Advances in Physics Theories and Applications
ISSN 2224-719X (Paper) ISSN 2225-0638 (Online)
Vol.53, 2016

Association of Striga Infestation to Basic Chemical and Physical Properties of the Soil in Tigray Region, Northern Ethiopia

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Abstract
A survey was conducted in 2014 to determine the association of striga with major chemical and physical properties of the soil. Similarly, strong association was observed between striga infestation and soil pH ($r(22)=-0.213$, $P<0.05$), available phosphorous ($r(22) =-0.408$, $P<0.05$), percent organic matter ($r(22) =-0.917$, $P<0.05$), total nitrogen ($r(22)=-0.097$, $P>0.05$) and soil texture . The influence of soil organic matter on level of striga infestation was observed superior (84%) to other soil chemical and physical properties. In conclusion, the highest level of striga infestation was recorded at kebeles which had got low soil organic matter and available phosphorous and sandy textured soils. Therefore management practices channeled towards improving these limitations have been suggested for controlling of Striga hermonthica in the region.
Keywords: striga infestation, sorghum population, soil properties, correlation, Tigray region

1. INTRODUCTION

Sorghum is dominant crop in Tigray (Northern Ethiopia). The average annual coverage of sorghum in the region is 255,000 ha (Shapiro and Wortmann, 2006). However the overall productivity is low (2.106 t/ha) compared to average production of developed countries (2.3 t/ha) (CSA, 2013). The low productivity of sorghum is attributed to infestation of parasitic weed mainly to *Striga hermonthica* (Del.) Benth (*Gebreyesus Brhane et al.,* ***2011).***

The genus striga comprises about 50-60 species (Taye, 2013). Among these striga species purple witch weed (*Striga hermonthica* (Del.) Benth.) and Asiatic witch weed (*Striga asiatica* (L) Kuntze) are the most economically important to production of sorghum in the world. Likewise *S. hermonthica* is the most damaging parasitic weed in the study area. Therefore *S. hermonthica* has been studied in this survey and will henceforth be referred to as striga.

The level of striga infestation is strongly correlated with decline of soil fertility (Samaké *et al*., 2005; Parker**,** 2008). Striga control or management does not have impact on cereal yield if soil fertility management is neglected (Ayongwa, 2011). The author also stated that a good supply of nitrogen to the soils leads to a reduction of striga germination. Different types of nitrogen fertilization suppress striga either by inhibition or stimulation of striga germination. The findings of Cardoso and his colleagues (Cardoso *et al*., 2010) indicated that direct application of phosphorous decreases the exudation of strigolactone and therefore reduces striga germination and also infestation of the weed.

Ayongwa (2011) demonstrated reduced germination and survival of striga with increasing application of the important source of soil organic matter such as farm yard manures (FYM). Thus, as the amount of soil organic matter increases striga infestation declines significantly. The local availability of organic manures promotes the use of both fertilizers so as to improve, not only soil properties, but also to increase crop yields and reduce the occurrence of striga. It has been reported that higher benefits are obtained by overall improvement of the soil physical, chemical and biological properties through recycling of organic materials, and increase in the availability of plant nutrients (Sanginga and Woomer, 2009).

Striga seed bank was significantly associated with soil pH. The optimal soil pH for good fertility of the soil is about 6.0-6.8 (Eriksson *et al*., 2005). The highest amount of striga seeds was also registered at pH range 6.2-6.3.This could imply that striga prefers the same pH as considered to be optimal for having good soil fertility i.e. when most necessarily plant nutrients are available (Larsson, 2012).

The association of striga infestation with soil texture is the function of moisture retention, nutrient holding capacity of the soil and rate of organic matter decomposition of the soils. The process of organic matter and nitrogen decomposition is significantly higher at sandy textured soils (Hassink *et al*., 1993). Soil texture indirectly affects striga infestation through physical restrictions on activity of microorganisms that determine the process of mineralization especially mineralization of organic matter and total soil nitrogen (van and Kuikman, 1990).

The annual yield loss and geographic distribution of *S. hermonthica* is steadily increasing, particularly in Sub-Saharan Africa. Most of the available research findings show that the average yield loss of sorghum due to striga exceeds 50% and in severe cases complete crop failure can occur (Abunyewa and Padi, 2003).

S. hermonthica is a major biotic constraint to production of sorghum in Tigray region. In addition the region is characterized by poor distribution and intensity of rain fall, poor fertility and structure of the soil (Tewodros *et al*., 2009). However, little or no research reports available that indicate association of *the weed* with soil physical and chemical properties in the study areas of the region. Therefore this study has been designed to assess the association of *S.hermonthica* infestation with basic soil chemical and physical properties.

