly milling a 70:30 millet:cowpea blend, without the above described treatment. This served as a control in the determination of the effect of the treatment on paste viscosity and sensory acceptability.

Chemical analysis

Moisture and crude protein were determined by AOAC (1997) methods 4.1.03 and 955.04, respectively. Ash, crude fiber and crude fat were determined by methods described by Ranganna (1986). Ash determination was by dry ashing at 450°C and crude fat by soxhlet extraction. Carbohydrate was determined by difference and energy by calculation. Iron, magnesium, potassium and sodium were determined using a Perkin Elmer atomic absorption spectrometer (U.S. Instrument Division, Norwalk, CT.) on digest of ash from ash determination. Magnesium and iron were determined by absorption spectrometry (Ihnat, 1981) at wavelengths of 248.3 and 285.2 nm, respectively. Potassium and sodium were determined by emission spectrometry at 766.5 and 589 nm, respectively. Phosphorus was determined by the colorimetric method, described by Kirk and Sawyer (1991). Nutrient density for a gruel containing 6% flour and anticipated nutrient intakes by children consuming 750 ml per day were calculated from the nutritional composition.

Viscosity determination

Viscosity was determined for gruels prepared from the 70:30 millet:cowpea treatment and control blends. The flour was mixed with water in a beaker to give suspensions containing 1, 1.5, 2.0, 2.5 and 3% flour. The beakers containing the mixtures were placed in a water bath and heated while stirring to reach 95°C within 10 minutes. The gruels were then held at room temperature until the temperature dropped to 40°C, which is approximately, the temperature at which children consume gruels.

Viscosity of the gruels were then determined using a Haake viscotester (Haake Mess-Technik, Kansruhe, Germany) with a SCII profile measuring system and a shear rate of 54 rpm. The gruel concentrations used were limited by the viscosity range which could be determined by this viscotester.

Sensory evaluation

Gruels containing 8% solids were prepared from the 70:30 blend (treatment and control) flours and evaluated for sensory acceptability. After weighing out the flour and measuring the volume of water required, the flour was mixed into a minimal amount of cold water (drawn from the measured volume) to allow complete suspension. The remaining water was heated to boiling and the suspension of flour in water added. The mixture was heated while stirring until it boiled for 5 minutes. It was left to cool to approximately 50°C before serving to panelists for evaluation.

Sensory evaluation was conducted by a 30 member untrained panel. Panelists were requested to score the gruels based on a 9 point hedonic scale, with 1 representing like extremely and 9 dislike extremely. The attributes evaluated included taste, aroma, consistency, and overall acceptability .

Replication and data analysis

The experiment was duplicated and for each experiment, each chemical or viscosity measurement was done a minimum of two times. Data for nutritional composition of the flours was analysed by Analysis of Variance (ANOVA) using M-STAT C package (Freed *et al.*, 1988) and means separated using the Least Significant Difference (LSD) test at 5% probability level. Viscosity and sensory evaluation data were compared using t-test.

Results and Discussion

Nutritional composition of finger millet-cowpea blends

The blends of millet and cowpeas were significantly higher in proteins than the millet flour (Table 1). Generally, incorporation of legumes into cereal based formulations increases their protein contents. It also leads to improvement of the quality of the proteins and an amino acid profile superior to both legume and cereal proteins. This is because cereals lack the essential amino acids lysine and tryptophan while legumes lack methionine. When combined, the two protein sources complement each other. Of the blends studied, the protein content of the 70:30 millet-cowpea blend of 14% (15.9% on dry basis) was closest to protein content of cerelac (15.82% on dry basis and 15.5% on wet basis). The protein content of the 70:30 millet-cowpea blend also satisfies the requirements by FAO for weaning formulations, i.e., minimum of 14% proteins. This blend may therefore be adequate to meet the protein requirements of weanlings. Daily protein intake would generally increase significantly by substituting millet porridge by 70:30 millet:cowpea blend, even without reduction in viscosity (Table 2). Further analysis is, however, required to determine the protein quality.

In terms of energy, there was no significant difference between the blends (Table 1) and the daily energy intake did not improve when the same level of solids of 70:30 millet-cowpea blend was used instead of millet, flour alone (Table 2). It is important, however, to note that the energy supplied by starchy gruels, is limited not only by the energy content of the flours from which they are prepared but solid content of the gruels. The starch in cereal based gruels gelatinise during heating in presence of water resulting in rapid viscosity increase (Whistler and BeMiller, 1997). Since infants normally consume gruels with a relatively light consistency, this tends to limit the proportion of flour in the gruels. According to Lorri (1993), the dry matter content of gruels served to children is in the range 5 -10%. A child aged 6 -24 months requires 810 -1150 kCal of energy daily and if 1/3 of this energy (270 - 383 kcal) is to be supplied by a gruel containing 6% (this approximately corresponds to 5% dry matter) of a flour whose energy density is 340 kcal/100g, such a child would need to consume 1.3 - 1.9 L of the gruel daily. In practice, a child within this age range is hardly able to consume 750 ml of porridge a day. There is therefore a need to increase the energy density of cereal based gruels.

The process used in this study combines different techniques known to increase the energy density of gruels. This process led to reduction of paste viscosity by up to 50% (Figure 1). The reduction in paste viscosity is attributable to hydrolysis of millet starch during malting and pregelatinisation of cowpea starch during roasting. The sugars produced during hydrolysis unlike the starch from which

Table 1. Nutritional composition per 100 g of finger millet-cowpea bends in comparison to cerelac.

	Millet:Cowpea					
	100:0	70:30	60:40	50:50	0:100	Celerac
Energy (Kcal)	340.6a	340.3a	339.3a	338.9a	334.4a	417
Protein (g)	8a	14.5b	16.8a	18.5d	29.8c	15.5
Fat (g)	1.4a	1.4a	1.3a	1.3a	1.2a	6.0
Fiber (g)	2.7a	3.3b	3.8c	4.1a	5.3c	4.5
Ash (g)	4.7b	4.3ab	4.1a	4.1a	3.9a	2.5
Water (g)	9.3a	9.1a	8.9a	8.7a	8.7a	2.5
Carbohydrate (g)	74.2c	67.4b	65.1b	63.3b	51.1a	69
Iron (mg)	7.0a	7.5b	7.5b	7.7bc	8.3c	7.5
Calcium (mg)	375a	325bc	300b	350c	245a	455
Phosphorous (mg)	250a	340b	370c	380c	440a	365
Magnesium (mg)	45.3a	42.3a	40.8a	44.8a	40.5a	-
Potassium(mg)	481a	550b	615c	640c	800a	550
Sodium (mg)	30.5a	55.0b	48.6b	43.3b	66.1a	210

Means within a row with the same letter are not significantly different ($P \leq 0.05$)

Table 2. Nutrient density of gruels containing 6% four and anticipated daily intakes.

	Nutrient Density /ml		Anticipated intake /day#		
	100% Millet	70:30 Millet:Cowpea	70:30 Millet: cowpea	%100 Millet	Cerelac
Energy (Kcal)	0.20436	0.20418	153.27	153.135	213.5 -417
Protein (g)	0.0048	0.0087	3.6	6.525	7.75 - 15.5
Fat (g)	0.00084	0.00084	0.63	0.63	3.0 -6.0
Fiber (g)	0.00162	0.00198	1.215	1.485	2.25 -4.5
Ash (g)	0.00282	0.00258	2.115	1.935	1.25 - 2.5
Iron (mg)	0.0042	0.0045	3.15	3.375	3.75 - 7.5
Calcium (mg)	0.225	0.195	168.75	146.25	227.5 -455
Phosphorous (mg)	0.15	0.204	112.5	153	182.5 -365
Magnesium (mg)	0.02718	0.02538	20.385	19.035	-
Potassium (mg)	0.2886	0.33	216.45	247.5	225 - 550
Sodium (mg)	0.0183	0.033	13.725	24.75	105 -210

Assuming intake of 750 ml of porridge per day or 50-100g of cerelac.

millet-cowpea gruel since this blend is low in lipids and may actually be deficient in the essental fatty acids which are required for proper growth.

Sensory acceptability

Gruels made from malted millet and roasted cowpeas generally received scores superior (like slightly - like moderately) to those for gruels made from the control flour (dislike slightly - neither like nor dislike). The low scores (Table 3) for the control samples may be due to the beany flavour resulting from cowpeas and the high viscosity of the gruels. Soaking of cowpeas leads to reduction in the beany flavour while roasting introduces a roasted flavour. The better taste scores for the malted samples were probably due to the sweetness from the sugars resulting from starch hydrolysis. The consistency of the gruels was affected by the malting of millet and roasting of cowpeas and from the sensory acceptability results, panelists preferred the less viscous gruels.

Conclusion

Blends of legumes and cereals have potential for serving as good low cost sources of proteins and may be consumed in form of porridge or even as solid pastes. Treatment such as soaking, dehulling and roasting of cowpea and malting could be used to improve organoleptic properties of such blends and to enhance the energy and nutrient density of gruels prepared therefrom. Unlike technologies such as extrusion, the aforementioned treatments have potential for application in domestic settings or at very low scale commercial level since they are simple and inexpensive.

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Effect of interplanting *Setaria* with *Gliricidia* on chemical composition and nutritive value when fed to growing sheep

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Abstract

Four cultivars of *Setaria sphacelata* were interplanted with *Gliricidia sepium* to study their compatibility. The plot sizes of *Gliricidia* were 8 x 4 m with inter-row spacing of 4 m and within row spacing of 50 cm. The *Setaria* cultivars were two ecotypes of *Setaria sphacelata* var. *Sericea*-Narok and Kazungula and two of *Setaria sphacelata* var. *Splendida* with Kenya and Tanzania origins. The spacing of *Setaria* within and between the rows was 50 cm. As a control, pure stand plots of *Setaria* and *Gliricidia* were also established. The effect of feeding different cultivars of *Setaria* supplemented with *Gliricidia* leaves to growing sheep on dry matter (DM) intake, digestibility and nitrogen balance was studied using a 4 x 4 Latin square design. Results from the compatibility study indicated that DM yield of either crop was not negatively influenced by the presence of the other. However, DM percentage of *Setaria* was significantly lower ($P \leq 0.05$) in the intercrop than in the monocrop. Dry matter yield for *Splendida* ex. Tanzania was significantly higher ($P \leq 0.05$) than that of the other cultivars in both the monocrop and intercrop. The presence of *Gliricidia* significantly increased ($P \leq 0.05$) contents of crude protein (CP) and neutral detergent fibre (NDF) of *Setaria*. Results from the feeding trial indicated no significant ($P > 0.05$) difference in DM intake for the different *Setaria* cultivars. The digestibilities of DM, CP, NDF and acid detergent fibre (ADF) were not different ($P > 0.05$) and nitrogen balance was similar and positive. There was no significant ($P > 0.05$) difference in daily weight gains of sheep fed the different cultivars. It was concluded that *Setaria* can be intercropped with *Gliricidia* without reducing the productivity of either forage and that *Setaria sphacelata* has potential as an alternative fodder crop in Uganda.

Key words: Alternative fodder crops, digestibilities, *Gliricidia sepium*, growing sheep, *Setaria sphacelata*

Introduction

Inadequate feeding is a major limiting factor to smallholder livestock production in Uganda (Bareeba and Mugerwa, 1990). The problems associated with feed shortages in terms of seasonal availability and quality can potentially be overcome by introducing more productive forages and using appropriate management practices. *Setaria sphacelata* is grown by farmers on soil bunds in banana plantations as a soil conservation measure and used as mulch or fodder. However its potential and management requirements as fodder are not well known. *Gliricidia sepium* on the other hand is the most widely cultivated multipurpose legume shrub and is commonly used to supplement grass-based diets (Mpairwe, 1994). The objective of this study was to assess the compatibility and productivity of *Setaria* cultivars grown with *Gliricidia sepium*. The effect of supplementing the different *Setaria* cultivars with *Gliricidia* on performance of growing sheep was also investigated.

Materials and Methods

Four *Setaria* cultivars were interplanted in a four-year stand of *Gliricidia* pruned to a height of 1 m from the ground to study their compatibility. The cultivars were *Setaria sphacelata* var. *sericea* – Narok and Kazungula and *Setaria sphacelata* var. *Splendida* of Kenya and Tanzania origins, respectively. The plot sizes of *Gliricidia* were 8 x 4 m with inter-row spacing of 4 m and within row spacing of 50 cm. The spacing of *Setaria* within and between the rows was 50 cm. As a control, pure stand plots of *Setaria* and *Gliricidia* were also maintained. The experiment was set up following a randomised complete block design with four replicates per treatment.

Setaria was harvested every 6 weeks at a cutting height of 15 cm while *Gliricidia* was harvested every 12 weeks at a cutting height of 100 cm. After taking fresh weight, 500 g samples were saved for laboratory analysis. The rest of the forage was dried under shade to make hay for the feeding experiment.

