Impact of Longhorn Beetles on the growth and survival of *Prosopis juliflora* in Bura Irrigation Scheme, Kenya

By

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DECLARATION

I hereby declare that this thesis is my original work and has not been presented for a degree or any other award in any other University

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DEDICATION

To my beloved wife Eunice Wambui and daughters: Susan Wanjiku and Joy Muthoni for their love and support.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABSTRACT

Prosopis juliflora has been rated one of the world's top 100 unwanted species because of its invasive nature. In Kenya some of the negative effects of *P. juliflora* include invasion of farmlands, pastureland and water ways. The high cost and poor success of mechanical and chemical eradication techniques have led to the search of an appropriate biological control agent. In Kenya there is no known biological control agent for *P. juliflora*. However, casual observation in Bura showed *Prosopis* trees drying up as a result of beetle's infestation. This project therefore aimed at identifying the beetles feeding on the *P. juliflora* and assessing the extent of their damage. Beetle samples were collected from 365 trees and identified at National Museum of Kenya. Identification was achieved through morphological appearances and measurement of body parts such as pronotum, elytra length, antennal length and body length as compared to type specimens at Museum. The extent of damage on *P. juliflora* was assessed by correlating percent dryness observed in *P. juliflora* and estimated percent damage. Results showed that the beetles belonged to the longhorn beetles, *Taurotagus griseus*. The beetles exerted significant damage on *P. juliflora* accounting for over 12.6% of *Prosopis* death in the study area. These results suggest that *T. griseus* can contribute significantly to the biological control of *P. juliflora*. However, further research is needed to determine the main factor(s) that influence *T. griseus* population dynamics, its host-seeking behavior and its effectiveness both in the lab and in the field.

CHAPTER ONE : INTRODUCTION

1.1 Background

Prosopis juliflora, a tree native to South and Central America and the Caribbean islands, was introduced into new areas mainly by travelers who observed the growth and usefulness of the species, particularly to the people living in arid and semi-arid areas. However, the tree has become a serious invasive weed in farm lands, pasture lands and water ways (Choge and Chikamai, 2004). Due to its fast-spreading nature, the shrub forms extensive impenetratable thickets that gradually choke up all other plant types including *Acacia spp.* and useful grasses as it out competes them. In Kenya, the tree has also been associated with teeth related problems in livestock as fleshy and sugary pods are sticky and easily collect around the base of the teeth leading to massive decay, wearing and loosening (Mwangi and Swallow, 2008).

Plant species such as *P. juliflora*, usually become invasive in introduced areas as they miss the natural enemies and their management practices do not follow the introduction. Cronk and Fuller (2001) defined an invasive plant as: 'an alien plant spreading naturally (without direct assistance of people) in natural or semi-natural habitats, to produce a significant change in composition, structure or ecosystem processes'. Invasive species are usually associated with economic, environmental and social losses in introduced areas (Anderson, 2005).

People's perception of invasive species depends on whether their economic needs are met by the species (Binggeli, 2001; Pasiecznik *et al.,* 2001). According to Pasiecznik *et al.* (2001), *P. juliflora* plays a leading role in the afforestation of arid lands, providing fuel energy resources, supplying feed and forage for grazing animals, furnishing construction timbers and furniture wood, supplementing food for humans and promoting honey production. Despite these benefits, it has been rated as one of the world's top 100 unwanted species because of its invasive nature (IUCN, 2004).

In Kenya the negative effects of *P. juliflora,* which include production of toxins that inhibit growth of under story vegetation and killing livestock (Pasiecznick *et al.*, 2001), have dominated the national and regional press in recent years. Some affected communities are demanding compensation for the loss of productive land from those responsible for sanctioning the introduction of the species (Choge and Pasiecznik, 2006).

Methods used in the attempt to eradicate the weed include mechanical and chemical techniques. The high cost and poor success of these techniques has led to the search for alternative means of control, such as biological control. In South America twig girdlers have been suggested as possible biological control agents (Hodkinson, 1991). Bruchid beetles have been introduced in South Africa to control *Prosopis* (Hoffman *et al*., 1993).

Biological control is defined as the action of parasites, predators or pathogens in maintaining another organism's population at a lower average density than would naturally occur (Zimdahal, 1993). Classical biological control has been practiced for over a century mainly in the control of important insect pests and weeds. However, introduction of an exotic biological control agent has a potential risk of damaging non-target organisms. In addition to classical biological control, conservation and enhancement practices of native natural enemies can be used for biological control (Hokkanen and Lynch, 1995).

The advantage of the latter strategy over classical biological control is that the natural enemy already exists in the environment. Unlike the exotic biological control agent, one that already exists in the environment does not need to be specific (Dejong *et al.,* 2002). In addition, manipulation and observation of the native natural enemy is easy (Bentley, 1992).

Beetles of several species that cause damage by boring tunnels through the wood of living trees and dead wood are possible biological control agents for the species of plants they attack. According to Fiorentino and Bellomo (1995), beetles that tunnel on several American *Prosopis spp* can kill a living plant. Longhorn beetles have been observed attacking and damaging *Senegalia* trees in Ethiopia (Eisa and Rooth, 2009). Since the genera *Senegalia* and *Prosopis* belong to the same family, Fabaceae, it is possible that the same group of beetles would cause similar damage to *P. juliflora* trees in Bura, Kenya. Longhorn beetles have been observed boring into *P. juliflora* trees in Bura area, coastal Kenya and have been suspected to be responsible for the unusual drying of some of the affected plants (personal observation), (Plate 1.1 and 1.2 respectively).

Plate 1:1: Longhorn beetle borer tunneling in a *P. juliflora* stem in Bura

Plate 1:2: Dry *P. juliflora* trees in Bura

1.2 Statement of the problem

Introduction of *P. juliflora* in Bura has brought many problems which have lately outweighed the benefits associated with it. Due to its invasive nature, *P. juliflora* is threatening livelihoods and the affected communities are calling for its eradication. However, eradication of *P. juliflora* has proven to be a difficult task as the tree is hardy and has very high coppicing power. Therefore there is need for a more effective method of at least controlling the spread of the species. Although much research has been done on biological control agents for *P. juliflora* in other countries e.g (Jones and Sforza, 2007), very little has been done in Kenya. Casual observation, however, indicates that longhorn beetles could potentially damage and eventually kill *P. juliflora*. There are no scientific facts to support this. The study therefore aimed at assessing the impact of longhorn beetles on growth and survival of *P. juliflora* and ascertaining if longhorn beetles has any potential in the control of *P. juliflora,* which would be of great significance since other methods have been found either to be ineffective or too expensive.

1.3 Research questions

This study focused on answering the following research questions:

a) Which species of woodborers attack *P. juliflora* in Bura?

b) How much damage is done by borers to *P. juliflora*?

c) Do wood-boring longhorn beetles have the potential to be used in biological control of *P. juliflora*?

1.4 Hypothesis

Drying of *P. juliflora* is not associated with infestation of the longhorn beetles

1.5 General objective

To assess the impact of longhorn beetles on growth and survival of *Prosopis juliflora* and to evaluate their potential in biological control of *P. juliflora* in Bura area, Kenya.

1.5.1 Specific objectives

a) Determine the species of longhorn beetles infesting *P. juliflora* in Bura.

b) Assess the extent of damage by longhorn beetles on *P. juliflora*.

c) Evaluate potential of longhorn beetles in biological control in terms of host age preference of longhorn beetles.

1.6 Justification

Prosopis juliflora is an invasive plant in Kenya. Like any other invasive organism, it colonizes and spreads very fast due to limited natural enemies, hence it out competes the local species. Major regional eradication programs have been undertaken on *P. juliflora* in USA, Argentina, South Africa and Australia, but no efficient and cost effective methods have been found (Cadoret *et al.*, 2000). Mechanical methods usually involving felling of trees, but it has not been successful due to *P. juliflora*'s excellent coppicing power. Chemical control has also been tried in USA and Australia (Jacoby and Ansley, 1991; Csurhes, 1996). Unfortunately, the method is environmentally unfriendly and cannot be sustained. Fire has also been utilized to manage *Prosopis spp.* in American grassland. However, it only kills young seedlings because older trees have protective thick bark. Biological control using bruchids that feed on *P. juliflora* seeds has been tried in South Africa (Zimmerman, 1991) with little success. Vertebrate herbivores consumes most of the pods before the beetles have the chance of damaging the seeds, and since *P. juliflora* seeds are indigestible in the herbivores' gut, their passage through the gut promotes their germination and dispersal. Since eradication efforts have been neither cost effective nor technically successful, there is need to find a more effective method of controlling the plant. Biological control using woodborers that damage the stem could be another option. However, very little information exists on the diversity of woodborers that attack *P. juliflora* in Kenya and the damage caused. Information obtained from this study was used to determine whether the woodborers especially those of longhorn beetles have the potential to be used as biological control agents of *P. juliflora*.

CHAPTER TWO : LITERATURE REVIEW

2.1 Ecology of *Prosopis* plant

Prosopis juliflora is a member of the family Leguminosae (*Fabaceae*) and sub-family Mimosaidea (Elias, 1981). It is an evergreen tree native to South and Central America, and Caribbean. In the United States, it is well known as mesquite. Concern about deforestation, desertification and fuel wood shortages in the late 1970s and early 1980s prompted a wave of projects that introduced *P. juliflora* to new environments across the world. Records indicate that the earliest introduction of *P. juliflora* to Africa may have been in Senegal, South Africa and Egypt in the early 19th Century (Zimmerman, 1991; Pasiecznick *et al.*, 2001). The first documented introduction of *Prosopis* in Kenya was in 1973 for rehabilitation of quarries near the coastal city of Mombasa (Johansson, 1990; Choge *et al.*, 2002). The same species were introduced into the semiarid districts of Barigo, Tana-River and Turkana in the early 1980s (Choge *et al.*, 2002). Today *P. juliflora*, has spread to many other parts of Kenya.

Under the right conditions, *P. juliflora* can produce a variety of valuable goods and services. According to Pasiecznick *et al.* (2001) and Geesing *et al.* (2004), *P. juliflora* fits very well into dry land agroforestry systems, improving soil, controlling soil erosion, stabilizing sand dunes, reducing soil salinity, providing fuel energy resources, supplying feed and forage for grazing animals, furnishing construction timber and furniture wood, supplementing food for humans and promoting honey production. Varshney (1996) considered *P. juliflora* as a very important dry-land resource in India where it is valuable tree species of the desert ecosystem. However, its usefulness has been over taken by its invasive nature as it is known to be a strong competitor for soil moisture, exclude toxins that inhibit growth of under story vegetation, lower water table, kill livestock and its pollen is speculated to cause human allergies, asthma and lung inflammation (Pasiecznick *et al*, 2001).

Prosopis juliflora has survived where other tree species have failed and in many cases become a nuisance (Mwangi and Swallow, 2005). The tree has succeeded in arid and semi arid areas mainly because it is a copious seed producer. In South Africa over six hundred thousand seeds were reported to be produced per tree per annum (Zimmermann, 1991). The seeds, characterized by coat imposed dormancy, germinate in flushes and establish a huge persistent seed bank in soil. Following germination, *Prosopis* seedlings grow vigorously (Mohamed, 2001). The rapidly growing root system and un-palatability of the foliage increase seedling survival rate and competitiveness particularly in heavily grazed areas and/or on uncultivated lands. The tree, often multi-stemmed with a spreading crown of pendulous branches hanging down to the ground, has a high capacity to fix sand dunes.

2.2 *Prosopis juliflora* as an alien invader

Based on its merits, *Prosopis* has been introduced and naturalized in different parts of the world (Africa, Asia, and Australia) during the last 100-150 years

(Pasiecznik *et al.*, 2001). However in many places where it has been introduced, it has become a serious weed. Exotic species become invasive when introduced into areas without proper management (Shiferaw *et al.*, 2004). Exotic plant species also become invasive in introduced areas as they miss the natural enemies and their management practices do not follow their introduction.

Invasive species are usually associated with economic, environmental and social losses in introduced areas (Anderson, 2005). The common problems are: reduction of pasturelands, decline in crop yield, loss of biodiversity, changing water flow, injuries and poisons to livestock and humans and the formation of impenetrable thickets (Anderson, 2005). *Prosopis* shows some of these characteristics. Invading *Prosopis* tends to form dense, impenetrable thickets, associated with unfavorable impacts on human economic activities. Millions of hectares of rangeland have already been colonized, and the invasion is still on progress in South Africa, Australia and coastal Asia (Pasiecznik, 1999). In northern Sudan, the Gash Delta of the Atbara River has almost been completely taken over by *P. juliflora* (Catterson, 1993). In the Awash basin of Ethiopia, it is aggressively invading pastoral areas in the Middle and Upper Awash Valley, and Eastern Harerge. *P. juliflora* is one of the three top priority invasive species in Ethiopia and it has been declared a noxious weed.

