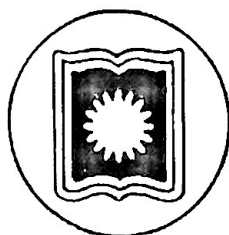


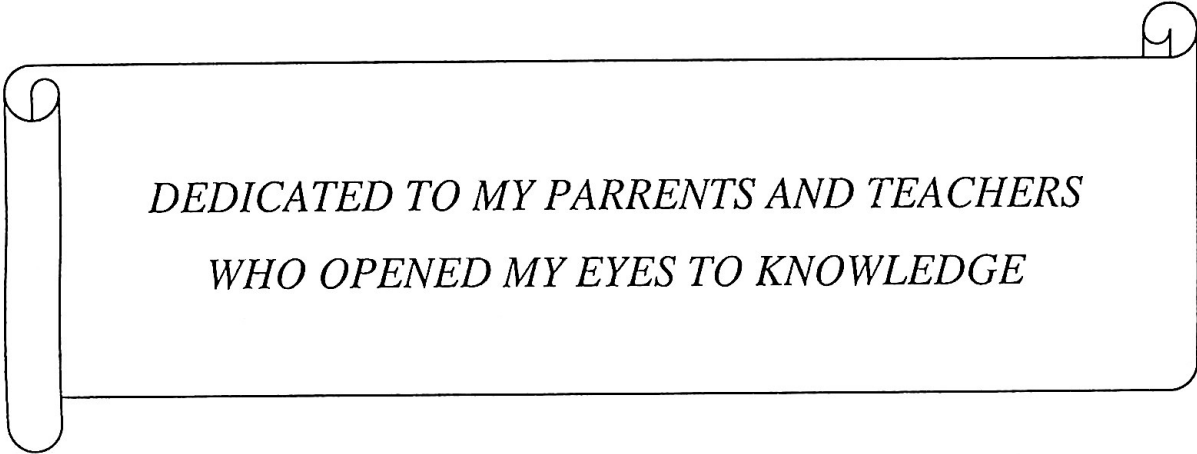
A STUDY ON THE PARASITISM OF *STRIGA* SPP. ON DIFFERENT HOST PLANTS IN BANGLADESH



**A Thesis Submitted for the Degree of Doctor of Philosophy
in Botany**

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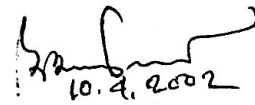
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2002



*DEDICATED TO MY PARRENTS AND TEACHERS
WHO OPENED MY EYES TO KNOWLEDGE*

DECLARATION

I hereby declare that the whole of the work now submitted as a thesis entitled "A study on the parasitism of *Striga* spp. on different host plants in Bangladesh" for the degree of Doctor of Philosophy in Botany at the University of Rajshahi is the result of my own investigation except where due acknowledgement has been given. The thesis has not been concurrently submitted in substance for any other degree.



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April, 2002

CERTIFICATE

This is to certify that Md. Abdur Rahaman Biswas, Assistant Professor, Department of Botany, Govt. Yasin College, Faridpur and Research scholar, Bangladesh University Grants Commission, worked under my supervision for the award of degree of Doctor of Philosophy on the problem entitled "A study on the parasitism of *Striga* spp. on different host plants in Bangladesh" since July 1998. This thesis embodies the original work done by him and has not been submitted before for any other degree. The references cited in it have duly been acknowledged. The style and contents of the thesis have been approved and recommended for submission.



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The Author

ABSTRACT

A brief survey of *Striga*, an angiospermic root parasite of sugarcane in the northern part of Bangladesh was carried out during three successive cropping seasons. Due to heavy *Striga* infestation in the field, most of the host plants (sugarcane) died and the whole field showed a burned appearance. Incidence of *Striga* infestation of sugarcane fields was highest in sandy loam soil in high lands. Growers generally abandon sugarcane cultivation in newly infested fields for a certain period due to its long period of seed viability.

Striga spp. started to appear above the ground from the end of April after early rain, during summer the parasite continued to grow up to October. Even in the early June population of *Striga* consists of plants with mature fruits, dispersing seeds, plants beginning to flower and plants still in juvenile stage of growth. During the months of June and July heavy occurrences were noticed. In the cane areas where *Striga* appeared comparatively earlier in the season were more affected.

The population density of *Striga* per sq. metre was more or less equal in number in all the visited areas due to more or less similar land topography, soil texture and environmental conditions. *Striga* spp. covered an area of 1300 sq. km and is more prevalent between the region of Varamara to Joypurhat. Comparatively higher degree of variation was observed for maximum quantitative characters of vegetative, floral and reproductive parts of *Striga* spp. Such variations reveal genetic differences. Three species of *Striga* are present in Bangladesh such as *S. densiflora*, *S. lutea* and *S. euphrasioides*. Among them *S. densiflora* is more common and destructive.

It is suspected that the place of first appearance of *Striga* was nearest to the oldest sugar mill of the country where the improved cane varieties were introduced as a seed cane from India and distributed among the growers. The

seeds of *Striga* spp. are very minute and tiny. *Striga* seeds were introduced here along with the seed cane from India, multiplied day by day and disseminated the adjoining region of the oldest sugar mill of the country.

It was observed that three species of *Striga* parasitized sugarcane, rice, cynodon and two unidentified grasses. *S. densiflora* attains one-third of its final height within juvenile stage and more than two-thirds of the final height within fruit setting stage. Final height was attained at seed release stage. The growth pattern, recorded as plant height (cm/day) was faster at juvenile stage, which increase slowly afterwards and coinciding with fruit setting stage. *Striga* spp. completed its life cycle quickly. The root exudates of suitable host plant stimulated *Striga* seeds to germinate when come in contact with it and a parasitic relationship becomes established. The ill-developed root system of this parasitic weed is less efficient to absorb water and mineral nutrient from the soil. Multicellular haustorium maintains connection between host and parasitic weed and possibly absorbs minerals and water from the host root. As a result, host plants are suffering from physiological disorder. *Striga* parasitized canes were stunted and attacked by different types of diseases. Finally the cane plants died when *Striga* released its seeds, resulting huge crop yield losses. The high significant value between control and *Striga* parasitized sugarcane in yield components of all the selected 5 improved cane varieties revealed that all the selected varieties were susceptible to *Striga* spp.

The best way to manage *Striga* problem is to eradicate it before fruit set and more than 9 weeding is needed. It is very costly, which makes this method discouraging to the growers. It is a localized problem in Bangladesh. Long distance dissemination is controlled by plant quarantine. Urea solution (2.5%) killed *Striga*, and high doze of urea fertilizer inhibited seed germination of *Striga*. It is fairly available, less costly and also less toxic. Cultivation of legume crops especially *Cicer arietinum* as crop rotation and burning of stubble are the easiest solution for *Striga* problem.

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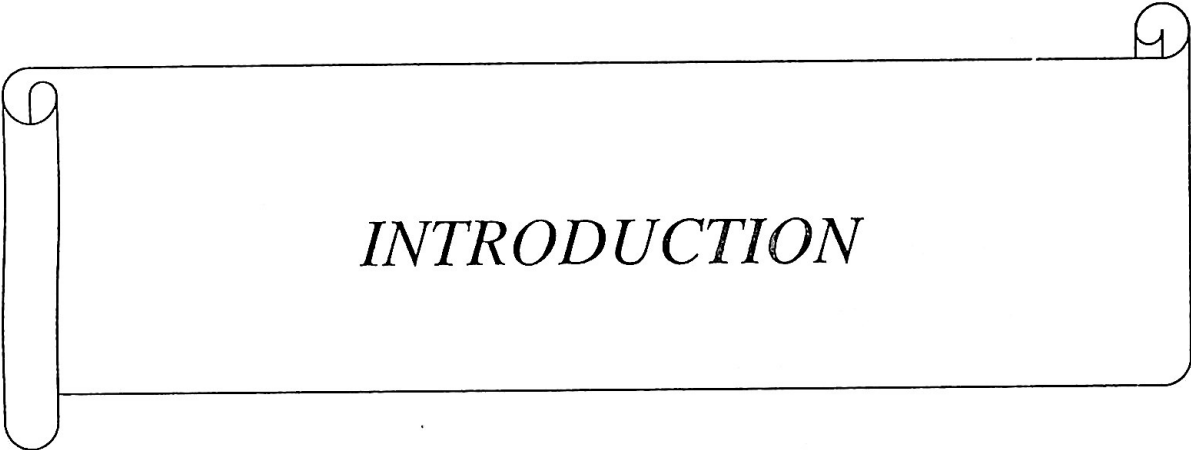
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CHAPTER I



INTRODUCTION

INTRODUCTION

With the advancement of civilization, the needs of modern men have increased manifold. Still the basic requirements of modern men to live on, are food, shelter, cloth and medicine. Of these, food stands first and to maintain the continuous supply of food to the every growing population of the mankind, various organizations, research institutes, and laboratories have been developed. Research in Biological Sciences plays an important role in this respect, specially breeding and pathology plays a vital role. Plant pathology depends on availability of genetic variability, adaptability, ecological amplitude and physiological capabilities of the organisms.

Bangladesh is situated within subtropical region in the North-Eastern part of South Asia between 23.34 and 26.38 North latitude and between 80.01 and 92.41 of East latitude. The general topography of the country is low, flat and fertile except some hilly regions in the North and North-East and in the South-East, including some old alluvial lands in the North and North-Western part. Sub-tropical moonsoon climate with flat and fertile alluvial lands is suitable for sugarcane and rice cultivation. The temperature in Bangladesh varies between 7-30°C and average rainfall from 127-508 cm. Relative humidity varies between 67.50-88.00% in winter and 55.40-88.70% in summer. All these climatic factors and the fertile alluvial soil constitute a favorable condition for the promising growth of sugarcane and rice in Bangladesh.

There are several crop plants in Bangladesh especially sugarcane and rice both of which are under the family Gramineae. Both have great economic importance. Because in Bangladesh rice is the main cereal and sugarcane is an important cash crop which is the raw materials of sugar and pulp industries in Bangladesh. Farmers usually grow rice and sugarcane alternately in the North-West region of Bangladesh. Rice is much more widely cultivated than sugarcane.

Sugarcane (*Saccharum officinarum* Linn.), a member of the family Gramineae is the second major industrial cash crop, next to jute in Bangladesh. It is the principal sugar crop in the country. Among many causes, sugarcane diseases play an important role to decrease the yield of sugarcane as well as sugar. The sugarcane is vulnerable to many diseases as the crop remains in the field for 12-15 months and passes through different environmental conditions. About hundred of diseases caused by fungi, bacteria, viruses, mycoplasma, nematodes and *Striga* have been reported from different parts of the world and these diseases play an important role to decrease the yield of sugarcane (Khurana and Singh, 1975). So far 38 sugarcane diseases have been recorded in Bangladesh, of which *Striga* is considered to be a major one (Ahmed and Mian, 1977). It is the earliest known sugarcane disease and is widely distributed in many sugarcane growing countries in the world. The disease was first reported from Queensland, Australia (Tryon and Henry, 1916; Bell and Cottrell-Dormer, 1932). In India (Luthra, 1921); In Kenya (McDonald, 1928) and the union of South Africa (Pearson, 1913). Disease incidence and losses of ten major diseases of sugarcane all over Bangladesh during 1996-97 presented in Table-1.

Rice is the main food crop in Bangladesh and widely cultivated than sugarcane. There are four types of rice grown in this country such as rain feed Aush, Aman, Boro and irrigated rice. Diseases play an important role to decrease the yield of rice crop. In certain areas of Bangladesh, it was also observed that *Striga* established parasitic relationship with rain feed rice, millet and some grasses.

Parasites causing plant diseases can be classed as either obligate or facultative according to their dependence upon the host plant. Obligate parasites only grow directly upon the host plant and cannot generally grow saprophytically on non-living organic matter. Their survival in the absence of the suitable host depends upon dormant resting stages in the life cycle, such as seeds or spores. However, facultative parasites are usually well adapted to a saprophytic existence and can survive long periods in an active stage in the absence of suitable host.

Table-1

Total loss of cane crop by ten major diseases in Bangladesh

Name of the diseases	Disease incidence		Crop loss (million tons)	Value loss (TK. millions)
	Range (%)	Average (%)		
Red rot	0-100	6.50	0.61	910
Wilt	4-45	6.00	0.57	570
White leaf	0-76	2.50	0.24	240
Ratoon stunting	0-20	2.50	0.23	230
Pine apple	0.5-15	2.00	0.19	190
Smut	0-35	0.10	0.01	10
Mosaic	0-15	1.50	0.140	140
<i>Striga</i>	0-90	0.04	0.004	4
Top rot	0-7	0.001	0.0001	0.10
Other disease	-	1.50	0.14	140

Crop clinic activities of sugarcane in Bangladesh. A report submitted by BSRI to the Ministry of Agriculture (MOA) on 4th June 1997, pp. 1-10

Root parasitism is found in the following diverse dicotyledon families of seed plants. Hyaraceae, Balanophoraceae, Krumariaceae, Lennoaceae, Santalaceae, Scrophulariaceae and Orobanceaceae (Kuijt, 1969 and Teryokhin, 1977) No parasitic monocot is known and there is only one parasitic Gymnosperm *Parasitaxus ustus* (Musselman, 1980).

Four genera of parasitic flowering plants are economically significant. The genera involved are *Striga*, *Aeginetia*, *Thesium* and *Orobanchae*. Dodder (*Cuscuta* spp.) is occasionally epiphytotic in tobacco seedbeds (Lucas, 1965) but seldom is of significance elsewhere. The three genera of flowering plants established as parasite on sugarcane (Hughes, 1962) all occur only in the African, Indian or Western Pacific areas and apparently the great sugar producing regions of the USA are free from this type of pest. The genera involved are *Striga*, *Aeginetia* and *Thesium*. Several species of *Striga*, three spp. of *Aeginetia* and only one sp. of *Thesium* are concerned. All three genera are capable of parasitizing other plants and in fact, in many instances the parasitism of sugarcane is more important than other crops.

The degree of parasitism varies from one genus to another, as also does the effect on the host plant. The *Striga* are green plants and as such apparently contribute something towards their own support; however, they exert damaging effect out of all proportion to the relative size of the weed and the cane plants. The *Aeginetias* have no chlorophyll and are wholly dependent on the sugarcane. *Thesium australe* the only species of *Thesium* recorded as a cane parasite is a green plant. Occasionally *Orobanchae* parasitized sugarcane in Bangladesh (Hedayetullah and Saha, 1942).

Striga spp. is an angiospermic partial root parasite on different host plants. Angiospermic parasite differs from other parasites in respect to the pathogenicity, which is clearly visible with the naked eye. This parasite does not obtain all of their nutrients from their host roots, they possess chlorophyll bearing leaves. The growth and flowering of the parasite in different soil types are influenced by environmental factors.

Striga is a Latin term ("Striga" a Witch) most of the species are known by common name "Witchweed". This is a logical name because the parasite "bewitches" its host before it emerges above the ground and becomes visible. The name also refers to the loss of yield of infected crops.

Witchweed (*Striga* spp.) is well known semi-parasite of sugarcane, cereals, maize and millets in India. Three species of *Striga* viz., *S. densiflora*, *S. euphrasioides* and *S. lutea* have been reported in India on sugarcane, rice, sorghum and some grasses (Sharma *et al.*, 1955).

Striga spp. is a noxious weed and obligate parasite because it can not complete its life cycle in absence of suitable host. Obligate parasite may cause only fairly mild symptoms such as growth malformation or they may ultimately kill the host.

A number of *Striga* species are involved in the parasitism of sugarcane. In Queensland, Australia *S. curviflora* Benth., *S. hirsuta* Benth. and *S. perviflora* Benth. may be involved (Hughes, 1962). In India *S. densiflora* Benth. *S. euphrasioides* Benth. and *S. lutea* Lour. (Sharma *et al.*, 1955); in Mauritius *S. asiatica* L.) O. Kuntze; and in South Africa *S. asiatica*, *S. lutea* Lour. (Pearson, 1913).

The genus *Striga* is a dicotyledonous plant belonging to the family Scrophulariaceae including 49 species. All are more or less parasitic on the roots of other plants and are confined to the tropical areas of Africa, Asia and Australia (Hughes, 1962). Of the 49 species of *Striga* only eight are totally root parasites and are known as agricultural pests causing yield reduction to a considerable extent. *S. hermonthica*, *S. euphrasioides*, *S. aspara*, *S. gesnerioides*, *S. asiatica*, *S. saugainales*, *S. densiflora* and *S. forbessi* are important species. *S. asiatica* and *S. hermonthica* grow as a root parasite on maize and sorghum in Sudan, South Africa and Burma, *S. euphrasioides* on sugarcane in India, while *S. gesnerioides* on tobacco in Rhodesia (Wilson and Jonson, 1953); *S. asiatica* parasitized not only the maize plant but also a number of wild grasses i.e. *Digitaria saugainales* (L.) Scop. (Eplee, 1973); in the USA while the same species attack *Oryza sativa* (Uttaman, 1950).

Striga species were already recognized as a problematic parasitic-weed before 1910 in both- India (Barber, 1904) and South Africa (Burt-Davy, 1905). It is one of the worst pests in the West Africa Sahel (Feil *et al.*, 1997).

Beginning from the last week of April, germination and seedling establishment started and continued throughout the end of September. In the early May the small green parasites were easily seen at the base of the host plants (Sugarcane) or in the inter space. Even in the mid-May, population of *Striga* consists of plants with mature fruits disseminating seeds, plants beginning to flower, and plants which are still in the juvenile stage of growth (Ahmed and Mian, 1977; Zuberi and Biswas, 1986). Such a long period of gradual germination and active growth provides a long period of seed production and dissemination. This makes it very difficult to control the parasitic weed by physical means (hand pulling or chipping) and by chemical treatments (hormone spraying).

Striga seeds are produced in enormous number. This number varies in different species. Each capsule produces about 400-2500 seeds and each plant produces about hundred or more capsules.

The seeds of *Striga* spp. are very minute, about 0.2×0.3 mm and produced in great abundance. Seeds of *Striga* remain in the ground in viable condition for a period of several years. Root exudate of the specific host is essential for germination of seeds of *Striga* spp. After germination, the parasite grows below the soil surface for about 4-8 weeks and produces underground stem and root. The underground portion of the stem contains buds in the axils of leaves. The roots of *Striga* form haustoria and penetrates the host root, from which, the parasite draw water and nutrients, eventually wasting and destroying the host.

Morphological characters comprise those structural and reproductive components of a parasitic plant that are easily defined, measurable and classifiable. Most of the variations for such characters are usually quantitative.

All genetic variations that are found in natural populations can be broadly grouped into two types. Firstly, the variations, which do not contribute positively to fitness thus, are disadvantageous to the individuals. In almost all environments these, while constantly generated by mutation pressure, are kept under control by natural selection. The second type of variability is termed as polymorphism which in some cases, at least is known to be adaptively advantageous and is thus maintained in populations.

It is well established that quantitative characters controlled by polygenes and their action may be readily modified by environment. It is obvious that the expression of a particular gene system may change with changes in the environment involved.

As a wide range of variation and greater genetic diversity of host this parasite is found in the region, it is important to study and classify the variants into different taxa to facilitate identification of authentic types, which are important in agriculture.

Recently some workers in India contributed much to the knowledge of this problem. Ramaiah *et al.* (1983) worked on different aspects of the parasite and brought out a very useful handbook on the identification (Table-2) and possible control of *Striga*.

The yield and its quality are very complex trait and influenced by many agronomic characters as well as by environmental fluctuations and infections by various agents of diseases. Plant breeders emphasize mostly on selection for yield and quality for crop improvement and such efforts often had dramatically enhanced the yield performance of many crops. But this conventional breeding procedure is very expensive and time consuming. But protecting the crop plants from disease causing agents, high production cane have also been realized with little expense of money and time.

Table-2
 Variability in *Striga* and key to main *Striga* spp. with host range

Key	Species	Host range
Leaves scale like, rarely exceeding 5 mm in length. Corolla variable in colour: White/mauve/pink/purple, 3-5 mm across, densely branched. Leaves green, 20-60 mm long.	<i>S. gesnerioides</i> (Willd.) Valke (= <i>S. orobanchoides</i> Benth.).	Cow pea, tobacco, <i>Euphorbia</i> , <i>Indigofera hirsuta</i> , <i>Tephrosia pedicellate</i> .
Calyx-ribs 5, flowers densely arranged; corolla white, 3-10 mm across; anther bluish black, plants sparsely branched, drying bluish.	<i>S. densiflora</i> Benth.	Sorghum, maize, millet and wild grasses.
Calyx distinctly 5-ribbed; flowers bright pink; corollatube 11-17 mm in length, bending characteristically at an angle immediately over the tip of the calyx, bracteole 2-3 mm wide.	<i>S. hermonthica</i>	Sorghum, pearl millet, maize, upland rice, finger millet, sugar cane and several wild grasses.
Calyx-rib 5, corolla tube 8-10 mm long, calyx length 4-5 mm; bracteole 1-2 mm wide.	<i>S. aspera</i> (Willd.) Benth. (= <i>Euphrasia aspera</i> Willd.)	Upland rice and wild grasses, occasionally observed on maize, sorghum and sugarcane.
Calyx-ribs 10 or more, but never more than 5 extending to top of the calyx lobws, remainder stopping at the sinus; corolla 5-10 mm across; corolla tube 5mm long, seeds 0.2-0.3 mm long.	<i>S. asiatica</i> (L) Kuntze (<i>S. lutea</i> Lour. = <i>S. hirsuta</i> Benth. <i>S. coccinea</i> Benth)	Sorghum, pearl millet, maize, finger millet, upland rice; also sugarcane.
Leaves narrowly lanceolate, 3-8 mm wide without teeth; corolla white, 5-10 mm across; calyx 15-17 ribbed, seeds are larger 0.3 × 0.5 mm.	<i>S. euphrasioides</i> Benth. (= <i>S. angustifolia</i> Don. Saldhana)	Sorghum, maize, sugarcane, upland rice and grass weed.
Leaves broadly lanceolate 10-15 mm wide, coarsely toothed; corolla salmonpink (rarely yellow), 10-20 mm across; corolla tube 20-25 mm long, sparsely pubescent; seeds 0.4 mm long.	<i>S. forbesii</i> Benth.	Maize, sorghum, rice and <i>Seteria sphecelata</i> .

This key and Host range is taken from "STRIGA IDENTIFICATION AND CONTROL HANDBOOK"

Information Bulletin No. 15, Page (14-36).

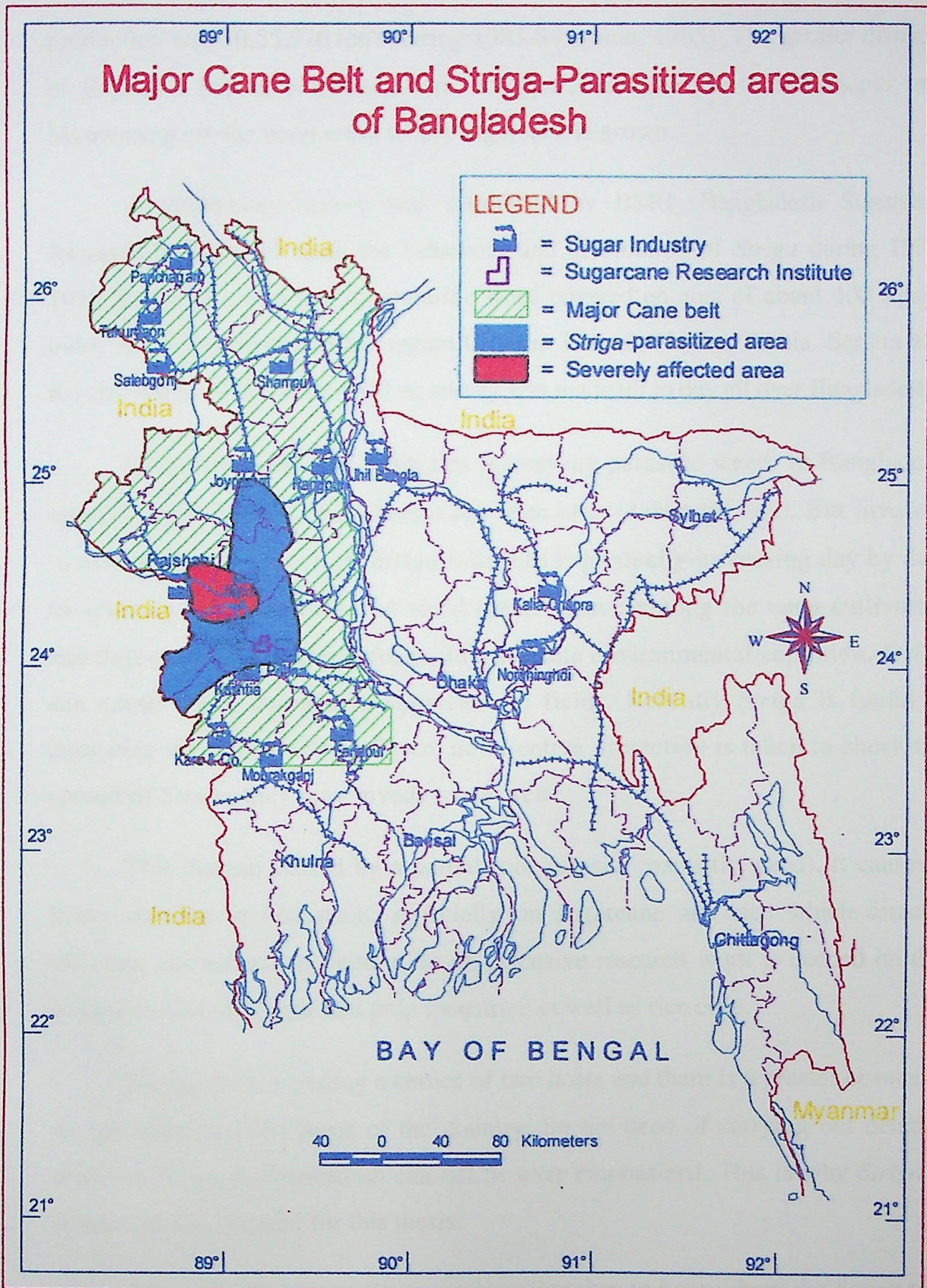
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS (ICRISAT) 1983

Exactly how *Striga* parasitizing with a host plant, reducing the yield and quality so drastically or even kill the host plants is not clearly known. The comparatively smaller size and the green leafy plant body of the parasite (*Striga*) must be only partially dependent on the host plant for its nourishment. But the way *Striga* kills its host indicates that the parasite in some way very drastically affects the host plants.