The effect of feeding different cultivars of *Setaria* supplemented with *Gliricidia* leaves to growing sheep on DM intake, digestibility and nitrogen balance was studied using 4 growing rams in a 4 x 4 latin square design. The animals averaging 7 months of age and 19 kg live weight were housed in digestion crates. The animals were offered a known quantity of *Setaria* hay twice a day at 0900 and 1600 hours to ensure that they feed *ad-libitum*. *Gliricidia* leaves were fed at a level of 8g Dm kg^{-1} body weight day^{-1} and this was done once prior to feeding *Setaria* in the mornings. Mineral lick and water were available all the time.

Animals were weighed before and after each experimental period, which consisted of a 14-day preliminary period, followed by a 7-day collection period. Faeces and refusals were collected from each sheep once a day prior to the morning feeding. Urine was collected in covered plastic buckets containing 50 ml of 0.5N HCl to prevent ammonia loss.

The DM of forages, faeces and refusals were determined by drying to constant weight in a forced air oven at 60 °C. The dried samples were milled to pass through a 1mm screen before chemical analysis. Nitrogen content of feeds, faeces and urine were determined by micro Kjeldahl method (AOAC, 1984). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined using procedures of Goering and van Soest (1970) and *in vitro* organic matter digestibility (IVOMD) was determined according to Tilley and Terry (1963). Data were subjected to analysis of variance (ANOVA) using MSTAT-C computer package and where significant, means were compared using Duncan's Multiple Range Test (Steel *et al.*, 1997).

Results and Discussion

The DM percentage and the DM yield of the *Setaria* cultivars are given in Table 1. The %DM was significantly lower ($P \leq 0.05$) in the intercrop than in the monocrop. Cultivar *Splendida* ex.Tanzania had lowest ($P \leq 0.05$) %DM than the other cultivars in both cropping systems. This could be attributed to cultivar reaction to reduced irradiance as a result of shadding which causes decreased leaf thickness and plant dry weight (Crowder and Chedda, 1982).

Although the DM yield of the monocrop was not significantly different ($P \geq 0.05$) from that of the intercrop, the values for the monocrop tended to be slightly higher than those for the intercrop (Table 1). The slight reduction in DM yield in the intercrop could be attributed to competitive interference for light at the grass/tree interface (Whiteman, 1980). But the DM yields were different ($P \leq 0.05$) among the cultivars under each system with *Splendida* ex. Tanzania registering the highest DM yield.

The results indicate no significant effect of intercropping on the DM yield of *Gliricidia* (Table 2). However, the %CP was significantly lower ($P \leq 0.05$) for the intercrop than the monocrop system. Similar results were obtained by Mpairwe (1994) who reported reduced DM yields of *Gliricidia* when interplanted with elephant grass. Therefore, *Setaria* would be more appropriate than elephant grass in an intercrop system.

The %CP for *Setaria* was higher ($P \leq 0.05$) in the intercrop than the monocrop probably due to improved microenvironment by the *Gliricidia* through nitrogen (N) fixation (Table 3). The fibre fractions (NDF and ADF) were significantly higher ($P \leq 0.05$) for the intercrop than for the monocrop. The %IVOMD for the cultivars in both systems was not different ($P \geq 0.05$), though *Setaria* cultivars in the monocrop had higher values than those in the intercrop.

There was no significant ($P > 0.05$) difference between the DM intake of growing sheep fed the different cultivars supplemented with *Gliricidia* (Table 4). Supplementation with *Gliricidia* did not affect *Setaria* DM intake or total DM intake. On the contrary, Mpairwe (1994) reported decreased ($P < 0.05$) elephant grass (another commonly used grass fodder) DM intake as supplementation level of *Gliricidia* increased from 0 to 12% of body weight. This implies that *Setaria* is a better alternative

Table 1. Dry matter (DM) yield of Setaria cultivars in the intercrop and monocrop cropping systems.

Cultivars	Intercrop		Monocrop	
	DM (%)	DM yield (t ha^{-1})	DM yield (%)	DM yield (t ha^{-1})
Kazungulu	12.9^{b}	15.85^{b}	15.8^{b}	16.70^{bc}
Splendida ex. Kenya	12.7^{b}	14.22^{b}	17.3^{a}	14.67^{a}
Narok	13.4^{b}	18.88^{b}	16.6^{a}	18.57^{b}
Splendida ex.Tanzania	10.5^{a}	20.98^{a}	13.8^{c}	25.08^{a}

Means within a column with different superscripts are significantly different ($P \leq 0.05$).

Table 2. Edible dry matter (EDM) yield and crude protein (% of DM) of G. sepium intercropped with Setaria cultivars.

Treatment	EDM (t ha^{-1})	%CP
Gliricidia monoculture	21.8	27.5^{a}
Gliricidia/Kazungula	20.3	24.2^{b}
Gliricidia/Splendida ex. Kenya	20.3	24.0^{b}
Gliricidia/Narok	19.6	21.9^{b}
Gliricidia/Splendida ex. Tanzania	20.1	23.6^{b}

Means within a column with different superscripts are significantly different ($P \leq 0.05$).

Table 3. The effect of cropping system on the chemical composition and IVOMD of four cultivars of Setaria sphacelata.

Cultivar	Chemical composition and IVOMD[1]							
	Monocrop system				Intercrop system			
	CP	NDF	ADF	IVOMD	CP	NDF	ADF	IVOMD
Kazungula	12.1	60.2	42.0	62.7	12.6	62.1	35.6	60.6
Splendida ex. Kenya	13.3	61.4	37.3	58.8	14.6	65.7	41.5	53.9
Narok	11.2	56.6	36.7	61.5	11.1	67.1	38.4	52.5
Splendida ex. Tanzania	13.5	56.8	35.4	71.1	15.7	63.7	38.2	62.0
Mean	12.5	58.8	36.3	63.5	14.7	64.7	38.4	60.5

[1]IVOMD = *In vitro* dry matter digestibility

fodder crop to elephant grass which has along growth cycle. There were no significant ($P<0.05$) differences in the digestibility coefficients of DM, CP, NDF and ADF of the diets (Table 4). Dietary protein supplementation is known to improve intake by increasing N supply to the rumen microbes which enables them to increase the rate of breakdown of digesta (van Soest, 1994). The high digestibility coefficients obtained in this study confirm the optimal level of *Gliricidia* supplementation of 0.8 Bwt as recommended by Mpairwe (1994).

Table 4. Daily dry matter intake and apparent digestibility by growing sheep fed Setaria hay supplemented with giricidia.

	Setaria cultivars				
	Kazungula	Splendida ex. Kenya	Narok	Splendida ex. Tanzania	SEM
DM intake (g/day)					
Setaria	517.9	511.1	500.1	559.1	± 21.2
Gliricidia	144.5	148.2	146.1	144.5	± 1.8
Total	662.4	659.3	646.6	703.6	± 20.1
Total DMI g/kg $W^{0.75}$	67.6	66.0	65.3	72.2	± 2.3
Apparent digestibility coefficients (%)					
DM	68.4	68.4	67.1	64.4	± 1.7
CP	66.5	64.8	65.1	61.7	± 2.1
NDF	63.9	65.1	59.7	61.7	± 4.4
ADF	65.6	61.7	62.4	62.6	± 3.2

SEM = standard error of the mean

Table 5. Nitrogen utilisation and weight gain by sheep fed Setaria cultivars supplemented with Gliricidia.

	Setaria cultivars				
	Kazungula	Splendida ex. Kenya	Narok	Splendida ex. Tanzania	SEM
Nitrogen balance/day					
Ingested	15.19^{ab}	15.96^{ab}	12.88	17.55^{a}	±0.79
Faecal	5.15	5.77	5.05	6.07	±0.47
Urine	4.58	3.78	3.94	4.68	±0.53
Total excreted	9.73	9.55	8.99	10.76	±0.67
Absorbed (apparent)	10.05	9.92	7.84	11.39	±0.54
Retained	5.47	6.14	3.89	6.71	±0.64
Percent intake					
Faecal	33.48	35.18	38.23	34.88	±2.14
Urine	30.23	23.86	30.29	27.28	±2.28
Absorbed	66.51	64.82	61.67	65.12	±2.14
Retained	36.19	40.96	31.29	37.85	±3.65
Percent of absorbed					
Retained	54.42	61.90	49.62	58.90	±9.01
Weight gain (g/day)	46.00	71.40	53.60	57.10	±10.90

Means in the same row with different superscripts are significantly different ($P<0.05$).
SEM = standard error of the mean

The results of nitrogen (N) intake, excretion and retention by sheep are presented in Table 5. Nitrogen intake by sheep fed on Narok cultivar was significantly ($P<0.05$) lower than those fed *Splendida* ex. Tanzania due to the differences in the DM intake of the two cultivars. Nitrogen voided in faeces and urine was similar ($P>0.05$) among the diets. The results of the study indicated no significant ($P>0.05$) difference in the efficiency of N absorption and retention between the cultivars. In contrast, Mpairwe (1994) reported improved N retention in sheep fed elephant grass supplemented with *Gliricidia*. There was no significant ($P>0.05$) difference in live weight gain of sheep fed the different diets. However, supplementation of a basal diet of elephant grass with *Gliricidia* improved live weight gains of sheep (Mpairwe, 1994). Similar results were reported for *Chloris gayana* supplemented with lablab seed meal (Maferwe and Mtenga, 1992).

Conclusion

The fact that DM yields of *Setaria* cultivars were not affected by intercropping with *Gliricidia* indicates that the two fodder crops are compatible. Hence *Setaria* may be an appropriate crop besides elephant grass in *Gliricidia*/grass intercrop systems. The results showed that supplementation of *Setaria* with *Gliricidia* leaves increased the efficiency of utilisation of the grass by sheep. Therefore *Gliricidia* leaves could be used as an economic protein supplement to improve nutritive value of grass based diets.

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Seed-borne fungi of cowpea: transmission and effect of *Macrophomina phaseolina*

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Abstract

Seed health testing by the blotter method was done to establish seed-borne fungi of cowpea seed samples collected from eastern Uganda. Twenty different fungal species were encountered on the seed samples of which *Fusarium semitectum, Phoma* sp., *Alternaria tenius, Aspergillus* sp., *Rhizopus* sp. *and Chaetomium* sp. were most common. was encountered more frequently in the first season than the second one, although its range of infection was low, 0.3-4.3%. Germination tests were done on 13 samples selected on the basis of their *M.phaseolina* infection levels and grouped as low (1.0-1.5%), moderate (1.8-2.5%) and high (2.8-4.3%) infection categories. There was no significant difference ($P \leq 0.05$) in germination percentage between chlorine treated and non-treated seed samples except in the high *M.phaseolina* infection category. In transmission studies, the fungus caused seed, stem and root rots. Affected seedlings wilted and later died and the transmission rate of the fungus was1:1.

Key words: *Fusarium semitectum, Macrophomina phaseolina*, seed, Uganda, *Vigna unguiculata*

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is attacked by a number of seed-borne diseases leading to poor plant establishment and consequently heavy yield losses (Diekman, 1994). Most of the important diseases are fungal with some classes or genera being more frequent than others. One of the effects of seed-borne fungal infection is the reduction or elimination of germination capacity (Neergaard, 1979). This has been attributed to invasion of seed tissues and their consequent disruption (Sinha and Khare, 1977; Neergaard, 1979) resulting in the reduction of seed quality (Buruchara, 1990).

Among the seed-borne fungi of cowpea, *Macrophomina phaseolina* (Tassi) Goid, is often important, as it causes seed and seedling rot (Sinha and Khare, 1977). The fungus is seed-transmitted (Sinha and Khare, 1977), or soil-borne (Sinclair, 1982) and is commonly encountered on cowpea seeds in Uganda (Nakawuka *et al.,* 1997) but no studies have been conducted to determine its transmission rate from naturally infected seeds to seedlings. Therefore, the present work was undertaken to identify the kind and amount of fungi associated with cowpea seeds from eastern Uganda, and to determine the significance and seed transmission rate of *M. phaseolina.*

Materials and Methods

Seeds of two local cultivars, *Ebelat* and *Ecirikukwai,* and the introduced, "Kenyan/Black" were collected from eastern Uganda, a (major cowpea growing region of the country). Samples (240) were obtained from farmers' harvests of first (May) and second (November) seasons of 1996. The samples were collected from 3 major cowpea growing districts, from individual households situated 5-10 km apart and transcending the three districts. From each farmer's seed lot, primary samples were drawn

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Seed health testing

The health status of the seeds was established using the blotter method (ISTA, 1993). Four hundred seeds from each sample were then plated on three layers of moist blotters in 9 cm diameter petri-dishes with 10 seeds/dish and incubated for 7 days under alternating cycles of 12 hours of darkness and 12 hours under near ultraviolet (NUV) light at 20-22 °C. Each incubated seed was then examined using a stereo microscope (x 50 - 60 magnification) for fungal growth. Fungi were identified according to their "habit characterers" (Mathur *et al.*, 1992). Infection level of each fungus was then computed as percentage of infected seeds in every 400 seeds per sample. The number of samples showing occurrence of a particular fungi was then computed as a percentage out of all samples tested (frequency of occurrence).

