Bracken fern *Pteridium aquilinium* invasion of agricultural fields, seed germination and soil properties in Tanzania

[1]Bagarama, F.M.; [1]Matata, Z.P.; and [1]Kagimbo, F.M.

[1]*Special Program Department,Tumbi Agricultural Research Institute P.O. Box 306 Tabora, Tanzania.*

ABSTRACT

Climate change and land use changes exert profound effects on the dynamics of flora in ecosystems.Invasion of bracken fern (*Pteridium aquilinium (L.)* Kuhn in crop fields in a field survey in Tumbi Agricultural Research Institute, Tabora, Tanzania. A total number of 66 fields were surveyed .The infestation of bracken fern was found in sweet potato, cassava, banana, maize, beans, and oil palm. Germination tests of certified seeds of maize (TAN 250), beans (Lyamungo 90), groundnut (Pendo) and Soybean (Uyole) were carried out using three treatments (a) rain water (control), (b) 10% aqueous root extract of *P. aquilinium* (c) 10% aqueous extract of the rhizospheric soil.The growth media in plastic pots was a 2kg composition of clay, sand, and forest soil in the ratio of 1:1:1.Pots were intially watered to field capacity with subsequent watering of 100ml twice a day for 14 days.Ten certified seeds of each variety were planted in a pot and replicated three times.The germination pecentage of the tested seeds was presented graphicaly.Soil analysis data show that P.aquilinium grows on very acidic soils. Results show that the 10% aqueous extract of *P. aquilinium* roots reduced the germination of maize, groundnut and soybean by 50%, 69%, 100% respectively. The 10% rhizospheric soil aqueous extract of *P. aquilinium* reduced the germination of maize, and soybean between 17%-34%, 10-20% respectively. The 10% aqueous extract of rhizospheric soil caused an inhibition of root growth and elongation inhibition of Pendo groundnut seedlings. This might likely be associated with Al toxicity in soil. This study confirms the toxicological effects of *P. aquilinium* on certified seeds. There is a need for soil acidity amelioration to improve crop productivity and the toxicological effects of *P.aquilinium* on legume crops.

Keywords: Aqueous extacts**,** *P.aquilinium*, seed germination, Soil degradation ,

INTRODUCTION

Invasive plants and weeds are the ecological response to climate change and anthopological disturbances. *Pteridium aquilinium* (bracken) is one of the world's most ubiquitous species,appearing in various plant communities, but an important characteristic is its ability to form dense patches that it strongly dominates(Cody and Crompton,1975);Rodwell,1990).These patches of *P. aquilinium* with low feeding value to vertebrates herbivores deter grazing(Scagg,1982;Pakerman and Marrs,1996). Anthopological disturbances in ecological setting result into plant succession and invasions(McDonald,2004; Hobbs and Huenneke,1992; Hobbs,1991). Bracken fern is an invasive weed with a world economic, social and environmental importance(Der et al.2009; Pakeman and Marrs,1992; Holm et al.1979).Bracken fern is a perennial fern that grows $\pm$ 1.5m high. It spreads quickly by means of branched underground rootstock.Those are covered with thich reddish hairs.The young leaves(croziers) are coiled and hairy.As they unfold, they become stiff, leathery and grossy green.The plant produce spores that resemble a rusty powder on the underside of the leaf.Spores are borne submarginally as a continnuous line closely following the leaf margin. *P. aquilinum*(bracken) is difficult to control for a range of reasons, including an extensive rhizome system (Le Duc *et al*;2003) and a high productivity that produce dense frond cover and deep litter, which combine to reduce understorey vegetation(Cox,2007; Marrs *et al*.2000).