Land use changes, competitive ecological advantages, and climate change are key factors thought to influence the probability of invasion (Pasiecznik *et al*, 2001). In

Australia and South Africa, for instance, *Prosopis* invasions followed periods of high rainfall when conditions for germination and establishment of seedling were favorable. In northern India, *P. juliflora* is a pioneer species that rapidly colonizes denuded/abandoned ravines. Invasions into riverine areas and degraded rangelands of Africa, Asia and Australia have resulted in high-density populations. Whatever the trigger for invasion, the principal factor in this process is the rapid and prolific seeding of mature *Prosopis* plants (Zimmerman, 1991). Seed production is estimated at 630,000 to 980,000 seeds per mature tree per year (Felker, 1979). These seeds are most likely to germinate when the sugary pods are consumed by domestic livestock as the seeds are scoured while passing through the animals' digestive tract. When the scoured seeds are dropped with moist feces there is high chance for germination to occur (Felker, 2003).

In Sudan, invading *Prosopis* is reported to depress the growth and survival of indigenous vegetation around it. Some farmers in the area of Kassala claim to have lost their farmlands to *Prosopis*. Others complain that it is not only costly to clear *Prosopis* but it also destroys agricultural crops. Still, others are wary of *Prosopis* thorns which are harmful to both farm workers and their machinery. Additionally, it is said to consume underground water, threatening the Beisha oasis in western Sudan (Sudan Update, 1997). Sudan has even passed a law to eradicate it (Sudan Update, 1997). In Ethiopia, the aggressive invasion of pastoral areas is displacing native trees, forming impenetrable thickets and reducing grazing potential.

In Kenya problems associated with *Prosopis juliflora* became noticeable when its weedy potential was first observed in the Tana Riparian ecosystem in 1985. Its control was however considered expensive and almost impossible because of its prolific seedling growth and seed dispersal by livestock (Otsamo, 1993).

2.3 Control of *Prosopis*

2.3.1 Mechanical control

According to Choge and Chikamai (2004), mechanical method involves removing the plants by people or by use of machines. Hands clearance was the first method used to deal with *Prosopis*. This involved felling of trees, uprooting of stamps and seedlins. Use of machines such as caterpillar tractors that uproot the trees is also common. According to Jacoby and Ansley (1991) it is effective. However, it is the most expensive method.

2.3.2 Chemical control

Chemical eradication involves the use of herbicides to kill invader plants. Common treatments involve use of systemic herbicide applications on stem or aerials. The herbicide of choice in USA and Australia was 2, 4, 5-T (Jacoby and Ansley, 1991). Other effective herbicides include clopyralid, dicamba, piclorum, triclorpyr, and ammonium sulphamate among others (Choge and Chikamai, 2004).

2.3.3 Biological control

Biological control approach involves the use of natural enemies such as predators (herbivores), parasites and pathogens for the regulation of target populations. The objective of effective biological control agent is to maintain another organism's population such as weed at a lower density than would naturally occur (Zimdahal, 1993). According to Greathead (1986) natural enemies could be utilized in three ways: (1) augmentation of species through the direct manipulation of their population, as by insectary mass production and periodic colonization (2) conservation through the manipulation of their environment to preserve natural enemies and (3) importation of exotic species and their establishment in a new habitat (classical biological control). Classical biological control refers to an approach whereby natural enemies from the original home of the species are introduced to the area it has invaded. However, this method has been criticized because the natural enemy may turn to non-target species. The use of indigenous natural enemy is gaining importance. In the natural range, *Prosopis* has many insect herbivores which feed on seeds and pods of the tree thus reducing the seed production and hence the invasion. In North America, where *Prosopis* is native, more than 657 species of phytophagous insects have been recorded from *Prosopis* trees (Ward *et al.*, 1977). Biological control measures such as using beetles, which damage the seed, were also tried in Australia and South Africa.

2.3. 4 Longhorn beetles as biological control agent

Long-horned beetles belong to Family Cerambycidae and most of them have relatively long lifecycle, a good example is *Arhopalus rusticus* (Coleoptera: Cerambycidae) whose lifecycle is between 2 and 3 years (Bense, 1995). The family has a wide range of species such as *Sybra alternans* (Coleoptera: Cerambycidae) which has been found to attack many tree species among them *Prosopis spp.* (Chen *et al.*, 2000). Dwinell and Ninkel (1989) noted that cerambycid beetles (*Monochamus spp*) are vectors of the pinewood nematode *Bursaphalenchus xylophilus*. Smith (2001) also reported a mass death of mature pine trees in the Melbourne between 2000 and 2001 and its possible association with the transmission of a nematode disease (*Bursaphalenchus spp.*) by newly introduced *Arphopalus rusticus* (Coleoptera: Cerambycidae).

Beetles infestation can spread and increase in a short time (Chen *et al.*, 2000), hence they can be used to control invasive plant species. According to Keena (2006) *Anoplophora glabripemis* (Coleoptera: Cerambycidae) is a recently introduced non-native species in North America that has the potential to destroy several tree species.

According to Paine *et al.* (2001) infestation by longhorn beetles particularly borers, are often focused on individual trees having specific characteristics (e.g. moisture stress, diseases or physical injury) and infestation frequently results in the death of the tree. Longhorn beetles affect trees in various ways. According to Vallentgoed (1991) woodborers in the family Cerambycidae make large holes in the wood. The larvae bore through the outer bark of the tree and feed within the phloem, cambium and outer layers of xylem tissues (McIntosh *et al.*, 2001; Hanks *et al.*, 1993; Borror *et al.*, 1989). The beetles also affect trees by acting as disease vectors. In Bura area, it was observed, prior to this study, many *Prosopis juliflora* trees attacked by longhorn beetles tend to dry and die (personal observation, 2009). In spite of the frequent attack of *Prosopis juliflora* by longhorn beetles, their potential for biological control has not been investigated.

Any weed-feeding insect of whatever feeding habit in any order, family, or genus can be considered potentially important in biological control of weeds (Debach and Rosen, 1991), and the biggest issue lies on whether generalist such as longhorn beetles can be used in biological control. Although host specificity form the basis of risk assessment, changes in the attitude of the regulatory authorities, makes introducing agents with broader host ranges less restrictive once the consequences of not controlling weeds outweigh the risks of agent introduction (Babu *et al.*, 2003), and according to Dejong *et al.* (2002) if the control agent is already present in the environment, it need not necessarily be specific.

2.3.5 Natural host for *Taurotagus griseus*

The research carried out in Ethiopia by Eisa and Roth (2009) showed *Senegalia spp.* as indigenous natural host of *T. griseus*. The genera *Senegalia* and *Prosopis* belong to the same family, Fabaceae. *Senegalia* trees occur in a wide area of semi-arid land across sub-Saharan Africa and it happens that it is in the same ecosystems that *Prosopis* has invaded. Many factors interfere with the health of *Senegalia* trees. Among the most important are insect pests such as longhorn beetles, and since *Senegalia* and *Prosopis* are close relatives, there is a high chance that the insects that attack *Senegalia* also attack *P. juliflora.*

CHAPTER THREE : MATERIALS AND METHODS

3.1 Description of the study Area

The study was conducted in Bura Irrigation Scheme, located in Bura District, Kenya (Figure 3.1). It lies south of the equator at 1°06'S, 39°56' E and about 100 m above sea level. According to the agro-meteorological classification Bura belongs to Zone VII, which has the lowest production potential and is suitable only for nomadic pastoralism (Sombroek *et al.,* 1982). The mean annual rainfall is 372 mm; mean monthly maximum and minimum temperatures are 33.4°C and 22.5°C respectively. Mean potential evaporation (class A pan) is 2,336 mm year^{-1} (Otsamo, 1993).

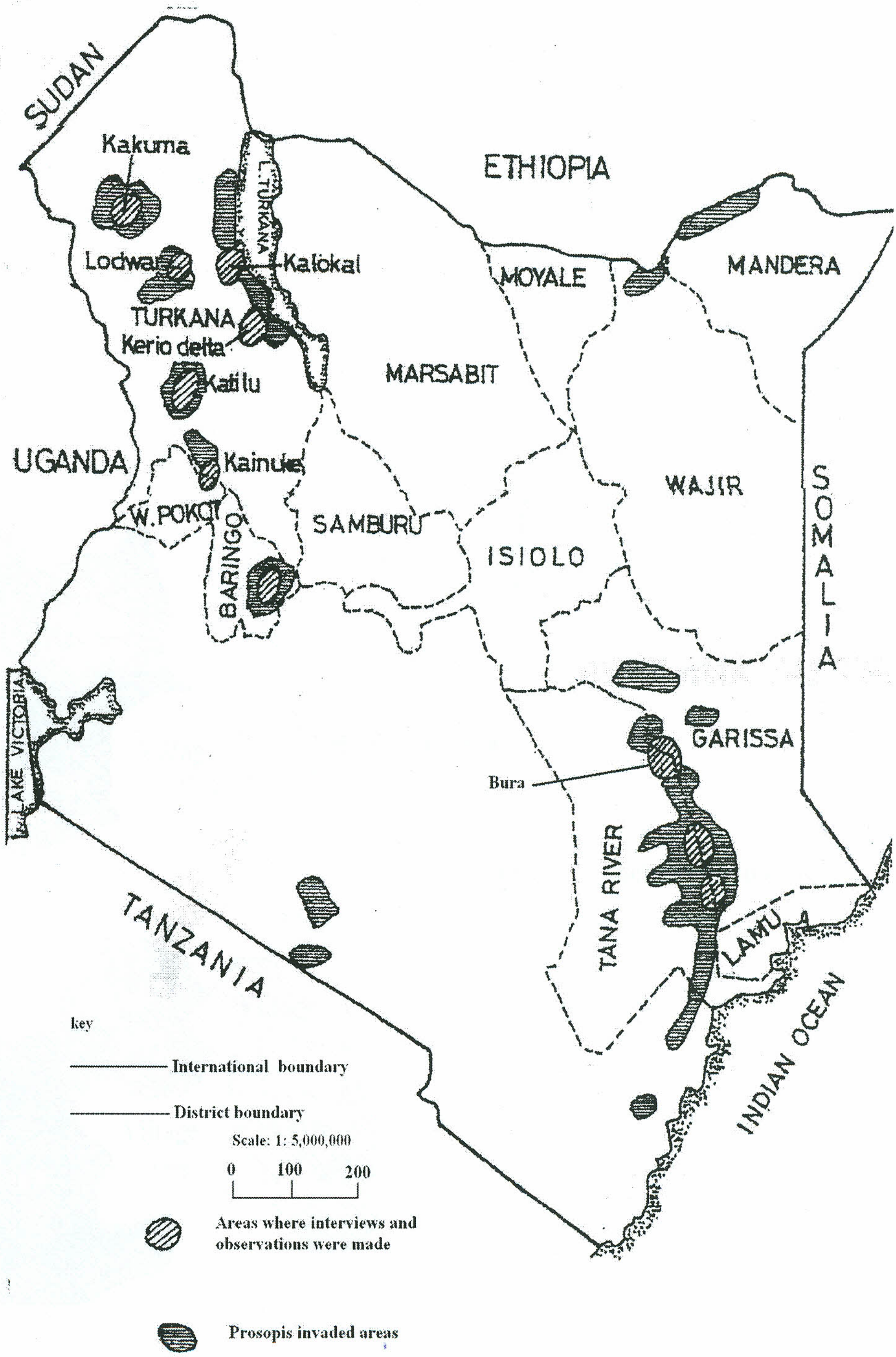
Generally, the area is covered by young alluvial soils (Sombroek *et al.,* 1982) with gently sloping plains in a west-east direction (Muchena, 1987). The vegetation is mainly shrub land (Gitonga and Maingi, 1988). The predominant plant species is *Prosopis juliflora* followed by *Senegalia spp*. (Personal observation, 2009).

3.2 Study site selection

Bura Irrigation Scheme comprises two almost equal blocks separated by a seasonal river known as Hirmani. The first block comprises six villages designated "village 1- 6' in this study (Figure 3.2). The second block comprises four villages "villages 7- 10" and the Bura town area. Two study sites (villages) were chosen randomly from each block. The 4 study sites randomly selected were village 2, 5, 9 and 10, and their co-ordinates are shown in Table 3.1.

