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Full Length Research Paper

Ecological Distribution and Abundance of the Parasitic weed, *Cassytha filiformis* L. (Lauraceae) in major Cashew, *Anacardium occidentale* L. growing regions in Tanzania

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Abstract
Cashew is one of the most important export cash crops in Tanzania in terms of foreign exchange earnings ranking second after tobacco. Currently this crop is facing infestation by exotic parasitic weed which was identified to be Cassytha filiformis L. (Lauraceae). Weed pest significantly cause economical losses if not controlled. Understanding weed ecology is the prerequisite for designing control strategies. We examined for C. filiformis ecology to understand its distribution and abundances in major cashew growing regions of Tanzania. A total of 3 regions (Mtwara, Lindi and Coastal) covering 27 localities were surveyed. Distribution of Cassytha weed was assessed based on; altitudinal gradient, soil types, vegetation types and locations. Abundances were determined based on number or frequencies of individuals infested by the weed and established severity scale. This study revealed that Cassytha was more prominent at lower than at higher altitude. The weed was dominated in sandy clay loams (52.70 %) and sandy soils (40.54 %) compared to clay soils (6.76 %). Cassytha filiformis was mostly found in cultivations and roadside compared to other types of vegetation assessed. Additionally, C. filiformis was more abundant in cultivations associated with settlements than cultivations located away from human settlements. Cashew and mango crops were severely affected compared to rest crops. Although Anacardiaceae family was mostly parasitized by C. filiformis, there was no clear evidence for host specificity by this weed. This information improves our understanding of C. filiformis ecology and can offers a tool to design appropriate control strategies.

Key words: *Cassytha weed, ecology, cashew plantation, sandy clay loam, Tanzania*

Introduction

The Tanzanian economy largely depends on agriculture (IFAD 2014). Agricultural sector itself contributes more than 25% of the Gross Domestic Product (GDP), provides 85% of exports, and employs 80% of the work force (IFAD 2014). Although Cereals, especially maize and sorghum are the most important field crops grown in Africa by commercial and resource-poor small-scale farmers, economically cash crops are the leading source of country's foreign total earnings (Kfir et al., 2002).

Cashew is among the main cash crops produced in Southern-Eastern regions of Tanzania (NARI 2007). It is the main export cash crops in Tanzania ranking second as a foreign exchange earner after tobacco (BoT 2012). Despite the fact that cashew nut is the leading source of income for over 280,000 households in the Southern-Eastern regions of Tanzania, insect pests and disease have been the most constraints resulting cashew nut yield loses of between 70% and 100% if not controlled (Sijaona 2013). However, in recent years' cashew production both in small and large scale is facing a new threat of a weed pest which has been confirmed in the present study to be an exotic species C*assytha filiformis L. (Lauraceae).*

Crop losses due to weeds, animal pests, pathogens and viruses continue to reduce food production and cash crops worldwide ((NAP 2013). In Tanzania about 30-40 per cent of overall total crop production is lost annually due to crop pest and diseases (NAP 2013).

Weeds are one of the major biological constraints that limit crop productivity (Milberg 2004; Falade & Labaeka 2016). Economical losses caused by weeds are higher when compared to other pests such as insects and fungi (Oerke & Dehne 2004). Weeds compete with crops for nutrients, space, light and water thus reducing crop yields (Akobundu 1987; Oudhia 2004). Studies in Africa indicated that, crop losses of 40 to 90 % occur if weeds are not controlled (Gianess 2009). For instance, poor weed management practices in cassava fields cause yield loss of 5t/ha (Fermont et al., 2009). Weeds infestation also encourage disease problems, serve as alternate host for deleterious insects and diseases, slow down harvesting operation, increase the cost of production, reduce the market value of crops and increase the risk of fire in perennial crops, plantation and forest reserves (Oudhia

2004). Weed pest, *C. filiformis* is reported to be indigenous in Hawaii (Nelson 2008), Australasia, Northern South America, and Central America, Japan and in South Africa (Weber 1981). It also appears to have been transported to many major islands as well as continents and now is effectively pantropical (Arnold & Wet 1993). The species is a widely distributed parasitic plant which attack and penetrates the hosts' tissues as it grows to obtain food and water (Abubacker et al., 2005). The parasitic weed is widely distributed throughout the regions of tropics much along the seashores up to the extent of 300m (Mythili et al., 2011). It is found to be parasiting on many other host plants like *Acacia*, *Azadirachta,* and *Mangifera* species (Mythili et al., 2011).