The effect of *Striga* on some economically important crop plants is well recognized all over the world. Different international Organizations and many Scientific Research Center and concerning departments of many universities are carrying out research on the problem to devise control measures (resistant variety, cultural methods, artificial germination of *Striga* seeds, herbicides, nitrogen manure, biological control etc.).

Despite its agronomic importance, very little information is available on this genus. Especially almost nothing is known about patterns of gene flow among the *Striga* species. An understanding of the relationship of its floral biology and breeding behaviour is important in relation to the actual and potential adaptability of the parasite to new hosts. Much work remains to be done along this line and this area of research deserves the attention of workers, particularly in the developing countries.

In Bangladesh *S. densiflora* Benth. locally known as "Bijlleghash" causing extensive damage to the sugarcane crops (Ahmed and Mian, 1977; Zuberi and Biswas, 1986), as well as rice crops (Zuberi *et al.*, 1987). *Striga* spp. has been recognized as a disease-causing agent of sugarcane in the North-Western region of Bangladesh. This covers an area of 450 square miles under the greater districts of Pabna, Rajshahi, Bogra and kushtia (Fig.-1) and causing a lot of troubles in sugarcane cultivation. It establishes contact directly with the vascular system of the host plant, suck water and nutrients and cause tremendous damages to the crop. It has become alarming for sugarcane cultivation since it is spreading fast over new areas.



Map Prepared from Survey Data

In Bangladesh about 4,11,740 acres of sugarcane were cultivated and the production was 70,55,976 ton's during 1983-84 (Anon, 1985). The greater districts of Rajshahi, Pabna, Kushtia, Bogra, Rangpur, Dinajpur, Jessore, Faridpur and Mymensing are the main areas where sugarcane is grown.

A Preliminary survey was conducted by BSRI (Bangladesh Sugarcane Research Institute) to study the behaviour and distribution of *Striga* during 1973-1978. It was observed that the parasitic weed covered an area of about 400 square miles and is distributed in the region between Ishurdi, Natore, Puthia, Sardha and Krisna (Anon. 1979). After 1979 no survey was made till to day all over Bangladesh.

Very little is known about this interesting parasitic weed. In Bangladesh no pathological study about *Striga* has been under taken till now. But invasion to new areas and area under *Striga* infection is gradually increasing day by day. In severely infested areas, the weed creates panic among the cane cultivators and thus reduces the cane acreage. In a suitable environmental condition, *Striga* can cause 100% damage to sugarcane in fields. Recently *Striga* is found to parasitize the upland rainfeed rice, no effective protection is taken to check the spread of *Striga*, they may invade more areas.

This disease caused by a partial root parasite (parasitic weed). It causes a heavy damage to host-plant, especially on sugarcane and rice which directly affecting our national economy. So an extensive research work is needed on this disease to save the sugar and pulp industries as well as rice crop.

The parasite is getting a choice of two hosts and there is a greater chance of its spreading to other areas of the country. So the need of carrying out detailed study on *Striga* in Bangladesh can not be over-emphasized. This is why *Striga* is selected as the material for this thesis.

Present study of investigation was undertaken to know about the *Striga* spp. and in this study the experiments were divided into five sectors.

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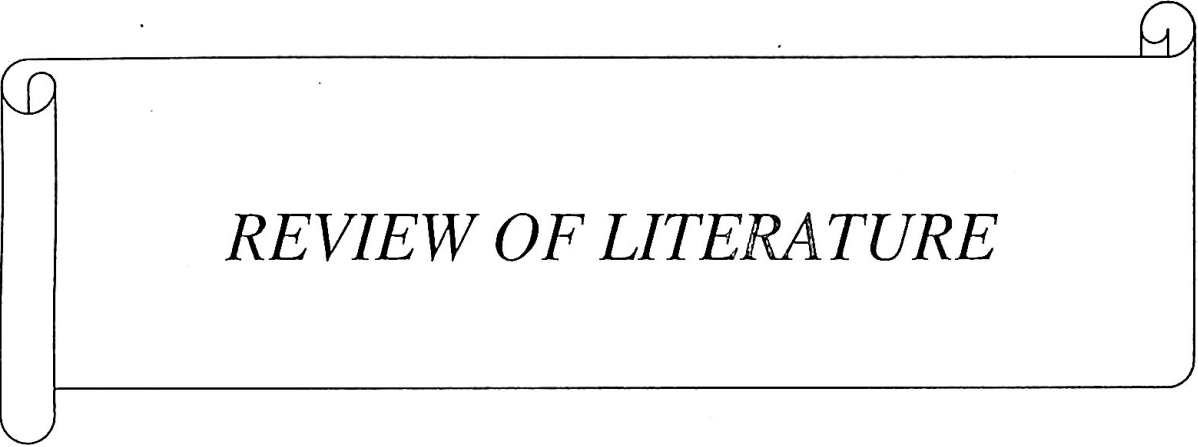
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Date 22/6/21

1. To assess the disease in different parameters.
2. Morpho-taxonomical and Pathological studies of *Striga* spp.
3. Host ranges and extent of damage.
4. Agronomic yield losses and biochemical changes of yield quality due to host-parasite interaction.
5. Life cycle of the parasite and its management.

The findings of the present work are presented in this thesis and are described with the support of current literature available in these lines.

CHAPTER II



REVIEW OF LITERATURE

REVIEW OF LITERATURE

Scientists develop their technology, which are beneficial to human being with the development of science and technology. The scientists of different regions of the world tried their best to isolate and characterize the pathogen and study its life-cycle and develop proper control measures.

Striga infestation is the major problem of sugarcane growers. This pest spreads very quickly in the new areas in the Northern part of Bangladesh, which directly affects the Food and Sugar Corporation of Bangladesh as well as our National Economy.

Striga Lour. is a root parasite of certain crops and known as a great yield reducer. Although it was known to the scientists before 19th century and very little work was done in the past. In recent years, this weed has drawn attention of workers in Africa, America, UK and India. In Bangladesh no pathological work was done on this noxious parasitic weed till now. As the parasitic weed is very ill studied and relatively less known in scientific literature, a brief review of literature is given below.

2.1 FIELD SURVEY

Striga has been reported as a cane parasite from Queens land, Australia (Tryon and Henry, 1916; Bell and Cottrell-Dormer, 1932), in India (Luthra, 1921), in Kenya (McDonald, 1928), in Madagascar (Hughes, 1962) and in the Union of South Africa (Pearson, 1913). A species of *Striga* was amongst the plants collected by Banks and Solander (Baily and Manson, 1901), in 1770 in what is now Queensland. They were in the 'Endeavour' with Captain Cook on his historic voyage which resulted in the discovery of the whole Eastern Sea-board of Australia, subsequently after European settlement of the continents, two other species were reported and the first collected *S. densiflora* Benth. was noted from several other localities. It was not until 1916 that *Striga* was mentioned as a

parasite of sugar cane in Queensland (Tryon and Henry, 1916). He recorded *S. perviflora* Benth. parasitizing cane in the Degilbo district in South Queensland where the parasite had been known for sometime. *Striga* has since been found in the Bundekin, Proserpine, Mackey and Bundaberg areas (Bell and Cottrell-Dormer, 1932) of Queensland but not been recorded in the adjoining more Southernly states of New South Wales.

The parasitic nature and subsequent damage to yield of affected crops have drawn the attention of the scientists, which stimulated research work on the problem in different countries of the world. Amongst the important works conducted on various parameters, the worth mentioning were Saunders (1942); Grobbelaar (1952), Timson (1931, 1934), in South Africa; Kumar (1952), Jenkins (1945), Uttaman (1950), Kumar and Abraham (1941), Kumar and Solomon (1940) and Solomon (1952), in India; Watt (1936), Andrews (1945), Doggett (1954a, 1954b, 1965), Willson-Jones (1953, 1956), Okonkwo (1964), Ogborn (1972) and many others in west Africa; Brown and Edward (1944, 1946), Brown *et al.* (1949, 1952), and Vallance (1950), in UK Eplee (1973) and Cook *et al.* (1972) in the USA.

In the Indian subcontinent *Striga* was first noticed as a parasite of cane crop in the Patiala state about 1914 (Luthra, 1921). Six years later, an investigation of a new disease in sugarcane fields of the 'bet' lands of the river Sutlej showed parasitizing with *S. densiflora* Benth. and *S. euphrasioides* Benth. Sharma *et al.* (1955) recorded *S. lutea* Lour. as being more common and more destructive than that of *S. euphrasioides* in the state of Bihar.

In Bangladesh *Striga* was reported to occur since 1940's (Ahmed and Mian, 1977) who reported this parasite to cover an area of about 400 square miles in the late 1960's. The areas included the whole of the Northern region of Bangladesh constituting the major cane growing areas of the country.

Anon. (1979) a preliminary survey was conducted to study the behaviour and distribution of *Striga* in the Northern part of Bangladesh. It was observed that the parasite has covered an area of 400 square miles and is distributed in the region of

Ishurdi, Natore, Puthia, Sardah and Krishna. The severely infested areas are Malunchi, Nandangachi and Arani areas in the district of Rajshahi and Natore. During May, June and July heavy occurrences of *Striga* were noticed. The cane areas where the parasites appeared comparatively earlier were more affected. Its incidence was observed on high and medium high land in sandy and sandy-loam soil.

Zuberi and Biswas (1986) reported that extent of damage caused by *S. densiflora* ranged from 81.70 to 73.00% of the sugarcane crops affected in badly infested areas of Ishurdi, Nandangachi and Sardah, whereas between 3.50 to 0.00% in Harian and Rajbari (newly infested areas) during 1985-86 cropping season. The growth of the affected canes was stunted and in badly infected areas, death of the host plants occurred due to *Striga* infection.

Sharma *et al.* (1955) reported *S. lutea* Lour. as being more common and more destructive than that of *S. euphrasioides* in the state of Bihar (India).

Rahman *et al.* (1988) reported that *Striga* covers an area of 450 square miles under the greater districts of Pabna, Rajshahi, Bogra and Kushtia and causing lot of troubles in sugarcane cultivation. It has become alarming for sugarcane cultivation since spreading fast over new areas. Assessment of losses in *Striga* infected canes compared to healthy one was made and found significant difference on millable canes, plant height, stalk weight and sucrose content between healthy and infected crops.

2.1.1 Parasitism of *Striga* spp. on different host plants in Bangladesh

Zuberi *et al.* (1987) observed *S. densiflora* parasitizing rice plants from Harian (Rajshahi) and Rajbari during 1986-87 cropping season. In adjacent regions of Ishurdi, a number of rice fields were heavily infected with this angiospermic root parasite, and an extensive damage occurred to the premonsoon broadcast (Aus) rice crop. Infected plants were severely stunted with smaller leaves; heavy infection kills the rice plants.

Parker and Reid (1979) have confirmed the existence in West Africa of distinct host specific strain that attack either sorghum or millets, each strain either sorghum or millet being almost lately unable to parasitize the other host.

Brown and Edward (1944) reported that a small percentage of germination has been obtained in laboratory experiments, but adequate germination occurs usually in the presence of host roots. While a number of the grass family were favoured host for *Striga*, the roots of other plants will also stimulate *Striga* seeds to germinate and a parasitic relationship become established. Cowpeas, dolichos bean and soybean may thus become parasitized. Andrews (1947) also observed that the *Striga* does not develop fully on them.

Kumar (1935) studied the germination of *S. asiatica*. Kumar (1940 and 1952) and Jenkins (1945) initiated the selection of resistant varieties. Then Rao (1948 and 1951) began the study of selection for resistant varieties of sorghum collecting from Burma and Africa. Uttaman (1950) was the first to study in detail *S. asiatica* in rain feed rice (*Oryza sativa* L.).

2.2 MORPHO-TAXONOMIC STUDIES OF *STRIGA* SPP.

Hooker (1885) described the morphology of *Striga* Lour. and he identified six species of *Striga*. Prain (1903) also described the morphology of *Striga* and he identified three species of *Striga*.

Saunders (1933) reported the formation of lateral outgrowths of the haustorium into the cortex of the host root and suggested that they function in absorption of organic food from the host. He further demonstrated that *Striga* seeds failed to germinate even under the influence of the host- root factors unless the seeds were first adequately treated for 10-12 days incubating them in the dark on filter paper kept wet in 10 ml water in sterilized petridishes at 25+2°C.

Following germination the radicle of the weed attack the host root and forms haustorium at the point of attachment. It has weakly branched root system. The underground stem is comparatively massive fleshy and whitish colour bearing 8–10 pair of small scaly leaves. The shoot becomes green and within a few weeks following germination it produces large number of flowers and fruits. Minute seeds (dust like) are formed and may remain in dormant condition for about 40 years (Hughes, 1962).

Matin *et al.* (1989) informed that *S. densiflora* bear's tap root system devoid of root hair. Roots become swollen at the point of attachment to the sugarcane roots. King (1974) found similar observation. *Striga* root can not absorb water and minerals from the soil possibly due to the absence of root hair. Haustorium of *Striga* penetrated into sugarcane root and formed a common bridge.

Saunders (1933) found that *Striga* is devoid of root hair, though their formation could be induced on the primary root of *S. asiatica*.

In an investigation on *S. senegalensis* (Okonkwo, 1970), root hair was produced frequently from the tip as well as other parts of the primary root. This supports that Saunder's germination of *Striga* seed is a root and not a hypocotyl as Pearson (1913) has reported.

Zuberi *et al.* (1989) described both the diffusates and the extracts of *S. densiflora* reduced the speed of germination and early growth of radicle and plumule of rapeseed. The extracts from green plants and underground stem were much more powerful than the diffusates in inhibiting the germination of rapeseed. Diffusates from the dry plants were also highly inhibitory to the growth of the young seedlings than the fresh plants.

2.3 HOST-PARASITE RELATIONSHIP OF *STRIGA* SPP. AND ITS PHYSIOLOGY AND ECOLOGY

Nelson (1958) working with *S. asiatica* and found that the weed was more common in light sandy loamy soils than in heavy clay. Though the parasite can synthesize carbohydrate only but all other nutrients drawn from host plant and as a result host plant suffer from diseases.

Lewin (1932) for the first time reported the existence of witchweed Physiologically adapted to certain hosts and suggested that there may be biological strains of *S. asiatica*. It has been shown by the radioactive tracer technique that both the subterranean and the green-leaved *Striga* seedlings obtain water and minerals from the host and make photosynthesis (Okonkwo, 1964).

Verma and Bajpai (1963) reported that most species of *Striga* require a host root within a few millimeters for germination. *S. euphrasioides* apparently do not need any host root exudate for germination.

Saunders (1933) reported the formation of lateral outgrowths of the haustorium into the cortex of the host root and suggested that *Striga* absorb organic food from the host through haustoria. Shaw *et al.* (1962) identified linkage between the *Striga* and host root. Ba (1983) also observed these types of linkage.

Stephens (1912) suggested that before the parasite developed green leaves, it depended for its supply of elaborated food material passed from phloem to xylem of the host root.

Stephens (1912), Uttaman (1950), Rogers (1959) and several workers have described the development of the young seedling of *S. asiatica*. *Striga* seeds failed to germinate unless located near the host root. On germination primary root attains a length of 2-4 millimeter within 4 days. The seedling dies if connection with a host root is not established at this stage.

The optimum temperature and length of preconditioning were studied in detail for *S. hermonthica* (Del.) Benth. by Vallance (1950). He showed that a temperature of 22°C to be more favorable than 27 or 32°C and optimum length of pretreatment time varied from 7–21 days. Reid and Parker (1979) confirmed that 23°C was a more favourable preconditioning temperature than 33°C was more effective. *S. densiflora* Benth. from India and *S. gesnerioides* (Willd) Vatke. from West Africa also showed slightly better response to higher preconditioning temperature, but results were less conclusive.

Shaw *et al.* (1962) and Rao (1987) reported that *Striga* root penetration appeared to be accomplished through chemical or enzymatic means rather than mechanical pressure, this tube like haustorium maintains connection between host and parasite and possibly absorbs minerals and water from host. Similar observation also described by Egley (1971) and Singh (1983).

Egley (1971) also informed that high humidity could inhibit growth in *S. asiatica* perhaps due to a reduced flow of materials from host to parasite.

Parker (1976) observed an influence of *Striga* on the root : shoot ratio of the host. The roots are being significantly stimulated in infected host, which are inhibited.

Kumar and Solomon (1940) informed that the germination of *S. asiatica* and *S. densiflora* was dependent on host-root exudate and tended to be depressed by light and that of *S. euphrasioides* did not require exudate but require light.

In England, there were prolonged attempts to isolate and identify the stimulant substances responsible for germination of seeds of *S. asiatica*. Much became known of the factors influencing germination but no positive identification of the stimulant was achieved (Brown and Edward 1944 and 1946 and Brown *et al.* (1949 and 1952).

Edward (1972) reported that a definite chemical factor might be involved and termed it a part of germination factor.

Hsiao *et al.* (1981) suggested that sodium hypochloride (Naocl) may not only disput seed coat permeability but may also remove or oxidize germination inhibitors. Naocl could enhance cowpea witchweed germination by any or all these mechanism.

Judith *et al.* (1988) reported that four synthetic multiring analogs of Strigol, a naturally occurring sesquiterpene lactone that promote germination of dormant seeds of *Striga* (witchweed) were found to stimulate germination of dormant *Lactuca* (lettuce) seeds.

Lakshmi and Jaychandra (1979) have recorded the specialization of *Striga* seed germination for *S. asiatica* relative to sorghum and millet strains, thus paralleling the situation in *S. hermonthica*. There were also differences in the histochemistry and weight of the seeds of the two strains. Thus specialization may result in the adaptive advantage of less intraspecific competition within the species.

Okonkwo (1966) informed that the seedling grew well and produced numerous adventitious roots in an angio-agar-sucrose medium. Upon maintaining the cultures for several weeks many roots callused and subsequently produced several shoot buds.

Okonkwo (1970) observed that the pretreated seeds germinate within 48 hours of sowing. On making contract with the host root, the root tip of the parasite becomes club-shaped, produces numerous root hairs and secretes viscid substances at the point of contact. During the early stage in the penetration of the parasite, root-surface cells in contact with the host root become densely cytoplasmic and growth into the host cortex takes place. At a late stage of penetration, the sub-apical root meristem is distinguishable.

Parker and Reid (1979) conducted reciprocal germination test using the different host and parasite strains. Their results clearly indicate that roots exudate play a role of these highly specialized systems.

Visser and Botha (1974) reported that the stimulant substances in crop root exudate could be readily separated by High Pressure Liquid Chromatography (HPLC) and that each crop demonstrated at least three "peaks" as shown by the *Striga* germination assay.

Vallance (1950) informed that a temperature of 22°C to be more favourable than 27 or 32°C for the germination of the seeds of *S. hermonthica* (Del.) Benth. He also studied the influence of moisture treatments, stimulant dilution and after ripening or germination of the seeds of *S. hermonthica* and reported that a prolonged wet period inhibits germination. However a prolonged drought at the beginning of the season may break wet dormancy of *Striga* seeds. Then host crops probably would suffer *Striga* damage.

Cook *et al.* (1972) reported that the natural stimulant substances present in root exudates at such low levels that their separation, publication and identification have proved difficult. Only two natural stimulant substances (strigol and strigol acetate) have so far been identified from cotton (*Gossypium hirsutum* L.) root exudates.

Wilson and Jonson (1955) is also the first to draw attention to the existence of physiological strains of *S. hermonthica* with different abilities to attack sorghum and millet.

Bharathalaksmi (1983) reported that *S. asatica* has a very wide ecological range and attacks a wide range of hosts cultivated under various conditions.

Parker *et al.* (1977) has found strains of host with both high stimulant production and resistance. Perhaps both the germination stimulant and the haustorial factor play a role in the host selection.

2.4 EFFECT OF *STRIGA* ON DIFFERENT AGRONOMIC YIELD CHARACTERS OF SUGARCANE

Eplee (1973) reported that *Striga* is the only genus in the family Scrophulariaceae which is a serious parasite of agricultural crops. *S. asiatica* (*S. lutea*) which causes considerable damage to zeo and other gramineous crops in the Carolinas of the Eastern United States and vast areas of South Africa. A vigorous control and quarantine program has limited damage to crop in the United States.

Visser (1987) working on *S. asiatica* and reported that infected plants (sugarcane) elongated at a slower rate than uninfected plants, but after 27 weeks they had attained the same length. DM yields were significantly lower in heavily infected cultivars variety of sugarcane.

Rahman *et al.* (1988) made assessment of losses in *Striga* infected canes compared to healthy one were made and found significant difference on millable canes, plant height, stalk weight and sucrose content between healthy and infested crops. The yield loss depends on *Striga* population and severity of infection. Due to heavy *Striga* infection in the field, most of the plants died, and the whole field showed a burned appearance.

Striga infection also caused highly significant differences in all other characters studied except pod length, and significantly reduced yields of all non-resistant varieties. Only the resistant variety SUVITA-2 did not suffer damage due to *Striga*, emphasizing the importance and value of resistant varieties. Under heavy infection much more severe damage would be expected. Although early-maturing varieties suffered less damage. (Aggarwal and Ouedraogo, 1989).

Aggarwal (1987) described with the exception of SUVITA-2 (*Striga*-resistant), yield of all varieties tested were significantly reduced by *Striga* infection. Kaya (the local farmer's variety) suffered the greatest reduction because of its long growing period and late flowering. The early and medium-maturing susceptible varieties were equally damaged by *S. gesnerioides*.

Lee and Goscco (1932) showed the effect of the parasite upon the host in both direct and indirect water and food stuff removal from host and stunting growth and yield reduction occur. In sugar cane the stem is stunted and this root parasitic weed reduces quality of juice.

2.4.1 Juice quality, quantity and sugar contents

The causal agent of red rot of sugarcane was reported to convert the cane sugar into glucose and alcohol which resulted in failure of the juice to crystallize on boiling (Dey, 1935). McKaing and Fort (1936) reported reduction in the quantity and quality of juice extracted from the sugarcane varieties POJ 36-M, POJ 213, POJ 234 and Co 281 due to the attack of red rot. Khanna and Chacravarty (1949) recorded loss in brix and purity by 52.30 and 45.10% respectively and 93.54% increase in invert sugar and 366.10% increase in gum content.

Edgerton (1959) reported that the sucrose content in red rot affected cane was always lower than the healthy cane. Sandhu *et al.* (1969) found decrease in sucrose content from 12.20 to 31.20% due to red rot. Singh and Waraitch (1977) reported significant increase in reducing sugars but corresponding decrease in sucrose content in the varieties Co 312, Co 710, CoJ 64, CoJ 67, CoL 9, CoL 29 and S 909-74. The mean increase in reducing sugar of 7 varieties was 203.03% and decrease in sucrose content was 29.89% in diseased cane compared to healthy cane. Further studies by Singh and Waraitch (1981) revealed that sucrose content (%) decreased gradually while reducing sugar increased due to red rot infection caused after 15.45 and 90 days of inoculation in the variety CoL 29. The mean increase of reducing sugar was 116.13% and decrease in sucrose content was 9.43% due to red rot infection.

Red rot affected canes give poor recovery because of impaired sucrose metabolism. Agnihotri *et al.* (1989) showed that infection by *C. falcatum* reduced the amount of total carbohydrate (sucrose) in diseased canes. Among the varieties tested, decrease in amount of total carbohydrates was greater in the red rot susceptible varieties like CoLk 8002, CoLk 7810 and Co 997 than in the resistant

ones like CoS 767, Co 1158 and CoLk 8001. The reduction in the amount of total carbohydrates was probably due to impaired biosynthesis of carbohydrates in the leaf tissue and consequently less accumulation in the parenchymatous tissue. *C. falcatum* produces abundant quantities of acid invertase (Singh, 1964; Agnihotri, 1990). This enzyme breaks the principal stored carbohydrate (sucrose) into glucose and fructose, which are rapidly consumed by the pathogen for growth and production of asexual and sexual bodies. Rao *et al.* (1984) recorded an increase in titrable acidity, moisture, reducing sugar, non reducing sugar and glucose ratio in the red rot infected cane varieties CoC 671 and B 3364.

