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Relationships between Agronomic Practices, Soil Chemical Characteristics and *Striga* Reproduction in Dryland Areas of Tanzania

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Abstract: The parasitic weed *Striga* poses a serious threat to cereal production in sub-Saharan Africa. For many years, technological packages for the control of this weed were proposed and implemented on farmers' fields. A survey was carried out in farmers' fields in 2010/2011 cropping season in selected dryland areas of Tanzania to: (a) determine the *Striga* plant counts, number of capsules/*Striga* plant and agronomic practices used by farmers to control *Striga*; and (b) evaluate the relationship between *Striga* reproduction, soil chemical characteristics and agronomic practices. Soil samples at 0-20 cm depth were collected from 20 different farmers' fields. The soil samples were analyzed for pH, organic carbon, N, P and K. Results showed that there was low adoption of recommended *Striga* control methods. Regression analysis of agronomic practices and soil chemical characteristics revealed a positive improvement of soil N and organic carbon and reduction of soil P and K content as one shifted from sole planting to intercropping. The results showed that potassium was highly positively related to number of capsules/*Striga* plant. There was a reduction in the number of capsules/plant as one moved from sole planting to intercropping. Based on these findings, K in the *Striga* infested in soils positively influenced *Striga* reproduction and seed bank replenishment, hence high soil K levels may lead to high *Striga* incidence.

Key words: Parasitic weed, *Striga* reproduction, dryland, agronomic practices, soil P and K.

1. Introduction

Soil fertility is an immense constraint to cereal production in Africa [1, 2]. Apart from the direct negative effects of low soil fertility on agricultural production and food security, low soil fertility increases susceptibility of the crop to biotic pests. A major biotic pest in Africa is the parasitic plant of the genus *Striga* (*Scrophulariaceae*). Most important species of *Striga* are *Striga asiatica*, *S. hermonthica* and *Striga forbesii* which are mainly found on cereals such as maize, sorghum, pearl millet and rice [3].

An important factor in the *Striga* life cycle is the production of large numbers of minuscule seeds that cause rapid increase in parasite population density once the first infestation has occurred [4]. The seeds remain dormant until they are chemically triggered by the host plant to germinate [5]. The large number of parasitic seeds produced increases of the chances that some *Striga* seeds will find a suitable host. Every year some seeds germinate, some revert to dormancy while others are added from the new growth, continually enriching the seed reserve in the soil [6].

For many years, technological packages were proposed and implemented on farmers' fields by researchers under assistance from different research programs and *Striga* control projects [7]. Components of the package included hand-pulling of mature *Striga*

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plants, killing adult plants before flowering by application of herbicides, application of nitrogen fertilizer, using trap crops as intercrops or in rotation with crops that are not hosts to *Striga* and sowing *Striga* resistant crop varieties. Whether farmers have adopted these technological packages in Tanzania has not been established. Raju et al. [8] and Farina et al. [9] observed that application of potassium in the absence of N promoted the stimulant activity in the host and led to increased *Striga* incidence while the presence or absence of phosphorus did not have an effect on *Striga* seed germination and infestation. All these studies did not provide any insight on the influence of these nutrients on *Striga* seed production and consequently *Striga* infestation. Therefore, the current study was undertaken to determine the *Striga* infestation levels, agronomic practices adopted by farmers in *Striga* control and the relationship between agronomic practices, soil chemical characteristics and *Striga* reproduction.

2. Materials and Methods

2.1 Selection of Survey

A survey was carried out in farmers' fields in 2010/2011 cropping season at Melela and Mbande villages in Morogoro and Dodoma regions, respectively. In Morogoro, the study area was located at Mvomelo district in the North-Western part of Morogoro. The climate in Mvomelo district can generally be described as a sub-humid tropical type. The mean annual rainfall of the district varies from about 750 mm (Melela) to about 1050 mm (Pangawe) [10]. Most areas in the district experience bimodal rainfall pattern characterized by two rainfall peaks in a year with a definite dry season separating the short and long rains. The short rain season is from October to December while the long rain season starts from March and ends in May. The onset of both rains and their distribution are irregular and unreliable [11]. The mean annual air temperature for most places in the district is about 24 °C. The soil is a very deep black mbuga soil with a firm consistence and predominantly sandy clay topsoil [10].

