EVALUATION OF OPTIMUM SOIL MOISTURE LEVELS AT WHICH *Striga asiatica* (L.) AND *Rhamphicarpa fistulosa* (Hochst.) Benth.CAN ESTABLISH A RELATIONSHIP WITH A HOST

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ABSTRACT

Pot experiments were conducted in a screen house to determine the optimum moisture levels required for either of the parasitic weeds, singly and in combination, to establish a relationship with rice. Studies were conducted in Morogoro, Tanzania, (525 m.a.s.l., 6°45" S and 37°40" E) September, 2012-February, 2013. Ten-litre plastic pots capacity filled with dry 5:1 (sand: clay) soil mixture up to 2cm below the rim were used. Treatments were arranged in split- plot with plant combinations (*Rhamphicarpa*+rice, *Rhamphicarpa* alone, *Striga*+rice, rice alone) as the main plot and moisture levels (saturation, field capacity, field capacity/saturation and field capacity/wilting point; the latter two were half way in between) as subplots. Rice variety 'Supa India' was used and treatments were arranged in a randomized complete block design with five replicates including a duplicate that was used for destructive sampling. Emergences of *Rhamphicarpa* were not significantly affected by moisture levels, however, the significant differences were observed on emergence of *Striga asiatica.* At 60 and 120 DAS, there were significant differences in weed counts at different moisture levels whereby 60 DAS, the maximum *Rhamphicarpa* counts was 40 and at 120 DAS the maximum *Rhamphicarpa* counts was 7.8 plants appeared in saturation moisture level. *Striga* at 60 DAS, showed significant differences in number at different moisture levels whereby at field capacity/wilting point 3 plants were recorded while at 120 DAS the maximum *Striga* number (9) was recorded at field capacity moisture level. Weed heights at 60 DAS was significant different in moisture levels whereby the tallest *Rhamphicarpa* plant (16.3cm) was recorded at saturation while for *Striga* (13.2cm) at field capacity/wilting point. *Rhamphicarpa* flowering took place at 76 DAS while *Striga* flowered at 83DAS.The rice damage caused by weeds at different moisture levels were observed in different areas whereby there was significant different in plant heights and the tallest rice plants (86.6cm) were recorded at saturation moisture level and *Striga*/rice plant combinations 60 DAS while at 120 DAS the tallest plant (119.5cm) was recorded at same moisture level and plant combination. Rice chlorophyll content (SPAD), stomatal conductance (mmol/(m^2·s) and in tiller numbers were significantly different however, there was no significant difference in leaf area(cm^2), specific leaf area ($cm^2.g^{-1}$) and in chlorophyll fluorescence (fv/fm).Weeds affected rice biomass where by *R. fistulosa* lowered rice biomass to 2.5g compared to rice planted alone (5.2g) and (5.06g) when planted with *Striga* at 60 DAS at saturation moisture level while at field capacity, Rice alone produced 2.86g, *Rhamphicarpa*/rice 1.2g and 1.6g for *Striga*/rice; this trend was observed at 120 DAS. The results conclude that moisture has effect to weed performance whereby *Rhamphicarpa* performed well in saturation moisture level while *Striga* preferred field capacity and field capacity/wilting point. Also *Rhamphicarpa* plants in field capacity/saturation caused same damage to rice plant as for *Striga* which tells that they can co-exist at field capacity/saturation.

DECLARATION

I, Msangi, Saidi Hamadi; do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Msangi, Saidi Hamadi (MSc. Candidate)	20/05/2014 Date

The declaration is confirmed by

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DEDICATION

This work is dedicated to my lovely mother Amina S. Lolila for her lovely care that she raised me with, my lovely wife Farida Mkenga, my sons Samir and Sabeer, my deceased father Mr Hamadi Msangi and Mr. and Mrs. Zuberi Msangi.

TABLE OF CONTENTS

ABSTRACT ii

DECLARATION iv

COPYRIGHT v

ACKNOWLEDGEMENTS vi

DEDICATION vii

TABLE OF CONTENTS viii

LIST OF FIGURES xiii

LIST OF ABBREVIATIONS AND ACRONYMS xiv

CHAPTER ONE 1

1.0 INTRODUCTION 1

1.1 Background Information 1

1.2 Problem Statement 2

1.3 Justification 2

1.4 Objectives 3

1.4.1 Main objective 3

1.4.2 Specific objectives 3

CHAPTER TWO 4

2.0 LITERATURE REVIEW 4

2.1 Weeds 4

2.1.1 *Striga asiatica* (L.) 5

2.1.1.1 Ecology and distribution 5

2.1.1.2 Dormancy and germination of *Striga* seeds 6

2.1.1.3 Economic importance 7

2.1.2 *Rhamphicarpa fistulosa* (Hochst.) Benth 8

2.1.2.1 Ecology and distribution 8

2.1.2.2 Botanical description........ 9

2.1.2.3 Economic importance 10

2.2 Effect of Moisture on Parasitic Weeds 11

CHAPTER THREE........ 11

3.0 MATERIALS AND METHODS 12

3.1 To determine soil moisture requirements for germination and establishment of *Rhamphicarpa fistulosa* and *Striga asiatica* in rice 12

3.1.1 Source of seeds 12

3.1.2 Experimental site 12

3.1.3 Treatments and experimental design 12

3.1.3.1 Saturation (Sat) 13

3.1.3.2 Field capacity (FC) 13

3.1.3.3 Field capacity/Wilting point (FC/WP)........ 14

3.1.3.4 Field capacity /Saturation (FC/Sat)........ 14

3.1.4 Planting 15

3.1.5 Data collected 15

3.1.5.1 Emergence of *Rhamphicarpa* and *Striga* seedlings 16

3.1.5.2 *Rhamphicarpa* and *Striga* heights........ 16

3.1.5.3 Flowering and capsule number........ 16

3.1.5.4 Capsule dry weight 16

3.1.5.5 Weed seed production 16

3.1.5.6 Weed root dry biomass........ 17

3.1.5.7 Weed shoots dry biomass........ 17

3.1.5.8 Total weed biomass dry biomass 17

3.2 To quantify the extent of host damage caused by the parasitic weeds singly in rice ... 17

3.2.1 Data Collected 17

3.2.1.1 Plant height, number of tillers 17

3.2.1.2 Chlorophyll content 18

3.2.1.3 Chlorophyll fluorescence (fv/fm) 18

3.2.1.4 Stomata conductance (mmol/m2s) 18

3.2.1.5 Root dry biomass (g) 18

3.2.1.6 Shoots dry biomass (g) 19

3.2.1.7 Number of green and dry leaves at harvest 19

3.2.1.8 Total rice biomass (g pot-1) 19

3.2.1.9 Leaf area (cm2) and specific leaf area (cm2 g-1) 19

3.2.2 Data analysis 19

CHAPTER FOUR **21**

4.0 RESULTS **21**

4.1 Weeds parameters 21

4.1.1 Emergence and number of *Rhamphicarpa* and *Striga* seedlings 21

4.1.2 Heights of *Rhamphicarpa* and *Striga* (cm) weeds 23

4.1.3 Flowering and capsule counts 25

4.1.4 Capsule dry biomass 26

4.1.5 Weed seed weight 26

4.1.6 Parasitic weed root dry biomass 28

4.1.7 Parasitic weed shoot dry biomass 29

4.1.8 Total Weed Dry Biomass 30

4.2 Rice parameters 32

4.2.1 Height (cm).. 32

4.2.2 Chlorophyll Content 33

4.2.3 Chlorophyll Fluorescence (fv/fm) 34

4.2.4 Stomatal Conductance 35

4.2.5 Root dry biomass 36

4.2.6 Shoot dry biomass.. 36

4.2.7 Total rice biomass.. 37

4.2.8 Tillers Counts 40

4.2.9 Number of green leaves at harvest.. 40

4.3 Number of dry leaves at harvest... 40

4.3.1 Leaf area (cm2) and specific leaf area (cm2./g) 41

CHAPTER FIVE.. **43**

5.0 DISCUSSION.. **43**

5.1 *Rhamphicarpa fistulosa* and *Striga asiatica* at different moisture levels and plant combinations 43

5.1.2 Response of *Striga asiatica* to moisture levels 45

5.2 Influence of *Rhamphicarpa fistulosa* and *Striga asiatica* on rice growth at different moisture levels and plant combinations.. 46

CHAPTER SIX... **50**

6.0 CONCLUSIONS AND RECOMMENDATIONS **50**

6.1 Conclusions 50

6.2 Recommendations 50

REFERENCES.. **51**

LIST OF TABLES

Table 1: *Rhamphicarpa* and *Striga* heights (cm) at different moisture levels and plant combinations 25

Table 2: *Rhamphicarpa* reproductive variables at different moisture levels and plant combinations from 60 to 120 DAS 27

Table 3: *Striga* reproductive variables at different moisture levels and plant combinations from 60 to 120 DAS 28

Table 4: *Rhamphicarpa* and *Striga* dry biomass (g pot^{-1}) 120 DAS in different moisture levels and plant combinations 32

Table 5: Rice heights (cm) at different moisture levels and plant combinations........ 33

Table 6: Rice stomatal conductance (mmol/(m^2 s)) in different moisture levels and plant combinations at different days after sowing........ 36

Table 7: Rice dry biomass (g pot^{-1}) 60 DAS at different moisture levels and plant combinations 38

Table 8: Rice dry biomass (g pot^{-1}) 120 DAS at different moisture levels and plant combinations 38

Table 9: Rice dry leaves, green leaves and tillers number at harvest in different moisture levels and plant combinations 41

Table 10: Rice leaf area (cm^2) and specific leaf area (cm^2/g) 60 DAS in different moisture levels and plant combinations 42

LIST OF FIGURES

Figure 1: *Striga asiatica* 7

Figure 2: *Rhamphicarpa fistulosa*. 10

Figure 3: Number of weeds at different moisture levels and plant combinations 23

Figure 4: Weed dry biomass (g pot^{-1}) 60 DAS at different moisture levels and plant combinations 31

Figure 5: Rice chlorophyll content (SPAD) in different moisture levels and plant combinations .. 34

Figure 6: Rice chlorophyll fluorescence (fv/fm) in different moisture levels and plant combinations 35

Figure 7: Rice total biomass (g pot^{-1}) 60 DAS at different moisture levels and plant combinations 39

Figure 8: Rice total biomass (g pot^{-1}) 120 DAS at different moisture levels and plant combinations. 39

LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
CDFA	California Department of Food and Agriculture
CV	Coefficient of variation
DAS	Days after sowing
DNMRT	Duncan Multiple Range Test
FAO	Food and Agriculture Organization
FC	Field Capacity
FC/SAT	Field Capacity/Saturation
FC/WP	Field Capacity/Wilting Point
LSD	Least Significant Different
MAFC	Ministry of Agriculture, Food and Cooperative
RH	*Rhamphicarpa* alone
RHRI	*Rhamphicarpa*+ Rice
RI	Rice alone
S.E	Standard error
SAT	Saturation
SPAD	Soil Plant Analysis Development
STRI	*Striga* + Rice
TMA	Tanzania Meteorological Agency

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Rice (*Oryza sativa*) is the second most important food and commercial crop in Tanzania after maize. The cultivated area is 681,000 ha equivalent to 18 % of Tanzania's cultivated land. About 71 % of the rice grown in Tanzania is produced under rain-fed condition. Tanzania is the major producer and consumer of rice in East Africa and about 90% self-sufficient in rice production (MAFC, 1998). The average yield is very low, 1-1.5 t per ha. Farmers grow a number of traditional varieties which mature late and yield is adversely affected by irregular rainfall pattern and occurrence of pests. The most common rice pests are weeds. Weeds compete with crop for important resources like light, water and nutrients. Yield decreases by weeds vary greatly, depending partly on the adequacy of light, water and nutrient supplies, but mainly on the competitive ability of the crop relative to that of the weed population (Fryer and Evans, 1970).