Sandhu *et al.* (1969) recorded that red rot caused reduction in brix of juice from 2.70 to 21.70%. Kamal *et al.* (1981) studied the effect of red rot on yield and juice quality in varieties Co 312, Co 453, CoS 786, BO 17, BO 78 and Co 1158 by artificial inoculation and found that there was a decrease in cane yield, weight of juice, sucrose content, purity percent and sugar recovery in disease canes in comparison to healthy canes. Singh and Waraitch (1981) recorded decline in sucrose level, purity and increase in content of reducing sugar, gums, titrable acidity, flavinoids and soluble salts in juice of variety CoL 29 attacked by red rot.

Kirtikar and Verma (1962) also reported that the average of sugar in juice of red rot infected cane decreased from 11.40 to 7.69% in the variety CoS 430. Rao *et al.* (1984) recorded a decrease in pH, sucrose, brix, juice quality, commercial cane sugar and recovery of jaggery.

Beniwal *et al.* (1989) reported that after 2 months of inoculation, the red rot development resulted in reduction of brix (7.03-40.94%), pol (7.43-38.70%), purity co-efficient (0.45-8.26%), extraction (4.97-40.79%), commercial cane sugar (7.84-43.31%) and increase in reducing sugars (19.23-409.52%) in the juice of different sugarcane clone. He further reported that the adverse effect of red rot on juice quality parameters was least in resistant clones Co 7314 and very high in the highly susceptible clones CoL 29 and S 78/560. In the clones viz., S 77/467, Co 1158 and CoJ 64, it was moderate and correlated with their level of horizontal resistance.

2.4.2 Study of some biochemical parameters of *striga* parasitized sugarcane

Disease development affects not only the total chlorophyll contents but also alter the ratio between chlorophyll 'a' and 'b'. A measurement of green pigments may indirectly denote the severity of disease especially in systemic disease. Chlorophyll estimation may also be required to relate other biochemical changes in the plant tissue (Mahadeven and Sridhar, 1982). They also reported that disease development caused impairment in the photosynthetic pigments, which affects the utilization of light energy.

Neema (1991) found that Sorghum red stripe virus significantly reduced the chlorophyll contents at all stages of growth.

Kaur and Dhillon (1989) concluded that the infection caused by *C. personatum* decreased the total chlorophyll content of groundnut leaves.

Emerson (1929) found correlation between chlorophyll content of leaves and rate of photosynthesis.

Murata (1962) reported a definite relationship of photosynthesis activity with tillering capacity, plant height and thickness of leaves, vegetative period and dry matter production in some Japanese rice varieties.

Borah *et al.* (1978) studied the change in the chlorophyll content in tealeaves, after infection with *Cephaeleurose parasiticum* considerable reduction of chlorophyll 'a' and chlorophyll 'b' was measured as a result of destruction of chloroplast and the functional laminar surface is considerably reduced resulting in indirect effect on the productivity of the plant.

Siddaramaiah and Hegde (1990b) reported that infection by *Cercospora moricola* induces changes in the chemical constituents of mulberry leaf; the total chlorophyll, chl. 'a' and 'b' decreased with the increase in disease intensity, whereas carotenoids, total amino acids and total phenol increased.

2.5 LIFE CYCLE STUDY OF *STRIGA* SPP.

The phenological stages of growth and development of witchweed on susceptible cowpeas C.V. IT 60 AR were investigated in pot experiments by Aigbokhan and Hussain (1991) and informed that the growth process of *S. gemeroides* lasted from 5 to 6 weeks (3 weeks underground and 2–3 weeks after emergence). Haustoria bearing single, double, and multiples were observed, although a single plumule was most common. During the growth of the parasite, little or no growth was observed in the host and in some cases, the host was killed by such an attack.

Kumar and Abraham (1941) observed chromosome numbers of the four main species of *Striga* i.e. *S. asiatica* (L.) Kunstze, *S. densiflora* Benth., *S. euphrasioides* Benth. and *S. gesnerioides* (Willd) Vatke—all of which were $2n=40$.

2.6 MANAGEMENT OF *STRIGA* PROBLEM

Experimental work on control methods began about the same time, and a series of experiments in Burma between 1913 and 1920 was reported by Sawyer (1925), close row spacing, good cultural practices, fertilizer use, burning of stubble, crop rotation demonstrated benefits in sorghum against *S. asiatica*. Watt (1936) published similar recommendations for *S. hermonthica* control in Kenya.

Saunders (1933) classified the biology of the parasite (*S. asiatica*) and he also selected some resistant sorghum varieties. The concept of cash cropping with Sudan grass (*Sorghum sudanense*) grown twice in a season, 6–8 weeks each time, then ploughed in as a green manure was thought to reduce the problem by 75%.

Timson (1934) also found that the use of 1.5% sodium chlorate as a direct spray in maize gave selective kill of *S. asiatica*.

Andrews (1945) in Sudan made useful observation on the ability of different crops to act as trap crops. Andrew's work in Sudan was followed by Wilson and Jonson (1953, 1956) who for the first time demonstrated the value of 2,4-D and MCPA for selective kill of emerged *S. hermonthica* and as a treatment to prevent or at least to reduce germination and attachment of the parasite.

Barner *et al.* (1994) informed that the herbicide imazaquin was tested for efficacy in *S. gesnerioides* and *Alectra vogelii* control when applied as a cowpea (*Vigna unguiculata*) seed treatment. Microscopic examination of the host root-parasite interface *in vitro* and the presence of some successful attachment on plant roots from treated seeds indicate that post attachment parasite mortality is the mechanism of control. This is encouraging because imazaquin seed treatments would not only protect the host but also lead to the decline of parasite leaves in the soil. An additional treatment of cowpea seeds with a material very efficient in stimulating germination of the seeds of this parasite should augment this effect because more parasite seeds would germinate and subsequently be killed by the imazaquin treatment after attachment.

Carsky *et al.* (1994) has described a technique for the control of *S. hermonthica* in sorghum cv. Djigari, Damougari and S-35. Sorghum was grown alone and with cowpea in order to compare the 2 cropping system. The growth of *S. hermonthica* was not inhibited when the cowpea rows were 80 cm from the sorghum rows. Alternating strands of sorghum and cowpea within the same row gave the best yield of sorghum and greatest reduction of *S. hermonthica* with capsules decreased with increasing cowpea ground cover, so that while cowpea may not reduce the *S. hermonthica* emergence, it may hinder the development of the weed and possible reduce the *S. hermonthica* seed bank over time.

Dogget (1954a, 1954b and 1965) reported that the particular advantage of the variety Dobbs (sorghum) with its partial resistance and apparently greater tolerance of *Striga* attack.

Dejongh *et al.* (1993) observed cowpea, cotton and soyabean in order to quantitatively identify non-host germplasm that will stimulate *S. hermonthica* seed germination. Three screening techniques were used; the agar-gell assay, the disc (double-pot) and the ring technique. The agar-gell results that cotton was more effective as a germination stimulant of *S. hermonthica* than cowpea and that is

assay was the least time-consuming of the 3 techniques tested. It was suggested that the ring-technique gave the best results as it allowed the detection of more significant differences between and with several crop varieties.

Eplee (1983) informed that the use of ethylene gas or a synthesized stimulant along foliage-active herbicides showed promise in significantly reducing *Striga* seed population in the soil.

Egley and Dale (1969 and 1970) reported that ethylene would stimulate *S. asiatica* and from the standpoint of control of *Striga*. It is one of the most important compounds.

Egley and Dale (1970) demonstrated that ethylene would stimulate *S. asiatica* and this natural gas is now being used on a substantial scale in the USA at about 1.5 kg /ha, to trigger "suicidal" germination of *Striga* seeds and so deplete the number of dormant seeds in the soil.

Chancellor *et al.* (1971) informed that ethephon has also been shown to stimulate both *S. asiatica* and *S. hermonthica*.

Foy and Jain (1986) discussed recent approach to the control of *Orobanche* and *Striga* spp. Cultural and chemical control methods have generally been ineffective due to the close ecological and physiological relationship between host and parasite. The only effective (but expensive) means of *Orobanche* control has been soil sterilization by either chemical fumigation or solarization. Ethylene has proved very effective on *Orobanche* seeds in the absence of host plant exudates. An integrated approach using seed germination stimulants and translocated herbicides such as 2,4-D for *Striga* and glyphosphate for *Orobanche* may give effective control.

Igbinnosa and Okonkwo² (1992) reported that the importance of chemical treatment in the control of witchweed seeds in the field is a recent development. In the USA for example 95% reduction in viable witchweed seeds has been recorded

when ethylene was sprayed in the soil. It would be interesting to find out what practical value the chemical tested in this work would have in developing the soil reserves of cowpea witchweed seed.

Roger and Ramaiah (1983) worked on pearl millet cultivars for resistance to *S. hermonthica* and few local varieties and breeding progenies have been identified as less susceptible especially serere 2A-9, 80S-224, P-2671 and P-2950.

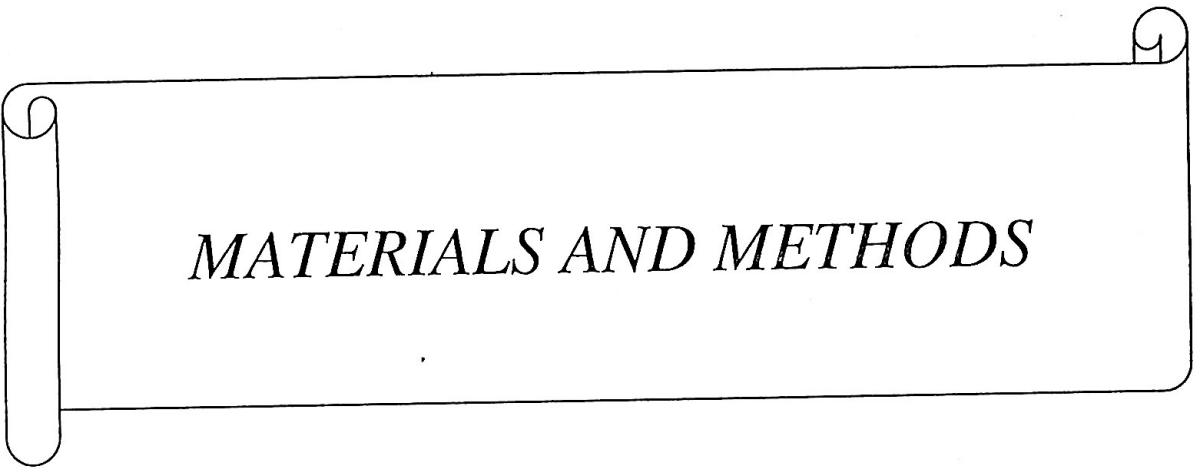
In Rhodesia Timson (1931) concentrated on the concept of catch cropping with Sudan grass (*Sorghum sudanense*) grown twice in a season 6-8 weeks each time that was thought to reduce the problem by 75%.

The worker in UK has been mainly at the weed Research Organization (WRO) Oxford, where the possibilities of selective control of *S. hermonthica* by herbicides have been explored but without real success (Parker, 1974).

Wilson and Jonson (1953 and 1956) first demonstrated the value of 2,4-D (2,4-Dichlorophenoxy acetic acid) and MCPA (Monochlorophenoxy acetic acid) not only for selective kill of emerged *S. hermonthica*, but also as a treatment a few weeks after sowing to prevent or at least reduce germination and attachment of the parasite.

Wilson and Jonson (1955) was also the first to draw attention to the existence of physiological strains of *S. hermonthica* with different abilities to attack sorghum and millets.

CHAPTER III



MATERIALS AND METHODS

MATERIALS AND METHODS

For the present study entitled "A study on the parasitism of *Striga* spp. on different host plants in Bangladesh" field survey on diseases was carried out in different locations of selected areas during sugarcane growing season from 1998 - 2001. Simultaneously field experiments were conducted in selected research site in Rajshahi district, Bangladesh during 1998-1999, 1999-2000 and 2000-2001 cropping seasons. Pot experiments were carried out in the Department of Botany, University of Rajshahi, Rajshahi, Bangladesh. Laboratory experiments were performed in the Department Botany, University of Rajshahi, Rajshahi Sugar mills laboratory, Rajshahi, Bangladesh; and Department of Soil, Water and Environment, University of Dhaka, Dhaka, Bangladesh. Five improved cane varieties (Isd-16, Isd-18, Isd-2/54, Isd-25 and Bs-96) were used in the present work as host crop.

3.1 FIELD INVESTIGATION

For the investigation of *Striga*-parasitized sugarcane and rice fields, five different locations were selected. The fields were managed by the local farmers and were used as the materials of this study. Twenty cane and ten rice fields including grassland were randomly selected from each location, which were thoroughly examined during 1998-99 cropping season. *Striga*-parasitized sugarcane and rice was marked by white sticks and noted in the notebook. It was noted that cowdung and chemical fertilizers (urea, super phosphate and murate of potash) were used according to the suggestions of RJSM i.e. 100 kg cowdung, 112 kg Urea, 112 kg TSP and 75 kg MP per acre. At the time of plantation 100 kg cowdung, 56 kg Urea, 112 kg TSP, 37.5 kg MP was applied. During the months of May-June, 56 kg urea and 37.5 kg MP were used. No weedicide, fungicide, insecticide or pesticides were used in the selected plots. Weeding was done early in the season only. A 50 meter measuring tape and four white coloured sticks were used as the materials for measurement of total area of the selected plots and white

sticks were used to mark one square meter for the count of the parasitic weeds at different stages of growth and number of host plants per square meter. Selected *Striga*-parasitized plots were observed after 10 days interval and data were recorded.

The methods of field investigation and collection of data are described under the following heads:

3.1.1 Measurement of area

Total area of the plots and *Striga* infested area were measured with the help of a 100 meter measuring tape.

3.1.2 Number of plot surveyed

Twenty cane plots and ten rice plots including grasslands were randomly visited in each location during 1998-99 cropping season. Number of infected plots was counted and noted.

3.1.3 Population of parasitic weeds and host plants within the plots

Number of parasitic weeds at different stages of growth (i.e. seedling, flowering and mature) and number of host plants per square meter were counted from five spots of each infested plot and noted in the notebook. Number of host plants per square meter was also counted from five spots of healthy plots and noted in the notebook. One square meter was marked with four white sticks, which was used as a single spot.

3.1.4 Measurement of disease

Disease incidence was recorded by adopting the grading formula of Siddaramaiah *et al.*, 1978 and mean values were obtained. The percentage of infected (parasitized) cane was calculated by the following formula.

$$\text{Percentage of infected cane} = \frac{\text{Number of infected cane}}{\text{Number of total cane}} \times 100.$$

3.1.5 Investigation of different hosts of *Striga* spp.

To find out the different hosts of *Striga*, a thorough investigation was carried out at different selected locations during 1998-99 cropping season.

3.2 MORPHO-TAXONOMIC STUDIES OF *STRIGA* SPP.

Samples of *Striga* spp. were brought to the laboratory for morpho-taxonomic study from *Striga*-parasitized sugarcane fields of Harian, Sardah, Nandangachi, Arani under the district of Rajshahi, Ishurdi under the district of Pabna and Varamara under the district of Kushtia. Samples of *Striga* spp. were randomly collected from different populations at wide ranging locations. Different qualitative and quantitative characters were studied. Some of the characters were used to classify the *Striga* plants. The selected characters were divided into three category i.e. vegetative, floral and reproductive characters.

The selected vegetative characters were plant height, number of branches and leaves, length and breadth of middle leaf, stem diameter at the base, length of glandular hair and straight hair, breadth at the base of both types of hairs and length and breadth of gland.

The selected floral characters were length of bract, calyx, corolla, long stamen, short stamen and pistil, corolla width and ovary diameter.

The selected reproductive characters were number of flowers, fruits, seeds, fruit length, fruit width, seed length and seed breadth. The details are given below:

3.2.1 Collection of data

Data on different qualitative and quantitative characters were collected on individual plants basis. Twenty mature plants were randomly selected from each sample. Data were collected at mature stage of growth for the following characters.

3.2.1A Plant height

The height of the selected plants was measured in cm from above the hypocotyl region to the apex of the shoot with the help on a meter scale.

3.2.1B Number of branches, leaves, flowers, bracts, bracteole, calyx tooth, calyx midribs, fruits and seeds

Total number of branches, leaves, flowers and effective fruits per plant of the selected twenty plants were counted and recorded. Number of bracts, calyx tooth and calyx ribs per flower were also counted and estimated seeds per fruit.

3.2.1C Stem diameter, leaf length and leaf breadth

Stem diameter at the base, length of the middle leaf and its diameter were measured in mm of the selected plants with the help of a meter scale.

3.2.1D Bract length, calyx length, corolla length, corolla width, pistil length, fruit length and fruit width

Length of bract, calyx, corolla, pistil and fruits was measured in mm of the selected plants with the help of a divider and a meter scale. The width of the corolla and fruits was also measured in mm.

3.2.1E Length of long and short stamen, glandular hairs length, glandular hair breadth at the base, gland length, gland breadth, straight hair length, straight hair breadth at the base, ovary diameter, seed length and seed breadth

Length of long and short stamen, length of straight and glandular hair and its breadth at the base, length and breadth of gland, ovary diameter and length and breadth of seeds were measured in μ with the help of an oculometer and calibrated it with calibration factor.

3.2.1F Observation and Recors

Root, underground scaly leaves, flower colour, bract size and its midrib, dry colour of whole plant and seed colour was observed closely and recorded.

3.2.2 Technique of analysis of data

The collected data were analyzed following bio-metrical techniques developed by Mather (1949) based on the mathematical models of Fisher *et al.* (1932) and Hayman (1958); De-Way and Lu (1959) and Allard (1960). Data were transferred to angular transformation where necessary. The techniques used are described under the following heads.

3.2.2A Mean

Mean of different characters was worked out by taking arithmetic mean of the randomly selected plants for each character. The arithmetic mean was calculated as follows:

$$\bar{X} = \frac{\sum_{i=1}^n x_i}{n}$$

Where,

$\bar{X}$ = Arithmetic mean.

Σ = Summation.

X = Individual measurement.

N = Number of measurement.

3.2.2B Variance analysis

Analysis of variance was worked out for sorting out the variance due to different populations and for testing the significance among the populations. Variance analysis for each character was carried out separately on mean value of 26 characters in each of the repeated experiment. Mean Square in the analysis of variance was calculated as follows:

$$S^2 = \frac{\sum x_i^2 - \left(\sum_{i=1}^n x_i \right)^2 / n}{n-1}$$

Where,

S^2 = Variance.

3.2.2C Variance ratio (F) test

F-test was carried out for test of significance among the variance within population. F values were calculated from the following table. Species fixed and cropping season random (mixed model).

ITEMS	DF	MS	F	EMS
Cropping season (Y)	S-1	MS ₁	MS ₁ / MS ₄	$\delta^2 + s.r\delta^2 Y$
Species (S)	Y-1	MS ₂	MS ₂ / MS ₄	$\delta^2 + r\delta^2 I + yr\delta^2 S$
S×Y	(S-1)(Y-1)	MS ₃	MS ₃ / MS ₄	$\delta^2 + R\delta^2 I$
Replicates (R)	S.Y(R-1)	MS ₄	MS ₄ / MS ₄	δ^2

Where,

S, Y, R designated for species, cropping season and within replicates respectively.

DF= Degree of freedom.

MS₁= Mean square of specieses.

MS₂= Mean square of cropping seasons.

MS₃= Mean square of interaction S×Y.

MS₄= Mean square within replicates.

Y.R δ^2 S= Variance due to specieses.

S.R δ^2 Y= Variance due to cropping seasons.

R δ^2 S×Y= Variance due to interaction S×Y.

δ^2 = Variance due to replicates.

MS = Mean square.

F = Variance ratio.

EMS = Expectation of mean square.

3.2.2D Standard deviation

Standard deviation is the average deviation of the individual observations from the mean. It is calculated as the square root of the variance as follows:

$$Sd = \sqrt{S^2}.$$

Where,

Sd = Standard deviation.

3.2.2E Standard error

If instead of taking one sample is considered, it will be found that the standard deviation of the different samples also varies. This variation is measured by standard error of mean, which was calculated as follows:

$$Se = \frac{Sd}{\sqrt{n}}.$$

Where,

Se = Standard error.

3.2.2F 't' Test

The significance of difference between two samples was determined by 't' test.

$$t = \frac{|\bar{X}_1 - \bar{X}_2|}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}.$$

Where,

$\bar{X}_1$ = Mean of sample 1.

$\bar{X}_2$ = Mean of sample 2.

S_1^2 = Variance of sample 1.

S_2^2 = Variance of sample 2.

3.2.2G Least significant difference (LSD)

LSD is used to estimate the difference of any two means of different populations. This is done as follows:

$$\text{Least significant difference (LSD)} = t \sqrt{\frac{2 \times MS_4}{r}}$$

Where,

t = Tabulated value (0.05).

MS_4 = Error mean square.

r = Number of replicates.

3.2.3 Component of variation

Components of variation were species phenotype, species genotype, Cropping season and interaction. These were measured as follows:

- i) Species genotype ($\delta^2 S$) = $MS_2 - MS_3 / y.r$
- ii) Cropping seasons effect ($\delta^2 Y$) = $MS_1 - MS_4 / s.r$
- iii) Interaction effect ($\delta^2 I$) = $MS_3 - MS_1 / r$
- iv) Species phenotype ($\delta^2 p$) = $\delta^2 S + \delta^2 Y + \delta^2 I$

Where,

S = No. of species.

Y = No. of cropping season.

R = No. of replicates.

$\delta^2 P$ = Species phenotype.

$\delta^2 S$ = Species genotype.

$\delta^2 Y$ = Cropping seasons effect.

$\delta^2 I$ = $S \times Y$ Interaction effect.

MS_1 = Mean square of species.

MS_2 = Mean square of cropping season.

MS_3 = Mean square of $S \times Y$ interaction.

MS_4 = Mean square within replicates.

3.2.4 Co-efficient of variability

Deviation is also expressed by the co-efficient of variation. Co-efficient of variability at different levels were calculated following Johanson *et al.* (1955); Burton and Devane (1953).

- a) Phenotypic co-efficient of variability (PCV) = $\delta^2 P / \bar{X} \times 100$.
- b) Genotypic co-efficient of variability (SCV) = $\delta^2 S / \bar{X} \times 100$.
- c) Cropping seasons co-efficient of variability (YCV) = $\delta^2 Y / \bar{X} \times 100$.
- d) Interaction co-efficient of variability (ICV) = $\delta^2 I / \bar{X} \times 100$.

Where,

$\bar{X}$ = Grand mean for respective character.

3.2.5 Method of calibration

3.2.5A Micrometry

It is a process by which micro-organisms and microplant parts are measured. Here we used two types of scale. One is oculometer and other is stagemeter.

3.2.5B Oculometer

It is a round small glass piece, which can be fitted in the eyepiece. An uncalibrated scale is marked on it.

3.2.5C Stagemeter

It is a slide. A scale is marked on it whose length is known, i.e. 1mm and it is divided into 100 small divisions. So 1 small division = 0.01mm.

3.2.5D Calibration

Oculometer was placed in the eyepiece and stagemeter on the stage under objective. After placing the oculometer scale on the stagemeter it was found that 7 small division of the oculometer adjusted with 10 small division of the stagemeter. So 7 small division of oculometer = 10 small division of the stagemeter.

It is known that,

$$1 \text{ small division of stagemeter} = 10 \mu.$$

$$\therefore 10 \text{ small division of stagemeter} = 100 \mu.$$

$$7 \text{ small division of oculometer} = 100 \mu.$$

$$\therefore 1 \text{ small division of oculometer} = \frac{100}{7} \mu.$$

$$= 14.29 \mu$$

It is the calibration factor.

Length and breadth of micro plant parts = No. of unit in oculometer $\times$ calibration factor

3.3 HOST PARASITE RELATIONSHIP

Several young *Striga* with sugarcane roots were carefully brought to the laboratory. The collected *Striga* plants were put in a big water pot and the muddy materials were washed very carefully. Some roots with host parasitic connections were found. Several such connecting-zone from different materials were washed, labelled and preserved.

The collected material for histological work was fixed in Formalin–Acetic acid–Alcohol (FAA) solution. The materials were dehydrated in ethyl alcohol series, infiltrated in Chloroform–Alcohol solution and embedded in paraffin wax. At right angles, sections were cut of a thickness of 10–12 μ with a rotary microtome, affixed to glass slides, stained with Safranin–Orange G Tanic acid–Iron Allum and mounted in Canada Balsam (Berylin and Misksche, 1976).

3.3.1 Estimation of moisture contents in sugacane leaves

The fresh leaf samples of sugarcane were collected at the three growth stages of *S. densiflora* i.e. seedling, juvenile and mature were weighed and oven dried at 70°C. Dry samples were weighed again and again up to moisture free stage. The collected leaf sample included only the four green leaves taking up to top visible dewlap (TVD).

Moisture content of healthy and *Striga*-parasitized sugarcane leaves were determined by the following formula.

$$\text{Percentage of moisture content} = \frac{\text{Fresh weight of leaves} - \text{Dry weight of leaves}}{\text{Fresh weight of leaves}} \times 100.$$

3.3.2 Estimation of total solid substances in sugarcane leaves

Total solid substances of healthy and *Striga*-parasitized sugarcane leaves were determined by the following formula.

$$\text{Percentage of solid substances content} = \frac{\text{Dry weight of leaves}}{\text{Fresh weight of leaves}} \times 100$$

3.3.3 Estimation of chlorophyll contents in sugarcane leaves

Chlorophyll contents in control (healthy) and *Striga* infected sugarcane leaves were determined with spectrophotometer according to Mahadevan and Sridhar (1982) as described below.