Cassytha filiformis continues to be a key constraint to cashew farmers in Tanzania, and the rate at which this species is spreading is alarming particularly in cashew growing regions. Limited knowledge exists in the ecology of *C. filiformis* in Tanzanian cashew growing regions. Understanding weed ecology (Nkoa et al., 2015; Talaka & Rajab 2013) or abundance (Norris 1992) is an important goal for weed management. Knowledge in eecology provides a basic understanding of the distribution and abundance of weeds (Booth et al., 2003). Information such as nature of crop (Adesina et al., 2012), soil type, vegetation type and location that can be considered as prerequisites for understanding causes in variation in the abundance or distribution of weed species (Mohler, 2001; Sit et al., 2007) is limited.

In the present study, we determined the abundance of *C. filiformis* and its distribution based on; soil type, vegetation type, nature of crop and locations. The presented results help to improve our understanding of *C. filiformis* ecology and they provide a tool to design control strategies.

Materials and Methods

Description of the study area

The present research was conducted for a period from March 2012 to June 2012 in three major cashew growing regions of Tanzania namely; Mtwara region (Mtwara rural and Newala) covering 12 villages, Lindi region (Kilwa and Lindi districts) covering 6 villages and Coast region (Rufiji, Mkuranga and Bagamoyo districts) covering 9 villages (Figure 1). Geographically the study area lies at Latitude 6^o 22' 50.45" S; 38^o 35' 47.25"E to 10^o 19' 21.95" S; 40^o 17' 41.6" E.

Sampling Technique

Distribution and abundance of Cassytha filiformis

Distribution of *C. filiformis* was determined based on: altitudinal gradient, (established as; lower (0-300m a.s.l), medium (301-400) and higher (above 400m a.s.l.), soil type and vegetation type. The geographical location of the host species were recorded in UTMS using Garmin 192 GPS. The host abundance was assessed based on number or frequency of individuals infested by the weed (Nkoa *et al.,* 2015) and severity score scale.

Information on vegetation type of the area, host species name for *C. filiformis* was identified with help of botanist from the University of Dar es Salaam Herbarium, Department of Botany and by using Flora of Tropical East Africa manuals where it deemed necessary. *Cassytha* weed distribution was established by enumerating *Cassytha* species occurrence along altitudinal gradient i.e. at an interval of 100m along the access roads which in this case were considered as transects. Locality altitude was recorded with GPS. Any plant that had *Cassytha* haustoria attached to the leaves, stems or branches were considered as host species for *C. filiformis* (Kokubugata &Yokota 2012). Severity caused by *Cassytha* was recorded as; less severe if the host was less affected with less than half of the tree smothered by the parasite, moderately severe if half of the host species is smothered by the parasite and has developed symptoms of wilting, leaf shading, chlorosis and inability to flower and severely infested if was completely dry and dead due to infestation.