2. MATERIALS AND METHODS

The research survey was conducted in 2014 in Tigray regional state located in the northern part of Ethiopia. Geographically, the region lies between 12º15'N and 14º57'N latitudes and 36º27'E and 39º59'E longitudes. It is bordered in the north by Eritrea, in the south by Amhara Region, in the East by Afar and in the west by Sudan (Ayenew Admasu, *et al*., 2011).

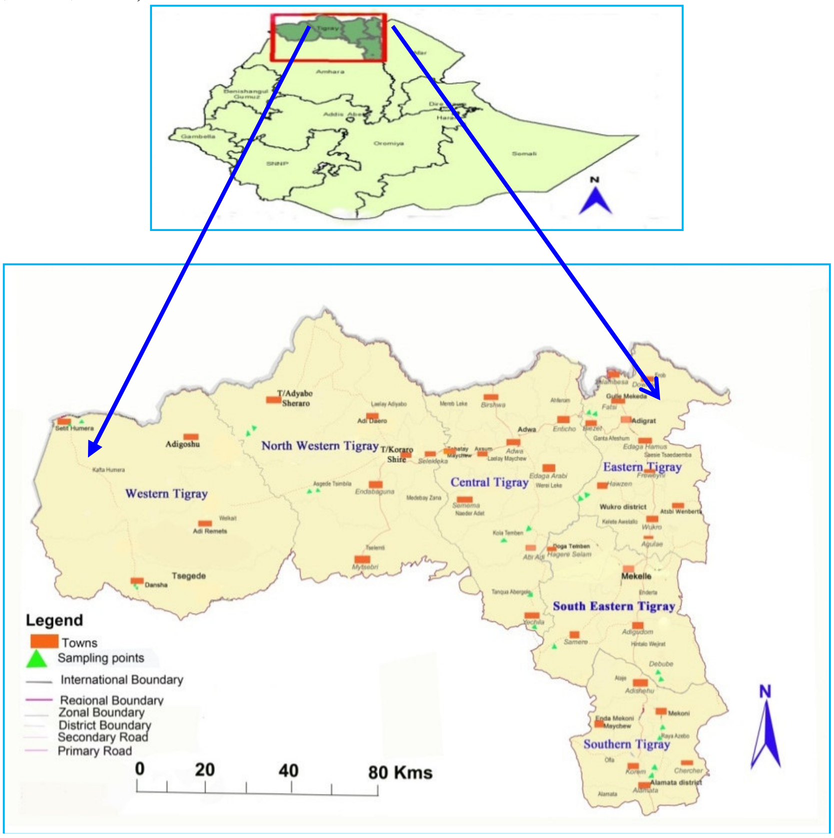

Figure 1: Map of the study area with survey routes

A total of six administrative zones and 12 main sorghum growing Woredas were selected from the whole of Tigray in consultation with Tigray Bureau of Agriculture and Rural Development experts. Two woredas and Kebeles were selected purposively from each zone and woredas respectively. Thus, a total of five sorghum growing fields were selected from each kebele using systematic random sampling method. Based on the suggestions of ILCA, (1990) an initial visit or informal survey was made before the commencement of the actual /formal research survey.

A total of 120 sampling fields were included in sampling of *S. hermonthica* throughout the study area. Accordingly field history like field management practices, preceding crops, and the type of variety that farmers grow was assessed by interviewing famers. Based on report of the field history the actual survey was conducted in fields sown by local cultivars of sorghum for at least three years and fields with no management practices for the last few years.

The actual survey was conducted when *S. hermonthica* was to an extent of full growth stage i.e. mid September to the end of October 2014. Sampling was made following community made gravel or asphalt roads. Road transect survey method was employed for sampling of striga and sorghum between farms within Kebele (Wittenberg *et al.,* 2004). Hence, two inverted 'M' patterned 50 meter long transects, on average one kilometer apart from each other was established by systematic random sampling method. Finally, 10 evenly spaced sampling points per field (1 m^2 each) were established. Accordingly a total of 1200 sampling points from 120 sampling areas were delineated and finally striga and sorghum count was made.