Reagent

Eighty% aqueous acetone ($\text{CH}_3)_2\text{CO}$.

Procedure

Control (healthy) and *Striga* infected leaf samples of sugarcane plant (1, 2, 3 and 4 TVD) were collected, cut into small pieces and mixed well. Five hundred milligram of mixed samples was homogenized with excess of acetone, in a mortar with pestle. The homogenate was decanted and filtered the supernatant through a buchner funnel using Whatman filter paper No. 42. Sufficient quantity of 80% acetone was added and repeated the extraction. The whole content was transferred from the mortar to the buchner funnel and washed with acetone until colourless.

The filtrate was pulled into a 100 ml volumetric flask and made to volume with 80% acetone. The absorbence was measured by spectrophotometer (spectronic-120, Milton Roy, USA) at 645 and 663 nm for the determination of chlorophyll 'a' and 'b' and at 652 nm for the total chlorophyll. The chlorophyll content was calculated on a fresh weight basis using the following formula.

$$\text{Chlorophyll 'a' (mg/g)} = \frac{12.7.A_{633} - 2.69.A_{645}}{a \times 1000 \times W} \times V.$$

$$\text{Chlorophyll 'b' (mg/g)} = \frac{22.9.A_{645} - 4.68.A_{663}}{a \times 1000 \times W} \times V.$$

$$\text{Total chlorophyll (mg/g)} = \frac{20.2.A_{645} - 8.02.A_{663}}{a \times 1000 \times W} \times V.$$

Where,

a = Length of light path in the cell (1 cm)

V = Volume of the extracts in ml.

W = Fresh weight of the sample in gram and A₆₄₅, A₆₃₃ and A₆₅₂ are the absorbencies of the extracts at 645, 633 and 652 nm respectively.

3.3.4 Study of some soil parameters

The soil was analyzed by the methods described by Petersen (1999).

3.3.4A Collection and preparation of soil samples

Soil samples of the experimental plot were collected from 0-20 cm depth at the time of *Striga* plant started to die with the help of an agor. Samples were collected separately from 9 spots both control and *Striga* infested areas of a plot where same ratio of fertilizer was used and same soil environmental condition was present. The collected samples were homogenized and marked infected and control (from non-infected sugarcane areas).

3.3.4B Air-drying

The soil samples were placed in a thin layer on a clean piece of paper on a shelf in the soil preparation room and left until it is air-dried (about one week in the dry season, longer in the wet season). Visible roots and plant fragments were removed from the soil sample and discarded. During drying the windows were kept open during working hours and fans were on continuously.

3.3.4C Grinding

The entire soil sample was passed through the grinder and subsequently through 2 mm stainless steel sieve. Only gravel particles and stones not passing through the 2 mm sieve are discarded. Aggregates not passing through the sieve must be returned to the grinder and treated again. The grinding and sieving were continued until the entire soil sample except gravel particles and stones had been passed through the sieve. The grinder and sieve were cleaned properly before grinding the next soil sample.

3.3.4D Storing

The ground soil sample was transferred to a plastic container with screw cap. The container was properly labelled and kept in the soil store.

3.3.5 Methods of soil analysis

Soil samples collected from the field were analyzed in the laboratory to determine physical and chemical properties.

3.3.5A Particle size analysis and Texture classes

Particle size analysis of the soil was made by hydrometer method as described by Day (1965). Textural classes were determined by Marshall's Triangular Co-ordinator.

3.3.5B Measurement of soil pH:

Soil pH was measured electrochemically by using Corning (Model-7) glass electrode pH meter. The ratio of soil to water was 1:2:5.

3.3.5C Determination of total organic meter

Soil organic carbon was determined by Walkely and Black's wet oxidation method as outlined by Jackson (1973). Soil organic matter was calculated by multiplying the percentage value of organic carbon by the conversion factor, 1.724.

3.3.5D Determination of total nitrogen

Total N was determined by micro-Kjeldahl's method as described by Jackson (1973).

3.3.5E Climatic conditions

Climatological data were collected from Meteorological Department, Shampur, Rajshahi.

3.3.6 Digestion of soil samples for the determination of total elements (P, S, Ca, K, Mg, Fe, Mn and Zn)

Soil samples were digested with nitric-perchloric acid (2:1) as described by Piper (1966) for determination of total phosphorus (P), sulfur (S), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), and zinc (Zn).

3.3.6A Total phosphorus

Total phosphorus in the nitric-perchloric acid digest was determined by vanadomolybdate yellow colour method (Jackson, 1973). The absorbance of yellow colour was measured by Spectrophotometer.

3.3.6B Total sulfur

Total sulfur in the nitric-perchloric acid digest was measured turbidimetrically (Hunt, 1980). The absorbance of the turbid solution was measured by Spectrophotometer.

3.3.6C Total Ca, K, Mg, Fe, Mn and Zn

Total calcium, iron, manganese and zinc in the nitric-perchloric acid digest were determined by Atomic Absorption Spectrophotometer. Potassium content was determined by using a Flame Photometer.

3.3.6D Determination of available phosphorus

Available soil P was extracted with Bray-II method (Bray and Kurtz, 1945). The colour in the extract was developed by ascorbic acid blue color method as described by Murphy and Riley (1962).

3.3.6E Determination of available sulfur

Available soil S was extracted with 500 ppm phosphorus from $\text{Ca}(\text{H}_2\text{PO}_4)_2$ (Fox *et al.*, 1964). The amount of S was measured turbidimetrically (Hunt, 1980).

3.3.7 Study of some leaves nutrients parameters

The leaf samples of control and *Striga*-parasitized sugarcane were collected at the two growth stages of *S. densiflora* (At the time of *Striga* emergence above the ground, and at the time of first flower appearance) and oven dried at 70°C and were used for different nutrient analysis. The collected leaf samples included only the four green leaves up to top visible dewlap (TVD). The oven dried leaf samples were ground into less than 2 mm size particles. The ground samples were preserved in plastic bottles. Methods of different nutrient analysis described in earlier chapter No. 3.3.5C, 3.3.6A, 3.3.6B and 3.3.6C.

3.4 EFFECT OF *STRIGA* ON AGRONOMIC YIELD CHARACTERS OF SUGARCANE

The agronomic yield characters of sugarcane stalk were recorded at final harvest of the crop. For yield data, number of millable cane per square meter was counted. Three randomly selected sugarcane plant hills of the central row were cut at the ground level by a sickle and after removing the trash and green tops, made into bundle. White tags were used for labeling the samples. The samples were brought to the laboratory. In the laboratory a meter scale was used for the measurement of stalk height, inter node length and stalk diameter at the base and at the top. A Torsion balance was used to take the weight of the individual stalk. The details are given below.

3.4.1 Collection of data

Data for different quantitative yield characters were collected as individual stalk basis from each sample.

3.4.1A *Number of millable cane*

Number of millable cane per square meter was counted from five spots of control and *Striga*-parasitized plot.

3.4.1B *Stalk height*

The height of the randomly selected stalk was measured in cm from top to the base.

3.4.1C *Number of internodes*

Total numbers of inter node per stalk of the randomly selected stalks was counted.

3.4.1D Inter nodelength

The length of the basal, middle and terminal inter node of the randomly selected stalk was measured in cm.

3.4.1E Stalk diameter

The diameter of the basal end and of the terminal end of the randomly selected stalks was measured in mm.

3.4.1F Unit stalk weight

Unit stalk weight was measured in gm from the randomly selected stalk.

3.4.1G Germination percentage of ratoon cane groves

Twenty control and twenty *Striga*-parasitized pots were selected for the test of germination percentage of cane groves. Pots were watered as and when required to maintain adequate moisture level for germination of ratoon cane grove and their normal growth, weeds other than *Striga* were removed from all pots. Only *Striga* plants were allowed to growing with sugarcane. Necessary and other cultural operations were done as per recommendations.

3.4.2 Juice quantity, quality and sugar contents parameters

To study the effect of *Striga*-parasitization on juice quality and biochemical changes of the selected 5 cane varieties namely Isd-16, Isd-18, Isd-2/54, Isd-25 and Bs/96 were planted on 19-12-99 with 3 replications in single row of 7 m length following RCB (Randomized Cubic Block) design in previously *Striga* infected field. Cowdung and chemical fertilizer (NPK) were used according to the suggestions of RJSM described in earlier chapter (Chapter 3.1).

To study the effect of *Striga* infection on juice quantity and quality in terms of extraction percentage, brix, pol, purity percentage and commercial cane sugar (CCS) in extracted juice. Twenty *Striga*-parasitized as well as control (healthy) canes were taken from each variety after 8 months of sugarcane plantation and 4 month of *Striga* emergence above the ground.

3.4.2A Juice extraction percentage

Twenty canes were collected randomly from 3 replicated control and *Striga*-parasitized plots and juice was extracted by mini power crusher which was made by Renwic and Joggesor, Ltd. Bangladesh. The extraction percentage was calculated by the following formula (Anon. 1970).

$$\text{Juice extraction percentage} = \frac{\text{Weight of juice}}{\text{Weight of cane}} \times 100.$$

3.4.2B Brix percentage (total soluble solid percentage) in juice

Direct brix reading in percentage was recorded with the help of a brix hydrometer (Range 0-30⁰) by immersing it in the juice. Later on, the readings were calibrated against the temperature with the help of a standard table (Spencer and Meade, 1952).

3.4.2C Pol percentage (sucrose percentage) in juice

Pol percentage was determined by dry lead method. About 200 ml of juice of which the brix was noted, added with sufficient amount of lead acetate in a conical flask and mixed with it thoroughly for clarification of the juice. Then the mixture was filtered through a filter paper (Whatman No. 42). Then clean transparent filtrate was taken in a polarimeter tube (completely full) and the reading was recorded in a polarimeter. Pol percentage (sucrose %) in juice was obtained from Schmitz's standard table against pol reading and the corrected brix number (Spencer and Meade, 1952).

3.4.2.D Purity percentage of juice

The purity percentage of juice was calculated by the following formula (Anon., 1970).

$$\text{Purity percentage} = \frac{\text{Pol}}{\text{Brix}} \times 100.$$

3.4.2E Commercial cane sugar (CCS) percentage

Commercial cane sugar was calculated by the following formula (Anon., 1970).

$$\begin{aligned}\text{CCS} &= \text{Pol in cane} - \frac{1}{2} (\text{Brix in cane} - \text{Pol in cane}). \\ &= \frac{3P}{2} \left(1 - \frac{F+5}{100} \right) - \frac{B}{2} \left(1 - \frac{F+3}{100} \right).\end{aligned}$$

Where,

P = Poll percentage of first expressed juice.

B = Brix percentage of first expressed juice.

F = Fibre percentage in cane.

3.4.2F Fibre percentage in cane

Fibre percentage in cane was determined by the prepared cane method (Anon., 1970). A sample of prepared cane was removed from the replicated cane sample collected for juice quality, quantity and sugar contents parameters described in chapter 3.4.2. The cane samples were cut into pieces, mixed thoroughly and transferred to a waddle type Grinder (A. H. KORTHOFF B.V) for crushing as per following procedure.

Procedure

The pieces of cane samples were grinding for approximately 15 seconds and again rapidly but thoroughly mixed the prepared samples. Approximately 200 g of the grinding samples were transferred to a pre-dried fibre bag. Fastened the top of the bag and it was transferred to the airtight container. The empty bag with sample plus (+) container were weight separately by an electric balance (Mettler H80) and recorded.

Washing

The bag was immersed in cold running water and squeezed at the commencement of washing at 15 minutes interval for a period of one hour. The bag was removed, squeezed to remove surplus water transferred to boiling water. The procedure was repeated for further an hour.

Drying

The surplus water was removed by squeezing and transferred to an air-circulated oven (Compenstat BRIT. PAT. No 882942). The fibre content was dried to constant weight at 100 to 105°C when removed from the oven, the bags were placed in the airtight container. The weight of container plus bag plus fibre was recorded. The bags were re-dried in the oven for one hour at 100 to 105°C and re-weighed after cooling in airtight container.

Fibre content in cane was estimated by the following formula.

$$\text{Fibre Percentage in cane} = \frac{W_3 - W_4}{W_2 - W_1} \times 100.$$

Where,

W_1 = Weight of empty bag + container before sample taken.

W_2 = Weight of sample + bag + container before washing.

W_3 = Weight of fibre + bag + container after washing and drying.

W_4 = Weight of empty bag + container after drying.

3.4.3 Biochemical changes of *Striga* infected sugarcane

For the study of biochemical changes, samples were taken after 8 months of plantation and 4 months of *Striga* emergence above the ground for estimation of total sugar, reducing sugar, non-reducing sugar and sucrose percentage. Throughout the present investigations, the chemicals used were of 'ANALAR' grade and glass wires were cleaned by commercial HCl before use.

3.4.4 Estimation of total sugar

The quantitative estimation of total sugar in the total tissues of control (healthy) and *Striga* infected sugarcane stalk was determined by the anthrone method (Dubois *et al.*, 1951). Anthrone, 10-keto-9, 10-dihydroanthracene, a reduction product of anthroquinone reacts by condensing with carbohydrate furfural derivative to produce a green colour in dilute and a blue colour in concentrated solution.

Reagent

a) **Anthrone Reagent:** The reagent was prepared fresh by dissolving 2 g of anthrone in 1000 ml of concentrated H_2SO_4 .

b) **Standard Glucose Solution:** A standard solution of glucose (BDH chemicals Ltd. Poole, England) was prepared by dissolving 10 mg of glucose in 100 ml of distilled water.

To develop a standard curve of glucose, 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1 ml of standard glucose solution were taken in different test tubes containing 0.0, 10, 20, 40, 60, 80 and 100 μg of glucose respectively and made the volume up to 1 ml with distilled water. Four ml of anthrone reagent was added to each test tube, heated in boiling water bath for 10 minutes and cooled in cooled water. After one hour the absorbance was measured at 625 nm using the blank containing 1 ml of water and 4 ml of anthrone reagent.

3.4.4A Preparation of ethanol extracts

Five grams of total tissue from randomly sampled control (healthy) and *Striga* infected sugarcane stalk was cut into small pieces separately and immediately plunged in boiling ethyl alcohol (80%) in a beaker and allowed to boiling for 5-10 minutes. Five milliliter of ethanol was used for every gram of tissue. The extracts were done on top of a steam bath. The extracts were cooled in a pan of cold water. The tissues were crushed thoroughly and passed through two layers of cheesecloth and re-extracted total tissues for 2 minutes in hot 80% ethanol. Three to 4 ml of ethanol were used for every gram of tissue. Then the extracts was cooled and passed through double layer of cheesecloth. Both extracts were pooled and the volume evaporated to about one fourth of the volume over a steam bath and cooled. This reduced volume of the extract, then transferred to a 100 ml volumetric flask and made up to the mark with distilled water. One milliliter of the diluted solution was then taken into another 100 ml volumetric flask and made up to the mark with distilled water (working standard).

3.4.4B Procedure

One milliliter of the diluted extracts was mixed with 4 ml of anthrone reagent and the volume was made 5 ml in test tube and mixed thoroughly. The test tubes were heated in boiling water bath for 10 minutes and then cooled in cold water. After one hour the absorbance was measured by spectrophotometer (spectronic-120, Milton Roy, USA) at 625 nm of wave length by setting the spectronic at zero with blank prepared in the above manner with distilled water instead of tissue extracts.

The amount of total sugar in the sample was calculated from the standard curve prepared from the glucose. Finally, the percentage of total sugar present in the sugarcane stalk was determined using the formula given below:

$$\text{Percentage of total sugar (g/100g)} = \frac{\text{Weight of sugar obtained}}{\text{Weight of sample}} \times 100.$$

3.4.5 Estimation of reducing sugar

Amount of total reducing sugar in the control and *Striga* infected cane samples was estimated by the method described by Miller (1972).

Reagent

a) Dinitrosalicylic acid (DNS) reagent

DNS reagent was prepared by simultaneously dissolved 1 g of dinitrosalicylic acid, 200 mg of crystalline phenol and 50 mg of sodium sulfite placed in a beaker with 100 ml of 1% solution of NaOH by stirring. The reagent was stored in a stoppered bottle at 4°C. The reagent deteriorates during storage due to atmospheric oxidation of the sulfite present. Such prepared reagent was stored without sulfite and added just before use.

b) Rochelle salt solution (40%)

Forty grams of sodium potassium tartarate was dissolved in distilled water and the final volume was made 100 ml exactly.

Procedure

The preparation of ethanol extract has been described earlier (Chapter 3.4.4A).

Aliquot of 3 ml of the prepared diluted extracts was pipette into a test tube and was added 3 ml of Dinitrosalicylic acid (DNS) reagent with it. The mixture was heated for five minutes in a boiling water bath. After the colour was developed 1 ml of 40% Rochelle salt (sodium potassium tartarate) solution was added when the contents of the test tube were still warm. Then the tubes were cooled under running tap water. A blank was prepared with distilled water instead of extracts and reagent only.

The absorbence of the solution was measured at 575 nm in a spectrophotometer (spectronic-120, Milton Roy, USA). The amount of reducing sugar in the sample was calculated from the standard curve prepared from glucose. Finally, the percentage of reducing sugar (g/100 g) present in the sugarcane stalk was determined using the formula given below:

$$\text{The percentage of reducing sugar} = \frac{\text{Amount of reducing sugar obtained}}{\text{Weight of sample}} \times 100.$$

3.4.6 Estimation of non-reducing sugar

The quantitative estimation of total non-reducing sugar of control (healthy) and *Striga* infected cane sample was determined by the following way:

$$\text{Total non-reducing sugar \%} = \text{Total sugar \% in cane} - \text{Reducing sugar \% in cane.}$$

3.4.7 Estimation of sucrose

Sucrose contents was calculated from the following formula (Ranganna, 1986).

$$\text{Sucrose percentage} = \text{Total sugar percentage} - \text{Reducing sugar percentage} \times 0.95.$$

Where,

0.95 = constant factor.

3.5 LIFE CYCLE OF *STRIGA DENSIFLORA*

To study the life cycle of *S. densiflora* with sugarcane, previously *Striga* infested fields of sugarcane at selected research site and earthen pot experiments in the Department of Botany, University of Rajshahi, were selected and investigated. The experiments were replicated in three cropping seasons.

3.5.1 Land preparation

The selected land for the experiment was prepared by ploughing five times using local plough followed by proper ladder and leveling using local made ladder. Cowdung and chemical fertilizer (NPK) were used according to the suggestions of the Department of Cane Cultivation and Extension, Rajshahi Sugar Mills Ltd. Rajshahi, Bangladesh (100 kg cowdung, 112 kg urea, 112 kg TSP and 75 kg MP per acre at the time of plantation, 56 kg urea and 37 kg MP during the month of May-June). Three budded sugarcane setts of selected variety Isd-18, were planted. No weedicide, fungicide, insecticide or pesticide was used. Weeding was done early in the season only.

3.5.2 Pot preparation

Hundred pots were numbered with black colour and filled up with sandy loam soil, which was collected from *Striga* free area. Cowdung and chemical fertilizer (NPK) were used according to the suggestions of the Department of Cane Cultivation and Extension, RJSM, Bangladesh. Twenty five mg seeds of *S. densiflora* was mixed well in each pot. Two sugarcane setts with two buds of Isd-18 were planted in each pot. Irrigation was applied when required to maintain

adequate moisture level for germination of the seeds of *S. densiflora* as well as sugarcane setts and their normal growth. Weeds other than *S. densiflora* were removed from all pots.

3.5.3 Collection of data

Data of host plant (sugarcane) sowing and date of emergence of *S. densiflora* above the ground was recorded. Twenty *Striga* plants were selected and labelled with white paper tags. Date of first flower formation and maturation of fruits, release of seeds and death of those selected *Striga* plants were recorded. Stem height of those selected *Striga* plants was also measured every ten days interval and recorded. Data on growth pattern (seasonal plant height, leaf length and leaf breadth) of control and sugarcane were also recorded every ten days interval for the study of host parasite relation ship.

3.6 MANAGEMENT OF STRIGA PROBLEM

It should be note here that though a general practice of eradication is followed for controlling weeds, but this conventional practice of control was not found effective for *Striga*. As such it was felt to find out an alternate management system and a pot experiment was conducted with the following treatments.

T₁=Eradication.

T₂=Direct spray of urea solution and the solution of plant hormone.

T₃=Application of different chemical fertilizer (NPK) ratio.

T₄= False host crop cultivation.

The research work was carried out in the Department of Botany, University of Rajshahi, Rajshahi, Bangladesh, during 1998-1999, 1999-2000 and 2000-2001 cropping seasons. Experiment was conducted in earthen pots of 8×12 cm size. The seeds of *S. densiflora* was collected from *Striga* infested areas of Rajshahi district. The seed was sun dried and kept in a refrigerator till its use. Sandy loam soil was collected from *Striga* free areas. Each pot was

numbered with black colour and filled up with collected soil. Four pots were taken for each treatment. Chemical fertilizer (NPK) in different ratio, such as 0, 0 and 0 g; 5, 5 and 5 g; 7, 7 and 7 g; 8, 8 and 8 g; 9, 9 and 9 g; 10, 5 and 5 g; 20, 0 and 0 g and 40, 0 and 0 g at the time of plantation and the collected seeds of *S. densiflora* (25 mg/pot) were mixed with the soil of the four pots of each treatment. In such pots two sugarcane setts with two buds of Isd-18, was planted. Chemical fertilizer (5, 0 and 5 g) was applied during May–June.

Vigna mungo, *Gossypium hirsutum*, *Pisum sativum*, *Lathyrus sativus*, *Lens esculenta* and *Cicer arietinum* were cultivated as a false host crop during 1998-99 cropping season with the seeds of *S. densiflora*. During 1999-2000 and 2000-2001 cropping seasons sugarcane (Isd-18) was cultivated of those treated pots.

Pots were watered as and when required to maintain adequate moisture level for germination of the seeds of *S. densiflora* as well as sugarcane setts and their normal growth. Weeds other than *Striga* were removed from all pots and only *Striga* plants were allowed to grow with sugarcane. Necessary other cultural operations were done as per recommendations.

3.6.1 Preparation of stock solution of plant hormones

Plant hormones such as 2,4-D, IAA and NAA were used. Twenty five milligram of each hormone dissolved in 25 ml methanol. One milliliter stock solution was added in 999 ml normal tap water and it was made 10 ppm (Bhojwani and Razdan, 1983).

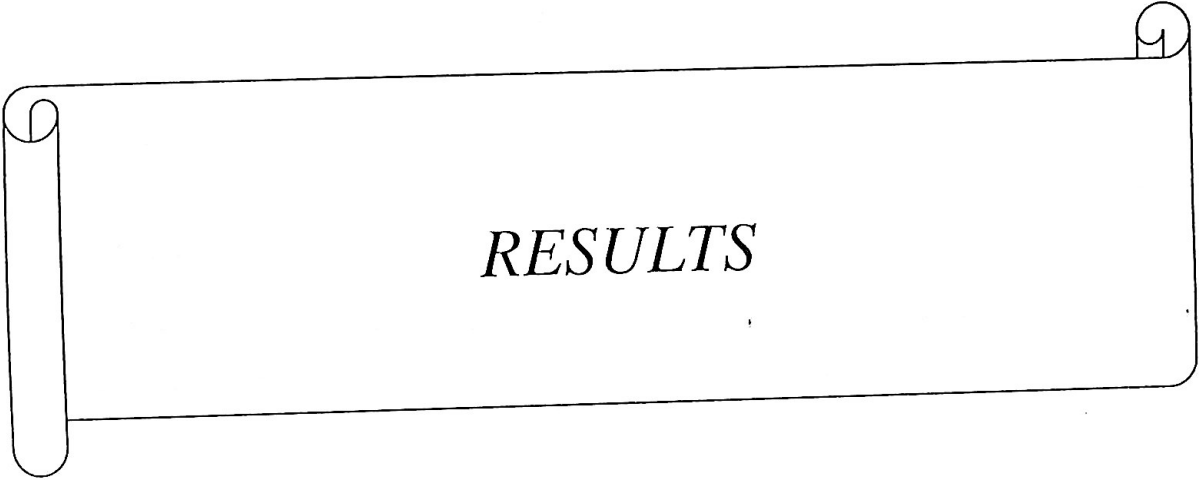
3.6.2 Procedure

For the control of *S. densiflora*, four concentrations of urea solution such as 1.00, 2.50, 5.00 and 7.50% were selected. The test concentration was sprayed on the *S. densiflora* in a sunny day in the existing normal environmental conditions. Ten concentrations of plant hormone (2,4-D) were also spread. The treatments were replicated thrice. The applications of the test doses were applied at 15 to 20

days interval with a control. After 60 days of last application of solution percentage of mortality of *Striga* and emergence of *Striga* seedlings above the ground were recorded. For the effect of chemical fertilizer, 8 dozes of NPK were applied at the time of sugarcane plantation for the suppression of seed germination of *S. densiflora*. During the month of April N:P 3:3 g/pot were applied except the control pots. Date of *Striga* seedlings emergence above the ground were recorded and number of seedlings of *Striga* were also counted.

Six robi-crops were cultivated for the suppression of seed germination of *S. densiflora*. Date of *Striga* seedling emergence above the ground were recorded and number of seedling of *Striga* were also counted.

CHAPTER IV



RESULTS

RESULTS

4.1 FIELD SURVEY

4.1.1 Symptoms

The affected sugarcane remained severely stunted and leaves became yellowish. Due to heavy *Striga* infestation in the field, most of the sugarcane died and the whole of the sugarcane plot showed a burnt appearance. Visible symptoms on the sugarcane plants were observed after 100 days of plantation at the flowering stage of *S. densiflora*. Infected sugarcane started to die at that time period and died after 130 days of plantation at the seed release stage of *S. densiflora* (Fig. 2, 3, 4, 5, 6 and 7).