In Dodoma, the study was conducted at Mbande which is situated in Kongwa district. Kongwa district is characterized by a long dry season occurring between late April and early December. The average rainfall ranges from 570 to 700 mm and about 85% of it falls between December and April [12]. Apart from the rainfall being relatively low, it is rather unpredictable in frequency and amount. Generally, the average maximum temperature in the area is 31 °C. The predominant soil type of the area can be described as thin stony soils with predominantly sand or sandy clay [13].

2.2 Surveys and Data Collection

2.2.1 Sampling Procedure

Stratified random sampling procedure was used to collect the data. The goal of stratified sampling was to achieve desired representation from the different subgroups in the population [14]. The method involves dividing the population into two subpopulations using given criteria, and then a simple random sample is taken from each subpopulation. The study area was divided into two strata based on regions, namely, Mbande-Dodoma and Melela-Morogoro. The two strata were considered to have distinct agricultural practices and climatic conditions.

2.3 Striga Intensity and Reproduction

In each site a total of 10 fields were randomly selected and visited. Emerged *Striga* plants were counted from each field as described by Kim [15]. In infested fields, a quadrant of 1 m^2 was randomly thrown three times and the number of emerged *Striga* plants was physically counted to determine the above ground *Striga* incidence. The extent and intensity of *Striga* infestation was assessed as described by MacOpiyo et al. [7]. *Striga* intensity was defined in five categories ranging from low to severe. Each category was assigned a specific range of *Striga* plant density. Low infestation was defined as having between 1 and 4 *Striga* plants per m^2, medium had between 4 and 9 plants per m^2, and severe infestation had more than 9 *Striga* plants per m^2. *Striga* reproduction was also determined by sampling 10 mature but unopened, green seed capsules from five randomly selected *Striga* plants in each field. These seed capsules were air dried and weighed. The total weight was adjusted by 10% as a correction factor for unremovable trash. The average weight per capsule was divided by 5×10^{-6} [16] to get an estimate of the seed production per capsule. The number of capsules per plant was counted for estimation of seed production per plant.

2.4 Soil Analysis

Soil samples were collected from different fields at 0-20 cm depth, taken to the soil laboratory and analyzed for physical (soil moisture) and chemical components (Organic carbon, N, P, K and pH). The fresh weight of the soil and the weight of oven dried soil were recorded. Then soil moisture content was estimated as follows:

$$\text{(i) PW (\%)} = \frac{\text{WS1 - WS2}}{\text{WS2}} \times 100$$

Where:
PW = moisture percentage of dry weight basis;
WS1 = weight of fresh wet soil (g);
WS2 = weight of oven dried soil (g).

Total nitrogen was determined by the Kjeldahl digestion and distillation procedure as described in soil laboratory procedures [17]. Soil organic carbon was determined by the modified Walkley-Black method as described by Nelson and Sommers [18] and soil pH was measured in a 1:1 soil-water ratio by using a glass electrode pH meter. Available phosphorus (P) was determined by the Bray 1 method [19]. Exchangeable bases K^{2+} displaced by ammonium acetate extracts were determined by atomic adsorption spectrophotometer [20].

2.5 Data Analyses

The questionnaires for the field surveys and observations were manually coded and analyzed by using the Statistical Package for Social Sciences (SPSS version 15). The regression analysis between agronomic practices, soil characteristics and number of capsules was done by using SPSS. The xlSTATA software was used for regression analysis between *Striga* counts, number of capsules and soil properties. Principal component analysis was performed on soil properties before a regression to be able to limit the number of variables measured afterwards.

An Ordinary Least Squares (OLS) regression technique was used to determine the relationship between agronomic practices, soil chemical characteristics and the number of capsules/plant. In order to eliminate multicollinearity, a correlation analysis was conducted to identify variables, which were significantly correlated (correlation coefficient, r ≥ 0.5) prior to performing a multiple linear regression. A general equation for a multiple linear regression (OLS) given *k* variables (a regress and (*k*-1) regressors) is specified as below [21].

$$\text{(ii)}\; Y_i = \beta_1 + \beta_2 X_{1i} + \beta_3 X_{2i} + \ldots + \beta_k X_{ki} + \mu_i.$$

Where Y is the dependent variable, $X_1 \ldots X_k$ is a set of explanatory variables, i denotes i^{th} household, μ is the error or disturbance term associated with the model, and $\beta_1 \ldots \beta_k$ are coefficients representing parameters estimators of the variables in the model.