A particular pernicious group of weeds is formed by parasitic plants. Among them one can distinguish obligate and facultative parasites. Obligate parasites are those parasites that cannot complete their life cycle without a host, while facultative parasites are parasites that can grow independently from a host and also can benefit considerably from attachment to a host. Although *Striga asiatica* is the most common and well known parasitic weed, recently *Rhamphicarpa fistulosa* has been reported as a considerable problem in East and West Africa (Rodenburg *et al.*, 2010/2011). *Rhamphicarpa fistulosa* is a facultative hemi-parasitic weed which was first reported in Tanzania by Johnson *et al.* (1998).

1.2 Problem Statement

Low actual yields in rain-fed rice are the result of poor yielding varieties, depleted soil fertility, diseases and weed infestation. The average rice yield obtained in Tanzania is very low (1.5 t ha^{-1}) compared to the estimated potential yields of 4-5 t ha^{-1} (MAFC, 1998). In recent years, *Striga spp.* and *Rhamphicarpa fistulosa* have been identified as important parasitic weeds hindering rice production (unpublished Kyela District Agricultural Reports., 1998). Generally *Striga spp.* grows in areas with annual rainfall ranging from 25-150 cm per year with decrease in severity of infestation in areas of high rainfall (Mohamed *et al.*, 1998). However, other species have been found to occur in wet areas and even in water logged conditions in Cote d'Ivore and Tanzania (Mohamed *et al.*, 2001). In Kyela district, southern Tanzania, along the flood-plain of Lake Nyasa (syn. Lake Malawi), *S. asiatica* is observed in rice cultivated uplands while *Ramphicarpa* thrives on rice fields on the lower hydromorphic and temporary flooded zones. Such an area can provide an ecological boundary where both *Rhamphicarpa* and *S. asiatica* could coexist when there is an appropriate host. This can be the case where a transition along the landscape to both systems could provide a suitable environment to support both parasites. Knowledge on optimum moisture level for weed germination could help to develop effective control methods.

1.3 Justification

Rhamphicarpa fistulosa is highly invasive and is ranked as an important constraint where it occurs. Rice is also the only crop that can be grown in temporary submerged areas where *R. fistulosa* thrives. On the other hand, *Rhamphicarpa fistulosa* does not occur as a single weed species in rice fields but rather as a component of a multi-species weed community. Therefore technologies should not merely target the control of *R. fistulosa* but contribute to the management of weeds in general.

Previous studies showed that *R. fistulosa* has similar germination requirements as *Striga angustifolia* such as *Rhamphicarpa* seeds need to be exposed to light in order to germinate (Parker and Riches, 1993; Neumann *et al*, 1998 and Ouedraogo *et al*., 1999). It is therefore pertinent to determine the germination requirements of *Rhamphicarpa fistulosa* and *Striga asiatica* so as to provide pointers for effective control practices.

1.4 Objectives

1.4.1 Main objective

To quantify soil moisture requirements for effective control of *Rhamphicarpa fistulosa* and *Striga asiatica*

1.4.2 Specific objectives

i. To determine moisture requirement for germination and establishment of *Rhamphicarpa fistulosa* and *Striga asiatica* in rice

ii. To quantify the extent of host damage caused by the infestation of either of the parasitic weeds in rice

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Weeds

Weeds are plants existing at places or times at which they are considered undesirable by man (Duke, 1985). Thus man's primary interest in weeds is finding methods for eliminating their presence. Weeds are the most important biophysical problem in rice production. Species of weeds, and sometimes biotypes within species, can vary greatly in growth habits and ultimately in their ability to compete with crops. Germination patterns differ markedly and sometimes erratically, causing differences in competition from year to year. Emergence and growth also vary from slow and even, to rapid and almost unpredictable. Different species and biotypes appear to respond differentially to various environmental conditions.

In cultivated land, weeds are subjected to the diverse and changing aspects of soils and the interrelationship with other plants and other living organisms. Ecological studies of weed interactions helps to gain insight in the mechanism of distribution and adptation of weeds to specific environmental conditions and are therefore indispensable for evolving suitable methods of weed control. Variation in competitive ability probably can be due to soil and air temperature, along with soil moisture content and rainfall. These conditions affect weed emergence and growth, herbicide effectiveness, the competitive interaction between crop and weed, and the ability of the crop to recover from early weed competition once the weeds have been removed.

A number of these weeds are parasitic. Watling and Press (2001) reported that parasitic weeds have considerable harmful effects on their host in terms of photosynthetic rate and total canopy photosynthesis over the life of the plant. Root parasitic weeds such as orobanche and *Striga* lack their own root system as such they compensate by penetrating the roots of host plants and thus depriving the essential nutrients for plant growth. This action causes stagnation of the host plants with the end result of low yield (Watson *et al.*, 1998). Largely, these effects can be classified in terms of direct effects of resources abstraction and indirect effects (Watling and Press, 2001). In contrast to non-parasitic weeds, the occurance of parasitic weeds is dependent on the presence of their specific host plants (Krocschel, 2001).The most important parasitic weeds are the obligate hemi-parasitic witch weeds, *Striga hermonthica* (Del.) Benth, *Striga asiatica* (L.) Kuntze and the facultative hemi-parasite *Rhamphicarpa fistulosa* (Hochst.) Benth.

2.1.1 *Striga asiatica* (L.)

2.1.1.1 Ecology and distribution

Striga asiatica is an annual parasitic weed of cereal crops. *Striga* has enormous impact on human welfare by affecting subsistence farmers (CDFA, 2006). *Striga* occurs in different continents such as Africa, Asia, Australia, and America. It rarely occurs in altitude greater than 1000m above sea level and is well adapted to conditions of semi arid tropic (Rao and House, 1972). In East and central Africa it occurs in Kenya, Tanzania, Sudan, Uganda, Congo and Ethiopia (Lagoke *et al.*, 1994). In 1972, Ogborn reported that *Striga* appears to thrive well on intermittent dry condition, low soil fertility and particularly low nitrogen status. This has also been reported by Johnson *et al.*, (1997) that *Striga asiatica* and *Striga hemonthica* are regarded as the most infectious and are found in free draining areas. However, other species have been found to occur in wet areas and even in water logged conditions in Cote d'Ivore and Tanzania (Mohamed *et al.*, 2001). *Striga asiatica* is associated to soils with a light texture and low soil fertility. The infestation is steadily increasing as a result of deplited soil fertility caused by continous cultivation of cereal crops. Pressure on land necessitatecontinous cropping of high yielding cereal crops without rotation has resulted to exhausted soils which favour *Striga* infestation in addition to soil moisture stress conditions (Khan *et al.,* 2007). However, a number of reports comfirm *Striga asiatica* occuring on black, clay, wet and alluvial soils which have a higher nutrient status, not normally associated with the parasite (Hansen, 1975; Cochrane *et al.*, 1997).

2.1.1.2 Dormancy and germination of *Striga* seeds

Striga seeds usually remain dormant for a few months after harvest ofthe crop untill they are exposed to favourable growth conditions and host-derived germination stimulants called strigolactones (Shen *et al.*, 2006). Maximum germination occurs when striga seeds are 9 months or older (Kust, 1963). However, Ayensu *et al.* (1984) reported *Striga hemonthica* germination of 80% within three months from collection.

The CDFA (2006) reported that, dormant seeds survive freezing for at least 49 days and can remain viable under field conditions for up to 14 years or more. Germination is complex and requires about a 1-3 week "conditioning" period at a suitable temperature regime under moist conditions, followed by a chemical signal from a nearby root of a host plant. Proximity of host root to seed must be within a few millimetres. Under these conditions, seeds germinate within 24 hours. After 3 weeks of conditioning without a chemical signal, germination ability of seeds decrease, and some seed may pass into a secondary dormancy. Flowers develop about 3 weeks after emergence. Viable seed is produced within 2 weeks of flowering. A minimum of 60 days is required from seed germination to seed production.

A germinated *Striga* seedling forms a specialized attachement and penetration organ called haustorium in response to host derived haustorium induction factors, these includes various phenolic acids, quinones, and flavonoids (Keyes *et al*., 2000 and Yoder, 2001). *S. asiatica* seedlings are not visible above ground, but white succulent shoots can be found attached to host roots. Once *Striga* appears above ground, it produces chlorophyll and becomes a semi parasite manufacturing part of its food requirements but continuing to depend on the host for water and minerals. Mature plants have green foliage above ground and that is sparsely covered with coarse, short, white, bulbous-based hairs.

Figure 1: ***Striga asiatica***

2.1.1.3 Economic importance

Striga asiatica takes nutrients and moisture by tapping directly into a host's root system (Invasive.org, 2006). Avery small parasite biomass with attachments of less than 4mm in size, results in large reduction in host height, biomass and eventually grain yield (Gurney *et al*., 1995).Yield losses of 5-15% are common, although locally, under severe infestations, losses can far exceed this amount. *S. asiatica* impairs photosynthesis of susceptible maize hosts through limiting stomatal conductance and sensitizes infested plants to photo inhibition. Symptoms in host plants include stunting, chlorosis, and wilting (CDFA, 2006; Elzein and Kroschel, 2004; Anon, 2006; and Gurney *et al.*, 2002). Under high infestation the host plant may die before flowering and symptoms may even be observed before the *Striga* emerges from the soil (Mbwaga *et al.*, 2000). One of the reasons why *Striga* has such devastating impact on the growth and yield of cereals relates to its dual mode of actions such as competing effectively with the host for carbon, nitrogen and inogarnic solutes (Frost *et al.*, 1997; Gurney *et al.*, 1995) and the so-called phytotoxic effect on the host plant within days of attachment which the parasite has (Berner *et al.*, 1995; Gurney *et al.*, 1995; Frost, 1995). The mechanism underlying the phytotoxic effect has not yet been clarified, but may involve the production of toxin (Musselman & Press, 1995).

2.1.2 *Rhamphicarpa fistulosa* (Hochst.) Benth

Rhamphicarpa fistulosa is an annual herbaceous flowering plant of the orobanchaceae family which is a parasitic weed of cereal crops in tropical Africa. *Rhamphicarpa* is a facultative hemi-parasite and as such not dependent on the presence of a host to complete the life cycle, even though the parasite obtains a reproduction advantage from parasitizing a suitable host plant (Ouédraogo *et al.*, 1999).

2.1.2.1 Ecology and distribution

Rhamphicarpa is not yet considered to be a widespread problem, though; in coming days it is likely to be more important weed than the most known parasitic weeds (Raynal-Roques, 1994; Rodenburg *et al.*, 2010). It has been found in Benin, Burkina Faso, Mali, Nigeria, Senegal, Tanzania and Uganda (Ouédraogo *et al.*, 1999; Lagoke *et al.*, 1994). *Rhamphicarpa fistulosa*'s prefered habitats are inland valleys or wetlands linked to run off habitats like the slopes of rock outcrops to interflow habitats along intermittent streams

(Deil, 2005). Here *Rhamphicarpa* parasitizes on wild grasses and is characterized as a west african class of mud vegetation. However, Hausen (1975) reported that rhamphicarpa is adapted to seasonally, wet, water-logged locations with open vegetation and is therefore mainly found in hydromorphic zones and unimproved rain-fed lowland ricefields (Rodenburg *et al.*, 2010;2011)

2.1.2.2 Botanical description

Rhamphicarpa has simple stem of much branches with broad leaves. The leaves are 10-60 mm long, reduced pinnatisect green leaves (Hansen, 1975; Philcox, 1990). Seeds are oval shaped, broader at the chalazal and the outer seed coat form a reticulate network covered by prominent ridges and absence of any protuberances. Seed size is about 200-550 µm (Ouédraogo *et al.*, 1999) whereby 1000 seeds weighs 11.3 mg (Rodenburg *et al.*, 2011). Seeds have 6-month dormancy period and require water and daylight for germination (Ouédraogo *et al.*, 1999). Flowers are solitary in axils of, or just above bracts. Corolla is white, cream, pale pink or pale blue. Roots are fibrous and branched, white and often connected to host plant roots.