Germination test

Thirteen seed samples with natural *M.phaseolina* infection were selected and categorised into low (1-1.5%), moderate (1.8-2.5%) and high (2.8-4.3%) infection category. The categories were developed based on an earlier study of various field samples of cowpea using the blotter method which showed that seed-borne infestation levels ranged from about 1to over 4%. Four hundred seeds from each sample were divided into two parts of 200 seeds each. One part was surface disinfected with 1% sodium hypochlorite solution for 2 minutes before testing for germination using the "on-top of paper "method (ISTA, 1993). The other part was not treated but was also tested for germination.The relationship between germination capacity and levels of infection by *M. phaseolina* was then tested using correlation analysis.

Transmission test

Two hundred seeds were taken from each of the 13 samples and divided into 2 equal parts. One part was surface sterilised with 1% Sodium hypochlorite for 2 minutes before sowing in 0.5 kg sterile plastic bags containing sterilised soil/sand mixture. For each part of the seed samples, 5 replicates each of 20 seeds each were sown in bags supported on a sterile wire tray and thereafter seedlings were grown in a screenhouse set at 17 and 37°C minimum and maximum temperatures, respectively, and relative humidity of 70-76%. Prior to sowing, the sterilised soil/sand was tested for the presence of fungi, in particular *M. phaseolina*, using the soil agar plate method to ensure that there was no soil-borne inoculum. Soil agar media was prepared by dissolving 4.25 g of corn meal agar in 250 ml of water, sterilised for 15 minutes at 121°C and a pressure of 1.06 bars. The agar was left to cool in a lamina flow cabinet and poured into sterile glass petri-dishes. Sterile soil/sand was then sprinkled on the agar, covered tightly and incubated at 23°C. After 24, 36 and 48 hours, the petri-dishes were examined for presence of *M. phaseolina*.

Control tests were set up along side test samples using *M. phaseolina*-free seed samples. The set up was done following randomised complete block design with 5 replications. Seedlings were harvested 4 times at 10, 17, 24 and 31 days after sowing (DAS). For each harvest, 5 bags were randomly selected from each replicate and the seedlings/ungerminated seeds carefully removed from the soil. In the laboratory, the seedlings and ungerminated seeds were washed in sterile water to remove the soil. Under a lamina flow cabinet, they were surface sterilised with 1% Sodium hypochlorite for 1 minute, rinsed for 5 minutes in 3 changes of sterile water (Kabeere, 1995) and put on sterile wire trays to dry for 1 hour. The seedlings were cut into roots, stems and leaves before plating on 3 layers of moist blotter paper (Nakawuka, 1996) in 9 cm diameter sterile glass petri-dishes. The different plant parts were plated in different dishes. The dishes were then incubated under alternating cycles of 12 h NUV light and 12 h darkness for 7 days, after which they were examined for the presence of fungi. The experiment was done twice and the data subjected to two-way analysis of variation (ANOVA) (Steel *et al.*, 1997). Where significant differences were detected, means were compared using Fisher's protected least significant differerence test (LSD) using the MSTATC computer program.

Results

Twenty different fungi were detected on the seeds: *Fusarium semitectum, F. solani, F. monoliforme, F. oxysporum, F. equiseti, Phoma* sp., *Alternaria tenius, A. zinniae A.sesamicola, Aspergillus* sp., *Rhizopus* sp., *Chaetomium* sp., *Macrophomina phaseolina, Phomopsis* sp.,, *Colletotrichum dematium, C. lindemuthianum, Bipolaris* sp., *Nigrospora* sp., *Botryodiplodia theobromae,* and *Curvularia* sp. Generally infection levels were higher for the first than second season (Table 1). Infestation levels differed with cultivar, being generally higher in the Kenyan originated cultivar.

Effect of Macrophomina phaseolina on germination of cowpeas

Table 1. Occurrence of seed-borne fungi and their mean infection levels on three common cultivars of cowpeas grown in Eastern Uganda in 1996.

Fungi	*Ebelat*		*Ecirikukwai*		*"Kenya"*	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Fusarium semitectum	43.0	20.0	40.7	39.5	69.7	10.0
F. solani	7.2	0.3	5.0	1.2	31.0	-
F. monoliforme	0.8	0.3	2.8	2.1	0.8	-
F. oxysporum	2.0	0.8	1.2	-	12.0	-
F. equiseti	0.5	5.9	0.3	10.7	-	1.8
Alternaria tenius	2.0	0.4	2.6	0.3	1.4	-
A. zinniae	0.7	1.7	2.0	1.9	0.5	0.3
A. sesamicola	0.6	0.6	-	2.2	-	0.5
Macrophomina phaseolina	0.9	0.9	1.3	-	1.8	-
Phoma spp.	2.8	0.9	6.1	0.7	1.3	0.3
Phomopsis spp.	1.3	0.4	0.7	0.3	0.3	-
Botryodiplodia theobramae	0.8	0.3	0.5	0.3	-	-
Bipolaris spp.	0.4	0.7	0.3	0.3	0.5	0.3
Colletotrichum dematium	0.5	27.1	0.3	6.9	-	31.5
C. lindemuthianum	0.5	6.5	-	4.5	-	6.1
Curvularia spp.	0.3	4.3	0.4	0.6	0.3	1.1
Acremonium spp.	0.8	0.4	-	0.3	-	2.0
Nigropora spp.	0.3	0.4	-	-	-	0.5
Aspergillus spp.	0.8	0.3	14.7	1.3	0.3	0.4
Rhizopus spp.	0.4	-	0.5	-	0.5	-
Chaetomium spp.	1.3	-	0.8	-	0.6	-
LSD (0.05)	0.7	0.6	0.6	0.7	0.5	0.6

For first season, total number of samples: *Ebelat*, n = 42, *Ecirikukwai*, n = 13 and *"Kenya"*, n = 5. For second season total number of samples: *Ebelat*, n = 37, *Ecirikukwai*, n = 20 and *"Kenya"*, n = 2.

Germination percentage ranged from 74-81% and 72-87% for non-surface sterilised and surface sterilised samples, respectively, in the low infection (LI) category. For the medium infection (MI) category, it ranged from 73-88% and 77-89% for non treated and chlorine treatments, respectively. And, in the high infection (HI) category, germination ranged from 60-79% and 80-84% for non treated and chlorine treatments respectively (Table 2).

Percentage of abnormal seedlings ranged from 14-16% and 11-16% for the low infection category, 8-21% and 10-12% for the medium infestation category, and 15-33% and 12-15% for the high infection category for the non treated and chlorine treatments, respectively (Table 2). The abnormal seedlings showed defects such as of deformed tap roots, twisted epicotyl and hypocotyl, decaying seedlings, malformed primary leaves and stunted roots (Plate 1).

There was no significant correlation between germination and *F. semitectum* infection for the low and high infection categories (Table 3), but there was a negative but weak correlation between germination and *M.phaseolina* infection levels for the low infection and high infection categories ($r = -0.652$, $P = 0.211$; $r = -0.410$, $P = 0.697$, respectively) (Table 3).

Table 2. Germination percentage of cowpea seed samples with different levels of Macrophomina phaseolina infection.

	% Germination		% of other categories			
	normal seedlings		abnormal seedlings		dead seeds	
Variety	NT	CL	NT	CL	NT	CL
Low infection (1.0-1.5%)						
SC.102 (*Ecirikukwai*)	81.3	85.8	13.7	10.5	5.0	3.7
PB.103 "	73.8	86.7	18.8	10.7	7.4	2.7
SC.208 "	76.5	72.2	16.3	16.2	7.2	11.7
SC.219 (*Ebelat*)	77.3	77.5	15.5	12.2	7.2	10.3
KB.212	76.7	80.0	16.0	14.7	7.3	5.3
LSD(0.05)	6.8	NS	3.7			
Moderate infection (1.8-2.5%)						
SC.114 (*Ecirikukwai*)	87.2	84.3	9.3	11.8	3.5	3.8
PB.120 "	88.2	88.3	7.8	9.8	4.0	1.8
SC.220 (*Ebelat*)	81.0	80.7	14.2	11.5	4.8	7.8
PB.204 "	72.8	76.3	20.7	11.7	6.5	12.0
PB.208 "	79.2	82.0	12.8	9.5	8.0	8.5
LSD(0.05)	NS	9.1	NS			
High infection (2.8-4.3%)						
KK.107 (*Ebelat*)	59.3	83.8	32.8	13.0	7.8	3.2
KB.113 "	63.0	79.3	29.5	14.6	7.5	6.0
PB.211 (*Kenya*)	79.0	81.0	15.0	11.7	6.0	7.3
LSD(0.05)	21.7	14.5	NS			

Percentage germination based on 200 seeds per treatment per sample, ** pooled data for 3 experimental repeats, NT = Non-surface disinfected, CL = treated with 1% Sodium hypochlorite (surface disinfected).

Transmission rate of Macrophomina phaseolina

M. phaseolina was isolated from diseased seedlings and **from ungerminated dead seeds. After** incubation of the seedling parts, the fungus was detected **mainly on stems but sometimes on leaves. After 17 DAS,** roots and ungerminated seeds usually **decomposed. There were no *M.phaseolina*** symptoms on the control samples in all the 3 infection **categories.The transmission rate of *M.***

Table 3. Correlation coefficient *describing the relationships* ***between germination capacity and infection levels*** *of* ***M.phaseolina.***

Infection category	Infection level %	Germination percentage*	Correlation coefficient	P value
low infection	1.3	83.1	-0.652	0.211
moderate infection	2.0	80.8	0.460	0.421
high infection	4.3	71.6	-0.410	0.697

* grouped mean for the non-treated and chlorine treated samples.

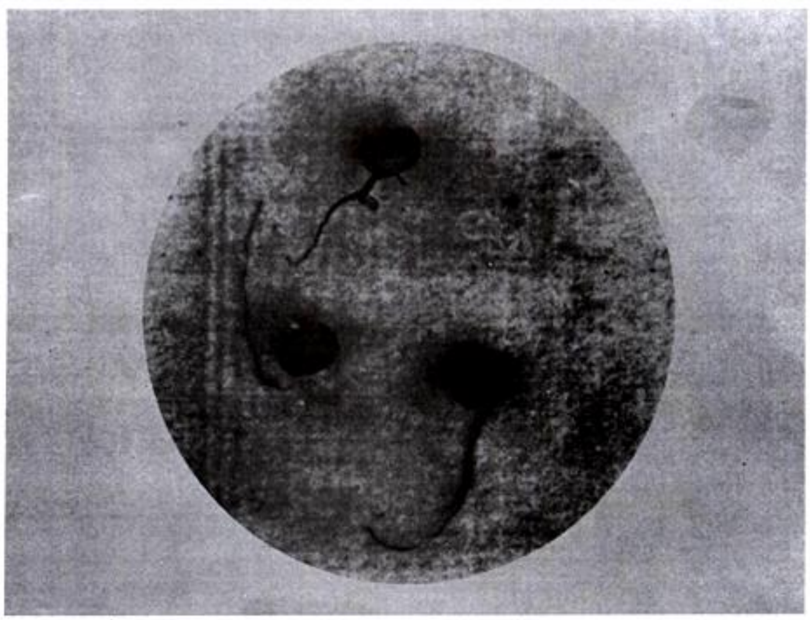

Plate 1. *Abnormal seedlings with M.phaseolina infection.*

Table 4. Transmission rate of Macrophomina phaseolina from infected seeds to seedlings.

Infection level	SC. 102	PB. 103	CS. 208	SC. 219	KB. 212	SC. 114	PB. 120	CS. 220	PB. 204	PB. 208	KK. 107	KB. 113	PB. 211
Initial infection level (%)	1.25	1.25	1.50	1.25	1.50	2.25	1.75	2.00	1.75	1.75	4.25	2.75	2.75
Transmission*	1.00	1.00	2.00	1.00	1.00	2.00	1.50	2.00	2.00	1.50	3.50	2.50	2.00
Transmission ratio[a]	1:1	1:1	1:1	1:1	2:1	1:1	1:1	1:1	1:1	1:1	1:1	1:1	1:1

* = percent recovery *of M.phaseolina* based on 100 seeds per sample and is the grouped mean for the non treated (NT) and Sodium hypochlorine (Cl) treatments.
a = ratio of the initial infection level to percent recovery of *M. phaseolina*.

phaseolina, is given as a ratio of diseased seedlings to the initial level of infection, was approximately 1:1 for all the 3 levels of *M. phaseolina* infection (Table 4).

Discussion

Infection of cowpea seeds by seed-borne fungi was generally higher during the first than the second season crop. This could be due to the fact that the first season's rains were longer than the second season and therefore more humid. Humid conditions generally favour most fungal epidemics (Williams, 1975).

The high infection level of *Fusarium semitectum*, a weak pathogen (Nakawuka *et al.*,1997), is probably due to contamination of the seeds from infected plant debris or soil. *Aspergillus* sp. and *Rhizopus* sp. also had high infection levels. These are storage fungi (Neergaard,1979), whose infestation increase with the storage duration and are known to decrease seed germination by invading the embryos of stored seed. In addition, they produce mycotoxins (Singh *et al.,* 1991) which greatly reduce seed quality as regards consumption.