Soil sampling was done manually using an auger from a depth of 15 cm. Five sub samples were prepared from a total of 50 sampling points and 5 sorghum growing farms at each Kebelie. The sub samples were thoroughly mixed to have a representative composite sample of the fields of the study site. Eventually 24 composite samples were prepared from a total of 24 Kebeles. Finally, the samples were air-dried, crushed and analyzed based on standard procedures of soil laboratory analysis for determination of soil reaction (pH), organic matter content, total nitrogen, available phosphorous and texture (Olsen and Sommers, 1982; Bremner and Mulvaney, 1982; Van Reeuwijk, 1992; Houba *et al*., 1989; Kettler *et al*., 2001). Hence the soil laboratory analysis result for basic chemical and physical properties of the kebeles is presented in table (1) and Table (2).

Table 1: The laboratory analysis result on basic chemical properties of the soils of the study areas

Woreda	kebele	Basic chemical properties of the soil			
		pH	% Organic matter	% Total Nitrogen	Available phosphorous
S/Samre	N/Hadinet	7.16	0.89	0.08	6.34
	Hadas Lemlem	6.33	0.90	0.04	2.8
T/Abergelle	Hadinet	6.42	0.58	0.04	2.12
	Giera	7.33	0.90	0.11	2.8
K/Tembien	Mitsa Werki	6.08	1.23	0.11	3.16
	Dabano	7.53	0.79	0.05	3.02
W/Tsegedie	Selam	6.41	0.99	0.05	1.88
	Z/Dansha	6.36	1.01	0.05	2.04
K/Humera	Adabay	7.87	1.03	0.05	1.82
	Rawyan	7.49	2.61	0.04	3.62
T/Adyabo	Adiaser	6.01	1.90	0.05	2.94
	Mentebteb	7.09	2.40	0.06	2.42
A/Tsimbilla	E-Hibret	6.02	1.02	0.05	1.88
	May Shek	5.58	2.08	0.05	2.12
Hawzien	May Gobo	6.79	1.84	0.04	2.18
	Koraro	6.73	2.04	0.06	1.74
G/Afoshum	Simret	6.52	1.96	0.10	3.4
	Wuhdet	6.53	2.05	0.04	4
Raya Azebo	Genetie	7.41	4.20	0.04	7.84
	K/Adishabo	7.21	3.06	0.12	8.16
G/Raya Alemata	Gergellie	7.47	3.32	0.14	8.52
	K/Lemlem	7.31	1.45	0.07	7.62
Hintallo Wajirat	Tsehafti	7.12	2.06	0.07	3.54
	Adi Keyh	7.82	2.26	0.09	12.08

ISSN 2224-719X (Paper) ISSN 2225-0638 (Online)
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Table 2: The laboratory analysis result on basic physical properties of the soil of the study areas

Woreda	Kebele	Relative proportion of soil particles			
		%Sand	%Silt	%Clay	Textural class
S/Samre	N/Hadinet	61	15	24	Sandy clay loam
	Hadas Lemlem	61	9	30	Sandy clay loam
T/Abergelle	Hadinet	73	1	26	Sandy clay loam
	Giera	61	15	24	Sandy clay loam
K/Tembien	Mitsa Werki	51	27	22	Sandy clay loam
	Dabano	57	21	22	Sandy clay loam
W/Tsegedie	Selam	47	27	26	Sandy clay loam
	Z/Dansha	41	37	22	Loam
K/Humera	Adabay	17	19	64	clay
	Rawyan	29	13	58	clay
T/Adyabo	Adiaser	47	31	22	Loam
	Mentebteb	11	13	76	clay
A/Tsimbilla	E/Hibret	59	17	24	Sandy clay loam
	May Shek	59	21	20	Sandy Loam
Hawzien	May Gobo	21	9	70	clay
	Koraro	51	17	32	Sandy clay loam
G/Afoshum	Simret	63	15	22	Sandy clay loam
	Wuhdet	67	15	18	Sandy Loam
Raya Azebo	Genetie	15	29	56	clay
	K/Adishabo	27	31	42	clay
G/Raya Alemata	Gergellie	27	31	42	clay
	K/Lemlem	61	11	28	Sandy clay loam
Hintallo Wajirat	Tsehafti	59	19	22	Sandy clay loam
	Adi Keyh	45	25	30	Sandy clay loam

The mean striga and sorghum count per total sampling points (10 m^2) per sampled field was summarized, thus prevalence of striga and sorghum per kebele was determined on average bases. Finally the correlation of striga infestation with population density of sorghum, basic chemical and physical properties of the soil was analyzed using SPSS version 20 software.