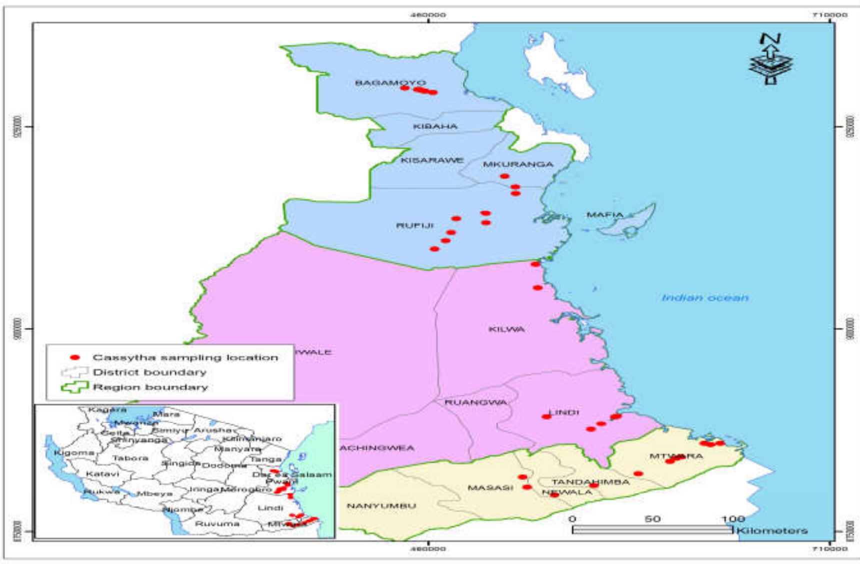

Fig 1: A map of the three Coastal regions of Tanzania where samples were collected

Data Analysis

Host species frequency (f) was obtained using the folllowing formula:

$$f = \frac{Number\ of\ plots\ in\ which\ species\ i\ was\ sampled}{Total\ number\ of\ sampled\ plots} x100$$

In order to digitize the distribution of the host species, the geographical data was processed using ArcGIS software. Vegetation classification was done according to White (1983). Soil textural classes were established in the field according to modified method by Thien (1979) which entailed estimating percentages of sand, silt, and clay separates present by a skilled and experienced field soil scientist. The abundance of host species infested with *C. filiformis* along altitudinal gradient was obtained directly by counting the number of host species infested with *C. filiformis* in each vegetation unit and the resulting data was manipulated using Microsoft Excel spreadsheet.

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Results

Distribution and abundance of C. filiformis based on soil and vegetation types

Results for soil and vegetation types preferred by *C. filiformis* are presented in Figure 2 and Table 1, respectively. Out of 74 sampled host plants, 39 (52.70%) were recorded in sandy clay loams, 30 (40.54%) in sandy soils whereas only 5 (6.76%) were recorded in clay soils (Figure 2). The main vegetation types of the study area were identified as; cultivations, wooded grassland, cashew nut plantations, bushland, woodland, riparian vegetation, thickets and wetland/flood plains.

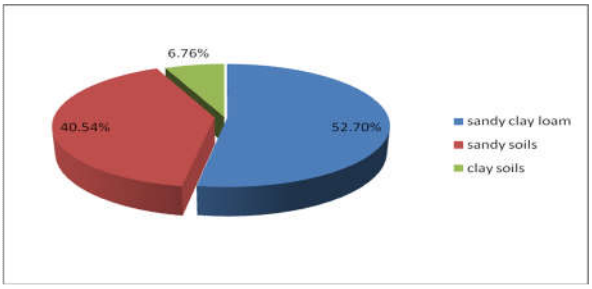

Fig 2: Soil types preffered by *C. filiformis*

C. filiformis was found to be most prevalent in cultivations and on road side vegetation followed by wooded grasslands, cashewnut plantations and degraded areas along the ocean shore (Table 1). In Cultivations, the most dominant crop species parasitized were cashew nut trees, oranges trees, maize, pineapple and cassava in which the first two crops were the most severely affected. Additionally, *C. filiformis* was more abundant in cultivations associated with settlements than cultivations located away from human settlements.