Macrophomina phaseolina, with pycinidia, was recorded on many samples from all the districts, implying its widespread occurrence. The presence of *M.phaseolina* on cowpea seeds is potentially important because it implies that the areas where the seed samples were collected from could be considered as reservoirs of the pathogen. The negative association between *M.phaseolina* and seed germination indicates that *M.phaseolina* adversely affects seed health. But, because the correlation coefficients were weak, higher levels (> 4.3%) are probably needed to cause significant reduction in seed germination. This is supported by the fact that germination significantly improved as a result of seed treatment with chlorine only for the high *M. phaseolina* infected (HI) samples. This was probably because these samples had high levels of fungal infection and the effect of pre-treatment was therefore apparent.

In the screenhouse, it was observed that all seedlings that showed *M.phaseolina* symptoms eventually died. This suggests that the seed-borne inoculum led to death of the infected seeds/seedlings and the pathogen had a high transmission rate of 1:1. This corroborates Songa *et al.* (1997) findings that most seedlings infected with *M.phaseolina* do not survive to maturity. The occurrence of such a wide range of seed-borne fungi on cowpea seeds suggest that cowpea is susceptible to many fungal diseases which are likely to affect its germination and subsequent growth and development. Therefore, seed health testing and sorting are necessary to ensure that appropriate control measures such as seed treatment are taken. This can help in averting crop failures due to seed-borne pathogens.

Acknowledgement

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Pollination, fruit set and yield of hybrid passion fruits

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Abstract

Passion fruits are increasingly gaining importance as fruit crops in Uganda. But yield greatly depends on numbers of flowers produced, fruit set and final numbers that survive to maturity. The above characteristics were studied on *Passiflora edulis f. edulis* and *P. edulis f. flavicarpa* Kawanda hybrid. The close genetic composition of some of the hybrids to one parent or the other was observed. Receptivity of the stigma, plant compatibility, pollen wetting and the number of pollen grains deposited on the stigma affected pollination levels.

Key Words: Compatible cultivars, flower abortions, *Passiflora edulis f. edulis, P. edulis f. flavicarpa*

Introduction

Fruit production in Uganda has steadly increased since 1995 when the Uganda government made deliberate efforts to popularise non-traditional cash crops as an attempt to expand her export base. Passion fruits (*Passiflora Spp.*) are some of the fruit crops that can be economically grown throughout Uganda. Additionally, fruit consumption substantially contributes to balancing diets of the rural poor.

However, fruit yields are dependent on the number of flowers produced, the number that sets fruits and the final fruit number that survives to maturity. It is likely that the plant size, pest control and fertility levels influence the final yields. Flowers of some passion fruit are self-sterile while some are self-incompatible (Akamine and Girorami, 1957). Care must, therefore, be taken in the selection and distribution of compatible cultivars (clones or hybrids) in the field to ensure maximum production (Howell, 1976; Burgos and LedBetter, 1994).

Kawanda hybrid passion fruits are an improved cultivar gaining popularity through out the country but has not been studied for importance of pollination, fruit set and yield. Earlier studies indicated that yields of 2,400 kg to 8,500 kg $ha^{-1}yr^{-1}$ were obtained from experimental plots of *Passiflora edulis f. edulis*, one of the parents of Kawanda hybrid at Kabanyolo (Emechebe and Mukiibi, 1973). However, Kawanda hybrid, a cross between *P. edulis f. edulis* 1and *P. edulis f. flavicarpa*, yields about 6,121 to 58,965 kg $ha^{-1}yr^{-1}$ (Musaana, 1986).

During 1998 and 1999 it was found necessary to identify the former hybrids at Kawanda, assign them names and study the pollination, fruit set and yield of the new selections. This study was then initiated with the aim of determining the importance of pollination on fruit set and yield of the selected hybrids, and self-compatibility status of the selections.

Materials and Methods

Two parental lines, i.e., *Passiflora edulis f. edulis* and *P. edulis f. flavicarpa* were planted in the field at Kawanda Agricultural Research Institute (KARI) in central Uganda. Included in the trial were four other genetically different hybrids. At maturity, data were recorded on five tagged plants per cultivar. Data recorded were; the number of flowers produced over a four month period between April and August of 1998 and 1999, floral opening time, duration of flowers, and the movement of the stigmatic lobes and their receptivity. Hand pollination was done at different stages of flower opening and fruit set was recorded. Artificial pollination was effected by bringing the exposed microsporangial surface covered with microspores in direct contact with the stigmatic surface, thus transferring pollen to the stigma. All the stigmatic lobes were pollinated. Self-pollination was done with pollen from the same flower or from another flower on the same plant. Fruit set or lack of it was then determined seven days after pollination using 50 flowers per cultivar. Mature fruit yields (number and weight) over two years i.e. 1998 and 1999 were then computed. The relationship of pollination to total fruit yields was also determined. The data obtained were then subjected to analysis of variance and means compared using Fisher's protected least significant difference test (LSD) at $P \leq 0.05$) using the MSTATC computer programme.

Results and Discussions

Four distinct hybrids were noted as having different gene markers for characters such a stem colour. The yellow passion fruit (*P. edulis. f. flavicarpa*) was the second parent (P_2) whose flowers opened from noon to about nine o'clock in the evening. Flowers of *P. edulis f. edulis*, the local purple type (P_1) opened mainly from early morning and closed by mid-day. Hybrid one (H_1) and two (H_2) opened between 10:000 a.m and 3:00 p.m. Hybrids 3 and 4 opened from 7:00 am to 1:00 p.m. In all cases the stigmas were found to be receptive on the day of floral opening. The most effective time of pollination was after the styles had completely curved after floral opening to touch the anthers (Table 1); with the resultant fruit set in all the hybrids and parents above 78%. This was therefore the optimum time for hand pollination when the stigmatic lobes were most receptive and offered the best condition for pollen germination and onward fertilisation.

Between 19 and 24 flowers, were either self or cross pollinated and their fruit set recorded (Table 2). The results indicate that H_3 was, for all practical purposes self incompatible and cross-compatible with all the other hybrids and P_1 though poorly compatible with P_2 .

The times at which flowers opened and closed for the two parents and hybrids plus the results of cross-compatibility tests indicate that H_3 was genetically closer to P_2 while H_4 was closer to P_1. Hybrids 1 and 2 were intermediate in behaviour. Backcrossing any of the hybrids, to P_1 would be easy while it would not be practical to backcross H_3 to P_2.

In the field, pollination and fruit set was also influenced by environmental factors. High temperatures in the morning encouraged anthesis and the pollen remained viable for 24 hours.

If there was rain and the pollen got wet, it bursted on contact with water, which resulted in fertilisation failure during rain. Pollen grains were, however, not destroyed by water after growth. Similar results were reported in yellow passion fruits (Kuhne, 1968; Purseglove, 1968).

Some fruits developed as many as 347 seeds. In cases where less than 100 seeds developed in the friuts, they were classified as hollow (Knight and Winters, 1962; 1964). Hollow fruit condition was observed when crosses were effected between H_1 and H_2, H_3 and P_2 and H_4 and P_1. Hollow fruit condition has been reported to be due to self-incompatibility, other genetic factors, and lack of pollination (Gilmartin, 1958; Ruberte-Torres and Martin, 1974; Howel, 1976). It should be noted that the hollow fruit condition was common in H_4 even for the flowers not artificially pollinated,. Selfing resulted in low fruit weight, fewer seeds and less juice per fruit. Similar results were reported by Knight and Winters (1964). A combination of the above factors that affected pollination, therefore, reduced fruit yields.

Results of mature fruit yields and weights per plant for the two years are shown and the figures 1 and 2 and reveal that H_3 had a large number of smaller sized fruits compared to H_1 and H_2. From visual observations H_4 had the biggest fruit size though it had a higher proportion of hollow fruits. Figure 1 also shows that continuous yields could be obtained throughout the year. This could also enhance higher production in H_3 which has compatibility problems.

Table 2. Fruit set by hand, self or cross pollination

Cross involved	No. of flowers pollinated	No. of fruits set	Percent fruit set
$P_1 \times P_1$	20	16	80.0
$P_1 \times P_2$	20	17	85.0
$P_1 \times H_1$	20	14	70.0
$P_1 \times H_2$	19	14	73.7
$P_1 \times H_3$	23	19	82.6
$P_1 \times H_4$	22	15	68.2
$P_2 \times P_2^*$	20	15	75.0
$P_2 \times H_1$	24	12	50.0
$P_2 \times H_2$	23	14	60.9
$P_2 \times H_3$	24	1	4.2
$P_2 \times H_4$	22	28	81.8
$H_1 \times H_1^*$	20	14	70.0
$H_1 \times H_2$	19	18	94.7
$H_1 \times H_3$	20	14	70.0
$H_1 \times H_4$	19	17	89.5
$H_2 \times H_2^*$	24	19	79.2
$H_2 \times H_3$	24	10	41.6
$H_2 \times H_4$	24	18	75.0
$H_3 \times H_3^*$	24	1	4.2
$H_3 \times H_4$	23	14	60.9
$H_4 \times H_4^*$	20	15	75.0

* = Self pollinated flowers; P_1 and P_2 = Parents; H_1 - H_4 = hybrids.

There were significant differences in monthly yields (Table 4) because of differences in moisture availability during the different months. More flowers were produced during the wet season due to new growth; conversely fewer flowers were produced during the dry spells due to no growth hence low fruit yields. Similar results were reported by Kuhne (1968) for yellow passion fruit and granadilla. The yield differences between the hybrids (Table 4) were high with H_1 and H_3 out yielding H_2 and H_4 during the two years. The yields for the two years for P_1, P_2, H_2 and H_4 are within the range reported in literature of 2, 400 to 44, 836 kg $ha^{-1}yr^{-1}$.

Yields can be high or low depending on genetic differences, plant age, pest and disease pressure, amount of rainfall and levels of pollination. In this study, yields of H_1 and H_2 were not significantly different during 1998 but were significantly different during 1999. The yields of H_1 and H_2 were, however, higher than those of the two parents indicating the presence of transgressive segregation for yield for the two hybrids. Transgressive segregation has been reported in passion fruit for yield, aroma and flavour (Morton, 1967; Kuhne, 1968; Ruberte-Tores and Martin, 1974). None of the hybrids used in this study yielded less than both parents.

Conclusions

Pollination or lack of it influenced the yields of the hybrids by producing empty fruits if a few pollen grains were deposited on the stigma or if there was a total lack of pollination. Pollen wetting before

Table 3. Analysis of variance for yield of the passion fruit hybrids for the year 1998.

Source	df	ms	F
Months	11	30925.8	6.89**
Hybrids	3	30836.0	6.87**
Error	33	4488.5	

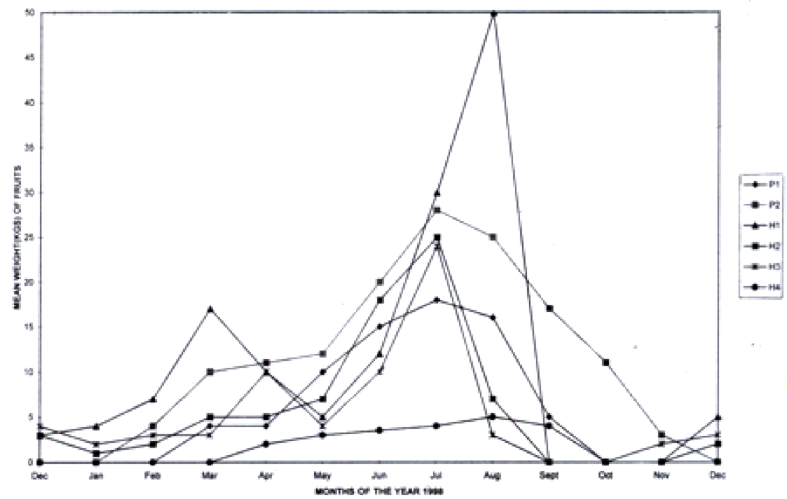

Figure 1. Yield of some selected passion fruit cultivars at Kawanda.

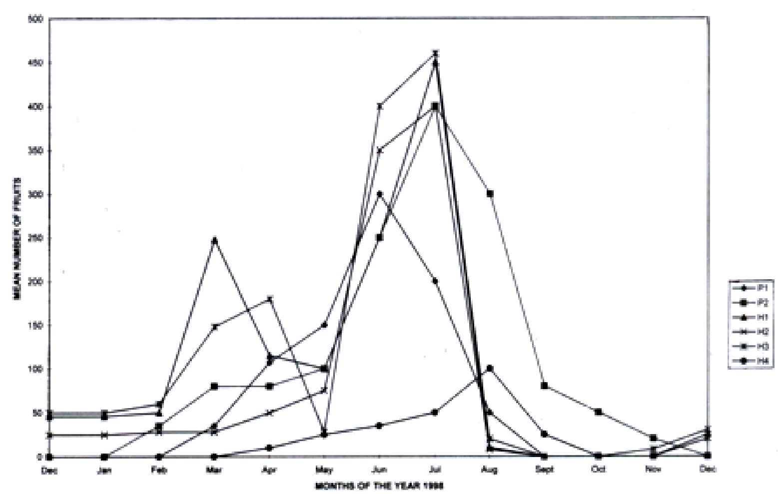

Figure 2. Mean number of fruits for selected passion fruit cultivars at Kawanda.