Table 3: Mean striga shoot (No/m2) in different locations of Tigray Region (N=120)

Locations (Kebeles)	N	Mean striga shoot (no/m^2)	Mean Rank
Nebar Hadinet	5	351	3
H/ Lemlem	5	278	5
Hadinet	5	400	1
Giera	5	299	4
M/Werki	5	219	10
Dabano	5	391	2
Selam	5	268	6
Z/Dansha	5	261	7
Adabay	5	221	9
Rawyan	5	81	21
Adiaser	5	155	13
Mentebteb	5	82	20
E-Hibret	5	252	8
May Shek	5	110	18
Mygobo	5	191	12
Koraro	5	145	15
Simret	5	152	14
Wuhdet	5	134	16
Genetie	5	33	24
K/Adishabo	5	59	22
Gergellie	5	54	23
K/ Lemlem	5	209	11
Tsehafti	5	129	17
Adi Keyh	5	85	19
Total	120	190	

3. RESULTS AND DISCUSSIONS

3.1. Association of Striga Infestation and Population Density of Sorghum

The correlation analysis result (Table 3) showed strong association between striga infestation and the population density of sorghum. The level of striga infestation was significantly and positively correlated (r (118) =0.537, P< 0.05) with population density of sorghum. This finding is in line with that of Esilaba *et al*. (2000) who stated that the emergence of striga is positively associated with the extensive roots systems of sorghum and the results increased the root surface area. Conversely results (Table 4) also indicated that there was no significant (P>0.05) association between the infestation level of striga shoots per plants of sorghum and number of sorghum per m^2.

If density of sorghum per m^2 increases beyond the required level, the plants tend to compete for resources which fall below the combined demand of the population. Sorghum responds to deficiency of nutrient and other stress through the release of chemical signals or germination stimulant hormones (strigolactone) to the rhizosphere. Consequently the chemical signal provides optimum condition for germination and subsequent growth of striga and enhances arbisicular mycorrhizal symbiotic association of the roots of sorghum (Gomez *et al*., 2008).

Table 4: Association of striga infestation with sorghum population per m^2

		sorghum per m^2	Mean	Std. Deviation
Spearman's rho	Striga per m^2	.537**	189.9367	106.46939
	sorghum per m^2	-	15.8725	6.66922

*= Correlation is significant at the 0.05 level (2-tailed) **=Correlation is significant at the 0.01 level (2-tailed)
List wise N = 24

Table 5: correlation of striga per plants of sorghum and sorghum per m^2

Model	Variable	Sorghum per m^2	Mean	Std. Deviation
Spearman's rho	Striga per plants of sorghum	.054	13.2958	8.18331
	Sorghum per m^2	-	15.8725	6.66922

*= Correlation is significant at the 0.05 level (2-tailed) **=Correlation is significant at the 0.01 level (2-tailed)
List wise N = 24

Table 6: Mean density of sorghum (No/m2) in different locations of Tigray Region (N=120)

Locations (Kebeles)	N	Mean sorghum plant stand per m^2(No/m2)	Mean Rank
Nebar Hadinet	5	14	14
Hadas Lemlem	5	24.6	3
Hadinet	5	26	2
Giera	5	19.2	6
M/Werki	5	35.6	1
Dabano	5	23.6	4
Selam	5	15.4	12
Z/Dansha	5	10.8	20
Adabay	5	18.2	7
Rawyan	5	16	10
Adiaser	5	15.6	11
Mentebteb	5	19.2	5
E-Hibret	5	17.2	9
May Shek	5	17.8	8
Mygobo	5	13.6	15
Koraro	5	13.6	17
Simret	5	14	13
Wuhdet	5	13.6	16
Genetie	5	8.8	21.5
K/Adishabo	5	8.8	21.5
Gergellie	5	7.2	23
K/Lemlem	5	6	24
Tsehafti	5	11.2	18
Adi Keyh	5	11	19
Total	120	15.875	14

3.2. Association of Striga Infestation and Basic Chemical properties of Soil

The correlation of soil reaction (pH) and average level of striga infestation revealed that soil pH was strongly and negatively correlated ($r(22)=-0.213$, $P<0.05$) to striga infestation. Accordingly as soil pH increases the average level of striga infestation significantly decreases. The soil laboratory analysis result (Table 1) revealed that the value of soil pH recorded at Hadinet was slightly acidic (6.42) whereas moderately alkaline (7.41) at Genetie. This suggests the highest level of striga infestation prefers the same pH considered to be optimal for most crop growths. This is in line with findings of Larsson, (2012) who stated that the highest level of striga seeds was observed at soil pH of 6.2-6.3 and this is considered optimal condition for having good soil fertility.