Table 1: The main vegetation types associated with the *C. filiformis'* host plant species

S/N	Vegetation Type	Frequency	Percentage
1	Cultivations	21	30.43
2	Roadside vegetation	16	23.19
3	Wooded grassland	9	13.04
4	Cashew plantation	7	10.14
5	Degraded area near the ocean	7	10.14
6	Bushland with scattered Coconuts and Cashew nuts	4	5.80
7	Reserved Woodlands	2	2.90
8	Flood plain	1	1.45
9	Riparian vegetation	1	1.45
10	Thickets	1	1.45

Host life forms mostly preferred by C. filiformis

As shown in Figure 3 below, plant life forms affected by *C. filiformis* were mostly tree species (75.36 %) followed by shrubs (23.19 %) and seldom parasite was found parasitizing grasses. In grassland the tall grasses particularly *Hyparrhenia* species were mostly affected.

Distribution and abundance of C. filiformis along altitudinal gradient

Surveys conducted covered 28 localities in three regions (Figure 4), in the altitudinal range between 0 m and 717 m above sea level (a.s.l.). Number of species and individuals infested by *Cassytha* along the altitudinal gradient is presented in Figure 5. It was found that the parasite infested more individuals and more diverse host plant species at lower altitude compared to higher altitude. The number of individual host infested at lower altitude up to 100 m a.s.l were 84 representing 27 plant species whereas at elevation between 200 m and 300 m a.s.l., the number of individual host were 13 representing 7 species. On the other hand the numbers of host individuals and their corresponding species number infested at relatively higher altitudes between 401 and 700 m a.s.l were between 1 and 2 suggesting low pest preference to distant localities from the coastal habitats.

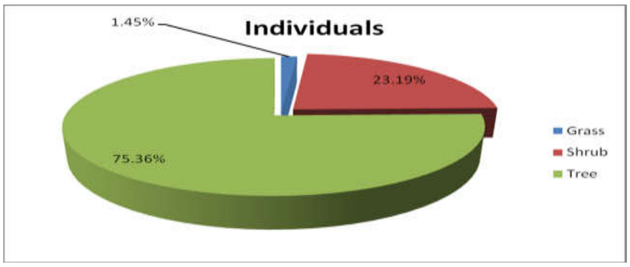

Fig 3: Host life forms infested by *C. filiformis*

The most severely infested surveyed areas were Kiwangwa and Machole in Coast and Lindi regions with respective infected host species numbers being 19 and 15. Other localities namely Ziwani and Mtawanya villages both in Mtwara regions were represented by 5 infested host species. Similarly, despite high species numbers in the two localities, most host species were recorded at lower altitudes to a maximum of 300 m a.s.l. The remaining localities recorded between 1 and 2 host species each. Lower altitude (100-200 m) covered Chiano, Jaribu, Mkani, Kazamoja, Kibiti, Kichi forest reserve, Kimanzichana, Kiwangwa, Mkiu, Tondo in Coast region; Machole, Marandego, Miteja, Mnazi mmoja in Lindi region; Mtawanya village, and Ziwani in Mtwara region. On the other hand areas which were located at higher altitude (401-700+) were Kikuyu, Mkomamoja, Mnyambe and Tandahimba in Mtwara region whereas part of Kiwangwa, Mwetemo (Coast region), Nanyamba and Tandahimba in Mtwara region were at medium altitude (301-400m). Thus the present study found that Coast and Mtwara regions were mostly impacted areas by the pest (Figures 4 and 5).

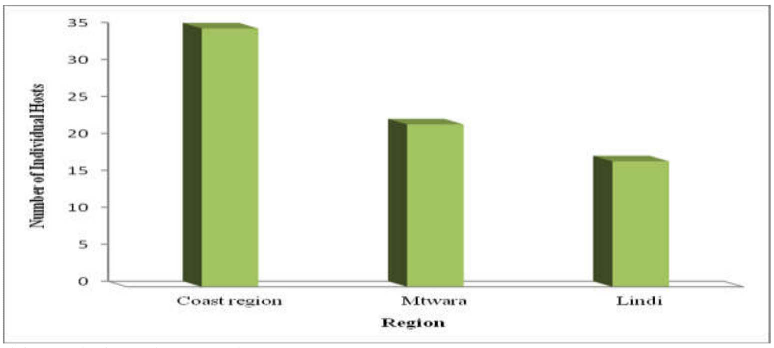

Fig 4: Number of individual hosts infested per region

As it can be noted from Figure 6 in some places at medium-higher altitudes (400-600 m a.s.l.), *Cassytha* was not recorded. At this elevation the parasite was missing because besides being far from the ocean the area was either open and/or dominated by grasses or more or less undisturbed woodland vegetation. In contrast, *Cassytha* was more dominant in cultivations or human disturbed areas at lower altitudes.