Figure 2: ***Rhamphicarpa fistulosa.***

2.1.2.3 Economic importance

Rhamphicarpa derives its nutrients from the host through a haustorium (Neumann *et al.*, 1998). When the haustorium comes in contact with a host, the haustorium develops a group of cells called endophyte that penetrate into the host root cortex and the endodermis to establish a direct connection to the xylems so as to allow the transfer of nutrients from the host (Parker and Riches, 1993; Press and Graves, 1995). *Rhamphicarpa* can cause significant yield losses in millet, sorghum and maize but the most widely affected crop is rice (Cissé *et al.*, 1996; Kuijit, 1969; Ouedraogo *et al.*, 1999). In lowland rice, infestation of *Rhamphicarpa fistulosa* reduces yield up to total crop failure depending on the levels of infestation and susceptability of the host. The affected rice plants show stunted growth with very low or no grain yield. In Kyela district of southern Tanzania, farmers reported riceyield losses of 30-100% under severe infestation of *Rhamphicarpa fistulosa* (Kayeke *et al.*, 2010). In other areas, rice farmers in central Benin estimated the yield losses to be more than 60% while in pot experiments and with relatively low infestation densities, Rodenburgh *et al.*, (2011) reported grain yield losses in excess of 60%.

2.2 Effect of Moisture on Parasitic Weeds

Weeds as other plants have different moisture requirement. In thecase of *Striga asiatica,* it was reported that the weed grows in areas with annual rainfall ranging from 25-150 cm per year with decrease in severity of infestation in areas of high rainfall (Mohamed *et al.*, 1998). However, other species have been found to occur in wet areas and even in water logged conditions in Cote d'Ivore and Tanzania (Mohamed *et al.*, 2001). Holm *et al.*, (1977) reported that *Striga* cannot succeed in wet, high rainfall areas. This was also reported by California Department of Food and Agriculture (CDFA) in 2006 that *Striga asiatica* does not grow in wet conditions. On the other hand, *Rhamphicarpa fistulosa* was reported to be adapted to seasonally, wet and water-logged locations (Hansen, 1975).This was supported by Deil, (2005) who also reported that *R. fistulosa* preferred habitats that are inland valleys or wetlands linked to run off habitats. All these reports suggest that parasitic weed species have specific or variable ecological niches where they can establish a relationship with their hosts.

The aim of this study was to evaluate the exact moisture level where these weeds (*Ramphicarpa fistulosa* and *Striga asiatica*) can germinate and establish a relationship with the host. The co-existence of the two weeds at the same moisture level was also evaluated so as to provide information for management strategies to be developed. This was due to variability of the ecological niches and the importance of the two weeds (*Rhamphicarpa* and *Striga*) observed in different areas where rice is produced.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 To determine soil moisture requirements for germination and establishment of *Rhamphicarpa fistulosa* and *Striga asiatica* in rice

3.1.1 Source of seeds

Rice seeds were obtained from a seedlot of Super India variety from Kyela District in southern Tanzania during 2011/12 cropping season. *Rhamphicarpa* and *Striga* seeds were also from Kyela District in Southern Tanzania during 2011/12 cropping season.

3.1.2 Experimental site

A pot experiment was conducted in a screen house at Sokoine University of Agriculture located at 06° 50'S and 37° 39'E and an altitude of 526 meters above sea level (TMA, 2009). The day temperature in a screen house during the experiment was ranging between 27°c to 35°c.

3.1.3 Treatments and experimental design

The experiment consisted of four soil moisture levels and four host/parasite combinations and five replications. Host/parasite combinations were *Striga* + rice, *Rhamphicarpa* + rice, rice alone and *Rhamphicarpa* alone. The moisture levels were saturation, field capacity, field capacity/wilting point and field capacity/saturation.

The experimental design used was a Randomized Complete Block Design and the treatments were arranged in split-plot where by the moisture levels were the sub- plots and the host/parasite combinations were the main- plots.

3.1.3.1 Saturation (Sat)

Saturation is the state where all soil pores are filled with water. Empty pots of 10 litres capacity were weighed, then filled with dry 5:1 (sand: clay) soil mixture up to 2cm below the rim and reweighed again. The weight obtained was subtracted from the weight of the empty pots to determine the weight of the dry soil. Water was gradually supplied to the pots with dry soil, leaving ample time to fill all the pores, until the addition of extra water created a flood layer of one centimetre. After the flood layer was created, the pots were weighed again to determine the difference between dry soil and saturated soil. The weight of dry soil was 18kg while the weight after saturation was 22.4kg therefore the amount of water added to reach saturation was 4.4 litres (equivalent to 4.4kg) per pot. During the experiment the weight of the pots with saturated soil was restored on a 2 day cycle by supplying the necessary amount of water to compensate the losses caused by evapotranspiration. The amount which was compensated was determined by weighing the pots whereby the average water loss per day during the experiment was 0.16 litres per pot. Pots of the saturation treatments were not poked.

3.1.3.2 Field capacity (FC)

Field capacity is described as the water remaining in a soil after it has been thoroughly saturated and allowed to drain freely, usually for one to two days (Watling *et al.,* 2001) or the maximum water content that the soil will hold following free drainage (Ejeta *et al.,* 2007).

Pots of 10 litres capacity were weighed and holes poked at the bottom. The pots were then filled with dry 5:1 (sand: clay) soil mixture and up to 2cm below the rim of the pot. The weight attained after filling the pot with dry soil was 18 kg. Water was added to completely saturate the soil and allowed to drain freely for 3 days and then the weight determined. The average weight at field capacity was 20kg per pot. During the experiment the weight of the pots at field capacity was restored on a 2 day cycle by supplying 0.42 litres of water (compensation for losses caused by evapotranspiration and draining). This was determined by weighing the pots and calculating the amount of water loss.

3.1.3.3 Field capacity/Wilting point (FC/WP)

In this moisture level the condition of field capacity was repeated but the volume of water to be used was at half the amount as used at FC. Pots of 10 litres capacity were filled with water to saturation and left to drain for three days. The condition attained at this period was field capacity where by the average weight of the pot was 20 kg. The difference between dry soil and soil at field capacity was two kilograms whereby this was divided into two so as to attain field capacity/saturation. During the experiment the weight of the pots was restored on a 2day cycle by supplying the 0.2 litres of water to compensate the losses caused by evapotranspiration.

3.1.3.4 Field capacity /Saturation (FC/Sat)

In this treatment, the volume of water needed to reach FC/Sat was the average of the volume of water used for field capacity (2 litres) and Saturation (4.4litres) which was 3.2 litres. After adding water into pots the weight attained per pot was 21.2 kg. The weight of the pots was maintained by restoring the amount of water loss on a 2day cycle and this worked out to be 0.7 litres per pot. This amount was obtained by weighing the pots to determine the daily water loss caused by evapotranspiration and draining as in this treatment the pots were poked.

All the host/parasite combinations were grown at four moisture levels and five replications. The entire set of treatments was duplicated to allow destructive sampling. A total of 160 pots were used whereby each plant combination had 40 pots including the duplicate as described.

- *Rhamphicarpa* + rice (RhRi) x 4 moisture levels x 5 replicates (20 pots × 2)
- *Striga* + rice (StRi) x 4 moisture levels x 5 replicates (20 pots × 2)
- *Rhamphicarpa* alone (Rh) x 4 moisture levels x5 replicates (20 pots × 2)
- Rice alone (Ri) x 4 moisture levels x5 replicates(20 pots × 2)

3.1.4 Planting

Pots were filled with sand and clay soils mixed at a ratio of 5:1 Sand: Clay. Clay soil was collected from Kauzeni village, 12km from Morogoro town while sand soil was collected from Mindu area, 8.2km from Morogoro town. After mixing up the soil in 5:1 sand: clay, the texture of the soil became sand:silt:clay with the composition of 88.5: 3.3: 8.2 (%) respectively. The chemical properties of the soil were 0.07% Nitrogen, 55.28ppm Phosphorus and 88.3ppm Potassium and pH of 5.92. *Striga asiatica* seeds (0.04g) were planted in the pots (10 litres capacity) by emptying each vial containing the seeds and mixing them through the upper 10 cm of soil of each pot. 500 seeds of *Rhamphicarpa fistulosa* were mixed with the soil in the upper 1cm of soil in each pot. Three rice seeds of Supa India variety were planted at the centre of the pot at 1cm depth. After emergence rice seedlings were thinned to one plant per pot. Fertilizer was applied at the rate of 50kg N per ha using foliar fertilizer (Omex foliar feed)

3.1.5 Data collected

Data collection was done in two sections, the first was from sowing to 60 days after sowing and the second was from 60 days to 120 days after sowing. The experiment was ended when the rice plants attained early maturity stage therefore data collected were of vegetative growth.

3.1.5.1 Emergence of *Rhamphicarpa* and *Striga* seedlings

Data on emergence of *Rhamphicarpa fistulosa* seedlings was recorded every three days from 7 DAS up to 30 DAS and then every 10 days until 60 DAS. Number of *Striga asiatica* emerged was recorded at 60 DAS and at 120 DAS.

3.1.5.2 *Rhamphicarpa* and *Striga* heights

Height for *Rhamphicarpa fistulosa* was measured at 30, 60 and 120 DAS and *Striga asiatica* at 60 and 120 DAS. The tallest plant from each pot was selected for height measurement.

3.1.5.3 Flowering and capsule number

Flowering dates of *Striga* and *Rhamphicarpa* were recorded from each pot through daily observation. The capsules were counted at 120 days after sowing whereby matured capsules were separated from their original plants and kept in paper bags to avoid the loss of seeds.

3.1.5.4 Capsule dry weight

At 120 DAS, weed capsules in paper bags were kept in the oven at 70°c for 48 hours then weighed using sensitive weighing scale. The weight of capsules from each pot was recorded and the capsules were kept for determination of the weight of the seeds produced.

3.1.5.5 Weed seed production

Amount of weed seeds produced was determined at 120 DAS by threshing the weed capsules dried at 70°c for 48 hours and separating the seeds with capsules which were then weighed using a sensitive weighing scale. The weight was recorded as g/pot.

3.1.5.6 Weed root dry biomass

After harvesting the above ground shoots, weed roots were washed and kept in refrigerator for 24 hours. Refrigeration was necessary to facilitate separation of roots of *Rhamphicarpa, Striga* and rice. In cold environment *Rhamphicarpa* roots change to black; *Striga* roots turn purplish and rice roots retain their original colour (white). After separation the roots were dried in the oven for 48 hours at 70°C and then weighed.

3.1.5.7 Weed shoots dry biomass

At 120 DAS weed shoots were cut at ground level and dried at 70°C for 48 hours then weighed. This was done after separating the weed capsules which were dried separately.

3.1.5.8 Total weed biomass dry biomass

The dry weights of weed shoot, roots, capsules and seeds from each pot were collectively added and the total weed biomass dry weight was obtained at 120 DAS.