Table 4. Yields of the four passion fruit hybrids and their parents (kgha⁻¹yr⁻¹).

Cultivar	1998	1999
P1	6,488c	6,745c
P2	36,800b	42,858b
H1	46,851ab	54,899a
H2	40,494b	47,846ab
H3	53,299a	58,900a
H4	6,427c	9,920c

Means in a column bearing the same letter are not significantly different (LSD, 0.01)

tube growth resulting in busted pollen grains or incompatibility of the cultivars were the main causes of pollination failure. The stage of pollination with respect to floral opening and stigmatic receptivity also affected pollination levels.

Hybrids 1 and 2 were genetically midway between the parents while hybrid 3 was closer to P_2 and H_4 closer to P_1. Peak yields were obtained in March and July which are the peak rainfall periods but some fruits were harvested from February to August. The use of irrigation accompanied with selective pruning of old branches can result in all year round crop production.

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Evaluation of maize introductions for resistance to turcicum leaf blight, maize streak virus disease and tropical maize rust in Uganda

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Abstract

In the tropics, turcicum leaf blight (TLB) (*Exserohilum turcicum*), maize streak gemini virus disease (MSVD), and tropical maize rust (*Puccinia polysora*) are endemic and the most important maize foliar diseases in many countries. Thus deployment of varieties with multiple resistance to these diseases is key in increasing production. This study evaluated the disease reactions of elite Ugandan varieties and Pioneer hybrid introductions by considering the rate of disease increase (r), intercept or initial amount of inoculum (Yo*), area under disease progress curve (AUDPC), lesion numbers and percentage leaf area blighted. Significant differences in susceptibility of Ugandan varieties ($P \leq 0.05$) to TLB blight were observed. Population 28 was most susceptible while Babungo 3 was most resistant. Regression analysis revealed a linear relationship between yield and turcicum leaf blight severity ($R^2 = 0.50^{**}$), but there was no significant difference ($P \geq 0.05$) in yield of Ugandan elite varieties. No significant differences were observed among Pioneer hybrids in susceptibility to all the three diseases and they were in general, considered resistant to all the three diseases and comparable to the elite Ugandan varieties. Epidemiological models and their resultant disease indices fitted to TLB and rust disease progress distinguished between the various varieties studied.

Key words: Epidemiological models, *Exserohilum turcicum*, maize streak gemini virus, *Puccinia polysora*, resistance, Uganda, *Zea mays*

Introduction

Maize (*Zea mays* L.) is a major staple grain in Uganda were it doubles as a source of livelihood to many households and of recent, a mainstay to the economy as a non traditional cash crop (Anon. 1984; 1990). The crop is grown in virtually all parts of the country although largest production occurs in the northern periphery of Lake Victoria and the higher altitude areas of Kigezi, Rwenzori, west Nile plateau, Mount Elgon and the fertile Sebei highlands (Anon., 1990).

In the typical cropping system, maize is grown from farmer saved seeds of mainly local land races, with less than 40% of the land planted to improved varieties. In the 1980's, yields averaged 890 kg/ha in Teso (Soroti and Kumi), to 2240 kg/ha in Buganda and central Uganda (Anon, 1984) and in the 1990s, they ranged from 900 to 2500 kg/ha with a national average of close to 1400 kg/ha; but yields of up to 4000 kg/ha have been achieved under good weather and management (Anon., 1984; 1990). Therefore, there is a possibility of doubling present production levels through improved seed selection, development and maintenance of high yielding varieties.

Low production has also been mainly attributed to various pests and diseases with maize streak gemini virus disease (MSVD), turcicum leaf blight (TLB) (*Exserohilum turcicum* (Pass) K.J. Leonard and E.G. Suggs (teliomorph: *Setosphaeria turcica* (Luttrell) K.J. Leonard and E.G. Suggs and, the tropical and southern rusts (*Puccinia polysora* Underw and *Puccinia sorghi* Schw, respectively) (Anon, 1990; Adipala., *et al.*, 1993 a & b; Bigirwa *et al.*, 1993; Okori *et al.*, 1999). Over the years, attempts have been made to study resistance mechanisms to these diseases and develop resistant varieties mainly to TLB and MSVD (Storey and Howland, 1967; Adipala *et al.*, 1993a; Bigirwa *et al.*, 1993; Kyetere, 1995; Ojulong *et al.*, 1996; Okori, 1999). However, very limited efforts have been made with respect to the maize rust (Hemingway, 1954; Storey *et al.*, 1958). These studies focused on the individual diseases and did not consider multiple resistance to the major diseases, which, accounts for the paucity of information on this phenomenon. Yet, all these three diseases are endemic in many areas of the tropics (Damsteegt and Bonde, 1993; Okori *et al.*, 1999) and several seed companies and the national programmes are releasing varieties into the market. Hence, we investigated the phenomenon of multiple disease resistance in elite local and exotic maize varieties, focusing on disease TLB, MSVD and maize rust.

Materials and Methods

The study was conducted at Kabanyolo, in central Uganda. (Latitude 0°28'N and longitude 30, 37°E, 17 km north of Kampala Uganda at an altitude of 1200 m above sea level). Two experiments were conducted during the first and second seasons of 1993. In the first study, nine varieties i.e., five pioneer hybrids (obtained from Pioneer Seed Company, Harare Zimbabwe) and four elite Ugandán maize varieties obtained from the National Maize Programme, were used to investigate the multiple resistance phenomenon in the test lines to the three major diseases TLB, MSVD, and maize rust and their adaptability to Uganda (Tables 1). In the second study, seven open- pollinated varieties and two hybrids were obtained fromthe Namulonge Agricultural and Animal Research Institute (Table 2) and used to study yield loss due to TLB in improved Ugandan varieties. In both studies, Population 28 (EV8428-SR), an introduction from Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), was used as a susceptible check to compare the levels of resistance to *E. turcicum*.

Table 1. Origin and sources of maize germplasm used in the first study.

Germ plasm	Source
YIF64W	Pioneer seed company Harare
PHB3242	Pioneer seed company Harare
PHB3407	Pioneer seed company Harare
PHB 3253	Pioneer seed company Harare
PHB3452	Pioneer seed company Harare
TOPCROSS	Namulonge Agricultural and Animal Research Institute
SINGLECROSS	Namulonge Agricultural and Animal Research Institute
LONGE 1	Namulonge Agricultural and Animal Research Institute
KWCA-SR	Namulonge Agricultural and Animal Research Institute

Table 2. Origin and sources of maize germplasm used in the second study.

Genotype	Origin	Known resistance
KWCA-SR	Uganda[a]	M.R.[e]
Pop 28	CIMMYT[b]	S[e]
Pop 29	CIMMYT[b]	S[e]
Gusau	I.I.TA.[c]	M.R.[e]
Babungo 3	I.I.T.A.[c]	R[e]
Single cross	Uganda	M.R.[d]
Topcross	Uganda	M.R.[d]
Longe 1	Uganda	M.R.[d]

[a]Kawanda composite – a streak resistant variety
[b]Centro Internacional de Mejoramiento de Maiz Y Trigo, Mexico
[c]International Institute of Tropical Agriculture, Nigeria
[d] Bigirwa *et al.*, 1993
[e]Adipala *et al.*, 1993b

The first experiment was arranged following a completely randomised block design (CRBD), with three replications. Each replicate had nine treatment units comprising of nine varieties, maize was initially seeded at a rate of two seeds per hill but was later thinned to one plant per hill at the four leaf stage. Each plot measured 4 x 2 m with a 1.5 m spacing between blocks and 1 m between the plots (cultivars). Two rows of a local commercial variety (KWCA-SR) bordered the experimental plots to reduce exogenous inoculum inflow. The land was prepared by conventional tillage, and weeded using handhoe whenever necessary. No fertilisers, fungicides or insecticides were applied during the experimental period.

The second experiment was arranged following a split-plot design of a completely randomised block design (CRBD), with three replications. Plants were established in two row plots, 3 m long, using the same spacing and seed rate as described in the first experiment. Each replicate contained three main inoculation plots i.e., no inoculation (control), one inoculation at Growth stages (G.S.4), and two inoculations one at G.S. 4 and the second at G.S. 5 with the nine varieties in the sub-plots. Experimental plots and replicates were boardered by three rows of a resistant variety Babungo-3 to reduce inter-plot spread of *E. turcicum*.

Exserohilum turcicum inoculum was prepared from conidia isolated from Kabanyolo originated infected maize leaves as described by Adipala *et al.* (1993a). In both experiments, plants were inoculated by placing about 30 infested sorghum kernels into the leaf whorls of each maize plant at (G.S.) 4, early whorl with four leaves) and 5, mid whorl with eight leaves). (Ritchie *et al.*, 1989). During the first season, plants were inoculated on 15 May 1993 at G.S. 4 and 4 June 1993 at G.S. 5 (Ritchie *et al.*, 1989). During the second season, plants were inoculated on 20 November 1993 (G.S. 4) and on 4 December (G.S. 5). In the case of maize rust and MSVD, epiphytotics depended on field based inoculum owing to the rather high inoculum load of the two diseases being endemic in the area. All disease recordings commenced approximately one week before tasseling (G.S. 6, late whorl) and continued at one week interval for four weeks. Ten plants per entry were sampled and the two leaves above the ear of the test plants were used for assessment (Adipala *et al.*, 1993c). In the case of TLB, disease severity was measured by visually estimating the total percentage leaf area blighted (Elliott and Jenkins, 1946), as modified to 0,1,5,10,25,50, > 75% by Adipala *et al.* (1993 a and b). The total number of lesions on the ear leaf and the leaf above the ear were also counted (Adipala *et al.*, 1993b). Incidence of MSVD and its severity was assessed using a 0,1,2,3,4 and 5 quantitative scale (Kyetere, 1995). Rust severity were rated using the severity scale used for rating MSVD.

Weekly severity data were used to characterise disease progression by calculating initial and final severities and area under disease progress curve (AUDPC) (Campbell and Madden, 1990). The weekly severity (%) data were also fitted to the linearised logistic model (TLB) and exponential model (rust and MSVD). The logistic model had earlier on been shown to best describe TLB disease progress (Adipala *et al.*, 1993a and b). While the exponential model was the most preferred model in the case of rust and MSVD because it best suits cases where the initial amount of inoculum is low and plant tissue un-limiting (Vanderplank, 1963; Campbell and Madden, 1990) as was the case in this study where epiphytotics were due to field borne inoculum. For both models, the apparent infection rates or slopes "r" and estimated disease at the beginning of the epidemics (Yo*), were computed using Microsoft Excel programme. Due to differences in assessment intervals, AUDPC values were standardised by dividing by the total number of days between the first and the last disease assessment dates (Campbell and Madden, 1990). The final severity at the different assessment, AUDPC, r and Yo* were subjected to analysis of variance (ANOVA) (Steel *et al.*, 1997), using Statview [513] Brain Power incorporated programs for Macintosh Computer. Where significant differences were recorded, means were compared using Fisher's protected least significant difference (LSD) test at 5% probability level.

A simple linear regression between final disease severity of TLB and yield was also run in order to determine the effects of TLB on maize yield because of its resurgence and extensive damage in some introduced varieties.

Results and Discussion

Maize rust disease

In general, there was more rust during the first than the second season of 1993 (Table 3) with the mean final severities ranging from 1.22 to 1.4 during the first and 0.67 – 0.96 during the second season. More disease developed perhaps due to higher resultant relative humidity during the first rains. Consequently, the AUDPC values were higher during the first than the second season (Table 3). Genotype reactions were significant during the second season (Table 3). In general, elite Ugandan varieties exhibited slower disease progress and pairwise comparisons among them revealed no significant differences in AUDPC and final severity during both seasons but significant differences between some Ugandan and Pioneeer hybrids. For example, the Pioneeer hybrid PHB3407 was significantly different from Topcross.

The apparent rate of infection rate (r) varied across seasons and varieties although no significant differences among genotypes occurred during the first rains (Table 4). The highest apparent infection rate was recorded on Longe 1 and PHB 3435 during the first season and on PHB 3253 and KWCA-SR during the second season (Table 4). The computed initial amcount of inoculum or intercept (Yo*) followed the same trend as the apparent infection rate during both seasons. The low but significant r and non significant Yo* values suggest that the mode of resistance to *P. polysora* among the cultivars studied was the rate-reducing resistance (Nelson, 1978, Parlevleit, 1979) corroborating Vander plank (1963) earlier reports.