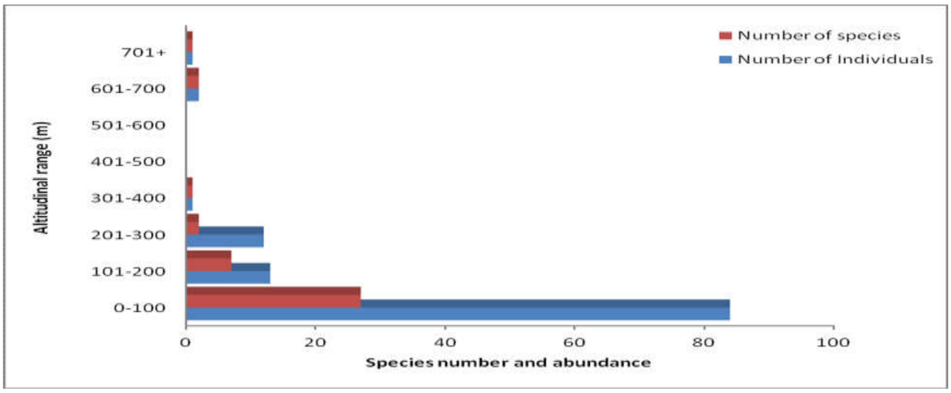

Fig 5: Number and abundance of host species infested with *Cassytha* along altitudinal gradient

Host preference and pestiferous effects of C. filiformis

Results in Figure 6 summarize species host preferred by *C. filiformis*. A total of 34 species belonging to 20 families were infected by *C. filiformis*. *Anacardium occidentale* (cashew tree) and *Citrus cinensis* (orange trees) were the most frequently affected hosts representing 14 individuals equivalent to 20% and 11 individuals (16%), respectively. Other species such as *Dicrostachyus cinerea, Pteliopsis myritifolia* and *Mangifera indica* (mango trees), were relatively moderately affected, the number of individual hosts recorded being 4 (6%) for the first two species and 3 (4%) for the latter. The number of individual of 1 to 2 was recorded for the rest of other species. Based on the observed results plant species under families Anacardiaceae, Rutaceae and Mimosaceae were consistently preferred hosts with their respective frequency of infestation being 21, 18 and 8 corresponding to about 30%, 16% and 12%, respectively. The remaining families were rarely parasitized and recorded frequency was between 1 and 4 species.