3.2 To quantify the extent of host damage caused by the parasitic weeds singly in rice

The materials and methods of this specific objective was the same to that of specific objective one in section 3.1.

3.2.1 Data Collected

3.2.1.1 Plant height, number of tillers

The height of rice plants was recorded after every 10 days up to 70 DAS, measured from the base of the plant to the tip of the tallest leaf. Number of tillers was recorded by counting the tillers formed by the rice plant. This was also from 10 DAS to 70 DAS.

3.2.1.2 Chlorophyll content

At 30 to 60 days after sowing, data on leaf chlorophyll content were collected using Minota Soil Plant Analysis Development Model (SPAD)-502 Chlorophyll meter. The measurements were done at a fully opened young leaf of rice plant in each pot with rice. Data from three parts of the leaf (top, mid and base) were recorded and the average data was obtained. This was done at 30, 40 and 60 DAS.

3.2.1.3 Chlorophyll fluorescence (fv/fm)

Chlorophyll fluorescence data were recorded at 40 and 50 DAS. These were recorded from a fully opened young leaf of the plant. This was done using chlorophyll fluorimeter whereby the clips were attached at the leaf for 15 minutes then the readings were recorded.

3.2.1.4 Stomata conductance (mmol/m^{2}s)

Stomata conductance was measured at 30 and 60 DAS using Leaf Porometer at young fully opened leaf of the rice.

3.2.1.5 Root dry biomass (g)

After harvesting the above ground shoots, weed and rice roots were washed and kept in refrigerator for 24 hours then separated. The reason of putting them in the refrigerator was to facilitate separation of roots as *Rhamphicarpa* roots changes to black when kept in cold environment while rice roots remains white. Also after 24 hours *Striga* roots turns to purplish colour which enhances the identification of them. After separation the roots were kept in the oven for 48 hours at 70°centigrade and then weighed. This was done 60 DAS at first sampling and 120 DAS at second sampling.

3.2.1.6 Shoots dry biomass (g)

At both samplings (60 and 120 DAS), rice shoots were cut at ground level and dried at 70°centigrade for 48 hours then weighed.

3.2.1.7 Number of green and dry leaves at harvest

This was done at 120 DAS where by number of green and dry leaves per pot were counted and recorded.

3.2.1.8 Total rice biomass (g pot^{-1})

The dry weights of shoots and roots were collectively added and the total biomass dry weight was obtained.

3.2.1.9 Leaf area (cm^2) and specific leaf area (cm^2 g^{-1})

At 60 DAS, rice leaf area per pot was measured whereby a young full developed leaf was selected for measurement. The area obtained was used to calculate the specific leaf area where by the measured leaf was dried and weighed; the specific leaf area was calculated by dividing the area by the dry weight of the leaf.

3.2.2 Data analysis

Data analysis was carried out with Genstat14th Edition. Data derived from the pot experiments were subjected to ANOVA. F-test was used to determine significant differences between treatments and significantly difference means were separated using Fisher's Least Significant Difference (LSD).

The statistical model used was $X_{ijk} = \mu + ßi + Mj + Ej + Ck + (M\times C)\ jk + E_{ijk}$, where; X_{ijk}= observations, μ = general mean to all treatments, ßi = effects of blocks /replications, Mj = main plot (moisture levels), Ej = Error due to main plot, Ck = Effect of sub plots (plant combinations), M×C = Effect of interaction of main plot and plant combinations, and E_{ijk} = Treatment error. **i, j** and **k** are the respective block, main plot and subplot.

CHAPTER FOUR

4.0 RESULTS

4.1 Weeds parameters

4.1.1 Emergence and number of *Rhamphicarpa* and *Striga* seedlings

There was no significant ($P > 0.05$) difference in *Rhamphicarpa fistulosa* emergence at different soil moisture levels and plant combinations. However, the number of *Rhamphicarpa fistulosa* plants differed significantly ($P < 0.05$) between the 7th day after sowing (DAS) and 120 DAS for the measurements taken in different moisture levels (Fig. 3) but they did not differ significantly ($P > 0.05$) in different plant combinations for the measurements taken at 10, 30, and 45 DAS.

The results showed that at 10 DAS in different plant combinations the number of *R. fistulosa* weeds increased from 81 to 120 but the highest number (120) was recorded for field capacity/saturation and the lowest (81) was obtained for field capacity. However, saturation and field capacity/wilting point had 85 and 90 *Rhamphicarpa* weeds, respectively, compared with field capacity. On the other hand, the measurements taken 30 DAS showed that in different plant combinations, the lowest number (110) of *Rhamphicarpa* plants was recorded for field capacity and the highest (154) was recorded for saturation. In addition, the results showed that field capacity/saturation and field capacity/wilting point had numerous *Ramphicarpa* weeds (119 and 134 respectively) compared with field capacity moisture level. The results at 45 DAS showed that the highest number of *R. fistulosa* (125) was recorded for field capacity/saturation and the lowest (50) was recorded for field capacity/wilting point. In addition, the field capacity had relatively several *Rhamphicarpa* (65) compared with field capacity/wilting point. However, the number of *Rhamphicarpa* where *R. fistulosa* was sown alone decreased with increase in DAS and at 120 DAS there was no *Rhamphicarpa* plant remained; the results obtained among different plant combinations for the measurements taken at 60 and 120 DAS showed significant ($P < 0.05$) difference (Fig. 3).

The results at 60 DAS showed that when *R. fistulosa* was sown alone the highest number (27) of weeds was obtained for field capacity/saturation and the lowest (2) was obtained for field capacity/wilting point but field capacity and saturation had almost equal (19) weeds. In addition, in different plant combinations the *R. fistulosa* weeds were 46 for field capacity/saturation and 8 for field capacity/wilting point; saturation and field capacity had relatively higher number (40 and 14respectively) of weeds than field capacity/wilting point. On the other hand, data for *Striga asiatica* collected 60 DAS in different plant combinations showed that the highest number (3) of weeds was obtained for field capacity/wilting point whereas field capacity/saturation and field capacity had only 1 *Striga* weed each.

Furthermore, the results obtained at 120 DAS showed that in different plant combinations the highest number (7) of *R. fistulosa* was obtained for saturation and few weeds were obtained for all other moisture conditions such as field capacity/wilting point (1), field capacity (2), and field capacity saturation (2). In addition, in different plant combinations the maximum number (9) of *Striga asiatica* was obtained at field capacity and the lowest (3) at field capacity/saturation but field capacity/wilting point had 8 *Striga* plants whereas saturation had no *Striga* plant.

On the other hand, the results generated for the *Striga asiatica* showed that the number of plants in different moisture levels differed significantly ($P < 0.05$) whereby many *Striga* seedlings emerged at field capacity and at field capacity/wilting point moisture levels followed by field capacity (Fig. 3).

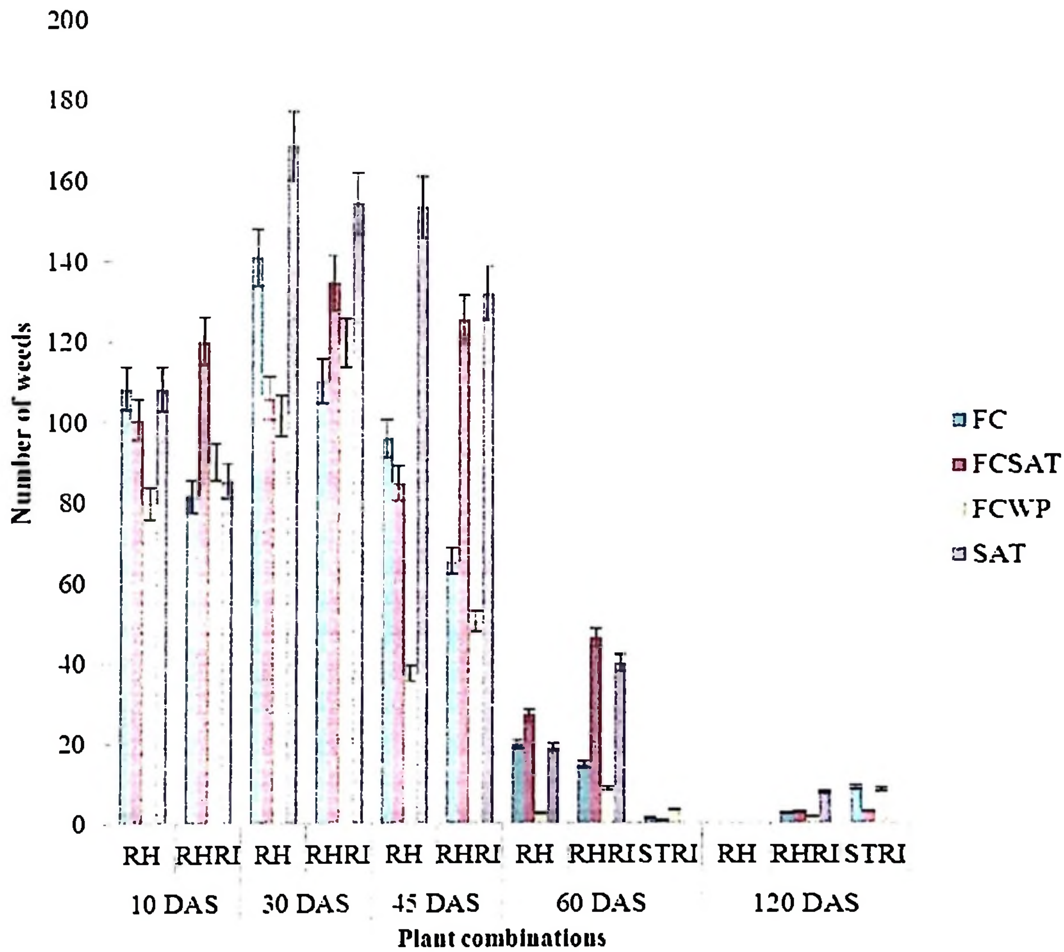

Figure 3: Number of weeds at different moisture levels and plant combinations

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RH-*Rhamphicarpa* alone, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice.

4.1.2 Heights of *Rhamphicarpa* and *Striga* (cm) weeds

The results of *R. fistulosa* from day 1 to 60 DAS showed insignificant ($P > 0.05$) differences in plant heights at different moisture levels. However, at 120 DAS, the heights differed significantly ($P < 0.05$) and the tallest plants were in saturation moisture level (Table 1). In addition, at 30, 60 and 120 DAS, the heights of *Ramphicarpa fistulosa* were significantly ($P < 0.05$) different for different plant combinations whereby the tallest plants were observed in *Rhamphicarpa*/rice plant combination (Table 1).

The results also showed that the heights of *S. asiatica* weeds differed significant ($P \leq 0.05$) at 60 and 120 DAS in different moisture levels whereby at 60 DAS, the tallest *S. asiatica* plants were in field capacity/wilting point and field capacity followed by field capacity/saturation while at 120 DAS the tallest plant appeared in field capacity/wilting point (Table 1).

At 30 DAS, the results showed that when *R. fistulosa* weed was sown alone the heights of *R. fistulosa* weeds varied under different moisture conditions in the order: field capacity (1.38 cm) > field capacity/saturation (1.2 cm) > field capacity/wilting point (0.82 cm) and these values were elevated for the *R. fistulosa* weeds grown in different plant combinations. The heights of *R. fistulosa* weeds increased for each moisture condition in different plant combinations and the order was: field capacity/saturation (6.1 cm) > saturation (5.4 cm) > field capacity (5.0 cm) > field capacity/wilting point (4.2 cm).