Maize streak virus disease

Incidence of maize streak virus disease was generally low throughout the experimental period, but was more common during the second than during the first season (Table 3). The hybrids YIF64W and PHB 3407 were not affected during the first season. Therefore, because of the low incidence the MSVD, data in Table 3 should be interpreted with caution: artificial infestation of the maize varieties may be needed.

Low disease incidence in part could have accounted for these observations coupled with the fact that most of the lines had MSV resistance genes incorporated. Additionally, MSVD severity is generally lower in late infected plants than those infected at seedling stage (Gibson and Page, 1997). This could perhaps explain why even infected plants showed low disease progress values. Increased MSVD incidence during second season, is similar to real field cases where higher incidences occur in fields where no closed seasons are observed or when a prolonged rain season occurs providing plenty of both host and alternative hosts for the vector (*Ciccadulina* sp.) (Storey and Howland, 1967; Gibson and Page, 1997).

Turcicum leaf blight

All plants developed wilt type (susceptible) lesions (Hilu and Hooker, 1963) with the mean final severities being higher during the first than the second season. The higher disease levels recorded during the first rains were attributed to the relatively wetter conditions and higher relative humidity which provided conducive conditions for disease development (Abadi *et al.*, 1989; Carson, 1995). AUDPC values followed the same trend as final severity (Table 3) with non significant differences ($P \geq 0.05$) among genotypes for AUDPC-PLAA during the first season but significant differences during the second season. On the contrary AUDPC for lesion numbers were significantly different during both seasons with the highest AUDPC recorded on YIF64W, PHB3424 and Longe 1.

Differences in apparent infection rates were significant ($P \leq 0.05$) only during the first season (Table 4). The hybrid YIF 64W had the highest r values during both seasons while hybrid PHB 3253 recorded

Table 3. Area under disease progress curve (AUDPC) of plant area affected (PLAA) by maize rust, maize streak virus disease (MSVD) and Turcicum leaf blight (TLB) on five pioneer hybrids and four elite Ugandan maize varieties grown at Kabanyolo during the first and second seasons of 1993.

	Rust		MSVD				Turcicum Leaf blight			
Variety	First	Second	First	Second	First	Second	First	Second	First	Second
	AUDPC				F.sev	F.sev	AUDPC PLAA			AUDPC LN
YIF64W	1.26±0.30	0.93±0.68	0.0	0.22±0.10	0.00	0.02	4.31± 0.71	0.93±0.17	1.11±0.94	0.78±0.11
PHB3424	1.59±0.44	0.82±0.00	0.13±0.01	0.08±0.08	0.10	0.17	4.02± 2.70	0.17±0.04	1.31±0.61	2.30±0.34
PHB3407	1.52±0.45	0.92±0.06	0.0	0.01±0.14	0.00	0.06	2.44± 0.47	1.08±0.66	0.88±0.07	1.70±0.20
PHB3253	1.15±0.10	0.84±0.16	0.19±0.11	0.13±0.07	0.03	0.80	0.57± 0.23	0.98±0.32	0.39±0.16	0.80±0.33
PHB3453	1.20±0.16	0.87±0.01	0.99±5.70	0.30±0.30	0.07	0.08	1.65± 0.30	0.40±0.20	0.96±0.30	0.07±0.32
Topcross	1.40±0.24	0.03±0.02	0.1±0.60	0.48±0.05	0.00	0.00	2.20± 1.30	0.48±0.17	0.73±0.32	1.09±0.13
Singlecross	1.50±0.49	0.63±0.32	0.12±0.70	0	0.17	0.16	2.90± 1.10	0.72±0.39	1.03±0.38	1.12±0.14
Longe 1	1.47±0.49	0.87±0.20	0.11±0.10	0.13±0.1	0.07	0.16	3.53±1.10	1.08±0.66	1.04±0.20	1.84±0.81
KWCA-SR	1.19±0.20	0.93±0.06	0.23±0.02	0.09±0.30	0.20	0.03	2.56± 1.23	0.17±0.62	1.08±0.38	1.84±0.20
Mean	1.36	0.87	1.36	0.16	0.07	o.15	2.66	0.66	0.94	1.35
LSD (0.05)	0.62	0.38	0.23	0.39	0.02	0.04	NS	0.38	0.77	0.90

[1] AUDPC standardised by dividing by the total number of days in the epidemic (Campbell and Madden, 1990). PLAA and LN are Plant leaf area affected and Lesion numbers, respectively

[2] F.sev = Final severity recorded 77 days after planting.

[3] Numbers in parenthesis are standard errors of the means.

[4] Data are means of three replicates

Table 4. Intercept (Y_0^*), slope (r), and final severity of plant area affected by maize rust Puccinia polysora and Exserohilum turcicum on five Pioneer maize hybrids and elite Ugandan maize varieties grown at Kabanyolo during the first and second season of 1993.

	Rust						Turcicum leaf blight					
	First rains			Second rains			Second rains			Second rains		
Variety	[1] Y_0^*	[1] r	[3] F.sev	[1] Y_0^*	[1] r	[3] F.sev	[2] Y_0^*	[2] r	[1] F.sev	[2] Y_0^*	[2] r	[1] F.sev
YIF64W	-2.78	0.43	1.19	-0.04	0.03	0.79	-14.01	0.41	2.61	-5.52	-0.20	0.21
PHB3424	-4.78	0.01	1.12	-0.06	0.44	0.92	-13.54	0.15	2.66	-5.32	0.16	0.54
PHB3407	-6.46	0.11	1.38	-0.06	0.35	0.96	-11.43	0.07	1.63	-4.95	0.003	0.50
PHB3253	-0.02	0.02	1.40	-0.06	0.99	0.80	-3.79	0.04	2.00	-4.73	0.002	0.50
PHB3453	-0.72	0.72	1.16	-0.04	0.42	0.95	-9.01	0.07	1.13	-3.61	0.04	0.48
Topcross	-0.10	0.01	1.37	-0.10	0.42	0.67	-11.80	0.01	1.42	-3.49	-0.04	0.64
Singlecross	-0.42	0.42	1.39	0.06	0.27	0.81	-9.32	0.08	2.08	-4.59	-0.03	0.73
Longe 1	-0.79	0.76	1.36	-0-05	0.77	0.77	-12.02	0.09	1.64	-5.03	-0.26	0.81
KWCA-SR	-0.79	0.02	1.17	-0.08	0.85	0.91	-2.94	0.02	1.69	-9.24	-0.01	0.91
Means	-1.74	0.28	1.28	-0.06	2.08	0.17	-9.81	0.04	1.87	-5.14	0.03	0.80
LSD (0.05)	-6.89	1.15	0.20	0.17	13.24	0.22	-8.48	0.13	0.88	NS	NS	0.40

1 Slope and intercept calculated using the linearised exponential model (Campbell and Madden,1990)
2 Slope and intercept calculated using the linearised logistic model (Campbell and Madden,1990)
3 F.sev = Final severity recorded 77 days after planting.
4 Data are means of three replicates.

Table 5. Slope (r), area under disease progress curve (AUDPC), final severity (Yf) of plant leaf area affected by turcicum leaf blight and yield of nine Ugandan maize varieties during the first season of 1993 at Kabanyolo.

Variety	r^d	AUDPC[a]	AUDPC[b]	Y_f^{ac}	Yield (t/ ha)
Longe 1	0.02	5.4	8.2	7.40	1.24
Babungo 3	0.10	4.5	6.6	7.50	1.38
KWCA-SR	0.11	5.2	9.1	9.32	1.34
Pop 42	0.10	3.5	4.3	4.6	1.20
Pop28	0.11	15.1	13.1	18.0	1.14
Pop29	0.08	5.2	6.7	10.9	1.20
Gusau	0.03	5.6	6.3	9.4	1.98

the lowest r values (Table 4). The initial amount of inoculum or intercept (Yo*) followed the same trend as the apparent rate of infection being higher on the hybrids that exhibited high disease progress than on those with low disease progress but not significant among genotypes. In general, the elite Ugandan varieties had lower disease levels and the resultant epidemiological parameters were thus lower than for the Pioneer hybrids (Table 4). The hybrid, PHB3253 was found most resistant and YIF64W most susceptible (Table 4).

The second study also experienced low disease levels during the first rains with final severity ratings ranging from 4.6% to 18% PLAA (Table 5). This probably accounted for the non-significant differences in final severity ($P \geq 0.05$) observed among the eight varieties studied. Highest disease levels were however, recorded on the susceptible check (Pop. 28) and the least on Babungo 3, a resistant check. The AUDPC values calculated from the weekly severity ratings followed a similar trend to the final severity ratings; and there was a high correlation between the two disease indices ($r = 0.95$; $P \leq 0.05$). Generally, apparent infection rate followed the same trend as AUDPC (Table 5). The wilt type lesions (Hilu and Hooker, 1963), low r and non significant Yo* values are indicative of rate-reducing resistance (Parlevliet, 1979) present in resistant elite Ugandan varieties. This corroborates earlier findings by Adipala *et al.* (1993a), who reported that Ugandan cultivars possessed polygenic resistance.

Linear regression of TLB final severity (percent leaf area blighted) on maize yield revealed a significant relationship (R^2 0.5, $P = 0.01$) between the two parameters during the wetter first season of 1993. Similar results were reported by earlier workers (Ullstrup and Miles, 1957; Bowen and Perdesen, 1972; Adipala *et al.*, 1993c). But, unlike in the earlier reported cases TLB accounted for up to 50% of observed variation in yield signifying its importance as a foliar maize pathogen.

Conclusion

These studies show that elite Ugandan varieties were more resistant than exotic Pioneer hybrids. However, the Pioneer hybrids were superior in grain yield and other desirable agronomic characteristics (data not shown). This would imply cautious release of introductions into new agro-ecologies particularly where some major diseases are endemic. These elite lines also showed multiple resistance to the three important foliar diseases studied, but a repeat of studies in particular for MSVD resistance is desirable.

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Screening tomato accessions for resistance to bacterial wilt

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Abstract

Eighty seven Makerere University tomato (*Lycopersicon esculentum* L.) accessions were screened for resistance to *Ralstonia solanacearum* under natural infestation. Most of the accessions showed susceptible reactions (>20%wilt), but accessions MT9, MT19, MT40, MT49, MT54, MT55, MT74, MT78, and MT98 showed resistant reaction (<10%wilt). Accessions MT2, MT65, MT69, MT70, MT80, and MT100 previously reported to be resistant to bacterial wilt proved susceptible to the disease. Additionally, latent infection was present in most of the selected resistant accession. Five isolates of *R. solanacearum* isolated from plants collected from different parts of Uganda were characterised by physiological tests. Based on Haywards classification scheme, all the isolates were biovar 3.

Key words: Biovar, host resistance, *Lycopersicon esculentum*, *Ralstonia solanacearum*, Uganda

Introduction

Bacterial wilt (BW) of tomato incited by *Ralstonia solanacearum (*syn. *Pseudomonas, Burkhoderia solanacearum)* is a devastating disease in many humid tropical regions with losses of up to 100% reported in Uganda (Opio, 1988). Since the bacterium is soil borne and resides in host plant xylem vessels, protective measures such as chemical control, soil fumigation and crop rotation have all proven ineffective for control. Planting resistant varieties has proven to be the simplest and most efficient method of BWdisease control. However, resistance to bacterial wilt in many varieties is not stable over locations presumably due to the existence of different races or biovars of the pathogen and variation in cultivar reactions in the backgound of different environments (Hanson *et al.*,1996).

We thus screened the tomato germplasm at the Makerere University Agricultural Research Institute, Kabanyolo (MUARIK) to identify accessions resistant to bacterial wilt. The presence of different biovars in Uganda was also investigated.

Materials and Methods

Field evaluation

During the second rains of 1997, bacterial wilt reactions of 87 accessions in the Makerere University Agricultural Research Institute Kabanyolo (MUARIK) gene bank were determined in a field known to be naturally infested with *R. solanacearum*. The experimental layout was a completely randomised block design (CRBD) with 3 replications. In each replicate plot, 10 plants were grown at a spacing of 60 cm within rows and 60 cm between rows. Prior to seedling transplant to the field, seedlings were raised in plastic sleeves containing steam sterilised soil and transplanted to the field 30 days after sowing. Rows of a susceptible cultivar Marglobe, were inter-planted with test lines to increase inoculum pressure and spread in the field.

Foliar fungal diseases were controlled with dithane M-45 at 7-day intervals until the end of the experiment. Resistance/susceptibility to BW was evaluated by weekly recordings of the incidence of wilted plants during the study period. Severity ratings were done using the scale developed by Rujput *et al.* (1994), i.e., highly susceptible (HS) 51-100%, susceptible (S) 21-50%, mildly resistant (MR) 11-20%, resistant (R) 1-10% and highly resistant (HR) <1% wilt.

Isolate collection

Five farms with bacterial wilt were purposely selected in the districts of Mbale Pallisa, Mpigi, Mbarara and Kabale in order obtain samples habouring *R. solanacearum*. From these farms, diseased tomato samples (2-3 whole plants per field) were collected and brought to the laboratory for isolation and identification of the wilt pathogen. Isolation of *R. solanacearum* was then done as described below.