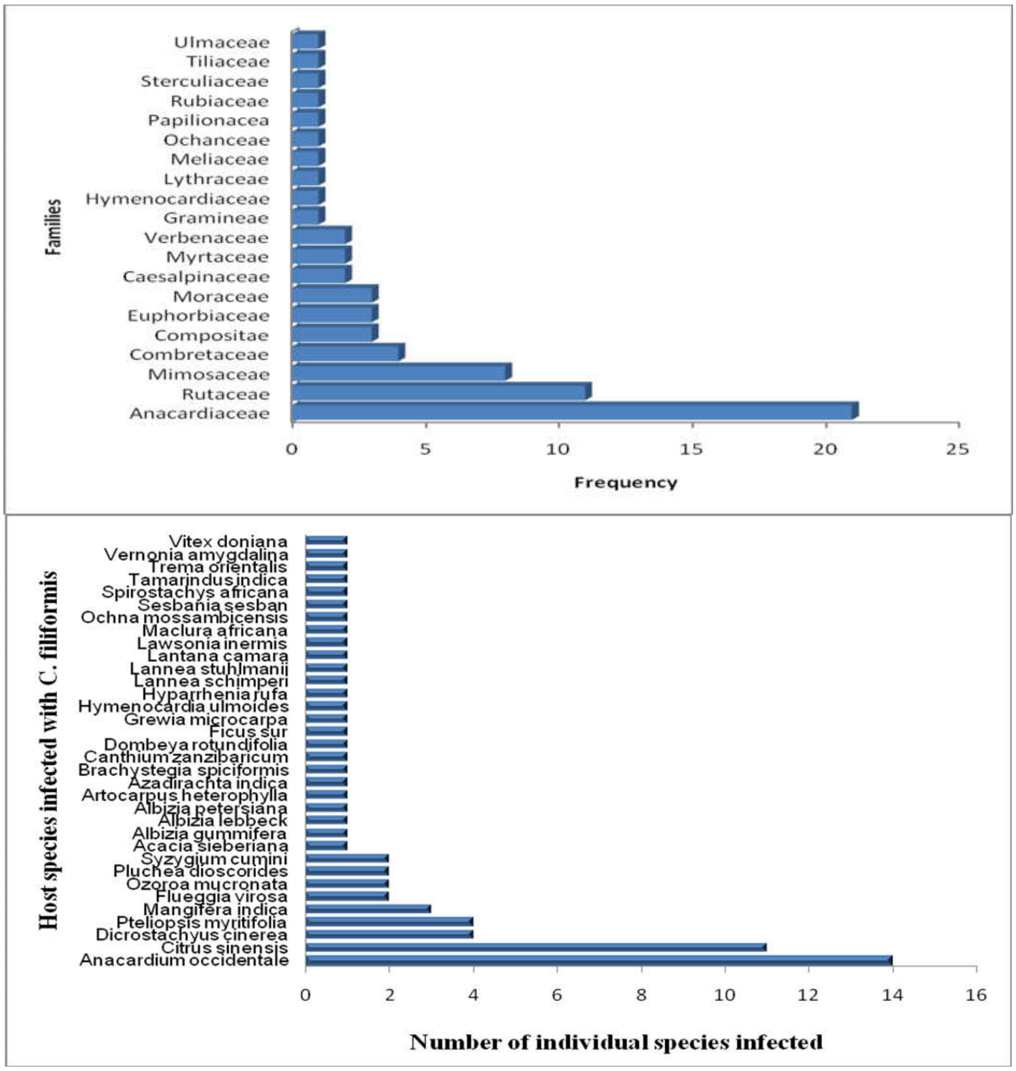

Fig 6: Frequency of host plant species and their corresponding families parasitized by *C. filiformis*

Discussion

Our results showed that, soil type, vegetation type and altitudinal gradient can greatly influence *Cassytha* weed distribution and abundances. It was found that despite the presence of different soil types in the regions surveyed, *C. filiformis* was commonly found on host species growing in areas dominated by sandy clay loams and sandy soils; and rarely on clay soils environment. This suggests that *C. filiformis* mostly prefers soils with high sandy fractions for its growth before locating host species in its vicinity. Perhaps sandy-loam soils create suitable microhabitat for *C. filiformis'* for its seed germination and growth.

Cassytha filiformis was abundant along the coastal areas than inland areas. This could be attributed to the nature of vegetation in this area which is characteristically more open coastal thickets, bushlands and wooded grasslands. Presence of these vegetation types is ecologically advantageous to *C. filiformis* since it requires a short/dwarf host species to cling on in the course of their early development mostly at seedling stage and establish their mode of nutrition fast enough before they die as the nutrient supply from their seeds get depleted. According to Hsuan et al. (1990), *C. filiformis* is common in open bushes by the sea.