On the other hand, the heights of *R. fistulosa* weeds for the data collected 60 DAS were only obtained for field capacity (0.6 cm) and saturation (2.46 cm) when grown alone. However, when grown in different plant combinations the heights of *R. fistulosa* obtained were in the order: saturation (16.34 cm) > field capacity/saturation (11.2 cm) > field capacity/wilting point (10.26 cm) > field capacity (9.12 cm). In addition, the heights of *S. asiatica* weeds obtained when sown in different plant combinations for the data taken 60 DAS were: field capacity/wilting point (13.2 cm) > field capacity (10 cm) > field capacity/saturation (4.2 cm) whereas saturation had no *S. asiatica* plants during measurements.

At 120 DAS, results showed that the heights of *R. fistulosa* weeds sown in different plant combinations were: saturation (45.2 cm) > field capacity (23.2 cm) > field capacity/saturation (22.2 cm) > field capacity/wilting point (21.4 cm) and that of *S. asiatica* weeds were: field capacity/wilting point (39.8 cm) > field capacity (29.6 cm) field capacity/saturation (26.4 cm) but saturation had no *S. asiatica* weeds during measurements.

Table 1: *Rhamphicarpa* and *Striga* heights (cm) at different moisture levels and plant combinations

Moisture level	Weed heights (cm) for different plant combinations						
	30 DAS		60 DAS			120 DAS	
	RH	RHRI	RH	RHRI	STRI	RHRI	STRI
FC	1.38 [ab]	5.0 [a]	0.6 [a]	9.12 [a]	10 [bc]	23.2 [a]	29.6 [b]
FCSAT	1.20 [ab]	6.1 [c]	0.0 [a]	11.2 [a]	4.2 [ab]	22.2 [a]	26.4 [b]
FCWP	0.82 [a]	4.2 [a]	0.0 [a]	10.26 [a]	13.2 [c]	21.4 [a]	39.8 [b]
SAT	2.0 [b]	5.4 [b]	2.46 [a]	16.34 [b]	0.0 [a]	45.2 [b]	0.0 [a]
S.E	34.1		7.37		5.18	10.35	9.48
CV%	26.3		117.9		75.6	73.9	39.6

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RH-*Rhamphicarpa* alone, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice

4.1.3 Flowering and capsule counts

Flowering ability of *Rhamphicarpa fistulosa* and *Striga asiatica* weeds was favoured by moisture levels. In different plant combinations, the results showed that flowering days differed significantly ($P \leq 0.05$) in different moisture levels whereby *Rhamphicarpa* weeds in field capacity/saturation moisture level flowered at 76.5 days, earlier than in other moisture levels including saturation (76.8 days), field capacity (78.3 days) and field capacity/wilting point (81.7 days) (Table 2). On the other hand, *Striga* weeds did not significantly ($P > 0.05$) different in days to flowering at different moisture levels whereby at field capacity, flowering started at 83 days; at field capacity/saturation (83.3 days) and field capacity/wilting point (83.4 days) (Table 3).

The number of weeds' capsules taken in different plant combinations were significantly ($P \leq 0.05$) different in different moisture levels. Various *Rhamphicarpa* capsules were produced at saturation moisture levels (20 capsules) while for *Striga* weeds, were at field capacity/wilting point (105 capsules) and field capacity moisture levels (104 capsules) (Table 2). On the other hand, very few capsules were produced by *Rhamphicarpa* weeds at field capacity/saturation (3), field capacity and field capacity/wilting point (9) moisture levels. In addition, the very few capsules (41) were obtained for *Striga* at field capacity/saturation moisture level and there was no data available at saturation moisture level as there was no *Striga* plant (Table 3).

4.1.4 Capsule dry biomass

In different plant combinations, there was significant ($P \leq 0.05$) difference in total dry weight of capsules at different moisture levels whereby the highest total dry weight (0.63 g) of *Rhamphicarpa* capsules was obtained at saturation moisture level (Table 2). However, largest total dry weights of *Striga* capsules were obtained at field capacity (0.5 g) and at field capacity/wilting point (0.5 g) moisture levels (Table 3).

4.1.5 Weed seed weight

The weight of weed seeds differed significantly ($P \leq 0.05$) with moisture levels in different plant combinations. The largest weight (0.35 g) of *Rhamphicarpa* seeds in *Rhamphicarpa*/rice plant combinations was obtained at saturation and the lowest (0.08 g) at field capacity moisture levels (Table 2). On the other hand, the largest weights (0.3 g) of

Striga seeds were produced at field capacity/wilting point and at field capacity moisture levels, respectively, and the lowest weight (0.1 g) was obtained at field capacity/saturation moisture level (Table 3)

Table 2: *Rhamphicarpa* reproductive variables at different moisture levels and plant combinations from 60 to 120 DAS

	Reproductive variables			
Moisture levels	Days to flowering RHRI	Capsule counts (pot^{-1}) RHRI	Capsule weights (g pot^{-1}) RHRI	Seed weights (g pot-1) RHRI
FC	78.3 ^{ab}	5.6 ^{ab}	0.16 ^{a}	0.08 ^{a}
FCSAT	76.5 ^{a}	3.6 ^{ab}	0.09 ^{a}	0.22 ^{a}
FCWP	81.7 ^{b}	9.0 ^{ab}	0.24 ^{a}	0.12 ^{a}
SAT	76.8 ^{a}	20.8 ^{c}	0.63 ^{b}	0.35 $_{b}$
S.E	26.5	6.76	0.22	0.19
CV%	104.4	138.7	154.7	204.2

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT.

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RHRI- *Rhamphicarpa*/rice,

Table 3: *Striga* reproductive variables at different moisture levels and plant combinations from 60 to 120 DAS

Moisture levels	Reproductive variables			
	Days to flowering STRI	Capsule counts (pot^{-1}) STRI	capsule weights ($g\ pot^{-1}$) STRI	Seed weights ($g\ pot^{-1}$) STRI
FC	83^{b}	104.4^{b}	0.5^{b}	0.3^{b}
FCSAT	83.3^{b}	41.2^{ab}	0.2^{ab}	0.1^{ab}
FCWP	83.4^{b}	105.6^{b}	0.5^{b}	0.31^{b}
SAT	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
S.E	23.84	46.15	0.23	0.15
CV%	44.3	73.5	76.2	83.5

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT.

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation,STRI-*Striga*/rice

4.1.6 Parasitic weed root dry biomass

At 60 and 120 DAS, *Rhamphicarpa* and *Striga* root dry weights showed significant ($P \leq 0.05$) difference at different moisture levels and plant combinations. At 60 DAS (Fig. 4), very small root dry weights were only recorded for *Rhamphicarpa* weeds when sown alone at field capacity/saturation (0.002g) and saturation (0.025g) moisture levels. In addition, in different plant combinations the largest root dry weight (0.603g) for *Rhamphicarpa* weeds was recorded at saturation moisture level but other moisture levels recorded small weights including field capacity/wilting point (0.287g) > field capacity (0.161g) > field capacity/saturation (0.095g). On the other hand, the root dry weights obtained for *Striga* weeds in different plant combinations were very small at different moisture levels such as: field capacity/wilting point (0.08g) > field capacity = field capacity/saturation (0.01g).

Furthermore, in different plant combinations at 120 DAS, (Table 4) it was observed that the largest dry root weight (2.3g) for *Rhamphicarpa* weeds was recorded at saturation moisture level and very small weights were recorded at field capacity/wilting point (0.5g), field capacity (0.3g) and field capacity/saturation (0.1g) moisture levels. On the other hand, the root dry weights of *Striga* weeds were only obtained at field capacity = field capacity/wilting point (0.2g) and field capacity/saturation (0.1g) moisture levels (Table 4).

4.1.7 Parasitic weed shoot dry biomass

The shoot dry weights of the studied parasitic weeds were significantly ($P \leq 0.05$) different in different moisture levels and in different plant combinations. The results showed that, at 60 DAS (Fig. 4) when *Rhamphicarpa* weed was sown alone the shoot dry biomass in different moisture levels were in the order: field capacity/saturation (0.021g) > field capacity (0.02g) > saturation (0.01g) > field capacity/wilting point (0.001g). However, in different plant combinations the shoot dry biomass slightly increased but the differences were as follow: saturation (1.878g) > field capacity/wilting point (0.328g) > field capacity (0.307g) > field capacity saturation (0.278g). On the other hand, shoot dry biomass of *Striga* weeds in different plant combinations followed the order: field capacity/wilting point (0.12g) > field capacity (0.09g) > field capacity/saturation (0.03g) and saturation moisture level had no weeds.

Furthermore, at 120 DAS,(Table 4) results showed that the shoot dry biomass of *Rhamphicarpa* weed in different moisture levels when sown in different plant combinations differed in different moisture levels such as: saturation (4.6g) > field capacity (1.2g) > field capacity/wilting point (1.1g) > field capacity/saturation (0.8g). In addition, in different moisture levels the shoot dry biomass of *Striga* weeds differed in the order: field capacity (0.8g) > field capacity/wilting point (0.7g) > field capacity/saturation (0.3g) and there were no weeds at saturation moisture level (Table 4).

4.1.8 Total Weed Dry Biomass

The results showed that there was significant ($P \leq 0.05$) difference in total dry biomass of the studied weeds in different moisture levels. At 60 DAS, (Fig. 2) results showed that when *Rhamphicarpa* was sown alone the total dry biomass differed with soil moisture levels such as saturation (0.035g), field capacity/saturation (0.023g), field capacity (0.02g) and field capacity/wilting point (0.001g). However, in different plant combinations the total dry biomass increased differently for each moisture level such as: saturation (2.481g), field capacity/saturation (0.565g), field capacity (0.467g) and field capacity/wilting point (0.423g). On the other hand, the total dry biomass of *Striga* weeds sown in different plant combinations differed with moisture levels (Fig. 4) such as: field capacity/wilting point (0.19g), field capacity (0.1g) and field capacity/saturation (0.04g).

Furthermore, at 120 DAS (Table 4) in different plant combinations it was observed that there were differences in total dry biomass for each weed in different moisture levels. The results showed that the total dry biomass of *Rhamphicarpa fistulosa* increased compared with the data taken at 60 DAS and these are in the order: saturation (7.86g), field capacity/wilting point (1.99g), field capacity (1.74g) and field capacity/saturation (1.25g). In addition, at 120 DAS, the total dry biomass of *Striga* weeds in different plant combinations also increased compared with that obtained at 60 DAS (Table 4). The biomass differed with moisture levels such as: field capacity (1.78g), field capacity/wilting point (1.74g) and field capacity/saturation (0.65g).