R. solanacearum isolation

Stem sections (15-20mm) were cut from infected samples and placed in test tubes containing 15ml sterile distilled water (SDW). Bacteria were allowed to flow from the vascular bundles for 20 minutes. A loopful of the extracted bacterial suspension was then streaked on triphenyl tetrazolium chloride (TZC) plates (Kelman, 1954) and incubated for 48 hours at 30°C. Characteristic *R. solanacearum* colonies were selectively subcultured to ensure their purity. Thereafter, single colonies of the fluidal type grown on TZC, (selected and maintained cultures) were stored as suspensions in sterile distilled water in screw capped bottles at room temperature. Biovar identification was based on the ability of strains to oxidise cellobiose, lactose, maltose, dulcitol, mannitol, and sorbitol (French, *et al.*,1995).

Data analysis

Final percentage wilting (%wilt) and final percentage survival (survival%) were computed from the last evaluation of each trial. Weekly percentage wilting data were then used to compute the area under disease progress curve (AUDPC) following the procedure of J.F.Wang (personal comm). It should be noted that percentage wilt and percentage survival data were arcsin transformed in order to normalise variances before performing analysis of variance (ANOVA) (Steel *et al.*, 1997). Fisher's protected least significant difference test (LSD) was used to compare means of significant study parameters. All statistical computations were done using MSTATC statistical package (Freed *et al.*, 1988).

Results and Discussion

In plants exhibiting compatible reactions, symptoms of BW were characterised by epinasty followed immediately by irreversible wilting beginning at the flowering stage. Disease incidence varied significantly (P<0.01) among the genotypes. Most of the entries were susceptible, but MT9, MT19, MT40, MT49, MT54, MT55, MT74, MT78, and MT98 showed a high level of resistance (Wilt incidence <10%). Five ascessions rated as mildly resistant (11-20%wilt), included MT8, MT48, MT61, MT72 and MT93. The remaining accessions were either susceptible or highly susceptible. The survival percentage of the cultivars ranged from 3%(MT14) to 96.67% (MT 55, MT74, MT78 MT9, MT19).

MT2, MT11, MT86, MT63, MT65, MT66, MT69, MT70, MT71 MT24, MT95 and MT100 were

Table 1. Mean survival (%) of selected tomato entries screened for bacterial wilt resistance at Kabanyolo

MT No.[a]	Cultivar/ Accession	Source[b]	Comments[c]	Wilt incidence (%)	Survival(%)
78	LA 2711	UC Davis	Salinity resistance	0.0	96.7
55	HYB Flash	Asgrow		0.0	96.7
74	Sun Coast	Florida		0.0	96.7
9	Nalfpacls 1	OARDC		3.3	96.7
19	CVF13-3	AVRDC		3.3	96.7
98	NC 820	NCARS		6.7	93.3
49	NVH4773	NK		10.0	90.0
40	GS12	NK		10.0	90.0
54	HYB Sunny	Asgrow		10.0	90.0
61	Pacesetter490	Asgrow		13.3	86.7
93	Stephens(S.Africa)	NCARS	V,F1&2	16.7	83.3
86	Cra66	NCARS	(French) BW	20.0	80.0
24	Kewelo	AVRDC	BW	23.3	76.7
12	Pink Red	OARDC		23.3	76.7
79	LA2710	UC Davis	Aluminium tol.	26.7	73.3
150	-	-		26.7	73.3
53	HYB Sunny	Asgrow		26.7	73.3
84	LA2662(Saladette)	UC Davis	Heat tol.	30.0	70.0
39	RomaVF	OARDC	V,F1&ASC	30.0	70.0
20	Rodade	AVRDC	BW	30.0	70.0
6	Ohio 7814	OARDC		30.0	70.0
22	PI 162679	AVRDC		30.0	70.0
66	CLN657BC1F2-285-21	AVRDC	BW,Tmv,N	33.3	66.7
81	LA2661(cv.Nagcarlang)	UC Davis	Heat&cold tol.	33.3	66.7
8.	Mountian pride	OARDC	TMV, N	20.0	80.0
48	NVH	NK	-	13.33	86.67
72	CLN657BCIF2-267-0-1AVRDC	-	-	16.67	83.33
52	HYB Humaya	Asgrow		33.3	66.7
34	Ohio CR-6	OARDC	Tmv,Fcrr,F1&2,V	33.3	66.7
62	Pacesetter882	Asgrow		33.3	66.7
30	Mbarara wild red2 (Malaya)	Uganda		36.7	63.3
15	86W15	OARDC		36.7	63.3
25	Carl Mart	AVRDC		40.0	60.0
95	Hawaii 7998	NCARS	BW	40.0	60.0
17	SenatorF2	AVRDC	-	40.0	60.0
11	Venus	OARDC	BW	43.3	56.7
63	CLN657BC1F2-274-0	AVRDC	BW,Tmv,N	46.7	53.3
47	NVH 4771	NK		46.7	53.3
71	CLN657BC1F2-267-0-3	AVRDC	BW,Tmv,N	46.7	53.3
41	GS20	NK		53.3	46.7
56	HYB Centurion	Asgrow		53.3	46.7
16	Flora-Dade	OARDC		53.3	46.7
60	Hybrid 898	Asgrow		60.0	40.0
94	8642D	NCARS	V,F,Cherry	60.0	40.0
100	Hawaii 7997	NCARS	BW	63.3	36.7
23	Healani	OARDC		66.7	33.3
59	Hybrid 896	Asgrow		66.7	33.3
1	Heinz	Uganda	From USA	66.7	33.3
38	Roma	OARDC		70.0	30.0
69	CLN475BC1F2-265-12	OARDC	BW,Tmv,N	70.0	30.0
65	CLN657BC1F2-285-20	OARDC	BW,Tmv,N	70.0	30.0
82	LA1272(88L1740)	UC Davis		73.3	26.7

Table 1. Contd.

MT No.[a]	Cultivar/ Accession	Source[b]	Comments[c]	Wilt incidence (%)	Survival(%)
70	CLN466BC1F2-45-34-9	AVRDC	BW,TMV,N	76.7	23.3
42	GS20	NK		76.7	23.3
87	87294	NCARS	V,F1&2	80.0	20.0
27	Kasese Medium	Uganda		83.3	16.7
4	Campbell28	OARDC		86.7	13.3
29	Mbarara Wild Yellow (Malaya)		90.0	10.0	
14	Marion	OARDC	F1,ASC,ST	96.7	3.3
80	CLN475BC1F1-265-4	AVRDC	BW,TMV,N	-	3.3
Marglobe				36.7	63.33
2	Saturn	OARDC	BW	63.3	36.7
Mean				43.6	56.36
LSD(0.05)				40.9	40.87
CV%				43.3	34.14

[a] MT = Makerere tomato accession code

[b] AVRDC- Asian Vegetable Research Development Center, NCARS = North Carolina Agricultural Research Station; Asgrow seed company; OARDC = Ohio Agricultural and Research Development Center.

[c] F= Fusarium wilt resistance, TMV = Tobacco mosaic virus resistance, V = Verticilium wilt resistance, N = Nematode resistance BW = bacterial wilt resistance

originally reported as highly resistant to bacterial wilt in North Carolina and Taiwan (Grimault *et al.*, 1994) but proved susceptible at MUARIK with the exception of MT 24, MT86 and which showed mild resistance. This suggested a locational breakdown in resistance, probably due to the existence of a different biovar.

All virulent isolates produced fluidal colonies with pink or light red centres after 48 hours on TZC medium. Of the five isolates so far tested, all belonged to biovar 3. Four of the 5 strains tested were from the lowland areas of Uganda, and the fifth from the highlands.

Based on the preliminary results, MT41, MT74, MT55, MT54, MT19, MT9, MT78, MT15, MT93, MT95, MT59, MT49, MT50, and MT86 appear to have resistance to *R. solanacearum* in Uganda. Additional field experiments are under way to determine the stability of resistance. More isolates of *R. solanacearum* are also being collected from other locations and hosts in Uganda in order to establish biovar distribution.

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The effect of plant architecture of open-pollinated and hybrid varieties of maize on their attractiveness to ant predators of termites

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Abstract

A field experiment was conducted at Namulonge Agricultural and Animal Production Research Institute during the short rains in 1998 to assess the effect of maize plant architecture on the activity of some termite predators. Nine varieties consisting of four Uganda hybrids, one local cultivar (Ekwakoit) from Serere, eastern Uganda, one Kenyan open-pollinated variety (Katumani), a Ugandan line (LP 16), Kawanda composite and Longe-1 were used in the study. The activity of two ant species *Odontomachus haematoda* and *Lepisiota* sp. was significantly higher ($P \leq 0.05$) in varieties characterised by an erect leaf system than varieties with decumbent leaf arrangement. The activity of *O. haematoda* had a positive correlation ($r^2 = 0.72$; $P \leq 0.05$) at mid-day sampling and during late evening sampling ($r^2 = 0.83$). Maize stem base wetness was observed to be a result of stem flow of water (accumulated dew) from the erect leaf axils to the soil at the base of the plant. Results of the study indicate the potential of exploiting indigenous predators in combination with host plant characteristics in the management of termites and possibly other soil pests of maize.

Key words: Decumbent leaf arrangement, erect leaf system, *Lepisiota* Sp., *Odontomachus haematoda*, *Zea mays*

Introduction

Since the early 1950's, persistent organo-chlorine insecticides were used to effectively control termites in annual crops. Following the restriction or banning of these substances on environmental and human health grounds, new and less persistent insecticides (Wood *et al.*, 1987), formulations of non-persistent insecticides (Majer, 1986) and baiting techniques (El Bakri *et al.*, 1989) have been developed for the control of termites. These, however, have not been widely used by smallholder farmers in developing countries due to high costs and, in some cases, poor availability (Logan *et al.*, 1990). Thus, alternative strategies are needed for the management of termites in smallholder agriculture where they can cause significant crop losses.

Host plant resistance and biological control are widely seen as providing both stable insect control and less environmental damage on non-target organisms than chemical pest control (Howarth, 1991, Thomas and Waage, 1996). Although the role of predators in regulating natural populations of termites is largely unknown (Wood *et al.*, 1987) termites are reportedly prey to a wide range of vertebrates and invertebrates (Wood and Johnson, 1986). Recent research reviews clearly indicate the important role of ants as predators of these pests (Grace, 1997).

Ants have frequently been used as biological control agents in the past (Claunsen, 1940; De Bach, 1974). In Uganda, *Odontomachus haematoda* and *Paltothyrus* sp. for example, are commonly seen attacking, killing worker termites and carrying away the dead bodies (Okwakol, 1991). Ponerine ants are also known to raid termite nests, causing extensive worker mortality (Sudd, 1970). Nests of *Myrmicinae* and *Componotinae* often occupy large portions of dead mounds, suggesting their ability to exterminate termite colonies and colonising the mounds (Okwakol, 1991). However, little is known about the impact of ants on termites under field conditions or the effects of plant architecture on predatory activity of ants. Habitat modification in perennial crops has in a few instances, effectively reduced pest populations by favourable habitat conditions for predatory ants (Majer, 1982, 1986) In this study, we examine the effect of different maize plant architectures associated with open-pollinated and hybrid varieties on the physical environment beneath the plants and on the activity of predatory ants in vicinity of the plants.

Materials and Methods

The study was conducted at Namulonge Agricultural and Animal Production Research Institute (NAARI), Mpigi, Uganda. Previous observations from trials conducted in this region of the country have reported that ground foraging ants (Hymenoptera: Formicidae) are the most obvious insect predators in maize fields (Sekamatte, 1998 unpublish.). The experiment was established during the second cropping season of 1998, a period usually characterised by shorter rains than in the first season. The experimental plots were 13 m x 10 m, and maize was planted at a spacing of 75 cm between rows and 50 cm between plants within rows, to give a seedling density of approximately 53,000 plants per hectare. Plots were separated by 1.5 m wide alleys and weeds were managed by hand-hoe weeding. Weeding was done three times, at a monthly interval starting three weeks after seedling emergence. The treatments were arranged in a randomised complete block design with nine treatments (maize varieties) and three replicates. The 9 varieties consisted of four hybrid varieties developed by the Uganda National Cereals Programme (hybrids A-D), one local variety from eastern Uganda (Serere), one Kenyan open pollinated variety (Katumani), a line from Namulonge (LP16) and the open pollinated Kawanda composite and Longe-1.

Sampling for ants

Ants were sampled by visual observations on three middle rows of every plot. By inspecting every other hill in the 3 rows, a total of 50 plants were sampled per plot. Observations were performed on three occasions 4, 20 November and 3, December, 1999 (corresponding to 60, 75, 90 days after planting, respectively). The average maximum and minimum temperatures on the three data recording days were 27.9 and 16.0 °C, respectively. Also, observations were made at three intervals of each sampling day i.e. 6.00 - 7.00 hr, 11.00 - 12.00 hr and 17.00 - 18.00 hr. Because of the difficulty of counting the number of individual ants foraging or nesting at each hill, especially for the small species, a relative index of abundance was used where; < 5 ants = +, 6-10 = ++ and > 10 +++.