High frequency of occurrence of *C. filiformis* in the cultivations, roadside vegetation and wooded grassland near the ocean indicates the contribution of both anthropogenic influence and presence of suitable geophysical and microclimate factors such as soils and light to the spread and performance of the parasite. Similar results are reported in Hawaii Island where *Cassytha* was abundant along roadways in bulldozed and developed lands (Nelson 2008).
Occurrence of *Cassytha* was less frequent in dense thickets, pristine areas such reserved woodlands and flood plains located more inland compared to other studied vegetation types. This suggests an association of the parasite with distance from the ocean and anthropogenic activities (Giesen et al., 2006). This may imply that most *C. filiformis* was brought from distant areas and dispersed

to the coastal vegetation along the sea shore by the action of sea water and inadvertently dispersed by man. Similarly, Quetin-Leclercq et al. (2004) reported for widely distribution of *C. filiformis* along the seashores throughout the tropics

The pestiferous effect of the parasite was particularly dependent on nature of the host bark. In woody species, host species with thin soft barks were relatively more preferred than species characterized by thick hard or scaly barks. The effect of infection of host plants by *Cassytha* is caused by its haustoria which penetrate the host epidermis and extend into more interior tissues, extracting cellular nutrients and water from plant phloem and xylem (Nelson 2008). However, it was interesting to note that plant species under family Apocynaceae particularly *Plumeria rubra* and *Thevetia peruviana* which were frequently associated with the parasitized species were not parasitized by *C. filiformis*. *Plumeria rubra* and *Thevetia peruviana* were abundant in Lindi particularly near the ocean and in Mtwara mostly in grave yards. Although experimental explanatory study on the allelopathic influence of *P. rubra* and *T. peruviana* on other plants is limited, lack of coexistence of *C. filiformis* with the two species above could be due to allelochemical effect of the two species which may be characteristic of the family and the nature of the bark. Allelochemicals play an important role in the agricultural and functional ecology (Fujii et al., 2004) and its importance in biological control of weeds and crop productivity have been highly recognized (Terzi 2008). However, in the study carried out in Pakistan by Mukhtar et al. (2010) *T. peruviana* and *Nerium oleander* both from the family Apocynaceae were found to be parasitized by *C. filiformis*. In this case the observation can be perhaps explained by the environmental factors such as temperature; light, nutrients and water availability that control production of allelochemicals in plants (Kruse et al., 2000). From this report and others cited therein, the amount of allelochemicals produced by plant depends much on its growth environment and age. This means the same species grown under different ecological environment may have different allelopathic effect.

Although plant species under family *Anacardiaceae, Rutaceae* and *Mimosaceae* were the most frequently parasitized, there was no clear evidence indicating *C. filiformis* species host specificity in all surveyed localities. These observations conform to those of Nickrent and Musselman (2004) who reports that the weed often covers and parasitizes dozens of host species simultaneously. Similar observations which showed *Cassytha* to be totally indiscriminate in host choice were also reported by Nickrent (2002), Heide-Jorgensen (2008) and Tsang (2010).

Conclusion

Along the altitudinal range *C. filiformis* was more prominent at lower altitudes than at higher altitudes and Coast and Mtwara regions are the mostly affected areas. *Cassytha* was more abundant on the coastal vegetation and less abundant on more inland vegetation.

There was no host specificity for *Cassytha* but infected hots were mostly tree species and rarely grasses. As for the various vegetation types investigated *C. filiformis* was widespread in cultivations/cashewnut plantations and degraded areas along the Indian Ocean shore whereas cashew and orange trees representing families Anacardiacea and Rutaceae were mostly affected.
Cashew is economically important cash crop hence infestation by weeds such *as C. filiformis* can reduce or entirely hinder flowering and fruiting setting phenology which greatly affects yield and hence economic gains (Pimented et al., 2005).

Understanding weed seed bank can help agricultural crop producers to predict the degree to which crop-weed competition will affect crop yield and quality (Davis et al., 2005). Therefore, further study on *Cassytha* weed seed bank is recommended. Moreover, studies on the allelopathic influence of *P. rubra* and *T. peruviana* on other plants is also essential.

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