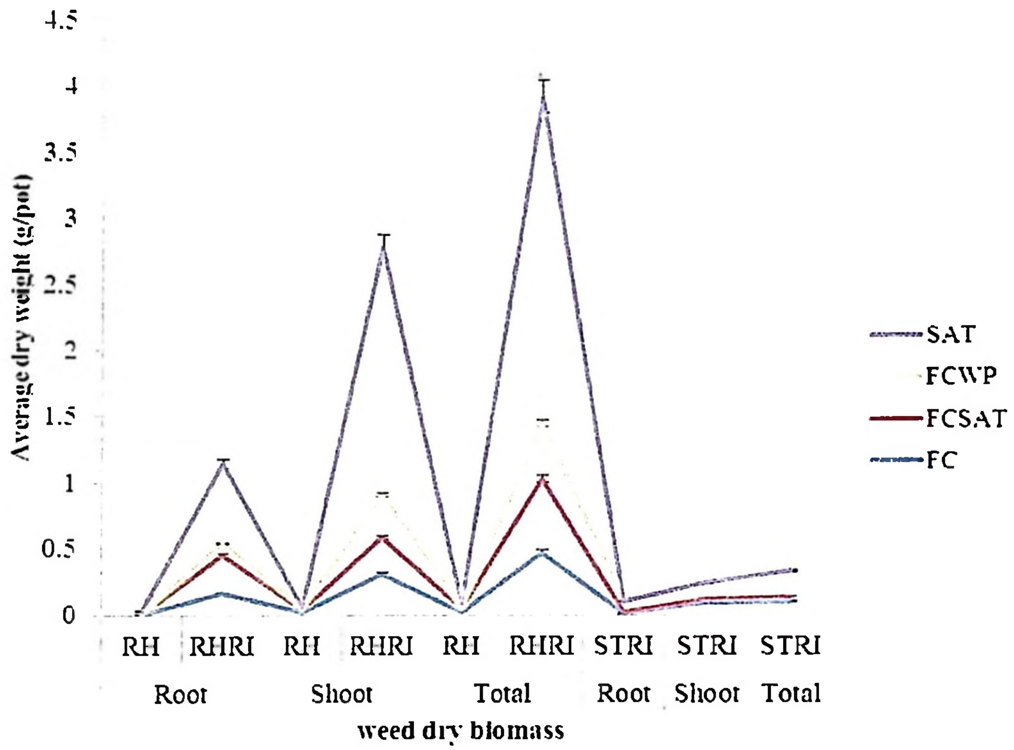

Figure 4: Weed dry biomass (g pot^{-1}) 60 DAS at different moisture levels and plant combinations

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RH-*Rhamphicarpa* alone, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice

Table 4: ***Rhamphicarpa*** **and** ***Striga*** **dry biomass (g pot^{-1}) 120 DAS in different moisture levels and plant combinations**

Moisture levels	Weed dry biomass(g pot^{-1}) *Rhamphicarpa* with rice				*Striga* with rice			
	Roots	Shoots	Capsule	Total	Roots	Shoots	Capsules	Total
FC	0.3 ^{a}	1.2^{a}	0.16^{a}	1.74 ^{ab}	0.2^{b}	0.8 ^{b}	0.5 ^{b}	1.78 ^{b}
FCSAT	0.1 ^{ab}	0.8 ^{a}	0.09 ^{a}	1.25 ^{a}	0.1 ^{a}	0.3 ^{ab}	0.2 ^{ab}	0.65 ^{a}
FCWP	0.5 ^{ab}	1.1 ^{a}	0.24^{a}	1.99 ^{ab}	0.2 ^{b}	0.7^{b}	0.5 ^{b}	1.74^{b}
SAT	2.3 ^{c}	4.6 ^{b}	0.63^{b}	7.86 ^{b}	0.0 ^{a}	0.0 ^{a}	0.0 ^{a}	0.0 ^{a}
S.E	0.69	1.13	0.22	7.87	0.08	0.038	0.23	0.7
CV%	166.8	117.5	154.7	48.7	68.9	83.8	76.2	67.6

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT.

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RH-*Rhamphicarpa* alone, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

4.2 Rice parameters

4.2.1 Height (cm)

Data for rice height was collected at 10 DAS and after every 10 day up to 60 days. Results indicated that there was significant ($P < 0.05$) difference in rice height at different moisture levels from 10 DAS to 120 DAS. Tallest (119.5 cm) rice plants were observed at saturation moisture levels in all stages of growth (Table 5). From 10 DAS to 50th day there was no significant difference in rice height at different plant combinations, but at 60 and 120 DAS the significant ($P < 0.05$) difference in rice height was observed at different plant combinations whereby tallest plants were at rice alone followed by *Striga*/rice plant combinations (Table 5).

Table 5: Rice heights (cm) at different moisture levels and plant combinations

Moisture levels	Rice height 30 DAS RHRI	RI	STRI	60 DAS RHRI	RI	STRI	120 DAS RHRI	RI	STRI
FC	33.0 [a]	36.8 [a]	31.9 [a]	57.8 [a]	67.6 [a]	63.5 [a]	62.9 [a]	87.4 [a]	76.9 [a]
FCSAT	35.8 [ab]	37.9 [ab]	33.7 [a]	63.4 [ab]	64.1 [a]	6.9 [a]	66.1 [ab]	94 [ab]	87.1 [ab]
FCWP	34.2 [a]	37.9 [ab]	36.9 [ab]	63.3 [ab]	72.6 [b]	65.9 [a]	72.4 [b]	88.8 [ab]	80.2 [ab]
SAT	41.4 [bc]	43.1 [b]	43.2 [b]	71.8 [b]	86.3 [c]	86.7 [b]	67.4 [ab]	113.2 [b]	119.5 [b]
S.E		4.67			7.58			13.87	
CV%		12.6			11			16.4	

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT.

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT-saturation, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

4.2.2 Chlorophyll Content

The results showed that, at 30, 40 and 60 DAS, there were significant ($P < 0.05$) differences in chlorophyll content (SPAD) at different moisture levels where by highest SPAD value at 30 and 40 DAS (31.64 and 37.84) was obtained at saturation moisture level and at 60 DAS was at saturation and field capacity/wilting point (Fig. 5). In different plant combinations significant differences in chlorophyll content were at 60 DAS when rice was planted alone and at *Striga*/rice plant combinations (Fig. 5).

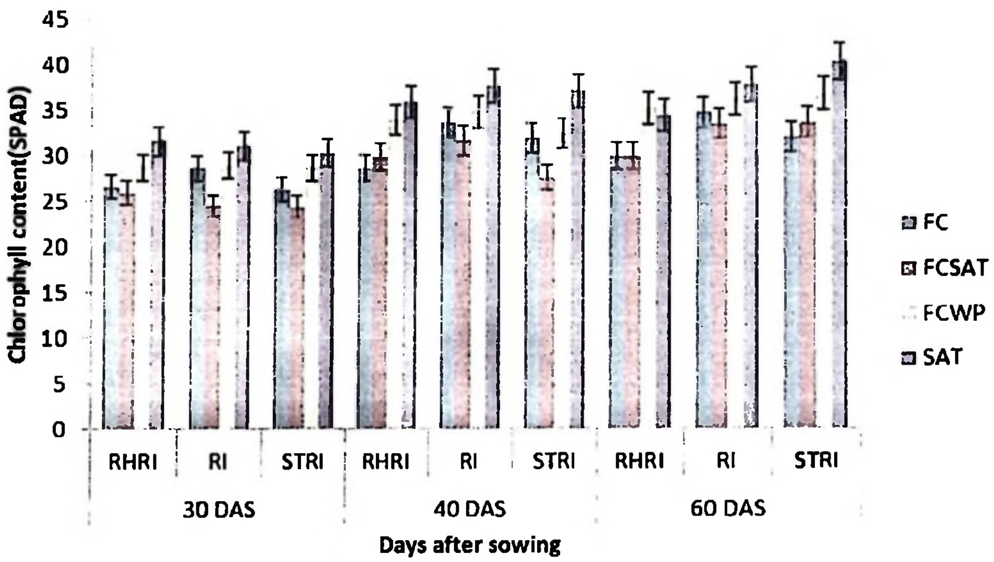

Figure 5: Rice chlorophyll content (SPAD) in different moisture levels and plant combinations

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RH-*Rhamphicarpa* alone, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

4.2.3 Chlorophyll Fluorescence (fv/fm)

Chlorophyll fluorescence measured at 45 and 60 DAS indicated no significant ($P < 0.05$) differences in chlorophyll fluorescence at different moisture levels and plant combinations (Fig.6).

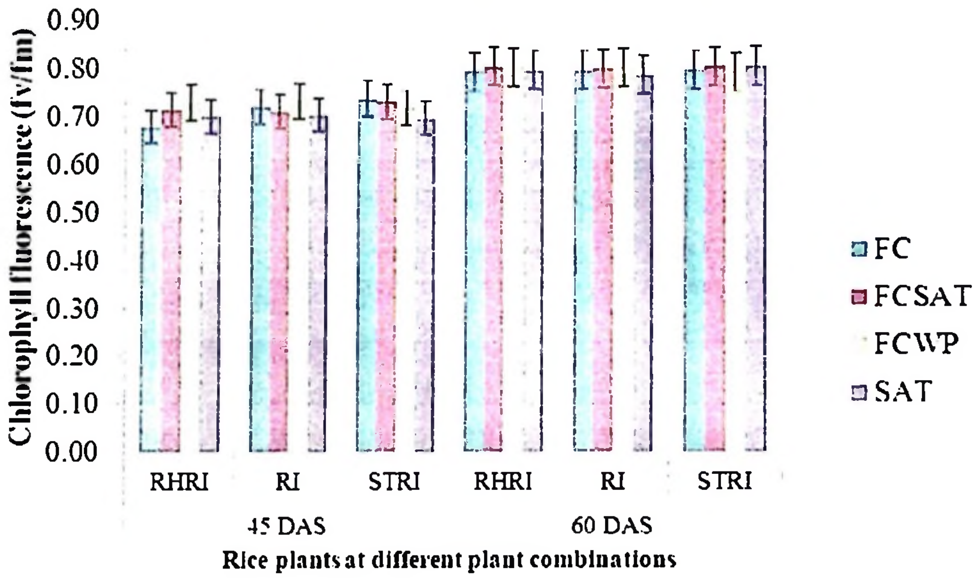

Figure 6: Rice chlorophyll fluorescence (fv/fm) in different moisture levels and plant combinations

Key: FCWP-field capacity/wilting point. FC- field capacity. FCSAT- field capacity/saturation. SAT- saturation. RHRI- *Rhamphicarpa*/rice. STRI- *Striga*/rice. RI-rice alone.fv-variable fluorescence yield.fm- maximum fluorescence yield

4.2.4 Stomatal Conductance

Rice stomatal conductance was measured at 35, 45, and 60 DAS whereby significant ($P < 0.05$) differences were recorded at different moisture levels and plant combinations. The highest stomatal conductance value (396 mmol/(m^2s)) was recorded at field capacity/wilting point moisture level 60 DAS while at 35 and 45 DAS, the increased values were at field capacity/wilting point moisture levels. in different plant combinations the significant ($P < 0.05$) differences in stomatal conductance were recorded at 35, 45 and 60 DAS whereby the rice plants grown alone obtained high vales compared to rice planted with *Rhamphicarpa* and *Striga* highest value (396 mmol/(m^2s)) was recorded for rice alone (Table 6).

Table 6: Rice stomatal conductance (mmol/(m^2·s)) in different moisture levels and plant combinations at different days after sowing

Moisture levels	Rice stomatal conductance								
	35 das			45 das			60 das		
	RHRI	RI	STRI	RHRI	RI	STRI	RHRI	RI	STRI
FC	83.7 ^{a}	132.5 ^{b}	115.6 ^{ab}	130.7 ^{a}	163.7 ^{a}	179.8 ^{b}	191 ^{a}	294 ^{a}	194 ^{a}
FCSAT	147.4 ^{b}	79.4 ^{a}	58.8 ^{a}	159.8 ^{a}	179.9 ^{a}	102.1 ^{a}	279 ^{b}	311 ^{a}	345 ^{b}
FCWP	145.7 ^{b}	200.5 ^{c}	185.8 ^{c}	189.8 ^{a}	253.9 ^{b}	194.5 ^{b}	266 ^{b}	396 ^{b}	191 ^{a}
SAT	133.9 ^{b}	113.4 ^{b}	114 ^{ab}	191 ^{a}	202.1 ^{ab}	194.9 ^{b}	179 ^{a}	363 ^{a}	331 ^{b}
S.E		68.8			82.55			120.5	
CV%		54.7			46.2			43.3	

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

4.2.5 Root dry biomass

Root dry biomass measured at 60 and 120 DAS indicated that there were significant ($P < 0.05$) differences in root dry weight at different moisture levels whereby at 60 DAS highest weight value (3.67g) was obtained at field capacity/wilting point followed by saturation moisture level (3.05g), while at 120 DAS the highest value (40.9g) was at saturation moisture level. Also in different plant combinations there was significant ($P < 0.05$) difference in rice root dry weight whereby at 60 DAS highest weight value (3.67g) observed when rice was planted alone (Table 7) while at 120 DAS the highest value (40.9g) was observed at *Striga*/rice plant combination and the lowest (2.21g) collected at *Rhamphicarpa*/rice plant combination (Table 8).