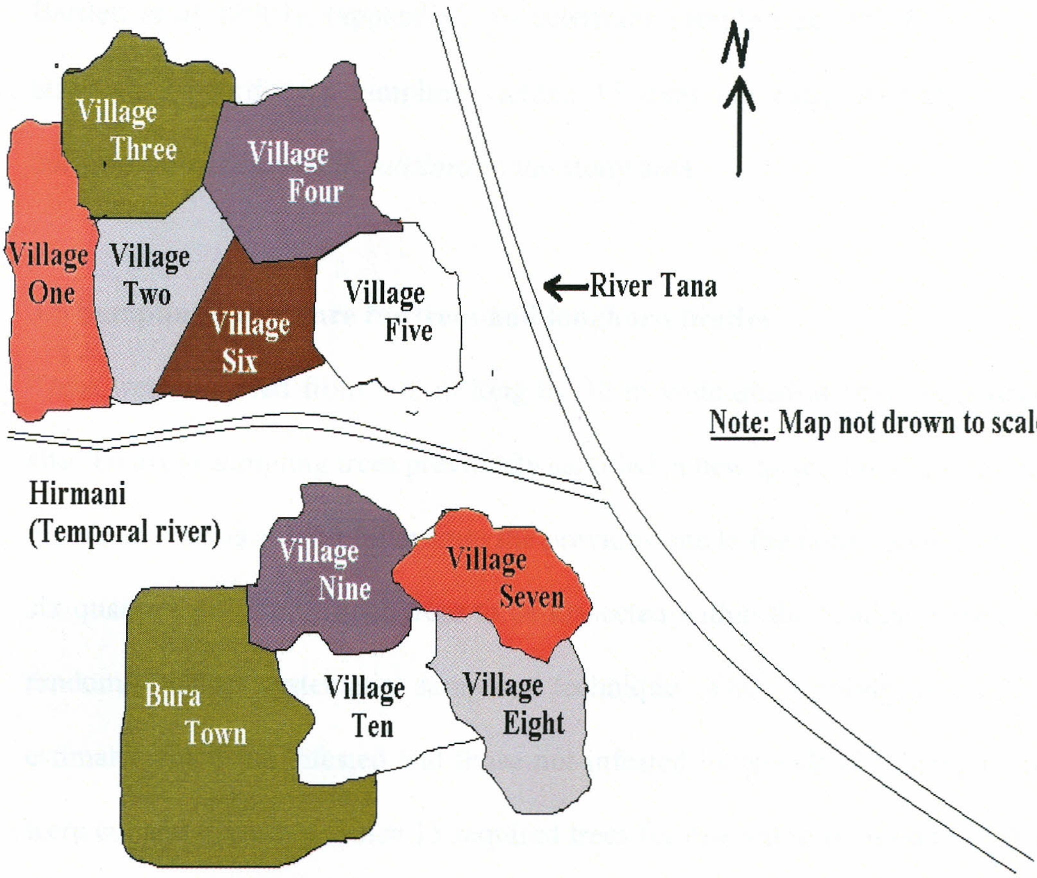
Table 3:1: Study sites co-ordinates taken by use of GPS receiver

Study sites		**Co-ordinates**
	Latitude (S)	Longitude (E)
Village 2	01°07.279′	039°49.532′,
Village 5	01°07.468′	039°51.864′
Village 9	01°10.006′	039°49.832′
Village 10	01°11.455′	039°51.156′



Source: Choge and Chikamai 2004

Figure 3:1: Map of Kenya showing the location of study area, Bura.



Source: Own map

Figure 3:2: Settlement villages from where sampling was done within Bura irrigation settlement scheme, Kenya.

3.3 Study design

The study was a descriptive survey research, which involved survey of stem borer occurrence on tree of *P. juliflora*. Sampling was carried out once every month.

3.4 Sample size determination

Pilot survey in the study area showed the abundance of *Prosopis juliflora* at approximately 0.08 trees / m^2, working out to a total of 6000 *Prosopis* trees in 24 quadrats of 100 m by 30 m which were turgeted for survey. Using the method of Bartlett *et al.* (2001), (appendix1) to determine sample size, 362 *Prosopis* were targeted. Proportionate sampling yielded 15 trees per each quadrat, assuming uniform distribution of *P. juliflora* in the study area.

3.5 Sampling procedure for trees and longhorn beetles

Trees were sampled from 100 m long by 30 m wide quadrat from each selected site. To avoid sampling trees previously sampled, a new quadrat was chosen every month and it was at least 50 m from the previous one to the north, giving a total of six quadrats per site. Fifteen trees to be dissected within the quadrat were chosen randomly using systematic sampling technique. The sampling interval was estimated for those infested and those not infested independently. Sampled trees were cut and dissected. Since 15 required trees for dissection is an odd number, if in one month 7 trees with powder and 8 without powder were dissected then in the following month it was vice versa. Choosing of equal number between the infested trees and those not infested to be dissected was purposeful, since the main aim was to determine if there was any association between infestation and presence of longhorn beetle.

Survey for longhorn beetles was conducted in each of the study sites every month from June to December, 2009. Trees in the quadrat were examined externally for signs of infestation. According to Amman and Cole (1983) external evidence of beetle's infestation consists of pitch tubes and boring dust at the base of the stem. Although pitch tubes may be absent, orange-brown dust around the base of the tree is a sure sign that the tree has been attacked. Powder around the tree base indicates active feeding of the borers. In each quadrat chosen, the number of trees with orange-brown powder and those without was recorded.

The stems were cut and dissected using a "panga", bow saw and/or a hand saw. Each plant sampled was examined for longhorned beetle. Any adult or immature stages of the beetles were collected and preserved in 70% ethanol for later identification. The larvae were put in boiling water for three minutes before preserving in 70% ethanol. Boiling water stops enzyme activities, thus preventing the preserved larvae from turning black and helps to retain flexibility (Booth *et al.*, 1990).

It was very difficult to collect any adult during the first field trips but later it was realized one could easily collect a pre-adult beetle which after three days acquired a complete adult beetle features. No eggs were collected but larvae, two pupae and adults were collected which indicated that they underwent complete metamorphosis. Pre adult were collected just at the end of external openings of the tunnel in the stem and one could tell whether an opening contained the beetle due to presence of whitish coat (pupal chamber) just about 3 cm from the opening.

3.6 Identification and sexing of beetles.

Identification of beetles was carried out using adult morphometric features which include total body length, elytra length, and antenna length, all 11 antennal segment lengths and length, and width of Pronotum and prothorax. length and width and leg length, were taken for adult beetle. Measurements were done using a dial caliper at their longest dimensions (Wang and Leschen, 2003). However, the leg, antennal and antennal segments were first stretched on a white paper, and the length measured directly on paper. For the larvae (borers) only the body length was measured. Photographic documentation of selected specimens was carried out using a digital camera, either directly or under dissecting microscope. All adult and larva longhorn beetles collected were identified at the National Museums of Kenya. This was done by comparing the morphometric measurements of the specimen collected in the field with those of the museum collection. All collections were done during the day.

Beetle sexing was carried out using both morphological and behavioral characteristics. The antennae were the main morphological characteristic used, as in males its length is approximately equal to the body length while in females it is much shorter though longer than elytra (Booth *et al.*, 1990). For behavioral characteristic, when adult beetles were captured and placed in cages, they immediately began to mate (Plate3.1) and characteristics of each mate observed.

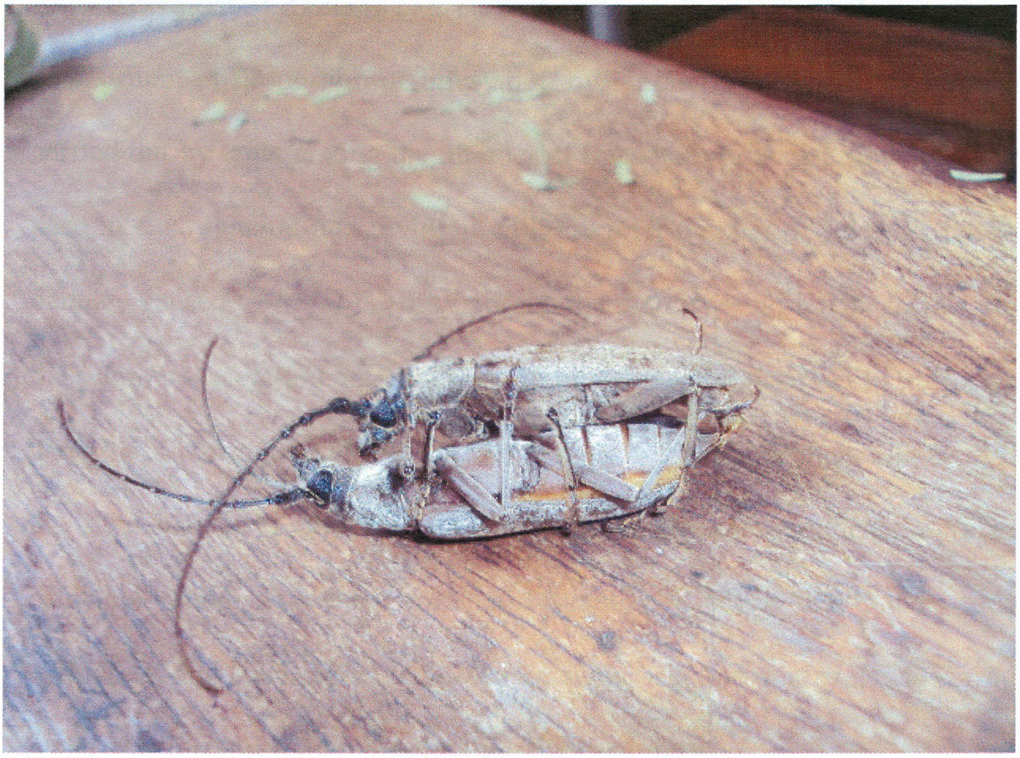


Plate 3:1: Adult longhorn beetles mating (photo taken at Bura)

Since there is limited literature on longhorn beetles collected from the field, the study used the statistical tests of morphomentric data, field observation, dissecting microscope (mg*10.2) and photographs taken by use of a digital camera to come up with a clear description of the beetles which could be used to formulate an appropriate identification features for the species. The study depended more on statistical tests that expressed relationships between body parts to come up with an elaborate description of the species since limited information on this particular group of beetles was available both in the literature and in the National Museums of Kenya, as proportional relationships between body parts are useful for species and sex identification (Wang and Leschen, 2003).

3.7 Assessment of damage caused by borers on *Prosopis juliflora*

Assessment of proportion of infestation by longhorn beetles on *P. juliflora* was carried out by enumerating the number of trees with brownish powder around the base in each quadrat and dividing with the total number of trees. To assess the damage caused to *P. juliflora* by borers, the diameter and length of the stem and the number, diameter and length of the tunnels were measured in millimeters by use of a 30 cm ruler and a string. To be able to measure tunnel and stem length, the stem had to be cut and laid horizontally. The measurements were used to calculate tunnel and stem volumes respectively. Since the tunnels are more cylindrical and stem more cone-like, the study used the mathematical formula $\pi r^2 h$ and $\frac{1}{3}\pi r^2 h$ respectively in estimating their volumes.

To determine whether the damage caused by the borers was permanent, two quadrats 100 m long and 30 m wide were marked. In each quadrat, the total number of trees was determined, and percentage dryness of each tree within the quadrat was estimated. Relationship between level of dryness before the onset of the rain and regrowth (presence of fleshy leaves and branches) after onset of rain in each tree within the quadrat was assessed. This was done by recording the number of trees with new and fleshy leaves one month after onset of the rain (mid-October 2009).

Percent stem damage by borer tunneling was determined by the following formula:

$$\frac{t_a}{s_a} x100$$

t_a and s_a are tunnel and stem volumes respectively .

Percent dryness on the other hand was estimated by counting the number of dead branches and dividing by the total number of branches per stem (Mueller *et al.*, 2005).

3.8 Determination of host age preference by longhorn beetles

The age of *Prosopis juliflora* plant preferred by longhorn beetles was determined by assessing the association between the age of *P. juliflora* and presence/ and or absence of longhorn beetle borers. A study conducted by Loewenstein *et al.* (2000) reported that there is positive correlation between age and diameter of trees. Diameter was measured at 30 cm above the ground as applied by Gehring *et al.* (2008).

The sampled trees diameter ranged from 25 to 210mm. The measurements were divided into four classes: 21-40mm, 41-60mm, 61-80mm, and 81mm and above, and given the following codes: 1, 2, 3, and 4 respectively. The codes 1, 2, 3 and 4 stood for young, middle age, old and very old trees respectively. In each category the number of trees where borers were found and those where the borer was absent were recorded. For tallying purpose presence of borers and absence of borers was coded 1 and 0 respectively. The two coding were combined in one column forming 8 different categories: 11, 10, 21, 20, 31, 30, 41, and 40 (i.e 11 stood for number of young trees where borers were present while 10 was for number of young trees where borers were absent, the purpose of double coding was to assist in constructing a contigence table (Appendix 3, columns 3 and 4).

3.9 Analysis

The data was analyzed by using Minitab software. Anderson-Darling normality test was used to examine whether or not the observations followed a normal distribution Chi square test was used to test for association between the presence of orange-brownish powder around the base of tree and: a) presence of longhorn beetle borer b) presence of brown-spotted borer. Minitab software was used to code absence and presence of each borer, and with and without the powder. The trees with powder was coded 2 and those without 3 (Appendix 3, column 1), the presence and absence of each type of larval form were coded 1 and 0 respectively (Appendix 3, column 4and 5). The coded data was tallied and used in contingence table.

One- way ANOVA was used to test if there was significant difference in means of various parts of the beetle (Wang and Leschen, 2003) such as the means length of: a) the three pairs of legs b) total body, elytra and antennal length, c) the 11 antennal segments. Where significant differences in means was found, mean separation was done by use of Tukey's Test. Separation of mean lengths of leg pairs unlike others was done for all adults collected from Bura combined as their measurement were taken before they were separated. t- test was used to compare morphometrics measurements for male and female beetles and in comparing beetles collected in this study with those in the National Museums of Kenya.