The results of the survey showed that the level of striga infestation was strongly and negatively associated ($r(22) =-0.917$, $P<0.05$) to soil organic matter content (Table 6). The amount variance in striga infestation explained by percent of soil organic matter was accounted for 84%. Whereas the variance explained by soil pH and available soil phosphorous was 4.5% and 16.65% respectively. This depicted that the influence of organic matter on Striga infestation was much important compared to the influence of soil pH and available soil phosphorous. Farms which have got relatively higher soil organic matter content were likely to have lower level of striga infestation. The soil laboratory analysis result (Table 1) indicated that the amount of organic matter content recorded at Genetie, Gergellie and Kara Adishabo was 4.2, 3.32 and 3.06 percent respectively, thus the lowest level of striga infestation was also observed in these kebeles. This is in agreement with the findings of Eriksson *et al*., (2005) and Ayongwa (2011) who stated that the incidence and survival rate of striga reduces as the amount of soil organic matter increased.

According to the guide line of Cohen (1988) the correlation analysis indicated that the association of total soil nitrogen and the level of striga infestation was weak ($r(22)=-0.097$, $P>0.05$). The association of total nitrogen and striga infestation was probably weak because in the current study the association of the level of striga infestation and nitrogen was made based on the association of striga infestation and total soil nitrogen, which does not indicate its uptake. This is in line with the finding of Cogger *et al*. (2002) who reported that knowing the total amounts of nitrogen doesn't tell us how much will become available for crop uptake during the growing season. Besides Ayongwa (2011) stated that a good supply of nitrogen to soil leads to a reduction of striga germination significantly. Camberato (2001), revealed that soil nitrogen (N) exists in two major forms, i.e. organic and inorganic form. More than 90% of soil nitrogen is in the form of organic (the form that plant could not make use of).

Phosphorous exists in the soil both in organic and in inorganic forms. The analysis was made based on the average level of striga infestation and available soil phosphorous. Hence, the correlation analysis results (Table 6) revealed that striga infestation was strongly and negatively correlated ($r(22) = -0.408$, $P<0.05$) to available phosphorous. The soil laboratory analysis result (Table 1) revealed that the amount of available phosphorous content in most study areas was found low compared to the required moderate amount phosphorous (15-25ppm). So, the highest level striga infestation was probability due to the presence of low available phosphorous in most kebeles. This was in agreement with the findings of Cardoso *et al*. (2010) who stated that the direct application of phosphate decreases the exudation of strigolactone, thus germination and subsequent establishment of *S. hermonthica*.

The correlation analysis revealed that there was strong association between soil pH and available soil phosphorous ($P<0.05$). However, when the pH is greater than 7.5, calcium can tie up phosphorus, making phosphorous less available to plants. Besides, soil pH was strongly associated ($P<0.05$) with percent of soil organic matter. Similarly, soil pH was positively associated with percent of total soil nitrogen ($P<0.05$). However, the strength of the association was found weak compared to the association of pH with available soil phosphorous and percent of soil organic matter (Table 6).

Soil organic fertilizers enhance basic chemical and physical properties of soil compared to inorganic fertilizers. The result revealed that soil organic matter has small effect on total nitrogen. However, its effect was not significant ($r(22) = 0.124$ $P>0.05$) compared to the effect on available phosphorous and soil pH.

Soil organic matter associates with the relative proportion of soil particles (sand, silt and clay). The result of this survey revealed that soil organic matter significantly improve the relative proportion of sand particles ($r(22)=-0.532$, $P<0.05$). In contrast, there was no significance difference between the association of percent soil organic matter and percent silt & clay particles (Table 7). This is in line with previous studies (Whitbread 1995; Bayu Wondimu, *et al.,* 2006; Adeniyan *et al.,* 2011) who all reported that the application of different types of organic manures enhanced available soil phosphorous, total soil nitrogen, exchangeable potassium and cation exchange capacity (CEC) better than synthetic fertilizer in all type soils. Similarly soil organic matter improves soil structure and texture, thus improved moisture retention capacity of the soil. Overall organic matter is better at enhancing basic chemical and physical properties of the soil compared to inorganic fertilizers.