4.1.2 Incidence of *Striga* infestation

Incidence of *Striga* infestation has been studied during 1998-99, 1999-2000 and 2000-2001 cropping seasons at the selected locations and the results tabulated in Table-3 to 11.

During 1998-99 cropping season, survey was done at Harian, Nalkala, Nawdara, Mukterpur, Askarpur and Dararchar of Rajshahi district under Rajshahi Sugar Mill area. During the present study, plots of Nawdara and Mukterpur, near Rajshahi University were selected at first and several visits were made. A total of 35 visits were made in the selected areas (Table-3). Survey was started on the 31st July of 1998 and continued up to January 1999. A total of 20 sugarcane plots including 10 rice plots and grasslands were randomly examined from each locality. It was observed that the highest percentage of *Striga* contaminated sugarcane field was found at Nawdara (50) and the lowest at Nalkala (20). Percentage of *Striga* infestation of sugarcane field was the highest at Askarpur (30) and the lowest at Dararchar (15) (Table-4). Mean contamination percentage was 34.00 and infestation percentage was 22.00. It was also observed that incidence of *Striga* was the highest at Dararchar (29.57) and the lowest at Nalkala (3.52). Mean with standard error of *Striga* incidence was 13.98 ± 4.67 (Table-5).

Table-3

Data on the survey of *Striga* spp. made in 1998-99 cropping season

Sl. No.	Date	Localities	Short description
1	31-7-98	Harian near RJSM	Sugarcane and rice plots including grasslands were visited. <i>Striga</i> was not observed
2	1-8-98	EXP. Farm RJSM	-do-
3	2-8-98	Mukterpur Sardah	Number of <i>Striga</i> at different stages of growth was observed, counted per square meter and number of host (sugarcane) per square meter counted and noted
4	2-8-98	Askarpur Sardah	-do-
5	4-8-98	Nalkala Harian	-do-
6	8-8-98	Dararchar Sardah	-do-
7	12-8-98	Mukterpur Sardah	Survey made in <i>Striga</i> contaminated areas and the <i>Striga</i> were collected for laboratory study
8	13-8-98	Askarpur Sardah	-do-
9	14-8-98	Nalkala Harian	-do-
10	15-8-98	Nawdara Sardah	No. of <i>Striga</i> at different stages of growth was observed, counted per sq. meter and number of host (sugarcane) per sq. meter were counted and noted
11	19-8-98	Dararchar Sardah	Survey made in <i>Striga</i> contaminated areas and the <i>Striga</i> were collected for laboratory study
12	23-8-98	Mukterpur Sardah	<i>Striga</i> infested cane plots were visited. <i>Striga</i> started to die
13	24-8-98	Nawdara Sardah	-do-
14	24-8-98	Askarpur Sardah	-do-
15	26-8-98	Nalkala Harian	-do-
16	30-8-98	Dararchar Sardah	-do-
17	6-9-98	Nawdara Sardah	-do-
18	10-9-98	Dararchar Sardah	Survey of <i>Striga</i> infested plot. <i>Striga</i> was observed associated with dead sugarcane and grasses

Table-3 Continued

Sl. No.	Date	Localities	Short description
19	12-9-98	Mukterpur Sardah	<i>Striga</i> infested cane plots were visited, <i>Striga</i> decaying
20	13-9-98	Askarpur Sardah	-do-
21	18-9-98	Nalkala Harian	-do-
22	18-9-98	Nawdara Sardah	-do-
23	22-9-98	Dararchar Sardah	It was observed that <i>Striga</i> associated with dead sugarcane and grasses were collected for laboratory study
24	29-9-98	Nawdara Sardah	<i>Striga</i> infested cane plots were visited. <i>Striga</i> decaying
25	3-10-98	Dararchar Sardah	<i>Striga</i> infested grassland were visited. Number of <i>Striga</i> at different stages of growth were counted per square meter and noted
26	9-10-98	Nawdara Sardah	<i>Striga</i> infested cane plots were visited. <i>Striga</i> decaying
27	15-10-98	Dararchar Sardah	<i>Striga</i> contaminated grassland was visited and <i>Striga</i> plants were collected for laboratory study
28	21-10-98	Nawdara Sardah	<i>Striga</i> infested cane plots were visited. <i>Striga</i> decaying
29	8-11-98	Dararchar Sardah	<i>Striga</i> contaminated grassland was visited
30	13-11-98	Nawdara Sardah	<i>Striga</i> infested cane plots were visited. <i>Striga</i> was not observed
31	2-12-98	Dararchar Sardah	<i>Striga</i> contaminated grasslands were visited
32	23-12-98	Dararchar Sardah	<i>Striga</i> contaminated grasslands were visited
33	8-1-99	Nawdara Sardah	<i>Striga</i> infested cane plots were visited. <i>Striga</i> was absent
34	15-1-99	Dararchar Sardah	<i>Striga</i> started to die
35	27-1-99	Dararchar Sardah	<i>Striga</i> decaying

Table-4

Incidence of *Striga* contamination and infestation of sugarcane fields at selected locations during 1998-99 cropping season

Localities	No. of plot surveyed	No. of plot contaminated	Percentage of contamination	No. of plot infested	Percentage of infestation
Mukterpur Sardah	20	8	40	4	20
Askarpur Sardah	20	7	35	6	30
Dararchar Sardah	20	5	25	3	15
Nawdara Sardah	20	10	50	5	25
Nalkala Harian	20	4	20	4	20
Mean	20	6.80	34.00	4.40	22.00
Standard error	-	1.07	5.33	0.27	2.28

Contamination refers to the field where sporadic appearance of *Striga* was observed, but no cane damaged

Infestation refers to the fields where damage to sugarcane by *Striga* was observed

Table-5

Comparison of the incidence of *Striga* infestation of sugarcane fields at selected locations during 1998-99 cropping season

Localities	Area in sq. meter of infested plots.	Area in sq. meter of infestation	Percentage of infestation	No. of cane in infested plot	Number of cane infested	Incidence
Mukterpur Sardah	13677.63	1065.13	7.80	197505	15380	7.80
Askarpur Sardah	10438.25	1010.25	9.68	174527	16891	9.68
Dararcchar Sardah	6702.05	1981.63	29.57	110718	32737	29.57
Nawdara Sardah	1076.58	208.29	19.35	17354	3358	19.35
Nalkala Harian	8297.00	291.90	3.52	133084	4682	3.52
Mean	8038.30	911.44	13.94	126637.60	14609.60	13.94
Standard error	2092.51	320.13	4.67	31212.89	5280.12	4.67



Figure-2 Photographic representation of healthy sugarcane plot



Figure-3 Photographic representation of *Striga* parasitized sugarcane plot at seedling stage of *S. densiflora* (*S*= *Striga* Seedling)



Figure-4 Photographic representation of *Striga* parasitized sugarcane plot at flowering stage of *S. densiflora* (S= *Striga*)



Figure-5 Photographic representation of damaged sugarcane field due to *Striga* parasitization



Figure-6 Photographic representation of healthy sugarcane in a pot



Figure-7 Photographic representation of infected sugarcane in a pot at flowering stage of *S. densiflora*

During 1999-2000 cropping season, survey was made at Muktarpur, Askarpur, Dararchar, Solowa, Nimpara, Daulatpur, Vatopara, Fakirpara, Nalkala, under Rajshahi district, Arambaria under Pabna district, Varamara and Jagati under Kushtia district, Faridpur, Mobarakaganj under Zenaidha district. A total of 24 visits were made in the selected areas (Table-6). Survey was started on the 1st of April and continued up to July. A total of 20 sugarcane plots including 10 rice plots and grasslands were randomly examined from each locality. It was observed that the highest *Striga* contamination percentage of sugarcane field was found at Muktarpur (65) and the lowest at Varamara (25). *Striga* infested percentage of sugarcane field was the highest at Fakirpara (35) and the lowest at Varamara (10). Mean contamination percentage was 47.50 and infestation percentage was 21.25 (Table-7). It was also observed that *Striga* incidence was the highest at Solowa (18.38) and the lowest at Nawdara (3.46). Mean with standard error of *Striga* incidence was (11.44 ± 1.78) (Table-8). No *Striga* infestation was present in Faridpur, Mobarakaganj and Jagati (personal communication with cane manager of respective sugar mill).

During 2000-2001 cropping season, survey was made at Muktarpur, Askarpur, Dararchar, Solowa, Nimpara, Daulatpur, Nawdara, Vatopara, Fakirpara, Nalkala, under Rajshahi district, Arambaria under Pabna district, Varamara under Kuishtia district, Barandra region and Joypurhat. A total of 14 visits were made in the selected areas (Table-9). Survey was started on the 1st of June and continued up to the 10th June. A total of 20 sugarcane plots including 10 rice plots and grasslands were randomly examined from each locality. It was observed that the highest *Striga* contamination percentage of sugarcane field was found at Solowa and Vatopara (60) and the the lowest at Varamara (20) (Table-10).

Striga infested percentage was the the highest at Fakirpara (30) and the the lowest at Nalkala and Varamara (10). Mean contamination percentage was 47.92 and infestation percentage was 19.58 (Table-10). It was also observed that *Striga* incidence was the the highest at Nalkala (15.65) and the the lowest at Nawdara

Table-6
Data on the survey of *Striga* spp. made in 1999-2000 cropping season

Sl. No.	Date	Localities	Short description
1	1-4-99	Mukterpur Sardah	Sugarcane and rice plots were visited. <i>Striga</i> was not observed
2	10-4-99	-do-	-do-
3	18-4-99	-do-	-do-
4	28-4-99	-do-	Seedling of <i>Striga</i> was found
5	10-5-99	-do-	Seedling and juvenile stage of <i>Striga</i> was observed
6	10-5-99	Askarpur Sardah	-do-
7	10-5-99	Dararchar Sardah	-do-
8	20-5-99	Mukterpur Sardah	Flowering stage of <i>Striga</i> was observed
9	20-5-99	Askarpur	-do-
10	20-5-99	Dararchar	-do-
11	30-5-99	Mukterpur Sardah	-do-
12	30-5-99	Askarpur	-do-
13	30-5-99	Dararchar Sardah	-do-
14	30-5-99	Slowa Sardah	-do-
15	10-6-99	Nimpura Sardah	-do-
16	11-6-99	Vatopara Nandangachi	-do-
17	12-6-99	Daulatpur Sardah	-do-
18	20-6-99	Nalkala Harian	Flowering stage of <i>Striga</i> was observed
19	30-6-99	Arambaira Ishurdi	-do-
20	30-6-99	Varamara Kuishitia	-do-
21	2-7-99	Fakirpara Nandangachi	-do-
22	5-7-99	Faridpur	No <i>Striga</i> infestation was found
23	6-7-99	Mobarakganj Zenaidha	-do-
24	7-7-99	Jagati Kushtia	<i>Striga</i> infestation is rare

Table-7

Incidence of *Striga* contamination of sugarcane fields at selected locations during 1999-2000 cropping season

Localities	No. of plot surveyed	No. of plot contaminated	Percentage of contamination	No. of plot infested	Percentage of infestation
Mukterpur Sardah	20	13	65	5	25
Askarpur Sardah	20	10	50	3	15
Dararchar Sardah	20	11	55	3	15
Solowa Sardah	20	9	45	4	20
Nimpura Sardah	20	8	40	3	15
Daulatpur Sardah	20	7	35	4	20
Nawdara Sardah	20	12	60	6	30
Vatopara Nandangachi	20	11	55	5	25
Fakirpara Nandangachi	20	10	50	7	35
Nalkala Harian	20	6	30	3	15
Arambaria Ishurdi	20	12	60	6	30
Varamara Kushtia	20	5	25	2	10
Mean	20	9.50	47.50	4.25	21.25
Standard error	-	0.73	3.67	0.45	2.23

Table-8

Comparison of the incidence of *Striga* infestation of sugarcane fields at selected locations during 1999-2000 cropping season

Localities	Area in sq. meter of infested plots	Area in sq. meter of infestation	Percentage of infestation	No. of cane in infested plot	Number of cane infested	Incidence
Mukterpur Sardah	20075	736	3.67	225844	8280	3.67
Askarpur Sardah	24542	4249	17.31	272416	47164	17.31
Dararcar Sardah	22867	1404	6.14	237817	14602	6.14
Solowa Sardah	18905	3475	18.38	238203	43785	18.38
Nimpara Sardah	15833	2763	17.45	169888	29647	17.45
Daulatpur Sardah	19593	3412	17.41	222576	38760	17.41
Nawdara Sardah	20762	719	3.46	224230	7765	3.46
Vatopara Nandangachi	31928	2954	9.25	318003	29422	9.25
Fakirpara Nandangachi	22355	2623	11.73	223550	26230	11.73
Nalkala Harian	15551	2793	17.96	217714	39102	17.96
Arambaria Isuordi	21130	2319	10.97	287368	31538	10.97
Varamara Kuishtia	53150	1855	3.49	712210	248557	3.49
Mean	23890.92	2441.83	11.44	279151.58	28429.33	11.44
Standard error	10154.76	315.53	1.78	40911.36	18717.21	1.78

Table-9

Data on the survey of *Striga* spp. made in 2000-2001 cropping season

Sl. No.	Date	Localities	Short description
1	1-6-2000	Mukterpur Sardah	Sugarcane and rice plots were visited. Seedling, juvenile and flowering stage of <i>Striga</i> was observed
2	1-6-2000	Askarpur Sardah	-do-
3	1-6-2000	Dararchar Sardah	-do-
4	2-6-2000	Solowa Sardah	-do-
5	2-6-2000	Nimpara Sardah	-do-
6	2-6-2000	Daulatpur Sardah	-do-
7	2-6-2000	Nawdara Sardah	-do-
8	4-6-2000	Vatopara Nandangachi	-do-
9	4-6-2000	Fakirpara Nandangachi	-do-
10	5-6-2000	Nalkala Harian	-do-
11	7-6-2000	Arambaria Ishurdi	-do-
12	7-6-2000	Varamara Kushtia	-do-
13	9-6-2000	Bharandra Region	Sugarcane is not cultivated here and <i>Striga</i> was not observed.
14	10-6-2000	Joypurhat	Personal communication with cane manager of Joypurhat Sugar Mills Ltd. <i>Striga</i> was observed nearest to Natore district.

Table-10

Incidence of *Striga* contamination of sugarcane fields at different locations during 2000-2001 cropping season

Localities	No. of plot surveyed	No. of plot contaminated	Percentage of contamination	No. of plot infested	Percentage of infestation
Mukterpur Sardah	20	10	50	4	20
Askarpur Sardah	20	11	55	4	20
Dararchar Sardah	20	10	50	4	20
Solowa Sardah	20	12	60	5	25
Nimpara Sardah	20	9	45	3	15
Daulatpur Sardah	20	9	45	4	20
Nawdara Sardah	20	11	55	4	20
Vatopara Nandangachi	20	12	60	4	20
Fakirpara Nandangachi	20	11	55	6	30
Nalkala Harian	20	5	25	2	10
Arambaria Ishurdi	20	11	55	5	25
Varamara Kushtia	20	4	20	2	10
Mean	20	9.58	47.92	3.92	19.58
Standard error	-	0.74	3.72	0.34	1.68

(1.46). Mean with standard error of *Striga* incidence was (9.53 ± 1.46) (Table-11). No *Striga* plant was found at Barind Region. In the sugarcane cultivated areas of Joypurhat Sugar Mills Ltd. sporadic appearance of *Striga* spp. was observed.

It was observed that contamination percentage of sugarcane fields was higher than that of infestation. During 1999-2000 and 2000-2001 cropping seasons contamination percentage of *Striga* contaminated field was more or less equal, but the lowest in 1998-99 cropping season. It was also observed that infestation percentage of sugarcane field was more or less equal during the three cropping seasons (Fig. 8).

It was found that *Striga* incidence was 11.34, 10.22 and 8.04 during 1998-99, 1999-2000 and 2000-2001 cropping seasons respectively. The highest percentage of infestation was found during 1999-2000 cropping season and the lowest in 1998-99 cropping season (Fig. 9).

4.1.3 Population density of hosts and parasitic weeds

Population density of host plants (sugarcane) and parasitic weeds (*Striga*) per square meter at different locality during 1998-99 cropping season ranged from 14.44 to 16.72 and 16.88 to 20.12 respectively. Number of parasitic weeds per host ranged from 1.01 to 1.30 (Table-12). The highest population density of the parasite per square meter was found at Nalkala (20.12) and the lowest at Askarpur (16.88). Population density of the host plants per square meter was more or less equal in every locality. Mean number of hosts and parasitic weeds per square meter was 15.97 and 18.84 respectively. Mean number of parasitic weeds per host was 1.18.

During 1999-2000 cropping season population density of host plants (sugarcane) and parasitic weeds (*Striga*) per square meter at different locality ranged from 9.96 to 14.00 and 16.70 to 25.20 respectively. Number of parasitic weeds per host ranged from 1.25 to 2.42 (Table-13). The highest population density of the parasitic weeds per square meter was found at Darachar (25.20) and the

Table-11

Comparison of the incidence of *Striga* infestation of sugarcane fields at selected locations during 2000-2001 cropping season

Localities	Area in sq. meter of infested plots	Area in sq. meter of infestation	Percentage of infestation	No. of cane in infested plot	Number of cane infested	Incidence
Mukterpur Sardah	15898.25	1042.00	6.55	218442	14317	6.55
Askarpur Sardah	20928.75	2246.75	10.74	263702	28309	10.74
Dararcar Sardah	21995.50	1199.00	5.45	300019	16354	5.45
Solowa Sardah	19373.40	2961.00	15.28	261541	39974	15.28
Nimpara Sardah	15572.00	2419.00	15.53	215984	33552	15.53
Daulatpur Sardah	20446.50	2902.67	14.20	284002	40318	14.20
Nawdara Sardah	39451.75	576.50	1.46	512873	7495	1.46
Vatopara Nandangachi	27976.80	1953.60	6.98	377127	26335	6.98
Fakirpara Nandangachi	24100.60	2969.60	12.32	327768	40387	12.32
Nalkala Harian	16602.00	2598.00	15.65	235748	36892	15.65
Arambaria Isuirdi	35366.33	2438.80	6.90	480982	33168	6.90
Varamara Kushtia	55061.50	1846.50	3.35	765355	25666	3.35
Mean	26064.45	2096.12	9.53	353628.58	28563.92	9.53
Standard error	3415.62	229.99	1.46	46742.84	3181.53	1.46

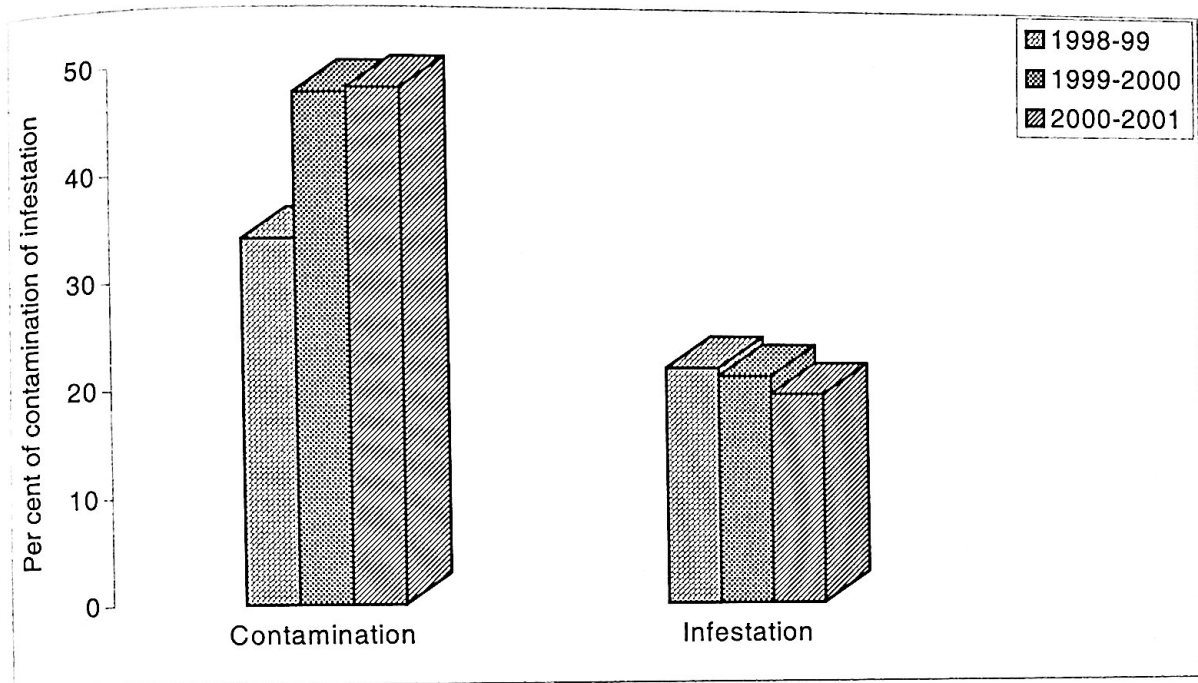


Figure-8 Graphic representation of the incidence of *Striga* contamination and infestation of sugarcane fields at selected locations during 1998-99, 1999-2000 and 2000-2001 cropping seasons

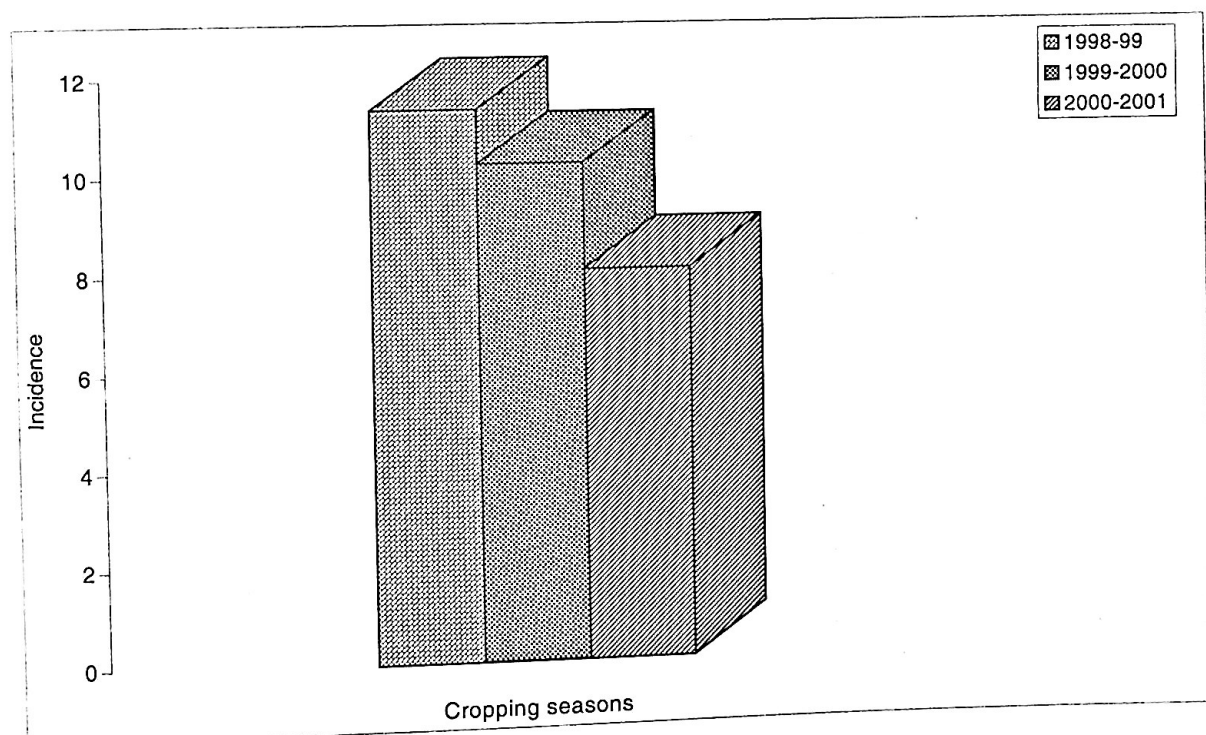


Figure-9 Graphic representation of *Striga* incidence at selected locations during 1998-99, 1999-2000 and 2000-2001 cropping seasons

Table-12

Population density of hosts (sugarcane), parasitic weeds (*Striga*) per sq. meter and number of parasitic weeds per host at different locations during 1998-99 cropping season

Localities	Mean number of <i>Striga</i> per sq. meter				Mean no. of cane per sq. meter	Mean no. of <i>Striga</i> per host
	Seedling	Flowering	Mature	Total		
Mukterpur Sardah	1.08	1.48	16.24	18.80	14.44	1.30
Askarpur Sardah	1.32	2.04	13.52	16.88	16.72	1.01
Dararcas Sardah	1.28	1.68	16.52	19.48	16.52	1.18
Nawdara Sardah	1.20	1.28	16.44	18.92	16.12	1.17
Nalkala Harian	1.32	1.92	16.88	20.12	16.04	1.25
Mean	1.24	1.68	15.92	18.84	15.97	1.18

Table-13

Population density of hosts (sugarcane), parasitic weeds (*Striga*) per sq. meter and number of parasitic weeds per host at different locations during 1999-2000 cropping season

Localities	Mean number of <i>Striga</i> per sq. meter				Mean no. of cane per sq. meter	Mean no. of <i>Striga</i> per host
	Seedling	Flowering	Mature	Total		
Mukterpur Sardah	1.53	1.75	16.15	19.43	11.25	1.73
Askarpur Sardah	1.60	1.70	18.15	21.45	11.10	1.93
Dararchar Sardah	1.72	1.64	21.80	25.20	10.40	2.42
Solowa Sardah	1.50	1.45	21.25	24.20	12.60	1.92
Nimpara Sardah	1.47	1.73	19.67	22.87	10.73	2.13
Daulatpur Sardah	1.67	1.70	18.24	21.61	11.36	1.90
Nawdara Sardah	1.52	1.76	15.12	18.44	10.80	1.71
Vatopara Nandangachi	1.60	1.52	18.40	21.52	9.96	2.16
Fakirpara Nandangachi	1.60	1.56	13.72	16.84	10.00	1.68
Nalkala Harian	1.47	1.60	20.53	23.60	14.00	1.69
Arambaria Ishurdi	1.52	1.52	19.04	22.08	13.60	1.62
Varamara Kushtia	1.50	1.70	13.50	16.70	13.40	1.25
Mean	1.56	1.64	17.96	21.16	11.60	1.85

lowest at Varamara (16.70). Population density of the host plants per square meter was more or less equal in every locality. Mean number of host and parasitic weeds per square meter was 11.60 and 21.16 respectively. Mean number of parasitic weeds per host was 1.85.