Pearson Correlation test was used to test whether there was a relationship between levels of borer damage and dryness of *P. juliflora.* Though data correlated were in percentages, test for normality showed they were normally distributed. To test host age preference, chi-square test was used to test for association between age of tree and presence of longhorn beetles. Finally, simple regression was used to test for the relationship between levels of dryness and regrowth in *P. juliflora*.

CHAPTER FOUR : RESULTS

4.1 Description of immature stages of beetle collected from Bura

Two types of larvae were recovered from dissected stems. One type was cream-white larvae (Plate 4.1) and was found boring in and feeding in the cambium region of the stem. The second was brown-sported larvae (Plate 4.2). The larvae were recognized as longhorn beetle larvae and moth larvae respectively. A total of 172 longhorn beetle larvae were collected in the whole study period. There was only one larva per tunnel/plant except in two cases where they were two. The borers were cylindrical and elongated ranging in length from 21 to 62 mm with a mean length of 47.55±0.71mm. The larvae were cream-white but the head was brownish (Plate 4.1). Only two pupae were collected from Bura (plate 4.3). When tree stems were cut, long black tunnels caused by the feeding larvae could be seen in the cambium region. Three hundreds and sixty five *P. juliflora* stems were randomly sampled and dissected, 46 of them were dry (Plate 1.2). All the dissected dry *P. juliflora* had tunnels. However, there was no borer found within at the time. In the field an average of 14.16±1.6 percent of *P. juliflora* were infested by longhorn beetle stem borers.

4.2 Description and identification of Adult longhorn beetles

Adult longhorn beetles collected as were identified as *Taurotagus griseus* (Guar), in the sub family Cerambycinae; family Cerambycidae. The species was grey in colour, with a coarse (rough) dorsal surface of the pronotum with irregular ridges and furrows. The margin has three broad swellings with the middle one being relatively broader than the others (Plate 4.4). Scutellum is triangular (Plate4.5). Elytra apices are separately rounded, and do not cover the entire abdomen, a small section of the last abdominal segment is exposed (Plate 4.6). As in any other Cerambycidae their tarsi was found to be megacyllene, tarsi with two divergent claws (Plate 4.7). In longhorn beetle, the second antennal segment was found to be the smallest. It was very difficult to observe and identify it as a separate segment by use of naked eyes but it was very clear under dissecting microscope (Plate 4.8). When observed under dissecting microscope, antennae were found to bear relatively long hairs, especially at the end of third segment (plate 4.9).

Plate 4:1: Longhorn beetle larvae from Bura

Plate 4:2: Spotted moth larvae from Bura

Plate 4:3: Longhorn beetle pupa from Bura

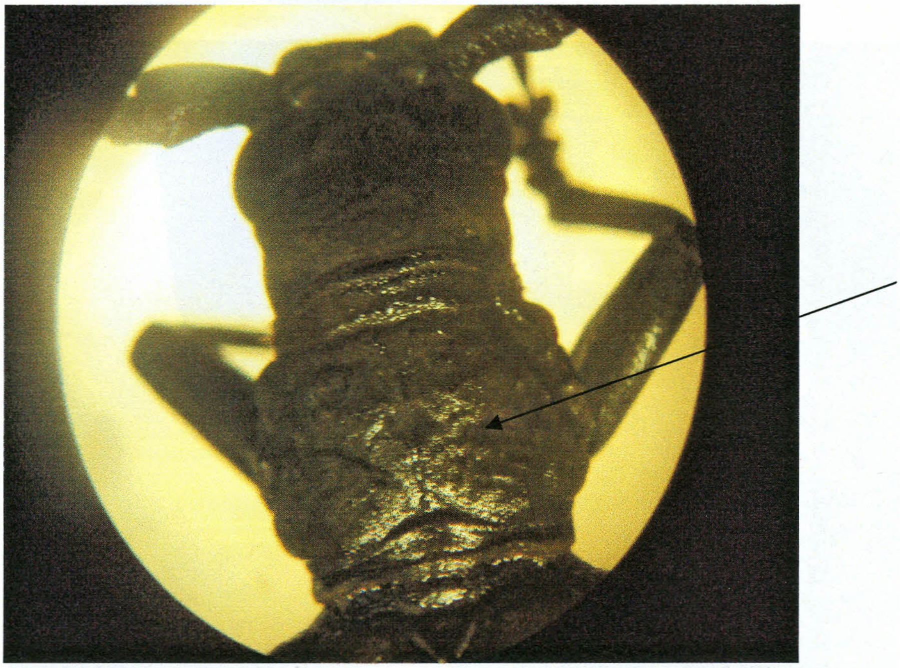


Plate 4:4: Adult longhorn beetle pronotum

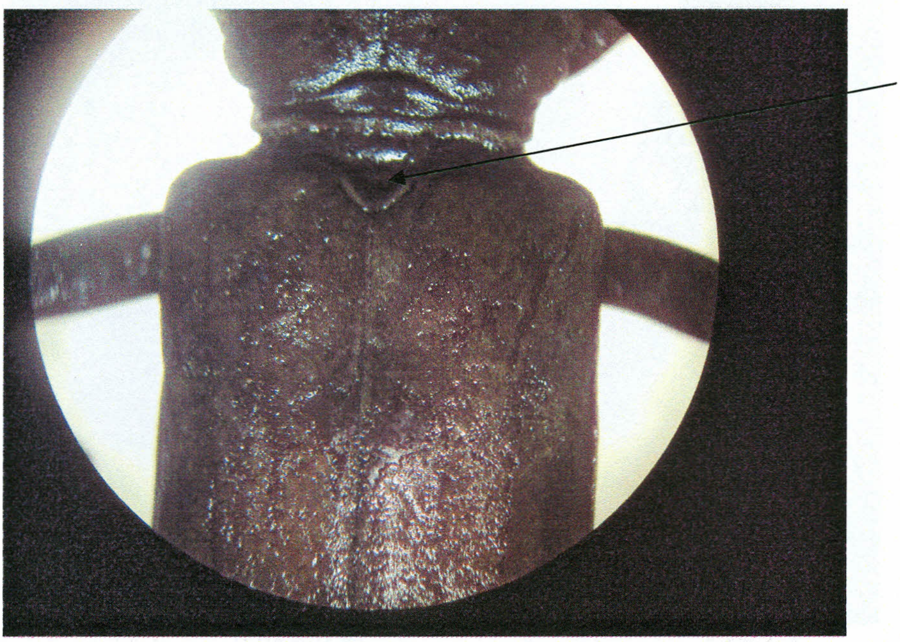


Plate 4:5: Adult longhorn beetle scutellum

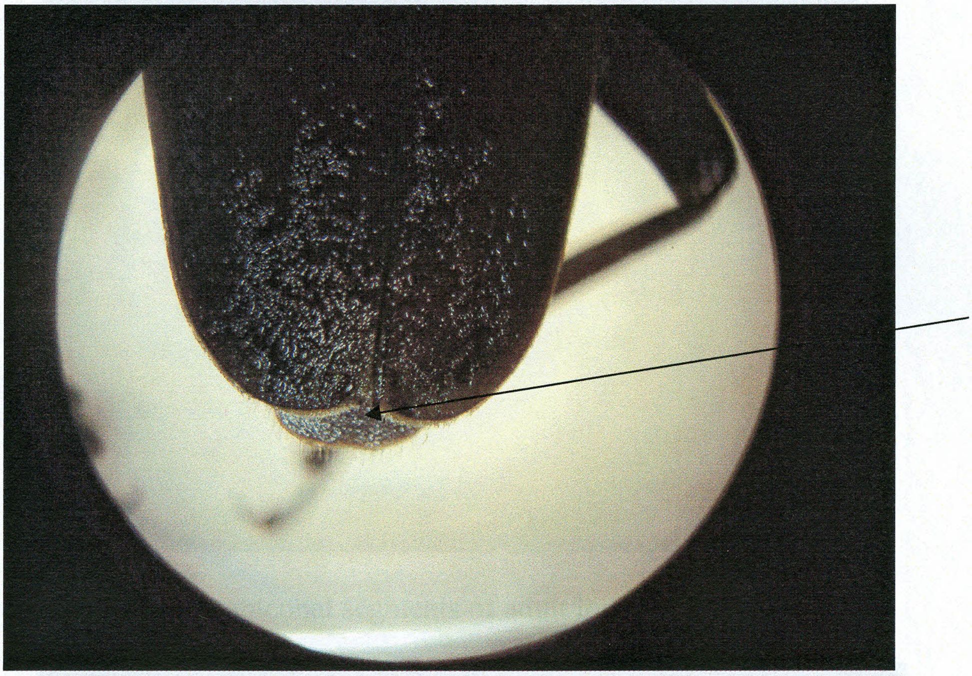


Plate 4:6: Elytra apices of adult longhorn beetle (From Bura)

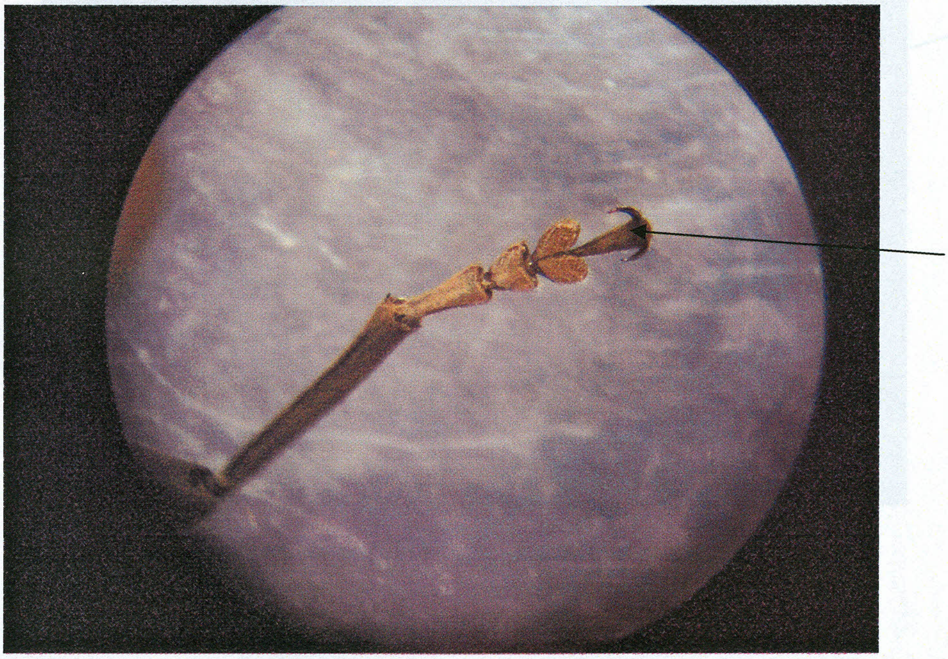


Plate 4:7: Divergent claws on the tarsi of adult longhorn beetle(From Bura)

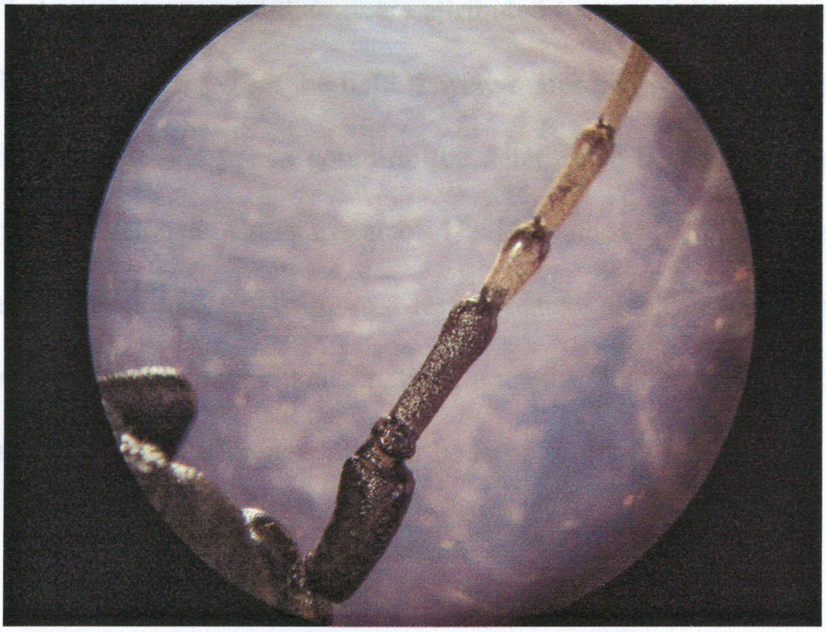


Plate 4:8: Some antennal segments of adult longhorn beetle

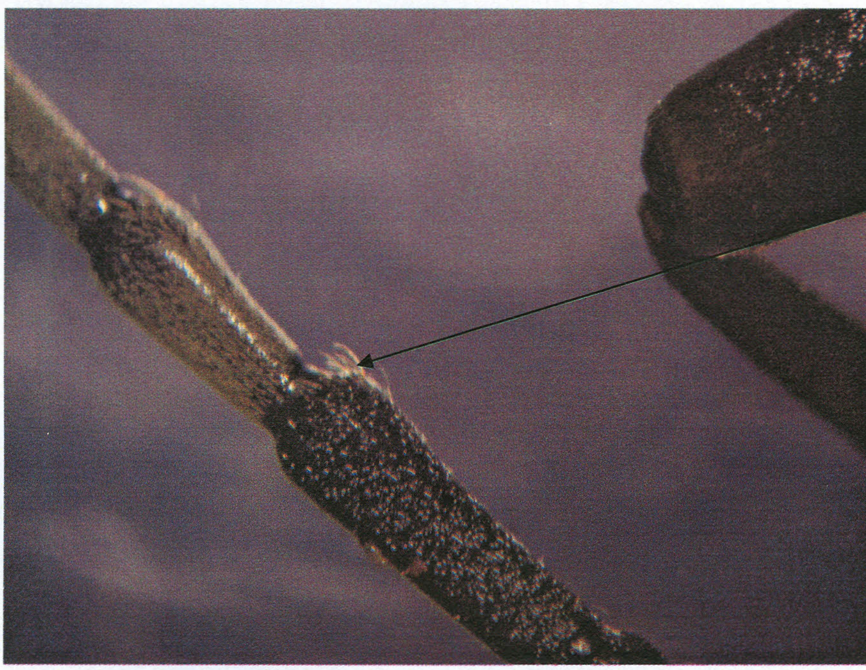


Plate 4:9: Hairs on third antennal segment of adult longhorn beetle

All the 21 adult longhorn beetles and a sample of cream-white larvae (borer) collected from the field belonged to the same species *T. griseus.* The differences that existed amongst them were attributed to sexual dimorphism. Out of 21 adult beetles collected from the field, 7 were males and 13 females. There was only one adult beetle whose sex could not be determined because their antennae were not fully developed. Comparison of 1^{st}, 10^{th} and 11^{th} antennal segment lengths of males and females using a t-test revealed significant difference (Table 4.1) suggesting that this characteristic is a useful tool for sexing. However, there was no significant difference in other body parts.