Moisture status of the soil at stem bases and degree of maize plant root exposure

It was casually observed during the previous cropping season that plants of the hybrid varieties collected dew during the night which later in the mid-morning dropped around the maize plant stem base, making the surrounding soil wet. Thus, during each sampling for ants, the moisture status (wet or dry) was recorded on each of the 50 sample plants per plot. For each of the 50 plants, the number of exposed root layers was also recorded. The proportion of plants with exposed roots was then expressed as a percentage and the frequency of occurrence of plants with a given number of root layers determined.

Termite damage to maize plants

All the sample plants in each replicate plot were examined for symptoms of termite damage. Damage on roots, stem base and leaves was recorded as a compound index (expressed as proportion of plants showing termite damage out of the sampled plants) for each treatment plot.

Statistical analysis

Data from the three sampling occasions were pooled to obtain seasonal means for the individual parameters. Statistical analysis for ant activity and moisture status of the soil around stem bases was done separately for each hour of sampling. The data for ant activity was arcsin transformed while that for soil moisture was square root transformed to normalise variances (Steel *et al.*, 1997). Analysis of variance (ANOVA) was performed and means separated by Tukey's honestly significant difference test (Steel *et al.*, 1997). A least squares regression analysis was also done to establish the relationship between ant activity and soil moisture at different hours of the day, root layers per plant, termite damage and percent plants with wet stem base.

Results

A description of the leaf system and variation in root exposure in the nine maize varieties used in the ant activity study is presented in Table 1. The erect leaf system is specific to the new hybrid varieties. Three of the hybrids (A,B & D) had a significantly higher ($P \leq 0.05$) number of exposed root layers than any of the other varieties (Figure 1). Hybrids B and D exhibited significantly more prop root layers than hybrids A and C. The open pollinated variety Katumani had significantly the lowest ($P \leq 0.001$) number of exposed root layers (Table 1).

Odontomachus haematoda and *Lepisiota* sp. were the dominant ants observed on maize plants during the growing season. Of the two species, however, *O. haematoda* showed greater activity in all the treatments, possibly because of its foraging behaviour. Ant activity in the early morning (6:00 – 7:00 h) was significantly lowest ($P < 0.05$) in Katumani plots (Table 2), a variety with the lowest root exposure (Table 1). Variety differences in respect to ant activity were more apparent, close to mid-day when temperatures rose above 25°C. At this time, significantly higher ($P < 0.05$) ant activity was

Table 1. Leaf architecture and degree of root exposure of the nine maize varieties used in the study

Treatment	Maturity days	Leaf system	% plants with exposed roots	Number of plants wth exposed root layers	Number of plants with wet stem bases
Longe - 1	118	decumbent	74.7a	0.89abc	0.71c
Serere	150	decumbent	83.1a	0.55bc	1.18bc
Katumani	95	decumbent	27.3b	0.03c	0.71c
LP 16	105	decumbent	87.3a	0.89abc	0.88bc
Kawanda	150	decumbent	67.3ab	0.90abc	0.71c
Hybrid A	125	erect	85.3a	1.15ab	2.59abc
Hybrid B	125	erect	95.3a	1 43a	3.53a
Hybrid C	125	erect	78.0a	0.15ab	2.67ab
Hybrid D	125	erect	86.7a	1.64a	2.67ab

Means within a column followed by the same letter(s) are not significantly different based on Tukey's test at $P < 0.05$.

recorded in plots with hybrid maize varieties (Table 2). The hybrids A, B and C characterised by an erect leaf system also showed a higher level of ant activity than the rest of the varieties, but the difference was only significant for hybrid B (Table 2).

No statistically significant differences among varieties were observed for *O. haematoda* activity during the evening sampling although their activity around hybrid varieties was always greater than that around open-pollinated varieties. *Lepisiota* sp. was most active during the evening in plots of hybrid A although this was not significantly different from 5 others (Table 2). The activity of this ant

Table 2. Mean percentage of maize plants with predatory ants in plots with different maize varieties in the early morning, mid-day and evening of 4th and 20th November and 3rd December 1998 at Namulonge.

Variety	Early morning		Mid - day		Late afternoon	
	Odont[2]	*Lepisiota.*	*Odont*[2]	*Lepisiota .*	*Odonto*[3].	*Lepisiota*
Longe-	112.75b	2.86a	11.08b	2.49a	15.19a	2.29abc
Serere	12.40b	3.04a	11.25b	1.44 a	12.19a	1.18c
Katumani	7.67b	3.21a	8.85b	2.58a	11.38a	2.46b
LP 16	23.67ab	2.97a	18.10ab	2.41a	14.03a	2.41abc
Kawanda	22.43ab	3.55a	18.73ab	2.21a	15.88a	3.68abc
Hybrid A	22.53ab	3.92a	30.57a	2.83a	16.63a	4.72a
Hybrid B	34.23a	3.06a	37.03a	4.12a	19.00a	4.19abc
Hybrid C	25.33ab	3.51a	33.97a	1.58a	10.70a	3.14abc
Hybrid D	21.93ab	3.16a	31.17a	3.28a	11.43a	4.70ab

[1]Means within a column followed by the same letter are not significantly different at $P \leq 0.05$, Tukey's honestly significant difference test. [2]*Odontomachus haematoda, Lepisiota* sp. [3] Pooled data for the recordings on 4, 20 November and 3 December.

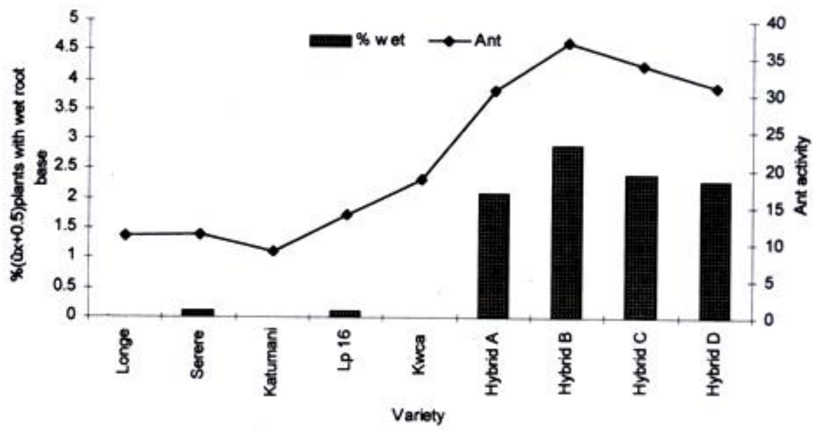

Figure 1. Effect of maize varieties on activities of O.haematoda and Lepisota ants in maize.

was greatest in the evening, possibly coinciding with the reduced activity of *O. haematoda* (Table 2).

There was no significant correlation between *Lepiosta* sp activity and the proportion of plants with wet soil at the stem base during the period from 6.00 to 7.00 h., between 11.00 and 12.00 h and between 17.00 and 18.00 hrs across all varieties. However, there was a significant positive correlation between activity of *O. haematoda* and the proportion of plants with wet soil at the stem base ($r^2 = 0.7205$, $P < 0.05$) (Figures 2 and 3).

Discussion

The results presented here are preliminary, as they cover observations of a single maize growing season, and will therefore require replication at different sites and season, and perhaps with more cultivars. Nonetheless, the results clearly indicate significant differences in the behaviour of predatory ants and termite infestation in phenotypically different maize varieties. The hybrid varieties in this study showed a significantly higher frequency of plants with exposed roots and a larger number of prop

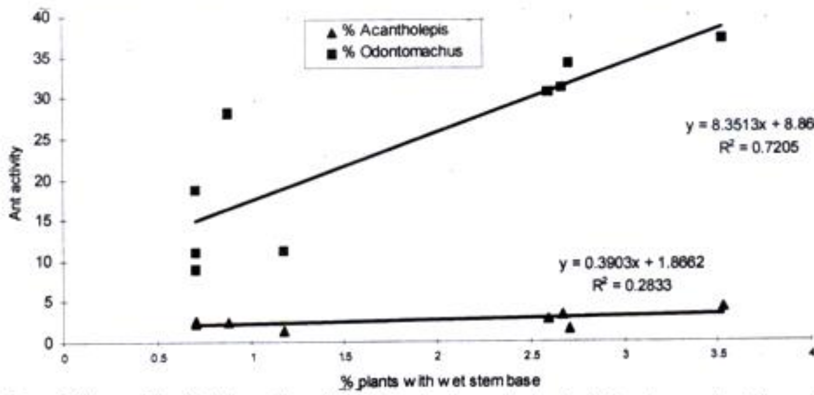

Figure 2. Linear relationship between the moisture status of soil around maize plants stem bases and predatory ant activity at mid-day.

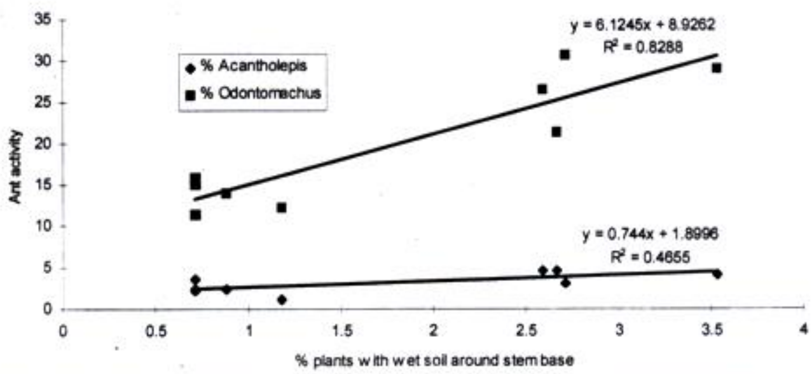

Figure 3. Linear relationship between the moisture status of soil around maize plants stem bases and predatory ant activity in the evening.

root layers as well as a more erect leaf architecture.

The latter feature appeared to result in greater amounts of stem flow of water from the leaf axils to the soil at the plant bases . These two features provide a generally more humid and shaded environment at the stem base of the hybrids as opposed to the open-pollinated maize varieties which we speculate is particularly favourable to the activity of the ant species studied. The strong positive relationship ($P< 0.01$, $r^2 = 0.72$) between plants with wet stem base at mid-day and ant activity (Figure 2) appears to be a result of the combined effects of the erect leaf system and well developed prop root system on ant activity. An even stronger relationship ($P< 0.01$, $r^2 = 0.83$) was obtained in late evening sampling (Figure 3). These features of hybrid varieties may be very important if the natural ant community is to be used as part of an integrated pest management programme. The use of ants as biological agents has a long history (Perfecto, 1990).

The preference for moist conditions for foraging by these species is revealed by the high level of activity observed immediately following rains (Sekamatte, pers. observation). Some evidence exists that plant architecture can influence dispersion of herbivores and searching by natural enemies (Thomas and Waage, 1996) but as yet, little is known about the effects of plant architecture on herbivore/natural enemy interactions (Price, 1986).

Although the importance of either ant species studied as predators of termites has not been quantified as yet, we have observed workers of both species attacking, killing and carrying workers of the three dominant genera of termites at Namulonge (*Pseudacanthotermes, Macrotermes* and *Microtermes*) on many occasions. It was particularly surprising that groups of the small *Acantholepis* sp. preyed on *Macrotermes* workers some several times their own body size. Individual *O. haematoda* were commonly seen carrying worker termites into large nests up to the time of harvesting. Ponerine ants are specialist termite predators but little work has been done on their effects on termite abundance in agro-ecosystems. However, the connection between ant abundance and reduced termite damage to maize was previously observed in a survey of farmers fields in 5 maize growing districts of Uganda where a strong negative correlation ($r^2 = - 0.57$; $P < 0.05$) between numbers of ant nests at the base of maize plants and termite damage to the plants was established across all sites (Sekamatte, 1998 un publ.). In eastern Uganda, ants appear to play an important role in reducing termite damage to maize. Ants have been used for hundreds of years in Yemen to control date palm pests (Claunsen, 1940), and in China to control citrus pests (Groff and Howard, 1924) and have been found to be effective biological control agents in temperate forests and perennial crops (Room, 1973; Majer, 1982). Studies in cotton (Jones and Sterling, 1979; Sterling *et. al.*, 1984; Fillman and Sterling, 1985) and in soybean (Whitcomb *et al.*, 1972) in the tropical and subtropical zones of USA emphasise the role of ants as natural control agents.

Other authors however, have cast doubts on whether ant species could be used in pest termite control (Grace, 1997). Indeed the use of ants alone may not offer satisfactory termite control to maize below an economic threshold. Their use however, in combination with other methods of biological and cultural control has potential for stable regulation of pest termites at a level below which would otherwise cause economic damage under conditions of smallholder maize producers in Uganda and probably elsewhere in sub-Saharan Africa. Preliminary studies on the use of proteinaceous and sugary baits to increase ant activity and thereby reduce termite damage to maize have given promising results in both on-station and on-farm trials (Sekamatte *et al.*, Unpublished).

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