A series of multiple regressions were conducted by using agronomic practices, number of capsules/plant and soil chemical characteristics as the regress until the best fits of the model were attained. The criteria for determining the variables that best defined the estimated model (goodness of fit) was based on the coefficient of determination (R^2); adjusted R^2, F statistic, significance of explanatory variable (t-value), the sign or direction of influence of the independent variables, and the number of significant explanatory variables in the model.

3. Results and Discussion

3.1 Striga Control Options

The majority of the farmers at Mbande (73.3%) and

Melela (78.6%) said they were not using any method to control *Striga* in their fields. Amongst *Striga* control options, hand-pulling, deep tillage and crop rotation were mentioned by the farmers during the surveys (Table 1).

The mean values for number of *Striga* plant counts, capsules/plant and fecundity were not significantly different between the two sites (Table 2).

The mean number of *Striga* plants per m^2 ranged from 14.30 (Mbande) to 24.6 (Melela) while the number of capsules/plant ranged from 67.40 (Mbande) to 89.10 (Melela). The fecundity values were 36,308 and 45,729 seeds/plant at Mbande and Melela, respectively. *Striga* infestation in the farmers' fields was extremely high as MacOpiyo et al. said [7] who categorized infestation levels as low (1 to 4 *Striga* plants per m^2), medium (4 to 9 plants per m^2) and severe (> 9 *Striga* plants per m^2). The number of *Striga* plants per m^2 in farmers' fields varied from 14.3 in Mbande to 24.6 in Melela. These field observations confirm the perception of an increasing *Striga* infestation trend as reported by several studies [22, 23].

3.2 Soil Chemical Characteristics and Agronomic Practices in the 20 Sampled Fields at Mbande and Melela

Majority of farmers at Mbande (86.7%) and Melela (100%) were not using fertilizers. Sole planting of sorghum was practiced by 73.3% and 76.7% of the farmers at Mbande and Melela, respectively (Tables 3 and 4).

The soil pH was not significantly ($P \leq 0.05$) different across the study areas. The means for soil moisture, nitrogen and phosphorus were significantly higher at Melela than at Mbande. The level of organic carbon and potassium were not significantly different between Mbande and Melela sites (Table 5).

The results revealed that the soils of the surveyed fields were poor in nitrogen and organic carbon content. This may be attributed to the type of cropping practices that are used by farmers. Sorghum production systems based on monoculture with long-term limited use of fertilizers have led to low soil fertility which is not only generating the *Striga* problem, but also an immense constraint to cereal

Table 1 Control measures used by farmers (% respondents).

Control	Mbande	Melela	Mean
Crop rotation	10.0	3.6	6.9
Hand-pulling	10.0	7.1	8.6
Deep tillage	6.7	10.7	8.6
None	73.3	78.6	75.9
Total	100	100	100

Striga plant counts/m^2, number of capsules/plant and fecundity.

Table 2 Striga counts/m^2, capsules/plant and fecundity.

	Striga counts/m^2	Number of capsules/plant	Fecundity
Mbande	14.30	67.40	36308
Melela	24.60	89.10	45729
Mean	19.50	78.20	41018
LSD	NS	NS	NS

Table 3 Fertilizer inputs used (% respondents).

Input	Mbande	Melela	Mean
None	86.7	100	93.3
Farmyard manure	13.3	0	6.7
Total	100	100	100

Table 4 Cropping system practiced (% respondents).