4.2.6 Shoot dry biomass

The significant ($P < 0.05$) differences were recorded in rice shoot dry weight at different moisture levels as well as plant combinations at 60and 120 DAS. In moisture levels, the highest weight value (2.35g) was obtained at saturation moisture level and *Striga*/rice plant combination at 60 DAS (Table 7). However, in 120 DAS, the highest shoot dry weight value (10.6 g) was recorded at saturation moisture level and *Striga*/rice plant combination (Table 8) while the lowest value (0.6g) at 60 DAS collected at field capacity moisture level and *Rhamphicarpa*/rice plant combinations (Table 7). At 120 DAS the lowest value (0.42g) was collected at saturation moisture level and *Rhamphicarpa*/rice plant combination (Table 8).

4.2.7 Total rice biomass

Results indicated that there were significant ($P < 0.05$) differences in total rice biomass at 60 and 120 DAS in different moisture levels and plant combinations. At 60 DAS, the highest weight value (5.2g) was obtained at saturation moisture level and this was recorded at rice planted alone, followed by 5.1g (*Striga*/rice) and 2.6g (*Rhamphicarpa*/rice) (Fig. 7). On the other hand, at 120 DAS, the highest value (56.6g) was obtained at saturation moisture level and this was at *Striga*/rice followed by rice alone (45.5g) and *Rhamphicarpa*/rice (3.2g). At 120 DAS, results indicated that rice biomass was affected much by *Rhamphicarpa* weeds compared to *Striga asiatica* (Fig. 8).

Table 7: Rice dry biomass (g pot^{-1}) 60 DAS at different moisture levels and plant combinations

Moisture levels	Rice dry biomass (g pot^{-1}) under different plant combinations					
	Root			Shoot		
	RHRI	RI	STRI	RHRI	RI	STRI
FC	0.62 ^{a}	1.61 ^{ab}	0.89 ^{a}	0.59 ^{a}	1.25 ^{ab}	0.72 ^{ab}
FCSAT	1.4 ^{ab}	0.84 ^{a}	1.06 ^{a}	0.80 ^{ab}	0.85 ^{a}	0.78 ^{ab}
FCWP	1.73 ^{b}	3.67 ^{b}	1.24 ^{b}	1.10 ^{abc}	1.91 ^{c}	0.84 ^{ab}
SAT	1.82 ^{b}	3.05 ^{bc}	2.72 ^{c}	0.68 ^{ab}	2.15 ^{c}	2.35 ^{bc}
S.E		0.94			0.421	
CV%		54.8			36	

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT.

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

Table 8: Rice dry biomass (g pot^{-1}) 120 DAS at different moisture levels and plant combinations

Moisture levels	Rice dry biomass (g pot^{-1})					
	Root			Shoot		
	RHRI	RI	STRI	RHRI	RI	STRI
FC	1.7 ^{a}	5.6 ^{a}	4.7 ^{a}	1.1 ^{a}	4.02 ^{a}	1.4 ^{a}
FCSAT	2.6 ^{a}	8.9 ^{a}	5.5 ^{a}	1.8 ^{ab}	4.62 ^{ab}	2.0 ^{ab}
FCWP	4.2 ^{a}	7.1 ^{a}	5.7 ^{a}	2.9 ^{ab}	4.54 ^{ab}	1.8 ^{ab}
SAT	2.2 ^{a}	31.7 ^{b}	40.9 ^{b}	0.4 ^{a}	9.0 ^{c}	10.6 ^{c}
S.E		6.094			1.977	
CV%		60.5			53.7	

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT.

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

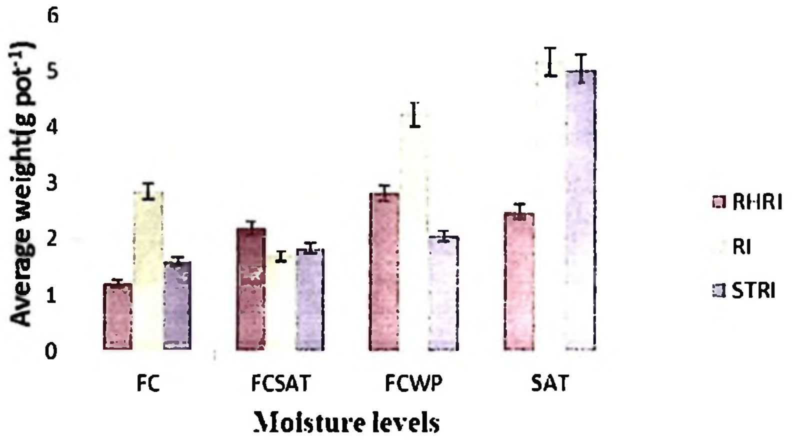

Figure 7: Rice total biomass (g pot^{-1}) 60 DAS at different moisture levels and plant combinations

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

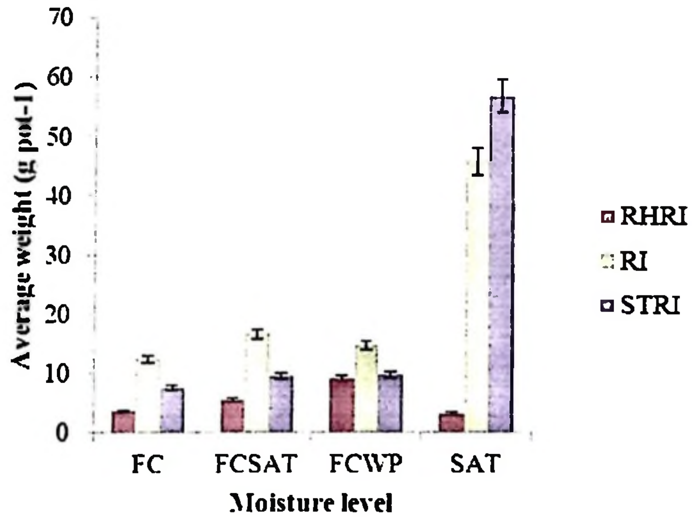

Figure 8: Rice total biomass (g pot^{-1}) 120 DAS at different moisture levels and plant combinations.

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturationRHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

4.2.8 Tillers Counts

Up to 120 DAS, the number of rice tillers were significantly (P < 0.05) different in different moisture levels whereby large number of tillers (2.8/pot) was recorded at field capacity/wilting point moisture level (Table 9). However, in different plant combinations there was significant (P < 0.05) difference in rice tillers number whereby the largest number (2.8) was recorded at rice alone plant combination. The lowest tillers count (1) was recorded at saturation moisture level in *Rhamphicarpa*/rice plant combinations (Table 9).

4.2.9 Number of green leaves at harvest

At 120 DAS, number of rice green leaves were significantly (P < 0.05) different in different moisture levels (Table 9) However, in different plant combinations there were also significant (P < 0.05) differences in rice green leaves whereby large number (7.6) of green leaves was obtained at rice planted alone followed by *Striga*/rice (6.6) and *Rhamphicarpa*/rice (0.6) plant combinations (Table 9). In different moisture levels, the largest number (6) of green leaves was recorded at field capacity/saturation followed by field capacity/wilting point (5.6), field capacity (4.8) and saturation (0.6).

4.3 Number of dry leaves at harvest

Rice dry leaves at 120 DAS were significantly different (P < 0.05) at different moisture levels whereby 11.4 leaves were recorded at saturation moisture level while in different plant combinations there were also a significant (P < 0.05) differences in rice dry leaves whereby 11.4 dried leaves were recorded at rice planted alone followed by *Striga*/rice (10.2) and *Rhamphicarpa*/rice (7) plant combination (Table 9).

Table 9: Rice dry leaves, green leaves and tillers number at harvest in different moisture levels and plant combinations

Moisture levels	Rice leaves and tillers number at harvest								
	Dry leaves			Green leaves			Tillers		
	RHRI	RI	STRI	RHRI	RI	STRI	RHRI	RI	STRI
FC	7.6 [ab]	9.4 [ab]	8.0 [a]	4.8 [b]	7.4 [b]	4.4 [b]	1.2 [ab]	2.6 [b]	1.2 [a]
FCSAT	6.8 [a]	8.8 [ab]	7.8 [a]	6.0 [b]	7.2 [b]	6.6 [b]	1.8 [ab]	2.4 [ab]	1.6 [ab]
FCWP	9.8 [ab]	10.6 [ab]	8.8 [a]	5.6 [b]	7.2 [b]	6.8 [b]	2.6 [b]	2.8 [b]	2.4 [b]
SAT	7.0 [a]	11.4 [b]	10.2 [ab]	0.6 [a]	7.6 [b]	6.6 [b]	1.0 [a]	2.6 [b]	2.2 [ab]
S.E		2.51			2.56			0.98	
CV%		28.3			43.3			47.9	

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT.

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

4.3.1 Leaf area (cm^2) and specific leaf area (cm^2/g)

In different moisture levels and plant combinations, there were significant ($P < 0.05$) differences in rice leaf area whereby the higher value ($36.1cm^2$) was recorded at field capacity/saturation where rice were planted without the parasite. The area was calculated when the plants were at 60 DAS (Table 10). However, the results for specific leaf area showed no significant differences ($P > 0.05$) in different moisture levels and plant combinations 60 DAS (Table 10).

Table 10: Rice leaf area (cm^2) and specific leaf area (cm^2/g) 60 DAS in different moisture levels and plant combinations

Moisture levels	leaf area (cm^2)			specific leaf area (cm^2/g)		
	RHRI	RI	STRI	RHRI	RI	STRI
FC	22.6 [a]	34.4 [a]	27.1 [a]	190.74 [a]	189.88 [a]	171.1 [a]
FCSAT	28.2 [a]	36.1 [b]	35.4 [a]	212.82 [a]	221.33 [a]	247.9 [a]
FCWP	17.9 [a]	30.2 [a]	33.3 [a]	199.94 [a]	219.28 [a]	180.4 [a]
SAT	19.1 [a]	30.0 [a]	17.0 [a]	194.44 [a]	190.95 [a]	192.7 [a]
S.E		11.68			55.51	
CV%		42.3			27.6	

Within columns, means followed by the same letter (s) are not significantly different at 5% level according to DNMRT.