During 2000-2001 cropping season population density of host plants (sugarcane) and parasitic weeds (*Striga*) per square meter at different locality ranged from 12.60 to 14.20 and 15.80 to 22.10 respectively. Number of parasitic weeds per host ranged from 1.14 to 1.58 (Table-14). The highest population density of the parasitic weeds per square meter was found at Nalkala (22.10) and the lowest at Varamara (15.80). Population density of the host plant per square meter was more or less equal in every locality. Mean number of host plants and parasitic weeds per square meter was 13.59 and 18.64 respectively. Mean number of parasitic weeds per host was 1.38.

It was also observed that during 1999-2000 cropping season number of parasitic weeds per host was the highest (1.80) and the lowest (1.08) in 1998-99 cropping season (Fig. 10).

4.1.4 Parasitism of *Striga* spp. on different host plant in Bangladesh

During 1998-99, 1999-2000 and 2000-2001 cropping seasons, at the time of survey, parasitism of *Striga* spp. on different host plants were also examined and recorded. It was observed that three species of *Striga* (*S. densiflora*, *S. lutea* and *S. euphrasioides*) parasitizing *Saccharum officinarum* and *Oryza sativa*. Among them *S. lutea* was recorded with the association of *Cynodon dactylon*, and two unidentified wild grasses (Table-15, Fig. 11-14).

4.1.5 Soil condition

It was observed that generally dry and high lands were infested with *Striga*, while in low lands, *Striga* was not observed. Soil samples were collected from control (*Striga* free land) and *Striga* infected land, soil particles analyzed and classification was made according to soil texture. It was found that both the lands bears silt clay (Table-16).

Table-14

Population density of host (sugarcane), parasite (*Striga*) per sq. meter and number of parasite per host at different locations during 2000-2001 cropping season

Localities	Mean number of <i>Striga</i> per sq. meter				Mean no. of cane per sq. meter	Mean no. of <i>Striga</i> per host
	Seedling	Flowering	Mature	Total		
Mukterpur Sardah	1.20	1.65	14.20	17.05	13.74	1.24
Askarpur Sardah	0.90	1.50	17.45	19.85	12.60	1.58
Dararchar Sardah	1.15	1.40	16.15	18.70	13.64	1.37
Solowa Sardah	1.80	1.56	17.24	20.60	13.50	1.53
Nimpara Sardah	1.00	1.80	15.80	18.60	13.87	1.34
Daulatpur Sardah	1.00	1.55	16.50	19.05	13.89	1.37
Nawdara Sardah	0.90	1.35	15.00	17.25	13.00	1.34
Vatopara Nandangachi	1.10	1.60	16.00	18.70	13.48	1.38
Fakirpara Nandangachi	1.15	1.50	15.10	17.75	13.60	1.31
Nalkala Harian	1.20	2.50	18.40	22.10	14.20	1.56
Arambaria Ishurdi	0.88	1.32	16.04	18.24	13.60	1.34
Varamara Kushtia	0.90	1.80	13.10	15.80	13.90	1.14
Mean	1.10	1.63	15.93	18.64	13.59	1.38

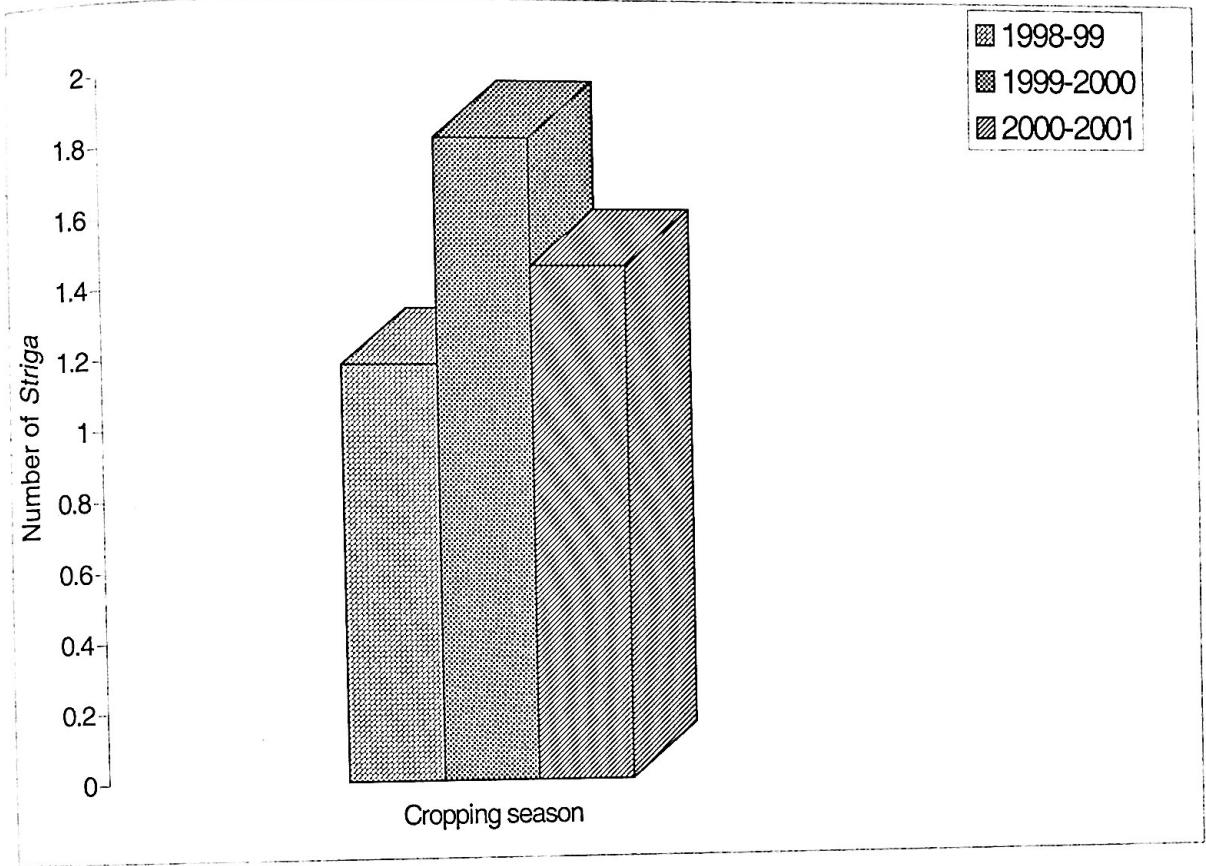


Figure-10 Graphic representation of number of *Striga* per host (sugarcane) during 1998-99, 1999-2000 and 2000-2001 cropping seasons

Table-15
Parasitism of *Striga* spp. on different host plants in Bangladesh

Name of the host	Species of <i>Striga</i>		
	<i>S. densiflora</i>	<i>S. lutea</i>	<i>S. euphrasioides</i>
<i>Saccharum officinarum</i>	+	+	+
<i>Oryza sativa</i>	+	+	+
<i>Cynodon dactylon</i>	+	+	-
Unidentified grass	+	+	-
Unidentified grass	+	+	-

Table-16

Particle density and texture classification of the soil samples of *Striga* parasitized and *Striga* free sugarcane field

Description	% silt+clay	% clay	% silt	% sand	Texture
<i>Striga</i> free	74	10	64	26	Silt clay
<i>Striga</i> -parasitized	76	10	66	34	Silt clay

Mean of three replications



Figure-11 Photographic representation of *Striga* associated with *Oryza sativa*
(S= *Striga*)



Figure-12 Photographic representation of *Striga* associated with *Cynodon dactylon*
(C=*Cynodon*)



Figure-13 Photographic representation of *Striga* associated with unidentified wild grass (G=Unidentified grass)



Figure-14 Photographic representation of *Striga* associated with unidentified wild grass

4.1.6 Climatic condition

Striga infestation was found to occur in the months of July-August, when maximum predisposing environmental factors for the growth and development of *Striga* spp. were found. During the months of August-September, heavy rainfall was occurred which helpful for the dissemination of *Striga* seeds by rainwater (Fig. 15-18).

4.2 MORPHO-TOXONOMIC STUDIES OF *STRIGA* SPP.

The results of morpho-taxonomic studies of *Striga* spp. described in two heads, such as qualitative characters and quantitative characters.

4.2.1 Qualitative characters

Short description of qualitative characters of *Striga* spp. described under the following heads:

Habit and Habitat

Herbs, wild, erect, solid, basal portion woody, apical portion herbaceous, aerial stem angular, sympodial branched, hairy, hair straight with pointed tip, maximum unicellular, few were multicellular, usually 2-3 celled, green in colour, black depending on drying of S_1 but rest two dull brown depending on drying.

Root: Root poorly developed, white in colour, black depending on drying of S_1 but rest two dull-brown. Root hair absent.

Stem: Aerial stem angular, green in colour. Underground stem rounded, white with scaly leaves. Scaly leaves absent in S_3 .

Leaves: Leaves simple, cauline, lower opposite, upper alternate, decussate, sessile, ex-stipulate, linear with straight hair, base auriculate, apex acute, reticulate venation, green in colour, dull brown when dry, but S_1 black.

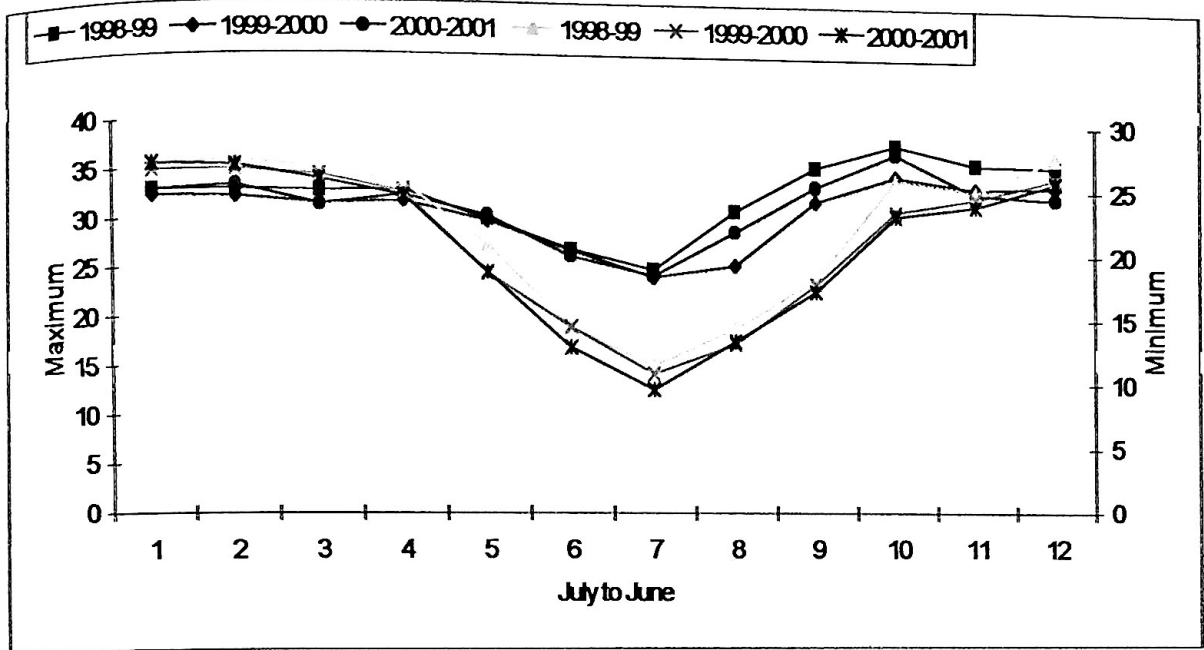


Fig.-15 Graphic representation of temperature in $^{\circ}\text{C}$ during 1998-99, 1999-2000 and 2000-2001 cropping seasons

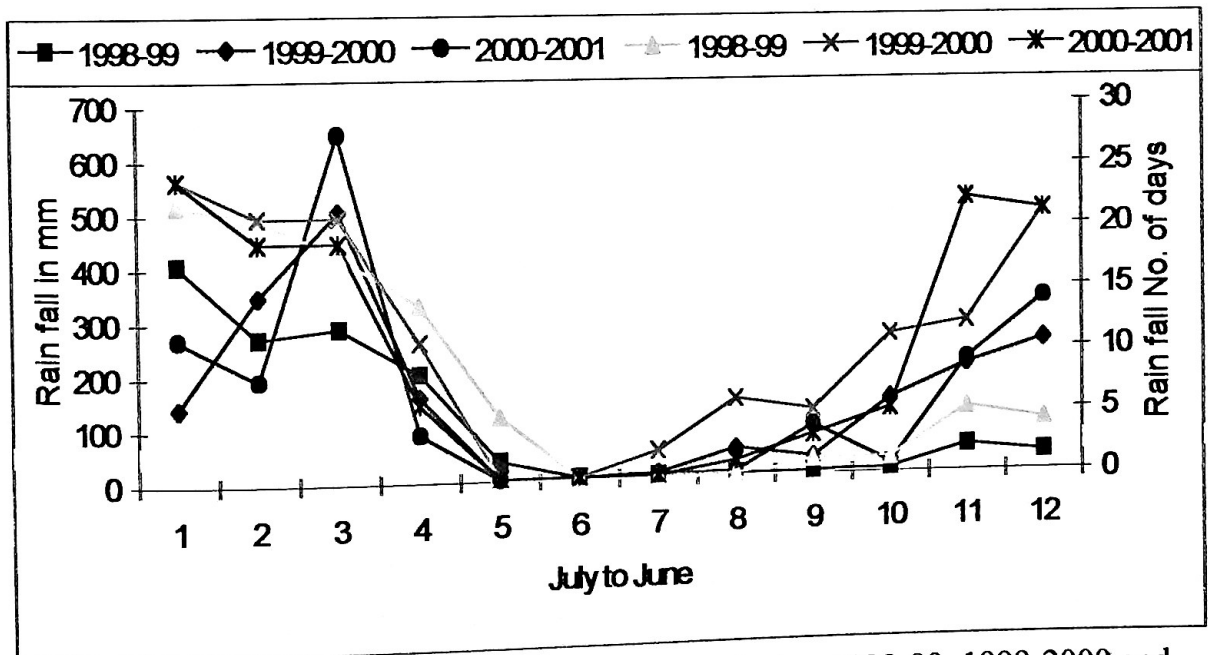


Fig.-16 Graphic representation of rain fall in mm during 1998-99, 1999-2000, and 2000-2001 cropping seasons

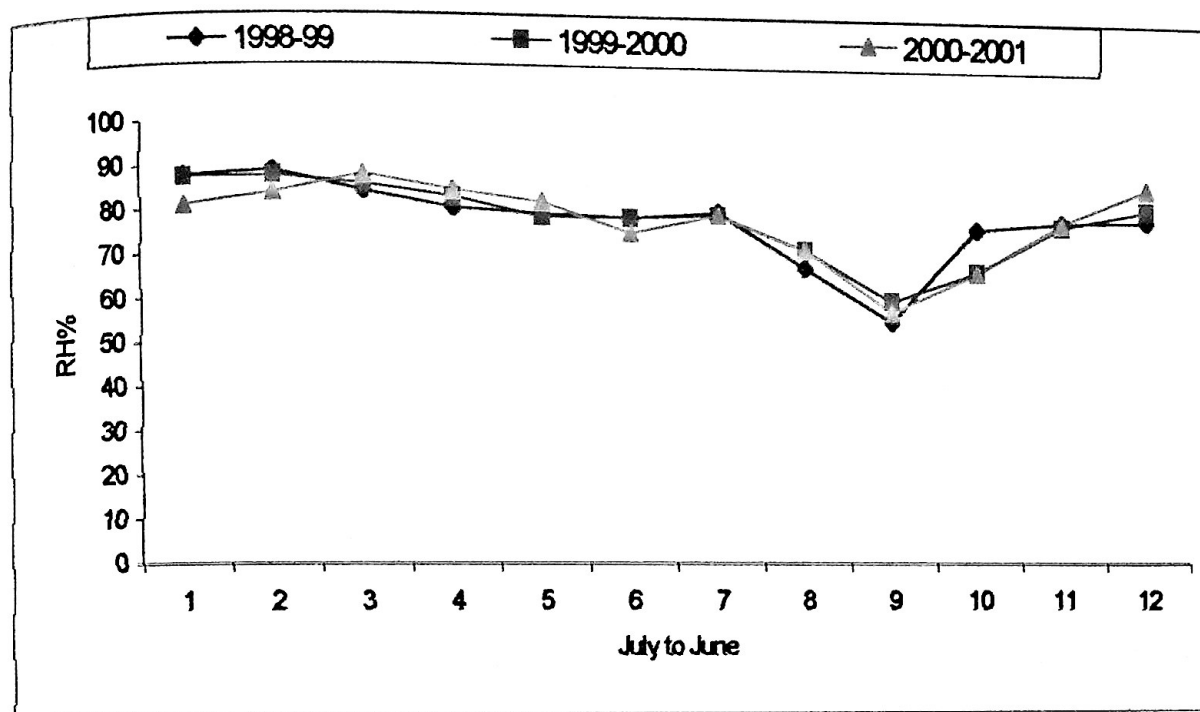


Fig.-17 Graphic representation of RH% during 1998-99, 1999-2000 and 2000-2001 cropping seasons

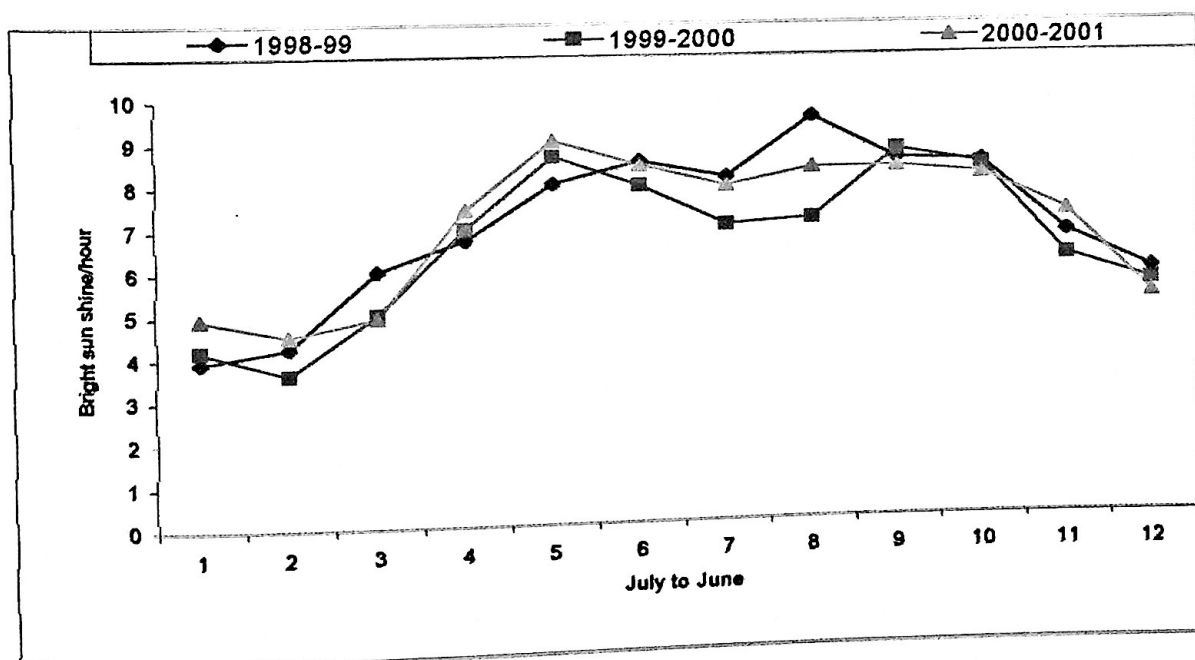


Fig.-18 Graphic representation of bright sun shine/hour during 1998-99, 1999-2000 and 2000-2001 cropping seasons

Flower: Flower axillary, simple sessile, bracteate, completely bi-sexual, zygomorphic, superior, white but creamy in S_2 . Inflorescence spike.

Bract: Two more or less equal bracts present and these were shorter than calyx. Bract mid-rib present only in S_1 (Fig. 19).

Calyx: Calyx tubular, gamosepalous, valvate, persistent with hair, sepals connate, green in colour. Number of calyx tooth 5. Calyx tooth unequal but more or less equal in S_3 . In S_1 four calyx tooth equal but one was small.

Corolla: Petal 5, connate in a two lipped, gamopetalous, imbricate. corolla tube cylindrical with two types of hair. Straight hair unicellular with pointed tip, present in the outer side of the corolla tube. Glandular hair multicellular with multicellular gland, present in the inner side of the corolla tube (Fig. 20). White petal present in S_1 and it turned violet when wounded and black when dry, S_3 also bear white petal, but S_2 bear creamy petal. Petal of S_2 and S_3 turned dull brown depending on drying.

Androecium: Stamen free, didynamous, number of stamen 4, 2 long and 2 short. Anther unicellular, vertical, dorsifixed, base obtuse (Fig. 21).

Gynoecium: Carpel-2, synocarpus, style-1, thickened, upward, stigma-1, entire, bifid (Fig. 22). Ovary rounded, two chambered with axile placentation (Fig. 23).

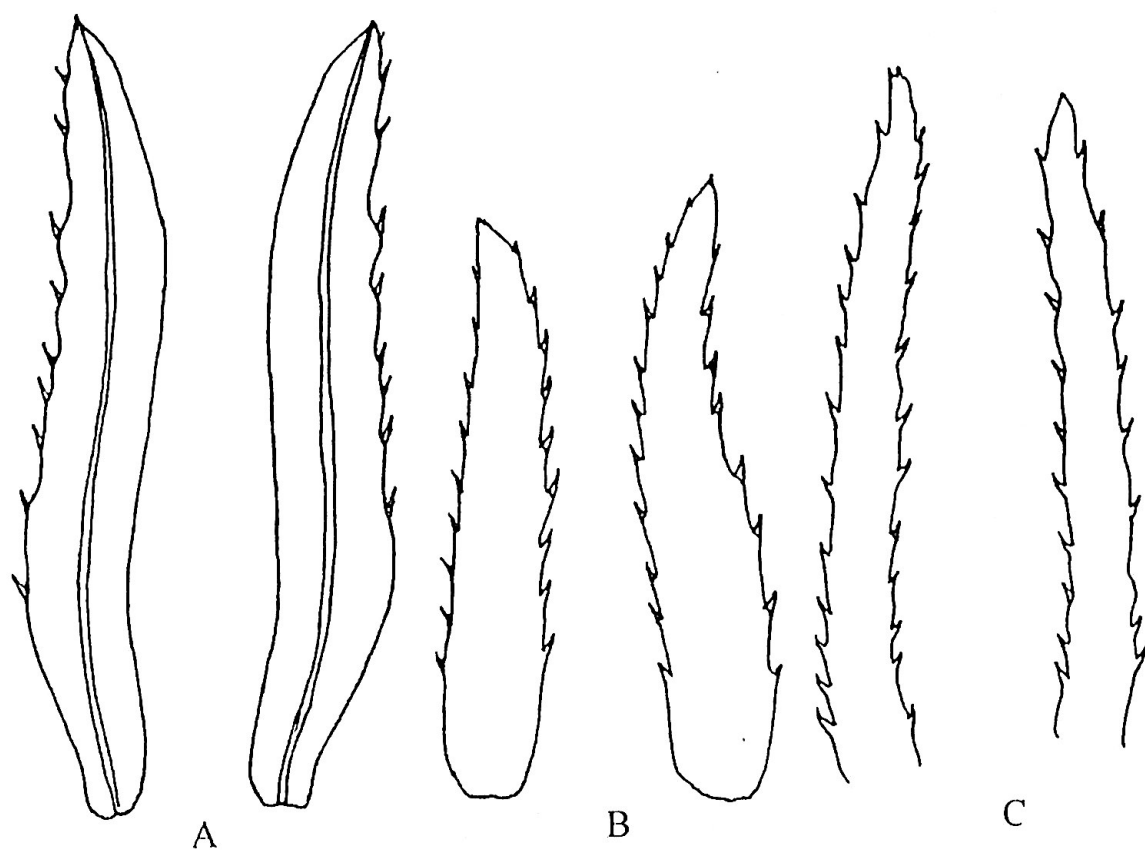
Fruits: Fruit capsule, subglobose loculicidal, valved, entire, firm, septiferous, separating from the placentas.