System	Mbande	Melela	Mean
Intercropping	26.7	23.3	25
Sole planting	73.3	76.7	75
Total	100	100	100

Table 5 Mean values of soil physical-chemical properties of the study sites.

	pH	MC (%)	Nutrient compositions			
			OC (%)	N (%)	P (mg/kg)	K (mg/kg)
Mbande	5.96	11.01	0.59	0.06	6.60	0.85
Melela	6.14	12.33	0.61	0.09	16.00	1.07
Mean	6.05	11.67	0.60	0.07	11.30	0.96
LSD ($P \leq 0.05$)	NS	1.33	NS	0.02	4.69	NS

MC = moisture content.

production in Tanzania. It has been reported that soil nutrient depletion in African cropping systems has expanded rapidly due to land use intensification and the lack of use of mineral and organic fertilizer inputs [1, 2].

3.3 Interaction Effect of Agronomic Practices on Soil Chemical Properties and Number of Capsules/Plant

The regression analysis of agronomic practices on soil chemical properties and *Striga* reproduction across the study areas is presented in Table 6.

Regression analysis of agronomic practices and soil chemical characteristics revealed a positive and significant improvement of soil N and OC as one shifted from sole planting to intercropping (Table 6). There was negative and significant effect on P and K as one moved from sole planting to intercropping. Similarly, there was negative and significant effect on the number of capsules/plant as one moved from sole planting to intercropping and positive effect as one shifted from intercropping to sole planting.

The reduction in the number of *Striga* capsules per plant as one moved from sole planting to intercropping could be due to improvement in soil N and OC, reduction in K and P and increased shading effect on *Striga*. Tenebe and Kamara [24] observed that *Striga* dry matter and the number of emerged *Striga* plants were significantly reduced when sorghum was intercropped with groundnut varieties. Similarly, Singh [25] and Singh and Emechebe [26] achieved greater *Striga* suppression when cowpea was planted closer to sorghum. The reduction in soil K and P when one moved from sole planting to intercropping could be due to increased competition for nutrients between the crops.

3.4 Interaction Effect of Soil Chemical Characteristics on Striga Counts and Capsules/Plants

Principal component analysis on *Striga* counts and capsules/plant led to selection of total nitrogen, phosphorus and potassium that contribute to much of the commulative variability of *Striga* counts and number of capsules/plant (Fig. 1).

The regression analysis showed that phosphorus × potassium and phosphorus × nitrogen × potassium interactions contributed significantly ($P \leq 0.05$) to the explanation of variation in *Striga* counts as reflected in their high standardized coefficients (Fig. 2).

The regression model showed that when other factors are held constant, *Striga* numbers increase by 3.47 if interaction of phosphorus and potassium increases by 1 unit. One unit increase in potassium, nitrogen and phosphorus with other factors held constant reduced *Striga* numbers by 32.54 units.

The regression analysis showed that the interactions of potassium by *Striga* counts, phosphorus by *Striga* counts contributed significantly ($P \leq 0.05$) to the explanation of variation in the number of capsules/plant

Table 6 Interaction effect of cropping systems on soil chemical characteristics and Striga reproduction across the study areas

Soil chemical characteristics		R^2	*Striga* reproduction		R^2
Explanatory term	Estimates		Explanatory term	Estimates	
Cropping system			Constant	-109.49**	
Constant	0.191 NS		Cropping system	-36.181*	0.43
N (%)	12.155*	0.67	Inputs used	56.715*	
OC (%)	1.679**				
P (mg/kg)	-0.029*				
K (mg/kg)	-0.574*				

*Regression is significant at the $P \leq 0.05$ level; **Regression is significant at the $P \leq 0.1$ level.

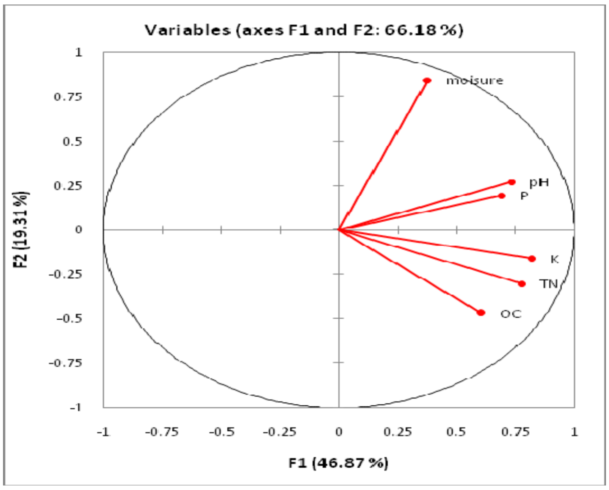

Fig. 1 Discriminate analysis ordination graph showing contribution of soil chemical characteristics to *Striga* counts and number of capsules/plant.