Table 7: Correlation of striga infestation with major soil chemical properties

		pH	% OM	% TN_2	Ava.P_2O_5	Mean	Std. Deviation
Spearman's rho	Average striga per m2	-0.213^{*}	-0.917^{**}	-0.097	-0.408^{**}	18.592	11.426
	pH	-	0.247^{**}	0.192^{*}	0.522^{**}	6.858	0.617
	% OM	-	-	0.124	0.439^{**}	1.774	0.894
	% TN_2	-	-	-	0.385^{**}	0.067	0.029
	Ava.P_2O_5	-	-	-	-	4.125	2.770

*=Correlation is significant at the 0.05 level (2-tailed) **= Correlation is significant at the 0.01 level (2-tailed). c. List wise N = 24 pH= a measure of soil reaction, %OM= percent of organic matter, % TN_2=Percent of total nitrogen, Ava.P_2O_5= Available phosphorous in parts per million

Table 8: Association of soil texture and percent of soil organic matter

		percent of silt	Percent of clay	percents of organic matter
Spearman's rho	percent of sand	$-.437^{*}$	-0.667^{**}	-0.532^{**}
	percent of silt	-	-0.221	0.305
	Percent of clay	-	-	0.326
	percents of organic matter	-	-	-

*=Correlation is significant at the 0.05 level (2-tailed) **= Correlation is significant at the 0.01 level (2-tailed).
c. List wise N = 24

3.3. Association of Striga Infestation with Soil Type

The level of striga infestation was strongly associated with moisture holding capacity and nutrient retention capacity of the soil. As presented in Table (8) the level of striga infestation was significantly influenced by the relative proportion of sand in the soil ($r(22)=0.532$, $P<0.05$). In contrast, there was no significance association between the level of striga infestation and the relative proportion of silt & clay particles in the soil.

Clay soil has higher moisture retention capacity and higher content of organic carbon. This was demonstrated by Vogt and his colleagues (Vogt *et al*. 1991) that a severe striga infestation was strongly associated not only with low soil fertility but also with poor moisture content of the soil. The relative proportion of soil particles was also significantly associated among the textural class of soil separates (sand, silt and clay). So, the relative proportion of clay and silt significantly influenced with increasing the relative proportion of sand particles. The analysis of variance (Table 8) showed that there was strong association between the relative proportion of silt, clay and sand.

Table 9: Correlation of striga infestation with soil texture in Tigray Region

		Percent of sand	Percent of silt	Percent of clay	Mean	Std. Deviation
Spearman's rho	Average striga per m2	0.532**	-0.302	-0.329	189.9367	106.469
	Percent of sand	1.000	-0.437*	-0.667**	46.25	18.329
	Percent of silt	-0.437*	1.000	-0.221	19.50	8.733
	Percent of clay	-0.667**	-0.221	1.000	34.25	17.399

*=Correlation is significant at the 0.05 level (2-tailed) **=Correlation is significant at the 0.01 level (2-tailed)
List wise N = 24

4. CONCLUSION

Appropriate planting density of sorghum cultivars/or varieties is likely to reduce the level of striga infestation in Tigray region (Northern Ethiopia). There is no indication that the level of striga shoots per sorghum plant will affected by number of sorghum per unit area of land.

The level of striga infestation is significantly affected by soil pH, organic matter content and available phosphorus. The highest level of striga infestation is most probability occurs at pH level suitable for availability of most plant nutrients (6.0-6.3). Similarly, the presence of optimum amount of available phosphorous and organic matter content in the soil will resulted in reduction of *S. hermonthica* infestation. The influence of soil organic matter on striga infestation was much more important compared to the influence of pH and available soil phosphorous. However there is no indication that total nitrogen will resulted in reduction of *S. hermonthica* infestation. But other research findings suggested that striga can be controlled using proper amount of source of nitrogen.

The level of striga infestation is significantly determined by the type of soil in which sorghum is growing. Therefore sandy type of soil significantly increases *S. hermonthica* infestation. However, there is no indication that striga infestation is affected with clay and silt dominated soils.

In conclusion the correlation analysis result of striga infestation to population density of sorghum, chemical and physical properties of the soil suggested that any action directed towards appropriate use of organic matter source, available phosphorous and practicing proper planting density of sorghum cultivars/or varieties resulting in significant reduction of *S. hermonthica* infestation. Finally the correlation analysis result revealed that the direction of the relationship between striga infestation and population density of sorghum, basic chemical and physical properties of the soil. However the degree of the relationship should be further determined. The study under report was limited and specific to study areas close to road sides. Therefore, detailed and broader studies however suggested further. This allow for specific conclusion on association of striga infestation to population density of sorghum, chemical and physical properties of the soil.

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