Seeds: The seeds of *Striga* spp. were very minute, oblong, tiny, reticulate, coffee brown but in S_3 dark brown in colour (Fig. 24-26).

4.2.2 Quantitative Characters

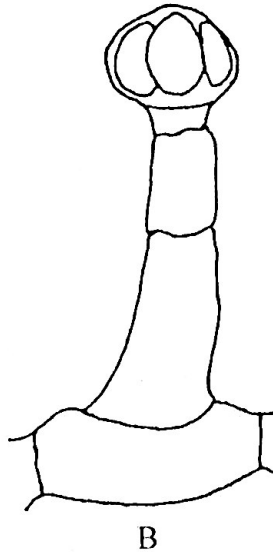
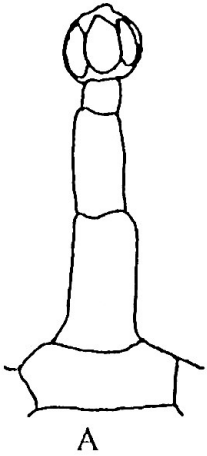
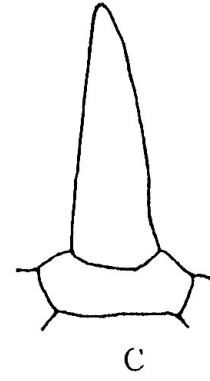
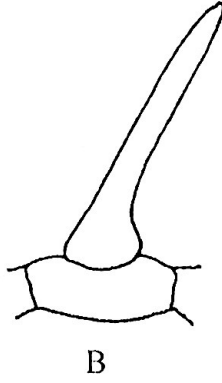
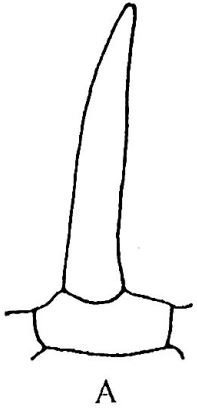
The results obtained from quantitative characters described under the following heads such as vegetative, floral and reproductive characters.

Figure-19 Camera lucida drawing of bract of the three species of *Striga*
A x20, Bx20 and C x30



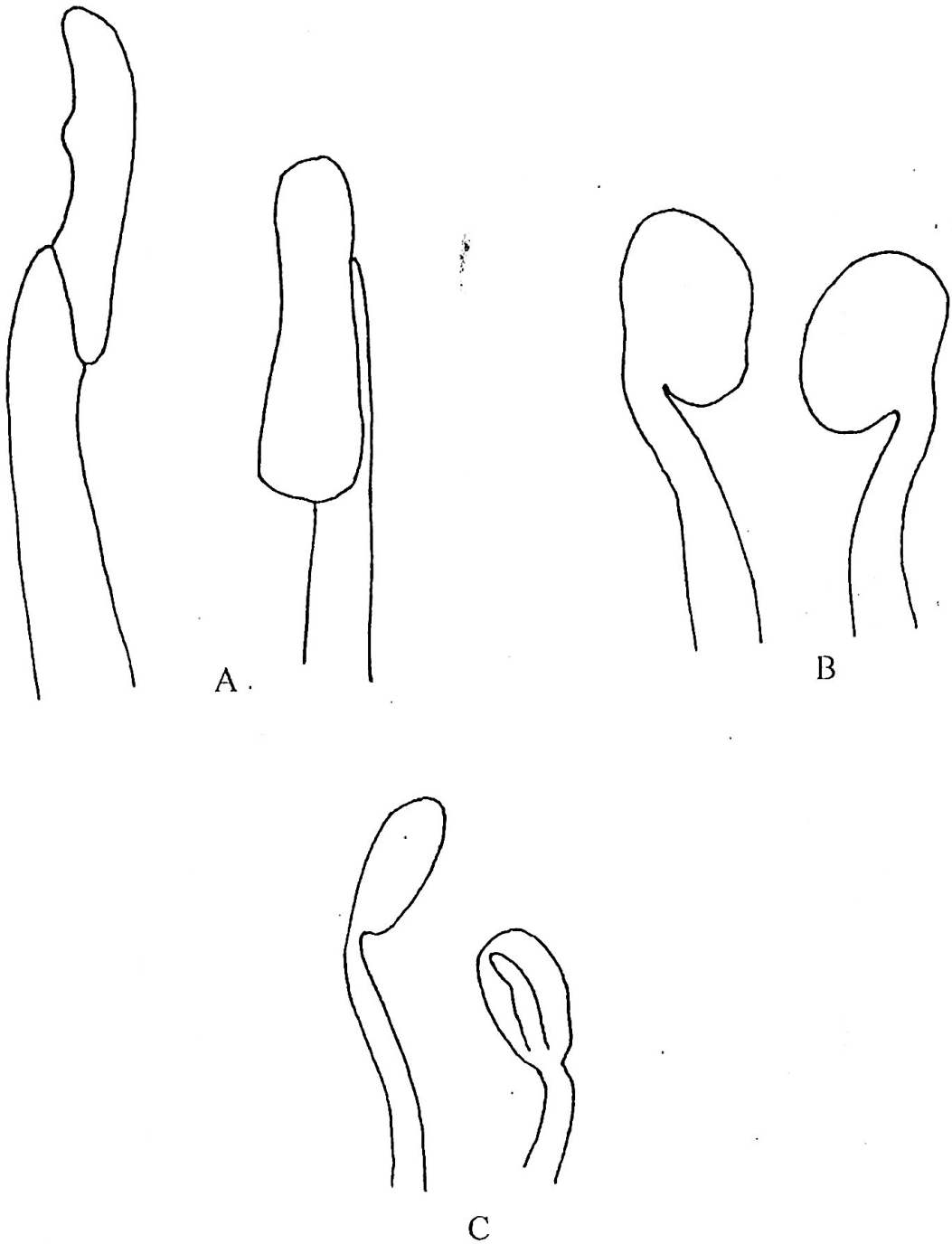
A=*Striga densiflora* B=*S. lutea* C=*S. euphrasioides*

Figure-20 Camera lucida drawing of straight and glandular hair of the three species of *Striga* x350



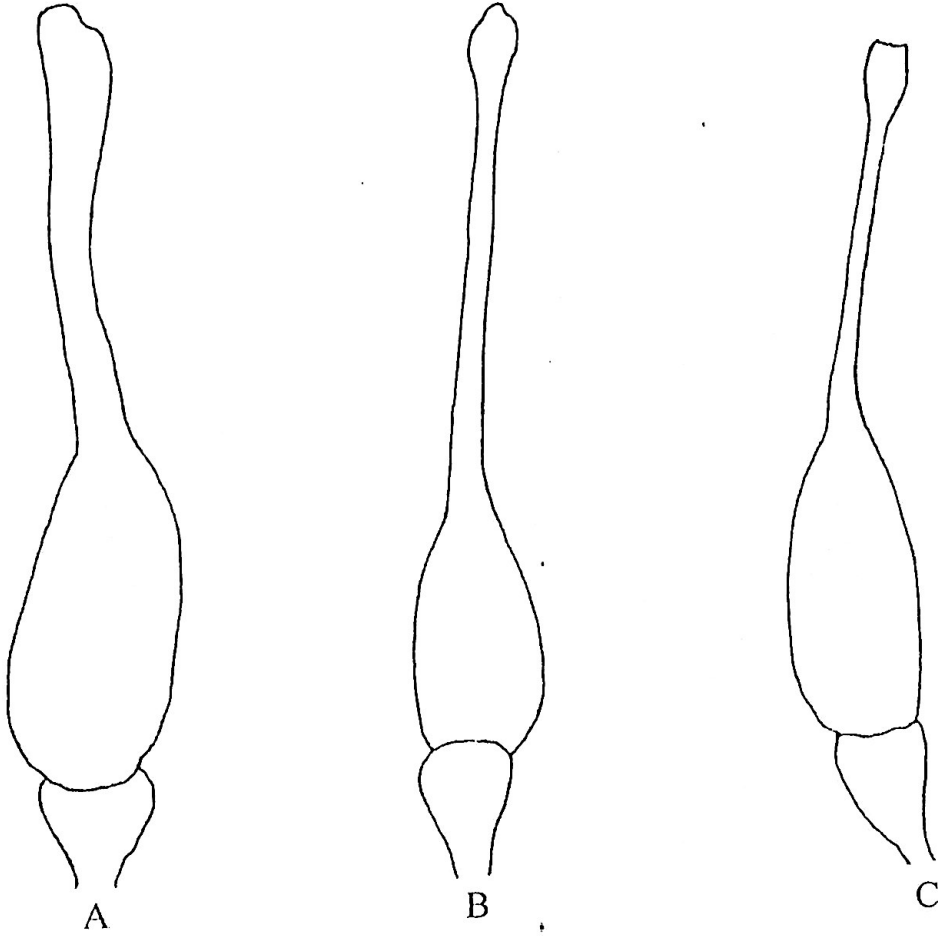
A= *Striga densiflora* B= *S. lutea* C= *S. euphrasioides*

Figure-21 Camera lucida drawing of androecium of the three species of *Striga*
Ax50, Bx50 and Cx30



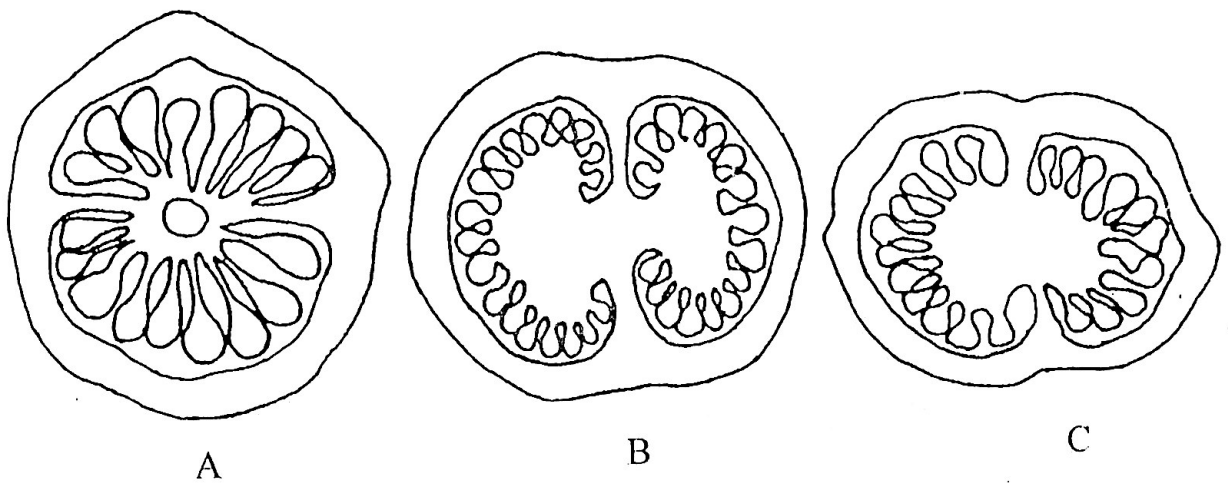
A=*Striga densiflora* B=*S. lutea* C=*S. euphrasioides*

Figure-22 Camera lucida drawing of gynoecium of the three species of *Striga* x20



A=*Striga densiflora* B=*S. lutea* C=*S. euphrasioides*

Figure-23 Camera lucida drawing of TS of ovary of the three species of *Striga*,
Ax50, Bx70, Cx50



A=*Striga densiflora* B=*S. lutea* C=*S. euphrasioides*



Figure-24 Photographic representation of the seed of *Striga densiflora*

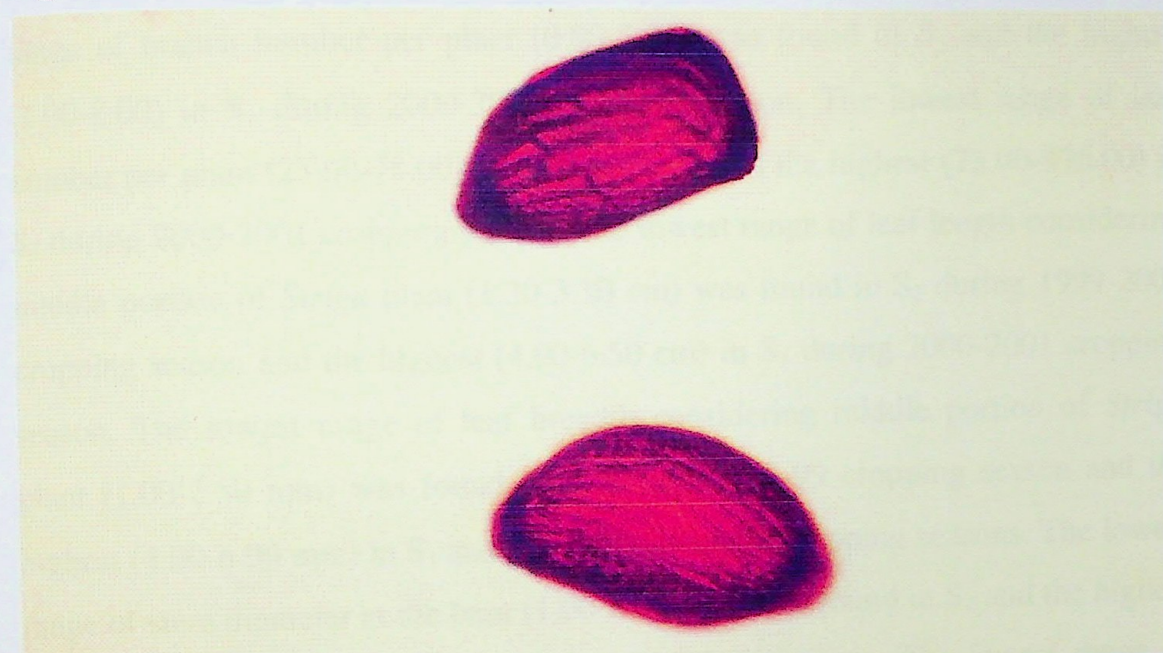


Figure-25 Photographic representation of the seeds of *S. lutea*



Figure-26 Photographic representation of the seed of *S. euphrasioiaes*

4.2.2A Vegetative characters

Twelve vegetative characters of *Striga* spp. were analyzed for the determination of range of variation, mean with standard error, analysis of variance and least significant difference and the results presented in Table-17 and 18. It was observed that the lowest range of plant height (7.00-29.00 cm) was found in S₂ and the highest (55.00-88.00 cm) in S₃ during 1999-2000 cropping season. The lowest range of branch number per plant (0.00-2.00) was found in S₃ and the highest (1.00-8.00) in S₁ during 2000-2001 cropping season. The lowest range of leaf number per plant (27.00-78.00) was found in S₂ and the highest (73.00-375.00) in S₁ during 2000-2001 cropping season. The lowest range of leaf length considering middle portion of *Striga* plant (1.20-3.10 cm) was found in S₂ during 1999-2000 cropping season and the highest (4.00-6.50 cm) in S₁ during 2000-2001 cropping season. The lowest range of leaf breadth considering middle portion of *Striga* plant (1.00-2.50 mm) was found in S₂ during 1998-99 cropping season and the highest (4.00-6.00 mm) in S₁ and S₃ during the three cropping seasons. The lowest range of stem diameter at the base (1.00-2.00 mm) was found in S₂ and the highest (4.00-5.00 mm) in S₁ during the three cropping seasons. The lowest range of straight-hair length (185.77-314.38 μ) was found in S₁ during 1999-2000 cropping season and the highest (142.90-388.20 μ) in S₂ during 1998-1999 cropping season. The lowest range of straight-hair breadth (14.29-28.58 μ) was found in S₃ and the highest (28.58-85.76 μ) in S₂ during the three cropping seasons. The lowest range of glandular-hair length (100.03-157.19 μ) was found in S₁ during 1998-99 cropping season and the highest (85.74-242.23 μ) in S₂ and S₃ during 1998-99 and 2000-2001 cropping seasons. The lowest range of glandular-hair breadth (14.29-28.58 μ) was found in S₁ during 1999-2000 and 2000-2001 cropping seasons, in S₂ during the three cropping seasons and in S₃ during 1998-99 and 1999-2000 cropping seasons. The highest range of glandular-hair breadth (14.29-35.73 μ) was found in S₃ during 2000-2001 cropping season. The lowest range of gland length (14.29-21.44 μ) was found in S₃ during 1998-99 cropping season and the highest

(14.29-28.58 μ) in S_1 and S_2 during the three cropping seasons but in S_3 during 1999-2000 and 2000-2001 cropping seasons. The lowest range of gland breadth (14.29-28.58 μ) was found in S_1 during the three cropping seasons and in S_3 during 1998-99 cropping season. The highest range of gland breadth (21.44-42.87 μ) was found in S_2 during the three cropping seasons.

Standard error of the 12 vegetative characters of *Striga* spp. during the 3 cropping seasons were less than the corresponding mean. The highest standard error was observed for leaves number per plant (± 23.18) in S_1 during 2000-2001 cropping season and the lowest for leaf breadth considering middle portion of *Striga* plant (± 0.07) in S_2 during 1998-99 cropping season.

Analysis of variance indicated that the item species was significant ($P < 0.05$) for the 12 vegetative characters except straight hair length and glandular hair length. The items cropping season and interaction ($Y \times S$) were non-significant ($P > 0.05$) for the 12 vegetative characters except the character stem diameter at the base. LSD values of the 12 vegetative characters were also shows that S_1 , S_2 and S_3 were significantly ($P < 0.05$) different (Table-18).

4.2.2B Floral characters

For the determination of range of variation, mean with standard error, analysis of variance and least significant difference of the 8 floral characters of *Striga* spp. were analyzed and the results shown in Table-19 and 20. It was observed that the lowest range of bract length (2.00-3.50 mm) was found in S_2 during 1999-2000 cropping season and the highest (6.00-9.00 mm) in S_1 during 2000-2001 cropping season. The lowest range of calyx length (4.00-6.50 mm) was found in S_2 during 2000-2001 cropping season and the highest (10.50-12.00 mm) in S_3 during the three cropping seasons. The lowest range of corolla length (6.00-9.00 mm) was found in S_1 during 1998-99 cropping season and the highest (14.00-15.00 mm) in S_3 during 2000-2001 cropping season. The lowest range of corolla width (3.00-4.00 mm) was found in S_2 during 1998-99 cropping season and the

Table-17
Range of variation and mean with standard error of twelve vegetative characters of the three species of *Striga*

Characters	Species	Range			Mean* with standard error		
		Y ₁	Y ₂	Y ₃	Y ₁	Y ₂	Y ₃
Plant height in cm	S ₁	48.00-84.00	49.00-84.00	48.00-85.00	63.15±2.25	63.5±2.18	65.75±2.18
	S ₂	11.00-37.00	7.00-29.00	7.00-31.00	19.60±1.66	16.30±1.37	17.65±1.43
	S ₃	48.00-79.00	55.00-88.00	49.00-88.00	65.15±1.73	70.75±1.94	68.60±2.43
Branch number per plant	S ₁	2.00-7.00	1.00-7.00	1.00-8.00	4.48±0.37	4.30±0.44	5.30±0.57
	S ₂	0.00-6.00	0.00-5.00	0.00-6.00	2.48±0.42	2.50±0.37	2.50±0.41
	S ₃	0.00-4.00	0.00-5.00	0.00-2.00	0.95±0.24	0.85±0.28	0.85±0.15
Leaves number per plant	S ₁	87.00-369.00	80.00-369.00	73.00-375.00	219.45±19.15	249.65±20.65	223.95±23.18
	S ₂	27.00-93.00	17.00-95.00	27.00-78.00	54.55±3.34	41.50±4.39	56.35±3.24
	S ₃	37.00-84.00	49.00-221.00	39.00-135.00	67.55±2.430	75.80±4.21	74.95±5.51
Leaf length (middle portion of <i>Striga</i>) in cm	S ₁	3.00-6.50	3.00-6.50	4.00-6.50	5.10±0.21	5.35±0.26	5.15±0.19
	S ₂	1.20-3.20	1.20-3.10	1.50-3.10	2.05±0.11	2.21±0.12	2.15±0.11
	S ₃	4.00-6.00	4.00-6.00	4.00-6.00	4.95±0.15	4.60±0.13	4.70±0.15
Leaf breadth (middle portion of <i>Striga</i>) in mm	S ₁	4.00-6.00	4.00-6.00	4.00-6.00	5.10±0.16	5.35±0.18	5.15±0.20
	S ₂	1.00-2.50	1.00-3.00	1.50-3.00	2.05±0.07	2.21±0.13	2.15±0.10
	S ₃	4.00-6.00	4.00-6.00	4.00-6.00	4.95±0.17	4.60±0.15	4.70±0.19
Stem diameter at the base in mm	S ₁	4.00-5.00	4.00-5.00	4.00-5.00	4.50±0.10	4.35±0.11	4.35±0.12
	S ₂	1.00-2.00	1.00-2.00	1.00-2.00	1.58±0.10	1.78±0.08	1.50±0.10
	S ₃	3.00-4.00	2.50-5.00	2.00-4.00	3.18±0.08	3.20±0.13	3.01±0.14

Table-17 continued

Characters	Species	Range			Mean* with standard error		
		Y ₁	Y ₂	Y ₃	Y ₁	Y ₂	Y ₃
Straight hair length in μ	S ₁	200.06-314.38	185.77-314.38	185.77-375.25	251.50±8.39	241.50±8.61	272.90±10.77
	S ₂	142.90-388.20	171.50-371.50	171.50-371.50	248.00±17.51	253.60±12.66	245.50±12.43
	S ₃	214.40-328.70	214.40-328.70	214.40-328.70	260.80±7.89	272.90±7.96	265.80±6.51
Straight hair breadth in μ	S ₁	28.58-71.45	28.58-71.45	28.58-71.45	47.16±3.75	49.30±3.51	45.73±3.53
	S ₂	28.58-85.76	28.58-85.76	28.58-85.76	65.23±4.19	55.73±2.91	63.59±3.02
	S ₃	14.29-28.58	14.29-28.58	14.29-28.58	21.44±1.47	18.22±1.32	21.08±1.42
Glandular hair length in μ	S ₁	100.03-157.19	100.00-171.48	100.03-171.48	127.90±4.21	140.04±4.71	137.90±4.79
	S ₂	85.74-242.23	71.45-242.23	85.74-242.23	126.79±8.81	113.96±10.48	115.75±9.50
	S ₃	85.74-242.23	71.45-242.23	85.74-242.23	126.79±8.81	113.96±10.48	115.75±9.50
Glandular hair breadth in μ	S ₁	21.44-28.58	14.29-28.58	14.29-28.58	23.23±0.71	20.01±1.11	19.65±1.15
	S ₂	14.29-28.58	14.29-28.58	14.29-28.58	25.37±1.10	24.29±1.31	24.65±1.32
	S ₃	14.29-28.58	14.29-28.58	14.29-35.73	24.65±1.32	27.15±1.52	27.51±1.30
Gland length in μ	S ₁	14.29-28.58	14.29-28.58	14.29-28.58	18.94±1.19	21.44±1.37	20.37±1.30
	S ₂	14.29-28.58	14.29-28.58	14.29-28.58	21.08±1.21	20.37±1.40	21.08±1.42
	S ₃	14.29-21.44	14.29-28.58	14.29-28.58	20.37±0.59	19.65±0.71	19.65±0.88
Gland breadth in μ	S ₁	14.29-28.58	14.29-28.58	14.29-28.58	23.94±1.19	25.37±1.68	24.65±1.68
	S ₂	21.44-42.87	21.44-42.87	21.44-42.87	30.37±1.32	28.58±1.04	29.15±1.37
	S ₃	14.29-28.58	14.29-42.87	14.29-42.87	26.44±0.91	29.30±1.55	31.44±1.90

* Mean of twenty replicates. Y₁=1998-99, Y₂=1999-2000 and Y₃=2000-2001 cropping seasons

Table-18

Analysis of variance for twelve vegetative characters of three the species of *Striga*

CHARACTERS	ITEMS	DF	SS	MS	F	LSD
Plant height	Cropping season (Y)	2	67.90	33.95	0.41	5.76
	Species (S)	2	93703.30	46851.65	560.07*	
	Interaction (Y×S)	4	531.80	132.95	1.59	
	Error	171	14304.75	83.65		
	Total	179	108607.80			
Branch number	Cropping season (Y)	2	4.04	2.02	0.71	1.04
	Species (S)	2	433.21	216.61	76.21*	
	Interaction (Y×S)	4	8.36	2.09	0.73	
	Error	171	486.05	2.84		
	Total	179	931.66			
Leaf number	Cropping season (Y)	2	2154.99	1077.49	0.34	24.91
	Species (S)	2	1160073.00	580036.40	183.25*	
	Interaction (Y×S)	4	11914.29	2978.57	0.94	
	Error	171	541256.10	3165.24		
	Total	179	1715398.37			
Leaf length considering middle portion of <i>Striga</i>	Cropping season (Y)	2	2.50	1.25	2.27	0.46
	Species (S)	2	347.93	173.97	315.30*	
	Interaction (Y×S)	4	1.65	0.41	0.75	
	Error	171	94.35	0.55		
	Total	179	446.44			
Leaf breadth considering middle portion of <i>Striga</i>	Cropping season (Y)	2	0.13	0.07	0.15	0.41
	Species (S)	2	325.30	162.65	363.10*	
	Interaction (Y×S)	4	2.27	0.57	1.27	
	Error	171	76.60	0.45		
	Total	179	404.30			
Stem diameter at the base	Cropping season (Y)	2	1.39	0.69	3.09*	0.30
	Species (S)	2	246.81	123.41	550.98*	
	Interaction (Y×S)	4	1.91	0.48	2.14	
	Error	171	38.30	0.22		
	Total	179	288.41			