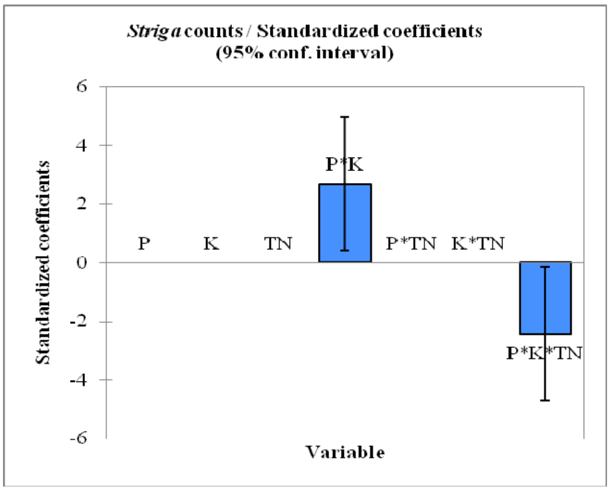

Fig. 2 Coefficients for regression model: Striga counts = 11.14 + 3.47*P*K – 32.54*P*K*TN (R^2 = 0.30).

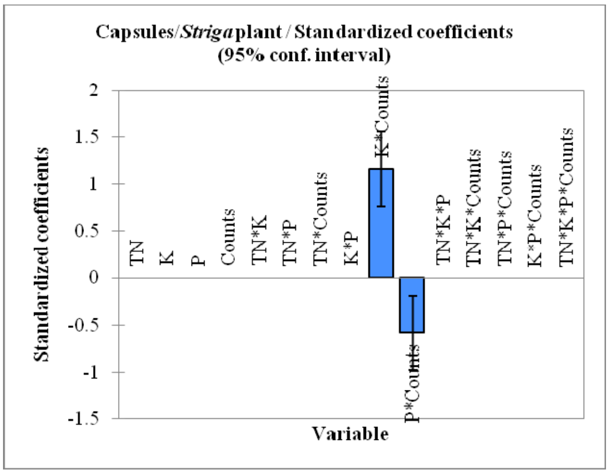

Fig. 3 Coefficients for regression model: Number of capsules/plant = 38.81 + 2.98*K*Counts – 7.16E – 02*P*Counts (R^2 = 0.71).

as reflected in their high standardized coefficients (Fig. 3).

The analysis revealed that when other factors are kept constant, capsules per plant increase by 2.98 if interaction of counts by potassium increases by 1 unit. Similarly, the interaction between *Striga* counts and P content reduced the number of capsules/plant when other factors are kept constant. The higher numbers of *Striga* and capsules/plant observed in farmers' fields could be due to the high soil K content. Potassium was positively associated to the *Striga* counts and the number of capsules/plant. Since N level was very low, K could have enhanced stimulant activity and increased the maximum number of emerged *Striga* plants and number of *Striga* capsules/plant. Raju et al. [8] and Farina et al. [9] observed that the application of potassium in the absence of N promoted stimulant activity in the host, leading to increased *Striga* incidence whereas the presence of phosphorus did not have an effect on *Striga* seed germination and infestation. The regression model showed that the interaction of phosphorus and potassium increased

Striga counts while the interaction of phosphorus and *Striga* plants reduced the number of *Striga* capsules/plant. The mechanism by which phosphorus reduces *Striga* reproduction has not been established.

4. Conclusions

Striga infestation levels in the study areas were invariably severe. There is low adoption of recommended Striga control methods such as hand-pulling and intercropping. The use of resistant varieties is not practiced at all while few farmers use fertilizer inputs. Moderate to high K levels in the *Striga* infested soils coupled with low N may enhance *Striga* reproduction and seed bank replenishment, hence lead to increased *Striga* infestation in sorghum fields.

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