Table 4:1: Comparisons of morphometric measurements for males and females *Taurotagus griseus* Collected from the field

	Mean ±SE (mm)		**t-value**	**P-value**
General body parts	Males (n=7)	Females (n=13)		
Body length	41.86± 2.06	46.3± 1.38	1.84	0.082ns
Elytra length	26.43± 1.36	27.54± 0.69	0.82	0.424ns
Antennal length	42.14±1.93	34.85± 2.18	2.21	0.041*
Prothorax width	9.29± 0.42	9.15± 0.32	0.25	0.807ns
Prothorax length	6.57± 0.3	6.38± 0.29	0.041	0.685ns
Pronotum width	9.57± 0.4	9.62± 0.37	0.07	0.944ns
Pronotum length	7.42±0.3	7.69± 0.24	0.68	0.508ns
1st antennal segment length	4 ± 0.22	3.23±0.16	2.77	0.013*
2nd antennal segment length	1 ± 0.0	1± 0.0	-	-
3rd antennal segment length	4± 0.22	3.77±0.17	0.83	0.417ns
4th antennal segment length	2.57 ± 0.20	2.38± 0.14	0.77	0.450ns
5th antennal segment length	3.86± 0.14	3.62± 0.14	1.10	0.285ns
6th antennal segment length	4.29 ±0.29	3.62± 0.18	2.08	0.052ns
7th antennal segment length	4.29± 0.29	3.69± 0.24	1.54	0.142ns
8th antennal segment length	4.29± 0.29	3.54± 0.37	1.36	0.190ns
9th antennal segment length	3.86± 0.34	3± 0.3	1.79	0.091ns
10th antennal segment length	4 ± 0.22	3± 0.3	2.26	0.036*
11th antennal segment length	5.86± 0.34	4± 0.57	2.27	0.036*

*significant difference, ns= non significance different. Df=18

Preserved museum specimens of *T. griseus* were similar to those collected from the field in many ways. The results of the t-test revealed that there was significant difference in antennal lengths of the 1^{st}, 10^{th} and 11^{th} antennal segments length and no significant difference between male and females *T. griseus* in body length, elytra length, pronotum width and length and the length of the 4^{th} antennal segment (Table 4.2). Males' antennal length was approximately same as body length in both the museum specimens and the field collection. Comparison between females collected from the field and those preserved in the museum showed significant variation existed only in body length (Table 4.3), while similar comparison among males indicated no body part was significantly different (Table 4. 4). Females *T. griseus* preserved in museum had a mean antennal length that was smaller than the mean body length but longer than the mean elytra length (antennal length 31.88 ±1.2; body length 41.38±1.6; elytra length 28.63±0.96) just as was the case with sample collected in the field (Table 4.1). Antennal segment lengths in relation to other segments were similar in both museum and field collections. The shortest antennal segment was the pedicel followed by 4^{th} antennal segment. Based on their similarities, longhorn beetles collected from Bura were identified as *Taurotagus griseus*.

Table 4:2: Comparisons of morphometric measurements for *Taurotagus griseus* male and female museum specimens

	Mean ±SE (mm)		t-value	P-value
General body parts	Males (n=3)	Females (n=8)		
Body length	46.33± 2.9	41.38±1.6	1.60	0.144ns
Elytra length	31.33± 0.88	28.63±0.96	1.60	0.145ns
Antennal length	47.00± 2.3	31.88 ±1.2	6.48	0.000*
Pronotum width	11.0± 0.58	9.63± 0.6	1.30	0.225ns
Pronotum length	8.67±1.2	7.75± 0.53	0.83	0.430ns
Ist antennal segment length	5.00±0.53	3.75± 0.16	2.96	0.016*
2nd antennal segment length	1.00± 0.00	1.00± 0.00	-	-
3rd antennal segment length	5.00 ± 0.58	3.75± 0.16	2.96	0.016*
4th antennal segment length	2.667± 0.33	2.375± 0.18	0.81	0.438ns
5th antennal segment length	4± 0	3.75± 0.16	-	-
6th antennal segment length	4.67±0.33	3:25± 0.16	4.26	0.002*
7th antennal segment length	4.33± 0.33	3 ± 0	-	-
8th antennal segment length	4.33± 0.33	2.75± 0.25	3.44	0.007*
9th antennal segment length	4.67± 0.33	2.375 ± 0.18	6.37	0.000*
10th antennal segment length	4.67± 0.33	2.375± 0.18	6.37	0.000*
11th antennal segment length	6.33± 0.33	3.123± 0.35	5.18	0.001*

* significant difference, ns= non significance different. Df=9

Table 4:3: Comparisons of morphometric measurements for *Taurotagus griseus* females collected from field and female preserved specimen in Museum

	Mean ±SE (mm)		t-value	P-value
General body parts	Field (n=13)	Museum (n=8)		
Body length	46.3± 1.38	41.38±1.6	2.29	0.034*
Elytra length	27.54± 0.69	28.63±0.96	0.94	0.358ns
Antennal length	34.85± 2.18	31.88 ±1.2	1.01	0.325ns
Pronotum width	9.62± 0.37	9.63± 0.6	0.01	0.989ns
Pronotum length	7.69± 0.24	7.75± 0.53	0.11	0.911ns
1st antennal segment length	3.23±0.16	3.75± 0.16	2.09	0.5ns
2nd antennal segment length	1± 0.0	1.00± 0.00	-	-
3rd antennal segment length	3.77±0.17	3.75± 0.16	0.08	0.938ns
4th antennal segment length	2.38± 0.14	2.375± 0.18	0.04	0.967ns
5th antennal segment length	3.62± 0.14	3.75± 0.16	0.61	0.549ns
6th antennal segment length	3.62± 0.18	3.25± 0.16	1.38	0.183ns
7th antennal segment length	3.69± 0.24	3 ± 0	-	-
8th antennal segment length	3.54± 0.37	2.75± 0.25	1.54	0.141ns
9th antennal segment length	3± 0.3	2.375 ± 0.18	1.52	0.145ns
10th antennal segment length	3± 0.3	2.375± 0.18	1.52	0.145ns
11th antennal segment length	4± 0.57	3.123± 0.35	1.13	0.145ns

* Significant difference, ns= non significant difference. Df=19

Table 4:4: Comparisons of morphometric measurements for *Taurotagus griseus* males collected from field and males preserved specimen in Museum

General body parts	Mean ±SE (mm) Field (n=7)	Museum (n=3)	t-value	P-value
Body length	41.86± 2.06	46.33± 2.9	1.21	0.26
Elytra length	26.43± 1.36	31.33± 0.88	2.21	0.058
Antennal length	42.14±1.93	47.00± 2.3	1.45	0.185
Pronotum width	9.57± 0.4	11.0± 0.58	1.71	0.187
Pronotum length	7.42±0.3	8.67±1.2	1.44	0.187
1st antennal segment length	4 ± 0.22	5.00±0.53	2.05	0.075
2nd antennal segment length	1 ± 0.0	1.00± 0.00	-	-
3rd antennal segment length	4± 0.22	5.00 ± 0.58	2.05	0.075
4th antennal segment length	2.57 ± 0.20	2.667± 0.33	0.25	0.807
5th antennal segment length	3.86± 0.14	4± 0	-	-
6th antennal segment length	4.29 ±0.29	4.67±0.33	0.77	0.463
7th antennal segment length	4.29± 0.29	4.33± 0.33	0.1	0.926
8th antennal segment length	4.29± 0.29	4.33± 0.33	0.1	0.926
9th antennal segment length	3.86± 0.34	4.67± 0.33	1.41	0.196
10th antennal segment length	4 ± 0.22	4.67± 0.33	1.67	0.133
11th antennal segment length	5.86± 0.34	6.33± 0.33	0.83	0.43

Df=8, All body parts not significantly different (p>0.05)

Comparison of the length and width of the pronotum, t-test was conducted and results are shown in Table 4.5. The pronotum were wider than they were longer, in male and female beetles collected at Bura. This was also the case for museum females but museum males, the difference was not significant.

Table 4:5: Comparison of pronotum morphometric between sexes

	source	n	width	length	t	p	df
Males	F	7	9.57 ± 0.4	7.42 ± 0.3	3.79	0.003*	12
Females	F	13	9.62 ± 0.4	7.69 ± 0.3	4.40	0.000*	24
Males	M	3	11.00 ± 0.6	8.67± 1.2	1.75	0.155ns	4
Females	M	8	9.62 ± 0.6	7.75 ± 0.5	2.37	0.033*	14

F= field, M= museum, * Significant difference, ns= non significant difference.

Comparisons of morphometric characteristics within sexes using one way ANOVA showed significant variation in mean length of: a) males' antennal segments b) female antennal segments c) the three leg pairs d) comparison among body length, elytra length and antennal (Table 4.6). These indicate the differences that exist between males and females of *Taurotagus griseus*.

Table 4:6: Summary of ANOVA tests

comparisons	F	P-value	Factor df	Error df
Comparison of length for three Legs pairs of specimen collected from the field	24.5	<0.0005	2	60
Comparison of antennal segment lengths for male collected from field	23.3	<0.0005	10	66
Comparison of antennal segment lengths for male Museum specimens	14.6	<0.0005	10	22
Comparison of antennal segment lengths for female collected from field	9.72	<0.0005	10	132
Comparison of antennal segment lengths for female Museum specimens	19	<0.0005	10	77
Comparison of body, elytra and antennal length for males collected from field	24.6	<0.0005	2	18
Comparison of body, elytra and antennal length for males Museum specimen	16.2	<0.005	2	6
Comparison of body, elytra and antennal length for females collected from field)	37.7	<0.0005	2	36
Comparison of body, elytra and antennal length for females Museum specimen	27.9	<0.0005	2	21

Post ANOVA (Turkey's) test showed that the length of all the three pairs of legs were significantly different. Separation of leg pair length means using Tukey test showed that none of the pair was equal to the other (fore leg 22.62± 0.56a; mid leg 24.86± 0.59b; hind leg 28.67± 0.69c) (Appendix 2). Further observation of digital camera photographs also shows the hind leg pair to be longer than others (Plate 4.10).

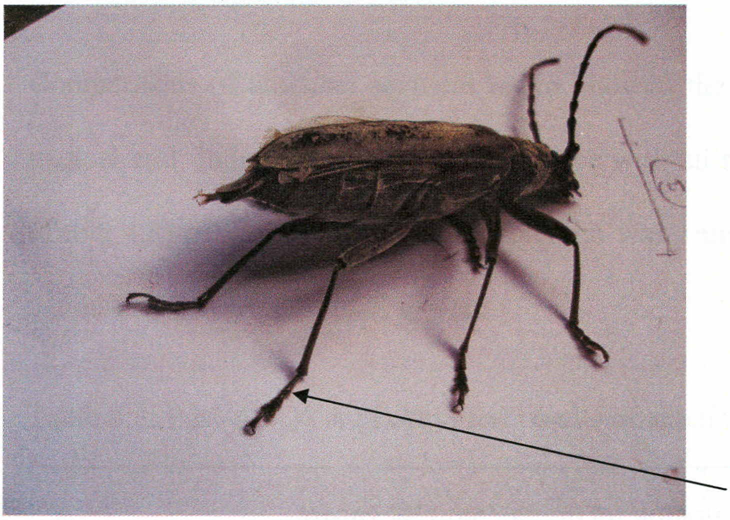


Plate 4:10: Photographic representation of *T. griseus* adult showing legs pairs length differences

Post- ANOVA (Tukey) test for body length, elytra length and antennal length revealed that in both Bura males and Museum males *T. griseus:* a) mean elytra length≠ body length, b) mean elytra length ≠ antennal length, c) mean body length =Antennal length. However, in females collected from the field none of the three parameters was equal to the other, while those females preserved in Museum only mean antennal length was equal to mean elytra length (Table 4.7).