Bracken fern is a fire climax vegetation, persisting in areas with frequent fire incidencies where it replaces other vegetation in plant communities. Croziers, fresh and dried fronds, rhizomes and even the stems are toxic to human and livestock if are eatern in large amounts(Botha and Venter,2002 ;Tempel, 1981). The clinical importance of *P. aquilinium* invasion in agroecosystems include its potential to increase cancer risks through direct or indirect intake by humans(Lattore *et al.*2009;Gerrenutti *et al.*1992;Santos *et al.*1987).*P. aquilinium* has been shown to posses antifungal properties(Hamza et al.2007).*P. aquilinium* possess allelopathic effects to cultivated plants and weeds(Veronica *et al*.1987),germinating seeds of conifers (Ferguson and Boyd,1988);Salmonberry(*Rubus parviflorus* Nutt.)Stewart(1975).*P. aquilinium* has been shown to inhibit the growth of annul crops such as ryegrass and clover(Lee and Cooke,1989).The allelopathic effects of *P. aquilinium* to other plants have been investigated further by,Gliessman and Muller(1978),Horsley (1993), and Dolling (1994) these studies have showed that *P. aquilinum* caused interference in the germination and growth of accompanying plants in the plant community. *P. aquilinium* produce polyphenols that degrade fertile soils.The phytotoxic potential of *P. aquilinium* have been investigate in various studies(Gliessman and Muller,1978;Gliessman and Muller, 1972).Phenolic compounds create unfavorable conditions for

seed germination of some plants (Northup *et al*.1998). Most of the studies on the allelopathic effects of *P. aquilinium* on plants have been conducted in developed world(Der et al.2009; Pakeman and Marrs,1992; Gliessman and Muller,1978; Gliessman and Muller, 1972).These studies investigated most the toxicological effects of *P. aquilinium* fronds(Nava *et al*.1987;Dolling et al.1994).Human disturbances in form of deforestation, forest fire, cultivation and grazing have resulted into the invasion of *Pteridium aquilinium* in agrosystems in Western Tanzania.

This paper presents findings from a study that investigated the invasion by *P. aquilinium* in crops and its implication to germination of certified seeds of common crops grown in western Tanzania.The objective of this research work was twofold, to assess the invasion of *P. aquilinium* in agrosystems and to evaluate the allelopathic effects of aqueous extracts of *P. aquilinium* root and rhizospheric soil on the germination of certified seeds of maize,bean,soybean and groundnuts.

This research would therefore test the invasion of *P. aquilinium* in agricultural fields has negative impacts to crop and soil productivity, while the general objective of the study was to investigate the effect of *P. aquilinium* on crop production in Western Tanzania.The specific objectives were to investigate the frequency of *P.aquilinium* incidencies in agricultural fields; to study the effect of aqueous extracts of roots and rhizospheric soil on seed germination; and to characterize soil properties under *P.aquilinium* dominance.

METHODOLOGY

This study was conducted in greenhouse at Tumbi Agricultural Research Institute in Tabora,Western Tanzania. A survey was conducted to assess the invasion of *Pteridium aquilinium* on the field crops.The study was conducted between January-August 2010.Village extension officers and farmers were key informats beside ground work verification. A list of fields invaded by *Pteridium aquilinium* was recorded. Soil was sampled at the depth 0-20cm from a heavily invaded field at Kitahana village E $030^0$40'.168,S 03^0.38.054, Elevation 1442 m asl, Kibondo district in Tanzania. Soil sampling for seed germination test was undertaken in October during the onset of the rains and sprouting of new *P. aquilinium* fronds during this time the concentration and movement of toxic substances is considered to be at peak (Dollin et al.1994).The soil was air dried and sieved, part of which was sent to the soil laboratory for analysis. Soil description was carried out as described by Landon(1984).The composite sample was prepared and subsequently analyzed at the central soil laboratory in Mlingano,following the National Soil Service Routine Soil Analytical procedures (NSS,1990) analysis was carried out.

Two kilogram of soil was put in plastic pots for seed germination. A 10% solution of rhizhospheric soil was prepared by mixing 500g of soil carefully detached from the main and lateral roots of *P. aquilinium* roots. A 10% solution was prepared by mixing 500g of grounded *P. aquilinium* roots in 5litres rain water. The preparation of aqueous extracts followed the procedure of Nava *et al*. (1987).However; the later investigators used *P. aquilinium* fronds, this study investigates the allelopathic effects of *P. aquilinium* roots and their rhizospheric soil. Roots of *P. aquilinium* were separated from soil, grounded in mortar without washing to minimize loss of toxic substances.*P. aquilinium* plants were sampled for fresh weight determination of above ground and below ground biomass. The ratio of rhizome to above ground mass was calculated. The relationship between the growth and distribution of bracken rhizomes and shoot growth and soil chemical implications was investigated in previous studies (Watt, 1940).