Key: FCWP-field capacity/wilting point, FC- field capacity, FCSAT- field capacity/saturation, SAT- saturation, RHRI- *Rhamphicarpa*/rice, STRI- *Striga*/rice, RI-rice alone

CHAPTER FIVE

5.0 DISCUSSION

5.1 *Rhamphicarpa fistulosa* and *Striga asiatica* at different moisture levels and plant combinations

5.1.1 Response of *Rhamphicarpa fistulosa* to moisture levels and plant combinations

Rhamphicarpa fistulosa emergence was not significantly different at different moisture levels and plant combinations. This study has indicated that *Rhamphicarpa* emergence was not sensitive to different moisture levels as seeds take only few days to germinate. From 7 DAS, *Rhamphicarpa* counts were significantly different between moisture levels. Since the highest *Rhamphicarpa* counts were recorded at saturation moisture level, this implies that *Rhamphicarpa* prefers saturation moisture level for its germination. The results from this study were in agreement with the results reported by Ouédraogo *et al.* (1999) that *Rhamphicarpa* prefers flooded areas where the soil is saturated (Fig.1). On the other hand, Ouédraogo *et al.* (1999) reported that when parasitizing cereals, *Rhamphicarpa* did not require flooded environment because its need for water is better supplied by the cereal hosts. This shows that presence of host plant favours the existence of *Rhamphicarpa fistulosa*. However, the number of weeds where *R. fistulosa* was sown alone decreased with increase in DAS leading to its total disappearance at 120 DAS (Fig. 3).

The height of *Rhamphicarpa fistulosa* was influenced by moisture levels and plant combinations. The tallest *Rhamphicarpa* plants (45.2cm) were observed in pots with saturation moisture level when *Rhamphicarpa* was planted with a host. This implies that during establishment, *Rhamphicarpa* roots start finding the host roots for attachment and subsequently become more vigorous than *Rhamphicarpa* plants which did not attach. This attachment allows *Rhamphicarpa* plants to absorb nutrients from the host by developing cells that penetrate into the host root cortex and the endodermis to establish a direct connection to the xylem. This has previously been reported by Parker & Riches (1993) that the attachment of the weed roots to the host allows the transfer of nutrients from the host to the weeds. In the absence of the host, *Rhamphicarpa* plants grew slowly and they were short such that the plants reached the height of 2.5cm only. These results are in agreement with earlier reports by Ouédraogo *et al.* (1999) who indicated that the presence of the host influenced the height of *Rhamphicarpa* as it was observed that in the absence of the host the main stem remained short and unbranched.

The earliest *Rhamphicarpa* weed flowering was observed at approximately 77 DAS and this was at field capacity/saturation moisture level. At field capacity/saturation moisture levels *Rhamphicarpa* plants 30 DAS were taller than in other moisture levels (Table 1) which could be the reason for its early flowering than *Rhamphicarpa* in other moisture levels. The results in this study were different from what were reported by Ouédraogo *et al.* (1999) that whether *Rhamphicarpa fistulosa* was grown in greenhouse or under natural condition, the flowering period started at about 140 days after sowing. This difference of 63 days could be attributed to the different environmental conditions such as temperature and day light.

Capsules produced were significantly different in number and dry weight in different moisture levels and plant combinations. At saturation moisture level, *Rhamphicarpa* produced 20 capsules per pot which was the highest values and also led to the highest capsule dry weight (0.6g pot^{-1}). This was observed also when *Rhamphicarpa* was grown together with rice (Table 2). The number of capsules was correlated ($r = 0.8$) to *Rhamphicarpa* seeds produced (Table 2). This was also described by Ouédraogo *et al.*

(1999) that capsule size is correlated with a number of seeds produced. Furthermore, *Rhamphicarpa* capsules and seeds produced were significantly ($P < 0.05$) different at different plant combinations which means at any moisture level *Rhamphicarpa* plants in presence of the host produced capsules and seeds. This was also reported by Ouédraogo *et al.* (1999) that there is a significant increase in seed and capsule numbers due to host presence.

At 60 DAS (Fig. 4) the results showed that when *Rhamphicarpa* weed was sown alone the total dry biomass differed significantly with soil moisture levels. However, in different plant combinations the total dry biomass was different according to moisture levels whereby the highest weight (2.481 g) was recorded at saturation moisture level (Fig 4). At 120 DAS, *Rhamphicarpa* accumulated more biomass (Table 4) at saturation moisture level when grown with rice. This shows that in presence of the host, *Rhamphicarpa* accumulates more biomass due to their ability to absorb nutrients from the host. This was also reported previously by Ouédraogo *et al.* (1999) and later confirmed by Rodenburg *et al.* (2011) that parasitizing *Rhamphicarpa* plants accumulate more biomass than *Rhamphicarpa* plants that grow independently.

5.1.2 Response of *Striga asiatica* to moisture levels

Striga asiatica exhibited an increase in number and height at field capacity and field capacity/wilting point than in other moisture levels. *Striga asiatica* 60 DAS in different plant combinations showed the highest number (3) of plants per pot at field capacity/wilting point. There was an increase in number of *Striga* over time whereas at 120 DAS they were 9 (nine) at field capacity moisture level and very few (3) at field capacity/saturation. This trend could be attributed by the depth which the seeds were buried in the pot. At saturation moisture level there was no *Striga* emergence. The results from this study were in agreement with the results reported by Ogborn (1972) that *Striga* appears to thrive well on intermittent dry conditions. This situation was also reported by Johnson *et al.* (1997) that *Striga hemonthica* prefers free draining areas. Furthermore, it was observed that heavy continuous rainfall can suppress *Striga* (Radosevich *et al.,* 1997). The earliest *Striga* produced flowers were at field capacity/wilting point moisture level and this was 83 DAS. Flowering was accompanied with the production of capsules and seeds whereby at field capacity/wilting point there were maximum number of *Striga* capsules compared to other moisture levels (Table 3). Significant differences in flowering were observed only at saturation moisture level where there was no *Striga* emergence. It has been reported (California Department of Food and Agriculture (CDFA); 2006) that *Striga* flowers developed about 3 weeks after emergence which differs from what was observed in this study which was about 8 weeks.

On the other hand, total dry biomass of *Striga* weeds sown with rice differed significantly whereby 60 DAS at field capacity/wilting point, *Striga* counts reached 0.19g. However, at 120 DAS total dry biomass of *Striga* weeds increased compared with that obtained at 60 DAS in different moisture levels (Table 4). The responses at different moisture levels suggest that, *Striga* prefers well drained soils than in areas with water lodged.

5.2 Influence of *Rhamphicarpa fistulosa* and *Striga asiatica* on rice growth at different moisture levels and plant combinations

The study revealed that there is significant ($P < 0.05$) effects of weeds on rice in different moisture levels. The height of rice plant at different moisture levels was significantly different from 30 to 60 DAS (Table 5). In plant combinations, the difference was observed from 60 DAS whereby the tallest rice plant (86.7cm) was recorded at saturation moisture level and *Striga*/rice plant combinations. At saturation moisture level, rice plant grown alone and that with *Striga* were taller compared to rice plants in other moisture levels and in presence of *Rhamphicarpa* weeds (Table 5). Reduction in rice height in other moisture levels agrees with the reported information that growth involves both cell growth and development of which is a process consisting of cell division, enlargement and differentiation (Jones and Lazenby, 1988). These processes are sensitive to moisture stress because of their dependence upon turgor. Salisbury and Ross (1992) reported that the inhibition of cell expansion is usually followed by a reduction in cell wall synthesis.

The rice chlorophyll content was significantly ($P < 0.05$) different at different moisture levels and plant combinations. At 30 DAS there was no significant difference between plant combinations but from 40 to 60 DAS, the difference in rice chlorophyll content was observed in different plant combinations. Compared to *Rhamphicarpa fistulosa* effects, rice in presence of *Striga* indicated higher chlorophyll content (40.58) as observed for rice planted alone than in presence of *Rhamphicarpa* (Fig. 5). However, Cochrane *et al.*, (1997) reported that the decrease in chlorophyll content is caused by phytotoxicity effects experienced by the host in association with the parasitic weeds. Evans (1983) also reported that weed infestations reduce photosynthetic rate of the host plant.

Furthermore, there were no significant ($P<0.05$) differences in chlorophyll fluorescence (fv/fm) at different moisture levels and plant combinations which means there was an equal stress caused by parasitic weeds (Fig. 6).

Plant combinations had effect on tillering ability of rice plant. The significant difference ($P < 0.05$) was observed between *Rhamphicarpa fistulosa* and *Striga asiatica* in affecting tillering ability of rice plant (Table 9). The maximum number of tillers per plant (2.8) was recorded when rice was planted alone while the lowest tillers number (1) was recorded when rice was planted with *Rhamphicarpa*. These results were in agreement with the results reported by Rodenburg *et al.* (2011) that *Rhamphicarpa fistulosa* caused significant effect on rice tiller number. However, moisture levels affected tillering whereby at field capacity/wilting point there was an increase of number of tillers compared to other moisture levels. However, Ali *et al.* (2005) reported that rice tillering was also affected by water depth and the maximum tiller number was recorded at moderately low moisture level.

Rice leaf transpiration rate indicated that the significant difference was only at 35th day after sowing in different moisture levels. At field capacity/wilting point, rice stomatal conductance was high (396 mmol/(m^2s)) compared to other moisture levels (Table 6). However, in plant combinations the rice plants grown alone had elevated stomatal conductance values. This could be attributed to the physiological stress caused by weeds to the host plant which led to effects to the stomata guard cells. Furthermore, Taylor *et al.* (1996) reported that host parasitized by *S. hemonthica* typically show elevated abscisic acid levels which was also described by Frost *et al.* (1997) that increased abscisic levels result in a reduction of host stomatal conductance. This implies that weed infestation has effects on stomatal conductance in rice plant.

The observed decrease in rice biomass was influenced by *Rhamphicarpa* and *Striga* weeds. It was observed that moisture levels have influence to rice roots dry weight but the major effects were due to different plant combinations. At 60 DAS, (Fig. 7) when rice was planted alone, the biomass value was 5.2g higher than when planted with weeds. On the other hand, at 120 highest value (56.6g) was obtained when rice was planted with *Striga* at saturation moisture level which means it was rice alone as there was no emergence of *Striga* in this moisture level (Fig. 8). This implies that, the increase of days leads to increase of weed effects to rice biomass especially for *Rhamphicarpa* infestation. The obtained results were in agreement with the results reported by Rodenburg *et al.* (2011) that *Rhamphicarpa* infestation caused significant loss in rice biomass. The decreased rice biomass reflects the yield loss which could be obtained as it was also reported that rice biomass and yield loss were associated with parasitic *Rhamphicarpa* biomass (Rodenburg*et al.*, 2011).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Management of moisture can be taken as an important component in integrated parasitic weed management. According to the results, *Rhamphicarpa fistulosa* thrived well at saturation moisture level in germination and development. In presence of the host, *Rhamphicarpa* grows more vigorously and produces larger amount of seeds than when sown alone. *Striga asiatica* prefers reduced soil moisture levels such as field capacity and field capacity/wilting point. At Field capacity and Field capacity/Saturation, both *Rhamphicarpa fistulosa* and *Striga asiatica* germinated and established a relationship with a host implying that they can co-exist. Thus the management strategies should focus on the two species at the same time. The rice biomass accumulation was 56.6g/pot in the absence of the parasites. But in presence of the parasites there were differences in the damage caused the two parasitic weeds. *Rhamphicarpa fistulosa* reduced rice biomass significantly by 94.3% from 56.6g to 3.2g/pot (6%) at 120 DAS compared to *Striga asiatica* which reduced rice biomass by 86%.

6.2 Recommendations

i. In controlling *Striga* infestations, it is recommended that the soil moisture be maintained at saturation level throughout the vegetative growth of rice; while for *R. fistulosa*, more studies are required to understand better its biology and ecology in order to guide the process of developing possible control measures.

ii. When *Rhamphicarpa fistulosa* and *Striga asiatica* occur together with rice, management of the weeds can be achieved by saturating the soil at early stage and maintaining the moisture at this level throughout the vegetative growth so as to control *Striga asiatica*.

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