Table 4:7: Post-ANOVA (Tukey) result summary of body length, elytra length and antennal length for *T. griseus*

		Mean± SE (mm)		
Body parts	Males F	Females F	Males M	Females M
Body length	41.86±2.1a	46.30±1.4a	46.33±2.9a	41.38±1.6a
Elytra length	26.43±1.4b	27.54±0.7b	31.33±0.9b	28.63±1.0b
Antennal length	42.14±1.9a	34.85±2.2c	47.00±2.3a	31.88±1.2b

F= *T. griseus* collected from field, M=Museum preserved *T. griseus*
Means followed by the same letter(s) within a column are not significantly different.

Comparisons of antennal segment legths showed the shortest segment to be the pedicel and indicated significant difference with all the other antennal segments (Table 4.8) of *T. griseus*, their mean length was 1mm. The feature will be very useful in the desription of *T. griseus.*

Table 4:8: Post-ANOVA (Tukey) test results of antennal segments for *T.griseus*

	Mean± SE (mm) length for antennae segments			
	Specimen collected from field		Museum specimens	
Antennal segments	Males	Females	Males	Females
1st	4.00±0.2a	3.23±0.2a	5.00±0.5a	3.75±0.2a
2nd	1.00±0.0b	1.00±0:0 b	1.00±0.0b	1.00±0.0b
3rd	4.00±0.2a	3.77±0.2a	5.00±0.6a	3.75±0.2a
4th	2.57± 0.2c	2.38± 0.2c	2.6±0.3c	2.36±0.2c
5th	3.86±0.1a	3.62± 0.1a	4.00±0.0ac	3.75±0.2a
6th	4.29±0.3a	3.62±0.2a	4.6±0.3a	3.25±0.2a
7th	4.29±0.3a	3.69±0.2a	4.33±0.3ac	3.00±0.0ac
8th	4.29± 0.3a	3.54± 0.4a	4.33±0.3ac	2.75± 0.3ac
9th	3.86±0.3a	3.00±0.3a	4.67±0.3a	2.38±0.2acd
10th	4.00±0.2a	3.00±0.3a	4.67±0.3a	2.38±0.2acde
11th	5.86±0.3d	4.00±0.6a	6.33±0.3a	3.12±0.4acde

Means followed by the same letter(s) within a column are not significantly different

4.3 Determining organisms responsible for tunneling of *P. juliflora* stems

There was significant association between the presence of brown powder and presence of longhorn beetle larvae (χ^2=311.17, df 1, p<0.05) (Table 4.9) in the *P. juliflora* plants. Moreover, the number of trees found with borers was very high among trees that had brown powder around their base compared to those without (Figure 4.1). However, there was no significant association between the presence of powder and presence of moth larvae (χ^2=0.7, df 1, p> 0.05) (Table 4.10). In both cases the number of moth larvae found with or without powder was very low (Figure 4.2).

Table 4:9: Contingence table to test the association between the presence of brown powder and presence of beetle larvae in *P. juliflora* trees

	No of tree with beetle larvae	**No of tree without beetle larvae**	**Total**
No of trees with powder	164	9	173
No of trees without powder	4	188	192
Total	168	197	365
x^2= 311.17,	**P<0.05,**		**df=1**

Table 4:10: Contingence table to test the association of presence of powder and presence of moth larvae

	No of tree with moth larvae	**No of tree without moth larvae**	**Total**
Trees with powder	6	167	173
Trees without powder	3	189	192
Total	9	356	365
x^2=0.7,	**P>0.05,**	**df=1**	

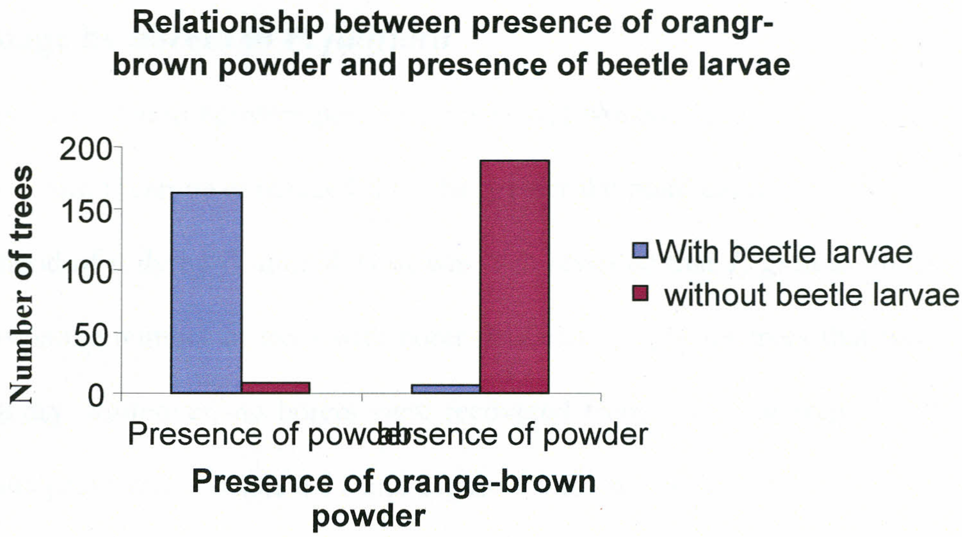


Figure 4:1: Number of powdered and non-powdered trees with longhorn beetle larvae

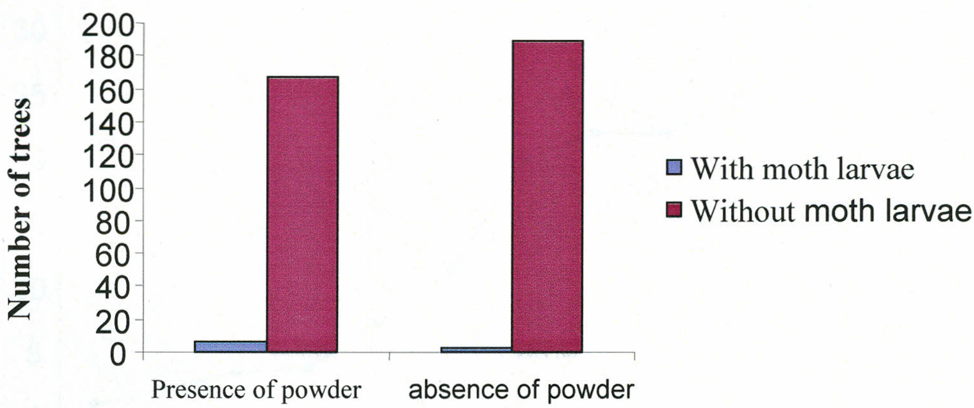


Figure 4:2: Number of powdered and non-powdered trees with moth larvae

4.4 Damage by borers to *P. juliflora*

There was a correlation between percent dryness and percent damage (r=0.86, $p < 0.05$). Therefore it can be concluded that, the greater the plant damage the higher the likelihood of it dying (Figure 4.3). It was also revealed that *T. griseus* attack flesh trees as the number of trees with borer declined sharply for trees that were over 60% dry. Moreover, no borers were recovered from trees that were 100% dry. Results presented in Table 4.11 and Figure 4.4 show that the drier, the trees, the fewer the borers. Level of damage in percentage was found to be 14.5± 0.75.

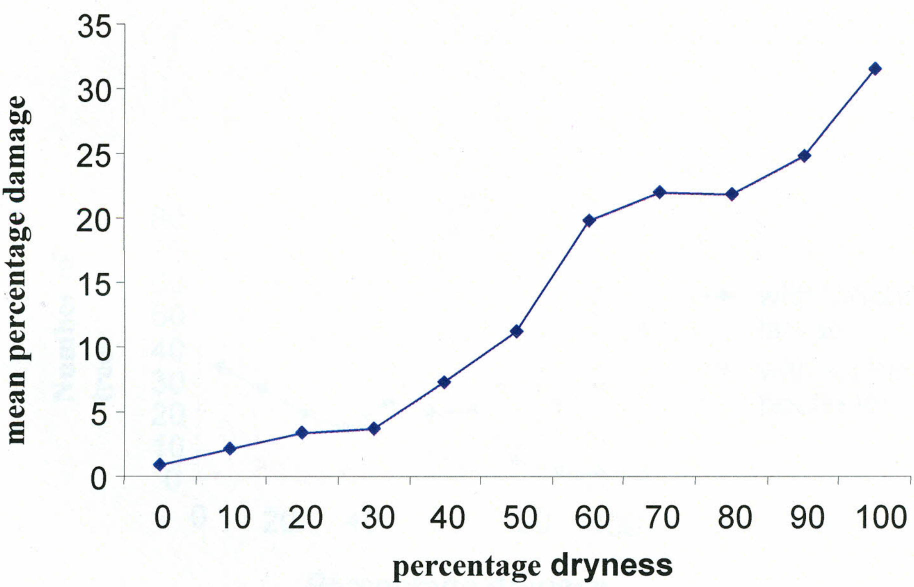


Figure 4:3: Relationship between mean percent damage against mean dryness

Table 4:11: Relationship between percent dryness, damage and the presence of beetle larvae in *P. juliflora* tree

Percentage dryness	Mean % damage	No. of trees with longhorn beetle larvae	No. of trees without longhorn beetle larvae
0	1±0.2	34	76
10	2.2±0.6	27	4
20	3.4±0.4	20	0
30	3.8±0.6	15	1
40	7.4±0.7	23	0
50	11.3±1.2	20	8
60	19.9±1.9	21	1
70	22±1.7	5	10
80	21.9±1.6	2	23
90	24.9±1.6	1	28
100	31.5±1.6	0	46

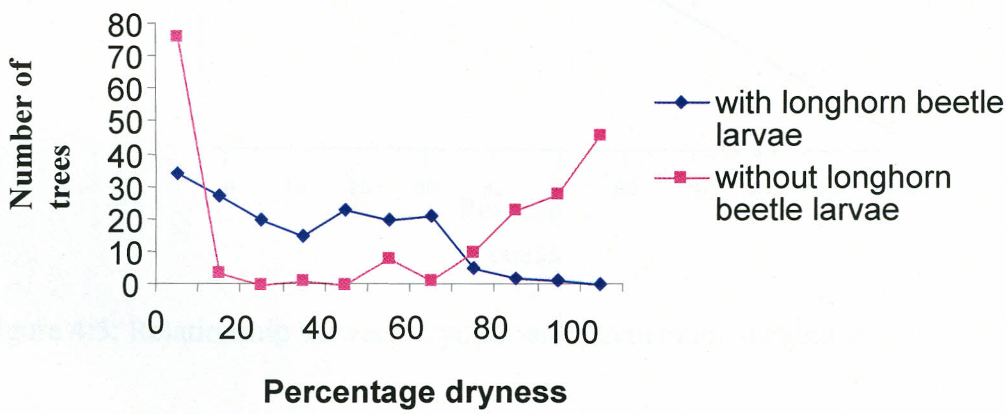


Figure 4:4: Relationship between longhorn beetle larvae and percentage dryness

4.4.1 Effects of percent damage on *P. juliflora* ability to regenerate

Regression analysis indicated that there was significant relationship between number of trees with regrowth and percent dryness in both quadrat A (ß=-0.163, R^2 =0.77, F-value=30.75, p-value<0.05, df=9) and quadrat B (ß=-0.276, R^2 =0.75, F-value=27.019, p-value=0.001, df=9). The results suggest that percent dryness can be used to estimate the number of trees with ability to regenerate.