Certified seeds of Maize (TAN250), Soybean var Uyole, Beans var Lyamungo 90 and groundnut var Pendo were germinated in the soil media consisting a mixture of sand, clay and forest soil in the ratio 1:1:1.The soil was watered to full capacity by a) Rain water b) 10% aqueous solution of *P. aquilinium* grounded roots c) 10% aqueous solution of rhizospheric soil. Subsequent watering of seeds was done by adding 100ml of aqueous extracts or rain water. Germination assessment was done 2 weeks after planting which allowed an assessment of root growth.

RESULTS AND DISCUSSION

Greenhouse Seed Germination Bioassay

The number of germinated seeds was converted into percentage per treatment. The results of this study show that certified seeds had a high germination percentage ranging from 90 -100%.Results in Fig.1 show that a 10% aqueous extracts of *P. aquilinium* rhizospheric soil extracts and root extracts reduced the germination of Soybean var Uyole by 77.5% and 100% respectively. The reduction of seed germination for groundnuts var Pendo for rhizospheric soil and root aqueous extracts were 60% and 100% respectively as shown in Fig.2. Fig.3 show that the germination of maize seeds (TAN250) was reduced by 20% by a10% aqueous root extracts and by about 40% by 10% aqueous *P. aquilinium* root extracts. These results agree with research findings of other investigators who find that *P. aquilinium* inhibit the germination of seeds of some plants (Dolling et al.1996; Ferguson and Boyd, 1988; Nava *et al*. 1987).In Table 2 the ratio of below ground rhizome biomass to that of above ground fronds biomass was between 1.3-4.0.These results indicate that *P.aquilinium* roots' biomass under the soil is more than above ground biomass. Storage of toxic chemical compounds in roots can adversely affect the germination of seeds that are planted immediately after land preparation.