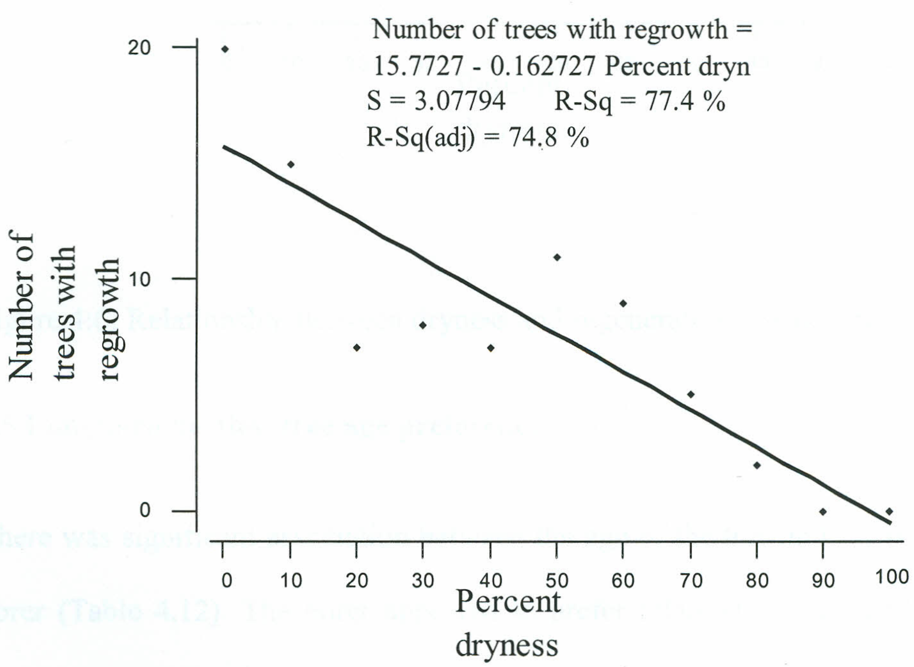


Figure 4:5: Relationship between dryness and regeneration quadrat A

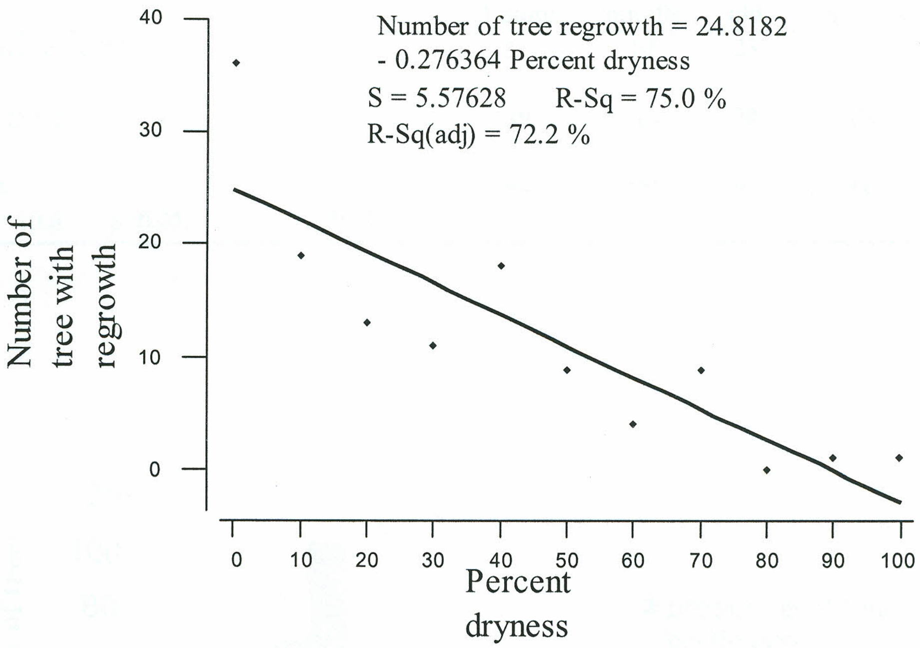


Figure 4:6: Relationship between dryness and regeneration quadrat B

4.5 Longhorn beetles' tree age preference

There was significant association between the age of the tree and the presence of borer (Table 4.12). The borer appeared to prefer relatively young and very old trees as number of trees found with the beetle borer was greater than those without unlike in middle and old aged trees (Figure 4.8).

Table 4:12: Contigence table for testing whether there is any association between age of *P. juliflora* trees and presence of longhorn beetle borers

Presence or absence of white borer	trees relative age				
	Young	middle	old	Very old	Total
Borer present	55	67	23	23	168
No borer	39	101	38	19	197
Total	94	168	61	42	365

$\chi^2 = 10.6$, $p<0.05$, df=3

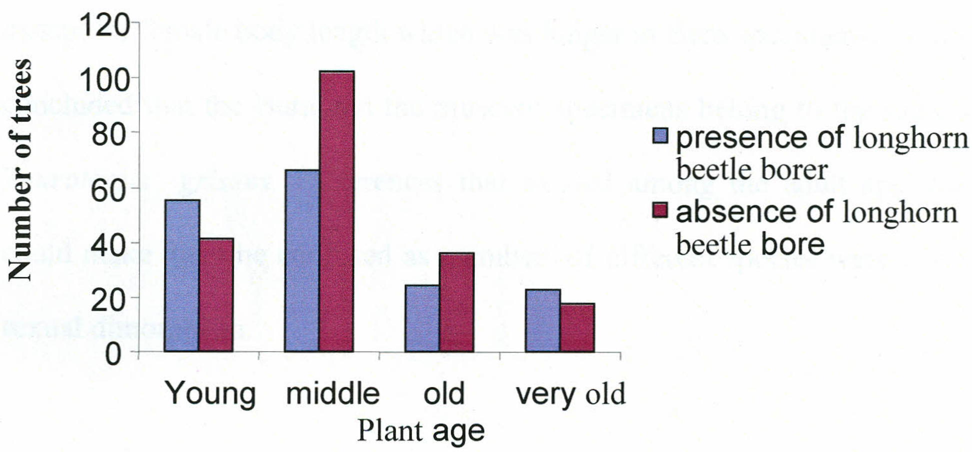


Figure 4:7: Tree age and presence/and or absence of longhorn beetle larvae (borer)

CHAPTER FIVE : DISCUSSION

5.1 Species of woodborers in Bura that attack *Prosopis juliflora*

The present study was the first of its kind in Bura, Kenya, and provided a vital basis for monitoring the potential of longhorn beetles in biological control of *P. juliflora*. Morphometric and photographs of the collected specimens when compared with preserved specimen in Museum helped in the identification of specimens at National Museum of Kenya. Morphometric measurements for field-collected adults were not significantly different from those of museum specimens except for female body length which was longer in Bura specimens. Hence it was concluded that the Bura and the museum specimens belong to the same species, *Taurotagus griseus*. Differences that existed among the adult specimens that could make them be confused as members of different species were attributed to sexual dimorphism.

Moreover, hind leg pair was longer than others (Appendix 2) (Plate 4.10), and this characteristic helped to classify the longhorn beetles collected to sub-family Cerambycinae where *T. griseus* belongs and distiquish it from members of sub-family Laminae where their hind leg pair is shorter in relation to other pairs (Booth *et al.*, 1990). The grey colour of the adults was probably a cryptic feature for camouflage as *P. juliflora* stems where they were found were grey in colour, hence it cannot be used as an identification feature for the species.

Immature insects feeding on and tunneling in the stems of *P. juliflora* were the longhorn beetle larvae (Table 4.9). Larvae from the family Cerambycidae have been described as wood-boring and destructive to shade, forest, fruit trees and freshly cut logs (Borror *et al*., 1989). This is a significant finding because there has been no previous report of *T. griseus* infestation of *P. juliflora*. Therefore, this report is the first instance of *T. griseus* in *P. juliflora.* It was not however, possible to tell whether the adult beetles laid their eggs in the stem or on it so that the larvae then bore into the stem since no eggs were recovered during the entire study. Since the two pupae and all the pre-adult specimens collected were found near the external end of the tunnel in the stem, it could be suggested that the position is to provide an easier way of adult exit from the stem. According to Booth *et al.* (1990) pupation in Cerambycidae generally takes place within the host in a pupal chamber which is near to outside surface, leaving the adult with only a short distance to cut through during emergence.

During the survey, it was observed that in most cases there was only one borer per stem. This was probably because of the oviposition behaviour of phytophagous insects which is often modified by the presence of conspecific eggs and larvae. Typically, females avoid depositing eggs on previously exploited hosts, a behavioral strategy to reduce the competition suffered by their offsprings. The stimuli permitting females to distinguish between the occupied and unoccupied hosts act as signals (Dempster 1992; Mudd *et al.* 1997; Seeley 1998; Li *et al.*

2001), which may come from conspecific eggs, larvae (Anbutsu and Togashi, 1996) or larval frass (Anderson *et al.*, 1993).

5.2 Damage caused by woodborers to *P. juliflora*

Wood boring beetles such as Cerambycidae play important role in various ecological processes should (Macfadgen, 2005). According to Booth *et al.* (1990) Cerambycidae are all plant feeders and because of their moderate to large size they can cause considerable damage. *Taurotagus griseus* larvae feed within the phloem, cambium and outer layers of xylem tissues thus damaging vital organs of the plant. However, the study found no evidence indicating adult longhorn beetle boring tunnel in *P. juliflora*.

5.3 Potential of *T. griseus* as biological control agents for *P. juliflora*

The results of this study revealed that *T. griseus* attacks and damaged *P. juliflora*. Therefore *T. griseus* has potential for use as a native biological control agent of *P. juliflora. T. griseus* was found to be a native natural enemy of *P. juliflora* since it was found to be principally responsible for the tunnels on tree stems (Table 4.9) (Plate 1.1). This study has shown that *P. juliflora* attacked by *T. griseus* borers weaken and may eventually lead to death of the trees. In addition, the damage caused to *P. juliflora* by *T. griseus* is permanent as regeneration ability of damaged trees decreases with an increase in dryness (Figure 4.6 and 4.7). This outcome is a necessary quality for a good biological control agent.

Taurotagus griseus was found to prefer relatively young and very old trees. Preference of young trees is probably because their stems were softer while for the later could be because many forest insects exploit trees that are physiologically weakened as a result of stress created by nutrient deficiencies, drought, flooding, overcrowding, and other variables (Coulson and Witter 1984). Fierke *et al.* (2007) argued that increased success of red oak borer *Enaphalodes rufulus* (Cerambycidae) could be caused by declining tree resistance. Resistance of trees to various diseases and insects varies in a complex manner with tree age. Old trees experiencing stressful conditions may not be able to defend themselves against pest attack. Since there is an association between presence of longhorn beetle borers and tree age, especially the preference of young trees by borer (Figure 4.8) shows that the beetle may kill the tree before maturity because it feeds extensively in the cambium (Booth *et al.*, 1990).

In classical biological control, the control agent must be host specific. If on the other hand the control agent is already present in the environment, as is in the case with *T. griseus* in Bura, it need not necessarily be specific (Dejong *et al.*, 2002). Additionally, according to Debach and Rosen (1991), any weed-feeding insect of whatever feeding habit in any order, family, or genus can be considered potentially important in biological control of weeds. Therefore, it can be concluded on the basis of this study that *T. griseus* has the potential to control and regulate the spread of *P. juliflora* without having an adverse effect to other vegetation. It was observed in the field that the tunnels which are as a result of *T.*

griseus borer attack, weakens the tree stem, which with only slight force of the wind, they fall down or kill the entire tree (plate 1.2).

Exotic tree such as *Prosopis juliflora* are assumed to have no natural enemies. However, natural enemies keep on evolving resulting to change in host (Thompson, 1998). *T. griseus* found feeding on *P. juliflora* might have evolved and changed host from indigenous *Senegalia spp.* Study by Eisa and Roth (2009) in Ethiopia reported longhorn beetle feeding on *Senegalia spp.* Moreover, According to Strong *et al.* (1984) it is much more common for native insects to recruit onto introduced plant species.

CHAPTER SIX : CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From this study, it can be concluded that:-

a) Collected beetles were identified as *Taurotagus griseus* Guer (Cerambycidae: Coleoptera)

b) *T. griseus* larvae were found to be the ones responsible for tunneling and probably contribute a lot to death of *P. juliflora* in Bura, Kenya.

c) *T. griseus* has the potential to be used as a biological control agent of *P. juliflora* since:

i) It is a native natural enemy of *P. juliflora*

ii) The damage caused by borers may lead to death of trees.

iii) *T. griseus* prefer young *P. juliflora.*

iv) Despite, the fact that these beetles may have a long life-cycle, they are able to spread very fast as their eggs are laid singly.

6.2 Recommendation

For further understanding of *T. griseus* and how it can be utilized in biological control of *P. juliflora*, the following consideration should be taken into account:

a) Given that very little is known and documented about *T. griseus*, further work on its biology and distribution is needed.

b) Since *T. griseus* has been found to be a native natural enemy of *P. juliflora* which is readily available in the environment, its application as a biological control agent can only be by its conservation. Therefore, a detailed study is required on factors that play a key role in its population dynamic to provide more information on its conservation status.

c) Study host-seeking behavior of *T. griseus* and host species preference.

d) Lab and field based trials of the effectiveness of *T. griseus* as a biological control agent.

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APPENDICES

Appendix 1. Table used in sample size determination

	Sample size					
	Continuous data (margin of error= *.03)*			Categorical data (margin of error= *.05)*		
Pop. Size	**a1pha=.10**	**a1pha=.05**	**a1pha=.Ol**		**Q=.50**	**Q=.50**
	t=1.65	**t=196**	**t=2.58**	**Q=.50** t=165	**t=1.96**	**t=2.58**
100	46	55	68	74	80	87
200	59	75	102	116	132	154
300	65	85	123	143	169	207
400	69	92	137	162	196	250
500	72	96	147	176	218	286
600	73	100	155	187	235	316
700	75	102	161	196	249	341
800	76	104	166	203	260	363
900	76	105	170	209	270	382
1,000	77	106	173	213	278	399
1,500	79	110	183	230	306	461
2,000	83	112	189	239	323	499
4,000	83	119	198	254	351	570
6,000	83	119	209	259	362	598
8,000	83	119	209	262	367	613
10,000	83	119	209	264	370	623

NOTE: Table developed by Bartlett, Kotrlik, & Higgins (2001).