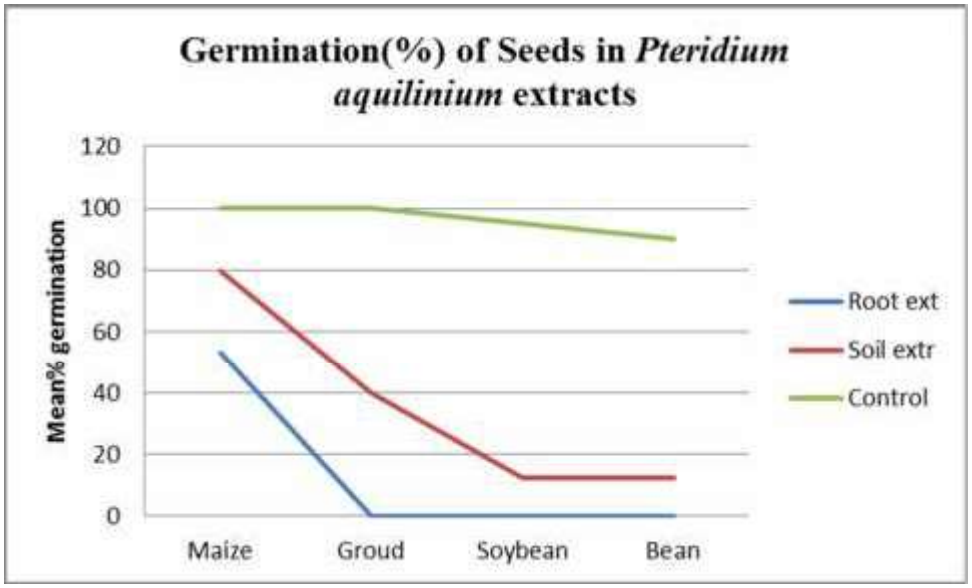

Fig. 3: Germination (%) of seeds in *P.aquilinium extracts*

Bracken fern invasion of crop fields

Field survey results show that,the ecology of bracken fern is the high rainfall areas in the Western highlands in Kasulu and Kibondo districts, Kigoma region western Tanzania.Bracken fern is also common in valleys in the dissected land scape common in the study area, dominated by Ferralsols(De Pauw,1984).The dominant land use is shifting cultivation in the mid-altitudes 1000-1400m asl.Ecology disturbance by human activities have increased the invasion of *P. aquilinium*.This agree with research findings by other researchers(McDonald,2004; Hobbs and Huenneke,1992; Hobbs,1991). Permanent coffee-banana homegardens are dominant in the highlands 1500 m asl and above.The homegardens are characterized by zero-grazing and land scarcity.Bracken fern is used for mulching banana and coffee fields and in some incidences was seen mixed in fodder for zero grazed cattle. Mixing *P. aquilinium* in fodder creates a pathway to human food chain through milk and meat.A total number of fields surveyed were 66 surveyed.The infestation of bracken fern was found crops such as sweet potato,cassava, banana,maize, beans and oil palm in patchy distribution.

Table 1: *P. aquilinium* invasion of sampled crops in western Tanzania

Crop surved	Frequency	Percent(%) of total
Sweet potato	5	7.6
Banana	2	3.0
Maize	8	12.1
Cassava	18	27.3
Coffee arabica	1	1.5
Oil palm	23	34.8
Beans	9	13.7
Total	66	100.0

Source: Survey Data, 2011.

Table 2: Characteristics of *P. aquilinium* during the on-set of rain season

Sampled *P.aquilinium* plants	Weight of fronds(kg)	Weight of rhizomes(kg)	Rhizome:Frond Ratio
18	4	5.6	1.4
10	1.0	1.5	1.5
25	3.0	4.0	1.3
31	3.0	6.0	1.2
10	1.0	2.5	2.5
10	0.5	2.0	4.0

Source: Survey Data, 2011.

Table 3: Soil characteristic of the *P.aquilinium* dominated soil in Tanzania

Horizon	Ap	BA	Bw	Bt	Bt
Sample depth(cm)	0-19	19-34	34-57	80-100	130-150
Clay%	70	76	74	85	89
Silt%	20	20	22	12	3
Very fine sand%	1	2	1	4	1
Fine sand%	2	2	1	-	1
Medium sand%	3	2	1	-	1
Coarse sand%	2	1	1	-	1
Very coarse sand%	1	-	-	-	-
Texture class	C	C	C	C	C
pH H_20 1:2.5	5.2	4.4	4.1	4.5	5.7
pH Kcl 1:2.5	4.4	4.1	4.1	4.4	5.5
Ec ms/cm	0.07	0.08	0.12	0.10	0.01
Organic C	3.1	2.0	1.2	0.5	0.3
Total N	0.18	0.13	0.08	0.05	0.04
C/N	17	15	15	10	8
Available P ppm	2	1	1	-	-
CEC NH_4OAC me/100g	14.6	11.3	7.2	4.3	3.4
Exch.Ca me/100g	3.3	0.3	0.3	0.7	0.2
Exch.Mg me/100g	1.3	0.2	0.1	0.4	0.2
Exch. K me/100g	0.13	0.05	0.07	0.05	0.03
Exch. Na me/100g	0.04	0.04	0.04	0.04	0.05
Exch.H me/100g	0.17	0.41	0.15	0.10	-
Exch.Al me/100g	0.18	0.88	1.10	1.00	-
Al saturation%	1	8	15	23	-

Fig.4: Root growth inhibition in groundnuts

CONCLUSION

Climate change and ecological disturbances have increased the invasion of *P. aquilinium* in agricultural systems in western Tanzania.In the presented study the effect of aqueous extracts of *P. aquilinium* roots and the aqueous extracts of rhizospheric soil on the germination of certified seeds of maize,bean,soybean and groundnuts was investigated.Results show that the germination of legume seeds, *Phaseolus vurgaris L.*),soybean(*Glycine max Merr*),groundnuts(*Arachis hypogea L.*) germination is reduced substantially.The germination of maize seeds is slightyly reduced compared to that of legumes.The soil under P.aquilinium is characterized by low nutrients and high Al Saturation.There is a need for soil ameliration to improve land and crop productivity in P.aquilinium invaded fields.

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