Appendix 2. Legs pair length in millimeters of *Taurotagus griseus* adults collected from Bura

Insect	Fore leg	Mid leg	Hind leg
1	27	28	30
2	23	24	28
3	25	27	32
4	22	23	27
5	25	29	33
6	25	28	32
7	20	24	27
8	22	24	29
9	18	20	23
10	18	19	23
11	22	24	26
12	24	26	30
13	24	26	30
14	21	23	26
15	25	28	33
16	25	26	31
17	26	28	33
18	20	25	30
19	21	23	25
20	22	25	29
21	20	22	25
mean	22.62a	24.86b	28.67c
SE	0.56	0.59	0.69

Appendix 3. Data obtained from *P. juliflora* trees

Presence/absence of brown powder	% dryness	relative age of *P.juliflora* plant	Presence/ absence of beetle borer	moth larvae	% damage
2	0	2	1	0	1.3
3	90	2	0	0	34.3
3	50	3	0	0	7.8
2	10	1	1	0	0.5
2	0	1	1	0	3.5
3	100	1	0	0	36.1
2	40	2	1	0	9.2
2	20	4	1	0	5.4
3	100	2	0	0	36.1
2	20	4	1	0	1.9
2	30	4	1	0	2.9
3	80	2	0	0	24
3	100	2	0	0	42.5
2	30	4	1	0	4.8
3	70	2	0	0	22.6
2	60	3	1	0	18.6
3	0	1	0	0	0
3	0	2	0	0	0
3	0	2	0	0	0
2	40	1	1	0	9
2	0	2	0	0	1.1
2	0	1	1	0	1.1
2	0	2	1	0	4.5
2	40	1	1	0	8.8
3	0	2	0	0	0
3	0	1	0	0	0
3	0	1	0	0	1
3	0	2	0	0	0
3	90	2	0	0	32.3
3	70	2	0	0	24.4
2	10	2	1	0	0.9
3	80	3	0	0	20.8
2	40	2	1	0	13.1
3	0	3	0	0	0
2	60	1	1	0	11.6
2	50	2	1	0	18.8
3	100	4	0	0	34
3	0	3	0	0	0
3	90	1	0	0	32.9
2	40	2	1	0	9.2
2	0	2	1	0	0.8
2	10	4	0	0	1.8
3	100	1	0	0	43.5

2	0	3	1	0	1.1
2	30	1	1	0	4.4
3	0	1	0	0	0
3	0	2	0	0	0
2	50	2	1	0	5.9
3	70	1	0	0	36.1
2	0	2	1	0	7
3	90	3	0	0	15.1
2	10	1	1	1	6.8
3	90	3	0	0	18.6
2	0	1	1	0	11.6
3	100	3	0	0	15.7
3	90	2	0	0	16.3
3	90	2	0	0	1.2
3	13	3	0	0	16.5
3	80	3	0	0	17.5
3	60	2	0	0	41.5
3	90	2	0	0	11.5
3	100	3	0	0	0
3	0	1	0	0	0
2	0	2	1	0	12
2	50	2	1	0	9.2
2	60	1	1	0	27.8
2	50	2	0	1	15.07
3	80	1	0	0	29.5
2	0	2	0	0	4.7
2	90	3	1	0	31.5
2	0	2	1	0	1.5
2	20	2	1	0	3.6
3	100	2	0	0	33.2
3	90	2	0	0	31.4
2	10	1	1	0	0.5
2	20	4	1	0	5.4
3	100	2	0	0	36.1
3	80	3	0	0	20.6
3	0	2	0	0	0
2	10	2	1	0	0.8
2	20	3	1	0	2.3
3	90	2	0	0	29.96
3	0	4	0	0	0
2	0	2	1	0	1.5
3	100	2	0	0	8.6
3	0	2	0	0	0
2	50	1	1	1	20.7
2	0	1	1	0	3.6
3	50	2	0	0	10.6
3	0	2	0	0	0
2	60	3	1	0	21.5
2	10	1	1	0	0.59
3	100	2	0	0	49.1

2	0	1	1	0	0.96
3	30	2	1	0	0.48
2	10	2	1	0	0.19
2	60	2	1	0	34.8
2	40	1	1	0	4.4
3	100	2	0	0	39.3
3	0	1	0	0	0
3	0	2	0	0	0
3	0	2	0	0	0
2	0	3	1	0	2.3
3	100	2	0	0	32.7
2	50	3	1	0	14.01
3	0	2	0	0	1.4
2	70	3	1	0	21.6
2	10	1	1	0	2.4
2	20	1	1	0	6.3
2	0	1	1	0	2.3
3	0	2	0	0	0
3	100	2	0	0	19.8
3	0	3	0	0	0
3	100	1	0	0	39.9
3	100	1	0	0	33.6
2	0	2	1	0	8.6
3	80	1	0	0	27
2	60	1	1	0	22.2
3	70	3	0	0	19.8
2	10	2	1	0	1.96
3	100	1	0	0	36.1
2	40	2	1	0	8.6
2	20	1	1	0	3.6
2	30	4	1	0	5.4
3	80	2	0	0	21.76
3	0	2	0	0	0
3	90	4	0	0	31.4
2	50	2	1	0	10.6
3	70	3	0	0	21.5
2	60	1	1	0	20.7
2	10	1	1	0	0.59
3	0	2	0	0	0
3	0	2	1	0	0.92
3	0	2	0	0	0
2	50	2	1	0	12
2	10	2	1	0	0.76
3	100	2	0	0	27.6
3	0	1	0	0	0
2	100	1	1	0	37.1
2	60	2	1	0	15.4
3	100	3	0	0	7.8
3	0	2	0	0	0
3	100	2	0	0	38.6

2	0	1	1	0	6.2
3	0	2	0	0	0
2	50	2	1	1	9.9
3	100	2	0	0	40.6
3	0	2	0	0	0
2	0	2	1	0	9.1
2	70	1	1	0	27
3	0	2	0	0	0
2	60	1	1	0	22.2
3	90	3	0	0	28.9
2	0	2	1	0	1.5
3	100	2	0	0	8.6
3	0	2	0	0	0
2	50	1	1	1	20.7
3	100	1	0	0	31.4
2	0	1	1	0	3.6
3	50	2	0	0	10.6
3	0	2	0	0	0
2	60	3	1	0	21.5
2	10	1	1	0	0.59
3	100	2	0	0	49.1
2	0	1	1	0	0.96
3	30	2	1	0	0.48
2	10	2	1	0	0.19
2	60	2	1	0	34.8
2	40	1	1	0	4.4
3	100	2	0	0	39.3
3	0	1	0	0	0
3	0	2	0	0	0
3	0	2	0	0	0
2	20	1	1	0	5.9
2	10	1	1	0	2.7
3	90	2	0	0	28.8
3	0	2	0	0	0
3	80	1	1	0	27.8
3	100	2	0	0	25.6
2	20	2	1	0	2.3
2	10	4	1	0	1.9
3	0	3	0	0	0
2	30	2	1	0	4.4
3	80	4	0	0	15.4
2	40	3	1	0	10.5
3	70	2	0	0	33.6
3	0	2	0	0	0
3	0	3	0	0	0
2	50	1	1	0	30
2	0	4	1	0	0.4
3	0	4	0	0	0
2	20	4	1	0	1.9
3	90	3	0	0	29.5

2	50	2	1	0	2.9
2	20	3	1	0	*
2	40	4	1	0	10.3
3	100	3	0	0	15.4
2	30	4	0	0	1.8
3	100	3	0	0	3
2	20	4	1	0	1.7
2	0	2	1	0	0.8
3	0	1	0	0	0
3	0	1	0	0	0
2	20	4	1	0	5.4
3	0	2	0	0	0
3	0	3	0	0	0
3	100	2	0	0	36.1
2	10	3	1	0	10.5
3	100	1	0	0	27
2	60	2	1	0	24
3	0	1	0	0	0
3	100	2	0	0	44
3	80	4	0	0	15.4
3	10	4	0	0	0.4
3	100	1	0	0	1.9
3	80	4	0	0	31.4
3	0	4	0	0	0
3	50	4	0	0	4.8
2	10	3	0	0	2
2	60	4	1	0	8.9
3	70	2	0	1	22.6
2	10	2	1	0	5.1
2	0	2	1	0	2.5
2	20	4	1	0	1.9
2	10	3	1	0	2.3
3	80	2	0	0	9.2
2	0	2	1	0	1.3
2	10	1	1	0	0.49
3	0	1	0	0	0
3	100	2	0	0	22.6
3	0	2	0	0	0
3	90	3	0	0	18.6
3	80	2	0	0	24
2	0	1	1	0	1.1
3	50	2	0	0	5.6
3	0	2	0	0	0
2	60	1	1	0	8.8
2	10	2	1	0	1.12
3	0	1	0	0	0
3	100	4	0	0	31.4
2	40	1	1	0	2.4
3	90	2	0	0	19.8
3	0	1	0	0	0

3	100	2	0	0	32.3
3	0	2	0	0	0
3	90	2	0	0	24.4
2	30	4	1	0	1.9
2	50	1	1	0	3.5
2	20	1	1	0	1.1
3	0	2	0	0	0
3	0	2	0	0	0
3	0	1	0	0	0
3	100	2	0	0	24.4
3	0	1	0	0	0
2	50	1	1	0	8.5
2	40	2	1	0	4.5
2	20	4	1	0	1.9
2	10	2	1	0	1.3
2	0	1	1	0	0.49
2	70	3	1	0	18.6
3	80	2	0	0	22.6
2	0	3	1	0	2.3
2	20	1	1	0	2.3
3	80	2	0	0	19.8
3	90	2	0	0	24
2	40	4	1	0	4.8
2	50	3	0	0	7.8
3	100	1	0	0	37.1
2	50	2	1	0	15.4
3	0	1	0	0	0
3	90	2	0	0	38.6
3	80	2	0	0	27.6
3	100	2	0	0	40.6
2	30	4	1	0	5.4
2	10	2	1	0	0.76
2	20	2	1	0	1.96
2	50	2	1	0	12
2	60	3	1	0	19.8
2	10	1	1	0	0.59
2	30	2	1	0	8.6
3	0	2	0	0	0
2	60	1	1	0	22.2
2	40	2	1	1	9.9
3	0	2	0	0	0
3	0	3	0	0	0
2	40	1	1	0	2.4
3	0	4	0	0	0
2	0	2	0	0	1.4
2	30	3	1	0	2.3
2	50	3	1	0	14.01
2	40	1	1	0	6.3
2	70	3	1	0	18.6
2	50	1	1	0	8.6

2	60	2	1	0	12
3	0	2	0	0	0
2	80	1	1	0	20.7
3	90	3	0	0	21.5
3	90	3	0	0	19.8
3	100	4	0	0	31.5
2	10	2	1	0	0.8
3	80	3	0	0	20.57
2	0	1	1	0	0.5
3	0	2	0	0	0
2	40	4	1	0	5.4
3	90	2	0	0	29.96
2	40	3	1	0	2.3
3	70	2	0	1	15.07
2	20	2	1	0	5.1
3	80	4	0	0	31.4
3	100	2	0	0	33.2
3	100	2	0	0	24
3	90	2	0	1	22.6
2	40	4	1	0	15.4
2	30	2	1	0	2.5
3	100	4	0	0	31.4
3	80	3	0	0	2
2	40	2	1	0	5.1
2	60	4	1	0	15.4
2	30	2	1	0	2.5
2	10	4	1	0	1.9
3	0	1	0	0	0
3	80	2	0	0	44
3	90	2	0	0	24
2	50	4	1	0	8.9
2	0	2	1	0	0.8
2	0	4	0	0	1.8
3	0	3	0	0	0
3	0	1	0	0	0
3	70	4	0	0	10.3
3	80	3	0	0	15.4
3	90	1	0	0	27
3	100	3	0	0	29.5
3	100	1	0	0	36.1
2	10	1	1	0	0.96
3	0	2	0	0	0
2	40	2	1	0	12
2	30	2	1	0	9.2
3	0	1	0	0	0
2	20	2	1	0	7
2	50	2	1	0	16.3
2	60	3	1	0	16.5
3	70	3	0	0	17
3	0	3	0	0	0

3	0	2	0	0	0
3	80	3	0	0	18.6
3	90	1	0	0	27.8
3	100	2	0	0	41
2	0	1	1	0	1.1
2	0	2	1	0	1.12
2	20	3	1	0	1.1
3	80	2	0	0	18.81
2	50	2	1	0	5.9
2	30	1	1	0	4.4
3	90	2	0	0	34.8
2	10	2	1	0	0.94
3	0	3	0	0	0
3	100	2	0	0	39.3
3	80	1	0	0	20.7
3	90	1	0	0	32.9
3	0	3	0	0	0
2	70	3	1	0	21.5
3	0	1	0	0	0
2	60	2	1	0	8.6
2	40	2	1	0	4.5
2	60	1	1	0	8.5