Table-18 continued

CHARACTERS	ITEMS	DF	SS	MS	F	LSD
Straight hair length	Cropping season (Y)	2	3896.69	1948.35	0.91	28.70
	Species (S)	2	1262.42	6431.21	3.00	
	Interaction (Y×S)	4	10345.92	2586.48	1.21	
	Error	171	366636.50	2144.07		
	Total	179	393741.50			
Straight hair breadth	Cropping season (Y)	2	387.69	193.85	1.09	8.26
	Species (S)	2	52797.15	26398.58	148.57*	
	Interaction (Y×S)	4	896.80	224.20	1.26	
	Error	171	30383.64	177.68		
	Total	179	84465.29			
Glandular hair length	Cropping season (Y)	2	733.74	366.87	0.27	22.96
	Species (S)	2	10817.52	5408.76	3.94*	
	Interaction (Y×S)	4	4807.33	1201.83	0.88	
	Error	171	234648.40	1372.21		
	Total	179	251007.00			
Glandular hair breadth	Cropping season (Y)	2	11.93	5.96	0.20	3.39
	Species (S)	2	945.51	472.76	15.82*	
	Interaction (Y×S)	4	252.01	63.00	2.11	
	Error	171	5110.09	29.88		
	Total	179	6319.55			
Gland length	Cropping season (Y)	2	3.96	1.98	0.07	3.21
	Species (S)	2	27.68	13.84	0.52	
	Interaction (Y×S)	4	72.63	18.16	0.68	
	Error	171	4575.21	26.76		
	Total	179	4679.48			
Gland breadth	Cropping season (Y)	2	26.27	13.13	0.32	3.98
	Species (S)	2	968.00	484.00	11.72*	
	Interaction (Y×S)	4	393.63	98.41	2.38	
	Error	171	7060.02	41.29		
	Total	179	8447.91			

Table-19
Range of variation and mean with standard error of eight floral characters of the three species of *Striga*

Characters	Species	Range			Mean* with standard error		
		Y ₁	Y ₂	Y ₃	Y ₁	Y ₂	Y ₃
Bract length in mm	S ₁	6.00-8.00	6.00-8.00	6.00-9.00	7.10±0.18	7.55±0.13	7.90±0.16
	S ₂	2.50-3.50	2.00-3.50	2.50-3.50	3.00±0.07	2.95±0.07	3.10±0.08
	S ₃	4.00-6.00	4.00-5.50	3.00-5.50	4.25±0.10	4.35±0.11	4.25±0.15
Calyx length in mm	S ₁	5.00-8.00	6.00-8.00	5.00-8.00	6.75±0.22	6.90±0.14	6.65±0.18
	S ₂	5.00-6.50	5.00-6.50	4.00-6.50	5.63±0.12	5.80±0.11	5.65±0.14
	S ₃	10.50-12.00	10.50-12.00	10.50-12.00	11.48±0.19	11.48±0.14	11.65±0.13
Corolla length in mm	S ₁	6.00-9.00	7.00-9.00	7.00-9.00	7.50±0.21	7.65±0.15	8.00±0.19
	S ₂	7.00-10.00	8.00-9.00	7.50-9.00	8.70±0.16	8.63±0.10	8.65±0.10
	S ₃	13.50-15.00	13.50-15.00	14.00-15.00	14.53±0.12	14.43±0.12	14.35±0.20
Corolla width in mm	S ₁	3.00-5.00	3.00-5.00	3.00-5.00	3.85±0.13	4.20±0.14	3.90±0.12
	S ₂	3.00-4.00	3.00-4.50	3.00-5.00	3.78±0.09	3.93±0.11	4.03±0.11
	S ₃	3.00-5.00	3.00-5.00	3.00-5.00	3.80±0.16	3.65±0.16	3.68±0.16

Table-19 continued

Characters	Species	Range			Mean* with standard error		
		Y ₁	Y ₂	Y ₃	Y ₁	Y ₂	Y ₃
Long stamen length in μ	S ₁	757.37-1014.60	757.37-1000.30	714.50-971.69	857.54 $\pm$ 19.06	844.51 $\pm$ 16.33	805.22 $\pm$ 19.34
	S ₂	928.85-1186.10	943.14-1143.20	885.98-1043.20	1039.60 $\pm$ 14.59	1026.70 $\pm$ 12.46	1026.00 $\pm$ 42.43
	S ₃	1043.20-1643.40	1043.20-1643.40	1043.20-1643.40	1316.10 $\pm$ 38.47	1256.80 $\pm$ 43.99	1314.00 $\pm$ 10.28
Short stamen length in μ	S ₁	543.02-700.21	543.20-685.92	528.76-685.92	605.90 $\pm$ 9.18	595.20 $\pm$ 8.11	595.18 $\pm$ 4.47
	S ₂	700.21-883.11	685.92-883.11	700.21-883.11	758.66 $\pm$ 12.75	768.51 $\pm$ 13.66	771.37 $\pm$ 14.66
	S ₃	914.56-1357.60	928.85-1357.60	914.56-1443.20	1091.00 $\pm$ 28.45	1109.60 $\pm$ 29.06	1112.50 $\pm$ 31.31
Pistil length in mm	S ₁	4.00-5.00	4.00-5.00	4.00-5.00	4.58 $\pm$ 0.11	4.78 $\pm$ 0.09	4.65 $\pm$ 0.13
	S ₂	7.00-8.50	6.00-8.00	7.00-8.00	7.43 $\pm$ 0.11	7.20 $\pm$ 0.14	7.23 $\pm$ 0.09
	S ₃	8.00-9.00	8.00-9.00	8.00-9.00	8.53 $\pm$ 0.09	8.43 $\pm$ 0.11	8.38 $\pm$ 0.10
Ovary diameter in μ	S ₁	414.41-528.73	371.54-585.89	342.96-614.47	460.85 $\pm$ 7.47	465.85 $\pm$ 12.51	489.43 $\pm$ 17.60
	S ₂	628.76-685.92	628.76-714.50	614.47-700.21	650.91 $\pm$ 3.36	663.77 $\pm$ 7.00	649.48 $\pm$ 6.09
	S ₃	1000.30-1128.90	1000.30-1128.90	1000.30-1128.90	1053.20 $\pm$ 8.74	1044.60 $\pm$ 7.33	1039.60 $\pm$ 7.40

*Mean of twenty replicates. Y₁=1998-99, Y₂= 1999-2000 and Y₃= 2000-2001 cropping seasons

Table-20

Analysis of variance for eight floral characters of three the species of *Striga*

CHARACTERS	ITEMS	DF	SS	MS	F	LSD
Bract length in mm	Cropping season (Y)	2	2.71	1.36	4.53*	0.34
	Species (S)	2	646.18	323.09	1076.98*	
	Interaction (Y×S)	4	4.09	1.02	3.40*	
	Error	171	50.85	0.30		
	Total	179	703.83			
Calyx length in mm Corolla length in mm	Cropping season (Y)	2	0.37	0.18	0.43	0.08
	Species (S)	2	1160.04	580.02	1343.72*	
	Interaction (Y×S)	4	1.03	0.26	0.60	
	Error	171	73.81	0.43		
	Total	179	1235.25			
Corolla length in mm	Cropping season (Y)	2	0.37	0.18	0.43	0.40
	Species (S)	2	1587.02	793.51	1867.40*	
	Interaction (Y×S)	4	2.63	0.66	1.55	
	Error	171	72.66	0.42		
	Total	179	1662.68			
Corolla width in mm	Cropping season (Y)	2	0.41	0.20	0.57	0.37
	Species (S)	2	2.43	1.21	3.40*	
	Interaction (Y×S)	4	1.92	0.48	1.34	
	Error	171	61.05	0.36		
	Total	179	65.80			
Long stamen length in μ	Cropping season (Y)	2	23792.13	11896.07	0.79	76.19
	Species (S)	2	6397611.00	3198806.0	211.72*	
	Interaction (Y×S)	4	52099.92	13024.98	0.86	
	Error	171	2583608.00	15108.82		
	Total	179	9057112.00			
Short stamen length in μ	Cropping season (Y)	2	1991.23	995.61	0.13	54.28
	Species (S)	2	7961124.00	3980562.0	519.07*	
	Interaction (Y×S)	4	6733.85	1683.46	0.22	
	Error	171	1311333.00	7668.62		
	Total	179	9281183.00			
Pistil length in mm	Cropping season (Y)	2	0.14	0.07	0.30	0.30
	Species (S)	2	447.35	223.68	927.80*	
	Interaction (Y×S)	4	0.76	0.19	0.78	
	Error	171	41.23	0.24		
	Total	179	489.48			
Ovary diameter in μ	Cropping season (Y)	2	641.71	320.86	0.18	26.19
	Species (S)	2	10309787	5154893.0	2887.45*	
	Interaction (Y×S)	4	13036.49	3259.12	1.83	
	Error	171	305282.60	1785.28		
	Total	179	10628748.00			

highest (3.00-5.00 mm) in S_1 and S_3 during the three cropping seasons, but in S_2 during 2000-2001 cropping season. The lowest range of long-stamen length (714.50-971.69 μ) was found in S_1 during 2000-2001 cropping season and the highest (1043.20-1643.40 μ) in S_3 during the three cropping seasons. The lowest range of short-stamen length (528.76-685.92 μ) was found in S_1 and the highest (914.56-1443.20 μ) in S_3 during 2000-2001 cropping season. The lowest range of pistil length (4.00-5.00 mm) was found in S_1 and the highest (8.00-9.00 mm) in S_3 during the three cropping seasons. The lowest range of ovary diameter (414.41-528.73 μ) was found in S_1 during 1998-99 cropping season and the highest (1000.30-1128.90 μ) in S_3 during the three cropping seasons.

Standard error of the 8 floral characters of *Striga* spp. during the 3 cropping seasons was less than the corresponding mean. The highest standard error was observed for short stamen length (± 31.31) in S_3 during 2000-2001 cropping season and the lowest for bract length in S_2 (± 0.07) during 1998-99 and 1999-2000 cropping seasons.

The analysis of variance revealed that the item species was significant ($P < 0.05$) for the 8 floral characters. The items cropping season and interaction ($Y \times S$) were non-significant ($P > 0.05$) except bract length. LSD values of the 8 floral characters were also shows that S_1 , S_2 and S_3 were significantly ($P < 0.05$) different (Table-20).

4.2.2C Reproductive characters

Six reproductive characters of *Striga* spp. were analyzed for the determination of range of variation, mean with standard error, analysis of variance and least significant difference and the results tabulated in Table-21 and 22. It was found that the lowest range of flower number per plant (3.00-6.00) was found in S_3 during the three cropping seasons and the highest (10.00-46.00) in S_1 during 1999-2000 cropping season. The lowest range of fruit number per plant (7.00-29.00)

Table-21

Range of variation and mean with standard error of six reproductive characters of the three species of *Striga*

Characters	Species	Range			Mean* with standard error		
		Y ₁	Y ₂	Y ₃	Y ₁	Y ₂	Y ₃
Flower number per plant	S ₁	10.00-14.00	10.00-46.00	5.00-41.00	23.65±1.87	26.86±2.00	24.65±0.87
	S ₂	1.00-16.00	2.00-14.00	2.00-7.00	4.80±0.68	4.35±0.60	3.86±0.36
	S ₃	3.00-6.00	3.00-6.00	3.00-6.00	4.50±0.25	4.45±0.23	4.35±0.24
Fruit number per plant	S ₁	80.00-150.00	70.00-145.00	70.00-185.00	107.30±4.12	112.30±4.69	112.75±6.33
	S ₂	6.00-53.00	3.00-54.00	3.00-53.00	19.15±2.40	23.05±2.65	24.10±2.57
	S ₃	7.00-29.00	7.00-33.00	7.00-30.00	13.70±1.30	15.10±1.70	15.20±1.60
Fruit length in mm	S ₁	4.00-6.00	4.00-6.00	4.00-6.00	5.15±0.13	5.20±0.14	4.95±0.13
	S ₂	4.00-5.00	4.00-6.00	4.00-5.00	4.35±0.10	4.55±0.10	4.63±0.10
	S ₃	8.00-9.00	8.00-9.00	8.00-9.00	8.60±0.10	8.68±0.11	8.60±0.12
Fruit width in mm	S ₁	2.00-3.00	2.00-3.00	2.00-3.00	2.75±0.10	2.55±0.11	2.63±0.10
	S ₂	2.00-3.00	2.00-3.00	2.00-3.00	2.45±0.09	2.33±0.08	2.28±0.08
	S ₃	3.00-4.00	3.00-4.00	3.00-4.00	3.28±0.08	3.23±0.08	3.28±0.08

Table-21 continued

Characters	Species	Range			Mean* with standard error		
		Y ₁	Y ₂	Y ₃	Y ₁	Y ₂	Y ₃
Seed length in μ	S ₁	271.51-385.83	271.51-385.83	257.22-385.83	332.96 $\pm$ 7.41	317.95 $\pm$ 8.03	335.82 $\pm$ 9.25
	S ₂	285.80-385.83	285.80-385.83	285.80-371.54	336.52 $\pm$ 7.51	332.93 $\pm$ 6.59	315.81 $\pm$ 5.48
	S ₃	500.15-643.05	500.15-628.76	500.15-600.15	555.17 $\pm$ 11.47	543.02 $\pm$ 8.98	535.16 $\pm$ 6.76
Seed breadth in μ	S ₁	142.90-214.35	157.48-214.35	142.90-228.64	170.74 $\pm$ 4.91	187.93 $\pm$ 5.10	177.91 $\pm$ 5.44
	S ₂	185.77-257.22	185.77-257.22	185.77-257.22	221.50 $\pm$ 5.44	215.78 $\pm$ 5.28	212.21 $\pm$ 5.51
	S ₃	228.64-328.67	288.64-328.67	228.64-328.67	277.80 $\pm$ 7.48	271.44 $\pm$ 7.42	265.08 $\pm$ 6.84

* Mean of twenty replicates. Y₁=1998-99, Y₂= 1999-2000 and Y₃= 2000-2001 cropping season

Table-22

Analysis of variance for six reproductive characters of the three species of *Striga*

CHARACTERS	ITEMS	DF	SS	MS	F	LSD
Flower number per plant	Cropping season (Y)	2	33.64 ^a	16.82	0.56	3.40
	Species (S)	2	17084.74	8542.37	284.61*	
	Interaction (Y×S)	4	82.82	20.71	0.69	
	Error	171	5132.45	30.01		
	Total	179	22333.66			
Fruit number per plant	Cropping season (Y)	2	556.13	278.07	1.18	9.50
	Species (S)	2	343168.00	171584.00	731.13*	
	Interaction (Y×S)	4	110.13	27.53	0.12	
	Error	171	40130.65	234.68		
	Total	179	383965.00			
Fruit length in mm	Cropping season (Y)	2	0.39	0.19	0.74	0.32
	Species (S)	2	594.45	297.23	1132.61*	
	Interaction (Y×S)	4	1.20	0.30	1.14	
	Error	171	44.88	0.26		
	Total	179	640.92			
Fruit length in mm	Cropping season (Y)	2	0.02	0.02	0.12	0.25
	Species (S)	2	18.99	9.49	59.34*	
	Interaction (Y×S)	4	0.09	0.04	0.27	
	Error	171	18.24	0.16		
	Total	179	37.34			
Fruit width in mm	Cropping season (Y)	2	310520.40	155260.20	1.40	22.48
	Species (S)	2	3421506.00	1710753.00	15.42*	
	Interaction (Y×S)	4	473117.00	118279.20	1.07	
	Error	171	18967382.00	110920.40		
	Total	179	23172526.00			
Seed breadth in μ	Cropping season (Y)	2	1431.53	715.77	0.99	16.66
	Species (S)	2	260131.90	130065.90	180.11*	
	Interaction (Y×S)	4	4046.71	1011.68	1.40	
	Error	171	123484.30	722.13		
	Total	179	389094.40			

was found in S_3 during 1998-99 cropping season and the highest (70.00-185.00) in S_1 during 2000-2001 cropping season. The lowest range of fruit length (4.00-5.00 mm) was found in S_2 during 1998-99 and 2000-2001 cropping seasons and the highest (8.00-9.00 mm) in S_3 during the three cropping seasons. The lowest range of fruit width (2.00-3.00 mm) was found in S_1 and S_2 during the three cropping seasons and the highest (3.00-4.00 mm) in S_3 during the three cropping seasons. The lowest range of seed length (285.80-371.54 μ) was found in S_2 during 2000-2001 cropping season and the highest (500.15-643.05 μ) in S_3 during 1998-99 cropping season. The lowest range of seed breadth (142.90-214.35 μ) was found in S_1 during 1998-99 cropping season and the highest (228.64-328.67 μ) in S_3 during the three cropping seasons.

Standard error of the 6 reproductive characters of *Striga* spp. during the 3 cropping seasons was less than the corresponding mean. The highest standard error was observed for seed length (± 11.47) in S_3 during 1998-99 cropping season and the lowest (± 0.08) for fruit width in S_2 and S_3 during the three cropping seasons.

The analysis of variance revealed that the item species was significant ($P < 0.05$) for the 6 reproductive characters. The items cropping season and interaction ($Y \times S$) were non-significant ($P > 0.05$). LSD values of the 6 reproductive characters were also shows that S_1 , S_2 and S_3 were significantly ($P < 0.05$) different (Table-22).

4.2.3 Component of variation

The δ^2P and δ^2S were partitioned into δ^2Y and δ^2I . The values obtained from the analysis of variance for the selected 26 characters and the results presented in Table-23. The maximum δ^2P and δ^2S were found in ovary diameter and the minimum in corolla width. Most of the characters exhibited low δ^2Y and δ^2I . Among the characters, short stamen length and ovary diameter showed the highest value respectively.

4.2.4 Coefficient of variability as percentage of mean

PCV, GCV, YCV and ICV were computed for the 26 characters separately and the results shown in Table-24. The highest PCV and GCV were estimated for ovary diameter and the lowest in corolla width. Most of the characters showed low YCV and ICV. Table-24 also exhibited that YCV and ICV were lower than PCV and GCV. The highest YCV and ICV were noted for leaf number per plant. Table-24 also exhibits that YCV and ICV were lower than PCV and GCV. The highest YCV and ICV were noted for leaf number per plant.

Number of calyx rib and its frequency presented in Table-25. Number of calyx rib 4-6, 5 was more frequent in S_1 ; 10-15, 13 was more frequent in S_2 and in S_3 14-18, 16 was more frequent. Maximum length of calyx rib (mean with standard error) was 5.90 ± 0.12 , 5.67 ± 0.09 and 9.13 ± 0.23 and minimum was 0.00, 4.16 ± 0.12 and 5.40 ± 0.16 mm in S_1 , S_2 and S_3 respectively. It was observed that S_1 bears more or less equal calyx ribs.

4.3 HOST PARASITE RELATIONSHIP

4.3.1 Growth Pattern of Sugarcane

Seasonal plant height and leaf length (mean with standard error) of control and treated sugarcane were presented in Table-26 and 27 respectively. It was observed that plant height and leaf length of treated sugarcane started to stunt after 70 and 80 days of sugarcane emergence above the ground respectively, when the seeds of *S. densiflora* germinated under the soil, but no sign of emergence above the ground was observed. Leaf breadth of treated sugarcane started to stunt after 90 days of sugarcane emergence above the ground at seedling stage of *S. densiflora* (Table-28).

It was also evident from Table-26 and 27 that plant height and leaf length of treated sugarcane stunted significantly ($P < 0.05$) after 100 and 110 days of sugarcane emergence above the ground at flowering and seed release stage of

Table-23

Component of variation of 12 vegetative, 8 floral and 6 reproductive characters of the 3 species of *Striga* during the 3 cropping seasons

Nature of characters	Characters	δ^2P	δ^2G	δ^2Y	δ^2I
Vegetative	Plant height in cm	782.77	778.65	0.83	4.95
	Branch number per plant	3.57	3.58	0.01	0.0035
	Leaves number per plant	9677.88	9617.63	34.80	95.05
	Leaf length (middle portion of <i>Striga</i>) in cm	2.86	2.89	0.01	0.04
	Leaf breadth in mm	2.72	2.70	0.006	0.03
	Stem diameter at the base in mm	2.05	2.05	0.008	0.011
	Straight hair length in μ	92.73	64.08	3.26	31.91
	Straight hair breadth in μ	438.03	436.24	0.27	1.52
	Glandular hair length in μ	95.11	70.12	16.76	41.75
	Glandular hair breadth in μ	9.28	6.83	0.40	2.85
	Gland length in μ	0.33	0.07	0.41	0.81
	Gland breadth in μ	10.22	6.43	0.47	4.26
Floral	Bract length in mm	5.37	5.37	0.02	0.02
	Calyx length in mm	9.66	9.66	0.004	0.004
	Corolla length in mm	13.23	13.21	0.003	0.02
	Corolla width in mm	0.02	0.01	0.002	0.01
	Long stamen length in μ	53099.24	53096.34	53.55	56.45
	Short stamen length in μ	66237.81	66314.64	111.22	34.39
	Pistil length in mm	3.72	3.72	0.002	0.006
	Ovary diameter in μ	85983.07	85860.57	24.41	146.91
Reproductive	Number of flower per plant	142.00	142.03	0.22	0.19
	Number of fruit per plant	2847.46	2859.27	0.72	12.53
	Fruit length in mm	4.95	4.95	0.001	0.005
	Fruit width in mm	0.22	0.21	0.001	0.01
	Seed length in μ	15672.34	15743.18	35.55	106.39
	Seed breadth in μ	2165.59	2150.90	0.11	14.80

Table-24
Coefficient of variability of 12 vegetative, 8 floral and 6 reproductive characters of the 3 species of *Striga* during the 3 cropping seasons

Nature of characters	Characters	PCV	GCV	YCV	ICV
Vegetative	Plant height in cm	1563.98	1555.74	1.66	9.89
	Branch number per plant	146.91	147.33	0.41	0.12
	Leaves number per plant	8188.41	8137.43	29.44	80.42
	Leaf length (middle portion of <i>Striga</i>) in cm	67.77	68.48	0.24	0.95
	Leaf breadth in mm	67.49	67.00	0.15	0.74
	Stem diameter at the base in mm	66.56	66.56	0.26	0.36
	Straight hair length in μ	36.08	24.93	1.27	12.42
	Straight hair breadth in μ	1014.49	1013.33	0.63	3.53
	Glandular hair length in μ	76.50	56.40	13.48	33.58
	Glandular hair breadth in μ	38.57	28.39	1.66	11.85
	Gland length in μ	1.62	0.34	2.02	3.98
	Gland breadth in μ	36.64	23.05	1.69	15.27
Floral	Bract length in mm	108.92	108.92	0.41	0.41
	Calyx length in mm	120.75	120.75	0.05	0.05
	Corolla length in mm	128.82	128.63	0.03	0.19
	Corolla width in mm	0.52	0.26	0.05	0.26
	Long stamen length in μ	5037.59	5037.32	5.08	5.36
	Short stamen length in μ	8047.26	8056.60	13.51	4.18
	Pistil length in mm	54.79	54.79	0.03	0.09
	Ovary diameter in μ	11873.17	11856.25	3.37	20.29
Reproductive	Number of flower per plant	1259.98	1260.25	1.95	1.69
	Number of fruit per plant	5789.87	5813.89	1.46	25.48
	Fruit length in mm	81.41	81.41	0.02	0.08
	Fruit width in mm	8.00	7.64	0.04	0.36
	Seed length in μ	3923.19	3940.92	8.90	26.63
	Seed breadth in μ	974.35	967.74	0.05	6.66

PCV= Phenotypic coefficient of variability, GCV= Genotypic coefficient of variability, YCV= Cropping season coefficient of variability, ICV= Interaction coefficient of variability

Table-25

Frequency of calyx-rib number, calyx rib length (mean* with standard error) and host range of *Striga* spp.

Spp.	No. of calyx ribs	Frequency	Rib length in mm		Name of the host	Name of the <i>Striga</i> species
			Maximum	Minimum		
S ₁	4	2	5.91±0.12	-	Sugarcane and rice	<i>S. densiflora</i>
	5	17				
	6	1				
S ₂	10	-	5.67±0.09	4.16±0.12	Sugarcane rice and wild grasses	<i>S. lutea</i>
	11	-				
	12	4				
	13	12				
	14	3				
	15	1				
S ₃	14	-	9.13±0.23	5.40±0.16	Sugarcane and rice	<i>S. euphrasioides</i>
	15	7				
	16	9				
	17	4				
	18	-				

*Mean of twenty replications

Table-26

Growth pattern (plant height in cm) of control and treated sugarcane

Measurement after days of emergence	Plant height in cm (Mean* with SE)		Plant height increased (cm/day)		't' value
	Control	Treated	Control	Treated	
10	6.83±2.15	6.78±2.44	0.68	0.68	0.04
20	12.68±1.54	15.95±2.65	0.59	0.92	2.77
30	25.73±2.94	21.15±2.20	1.31	0.25	2.62
40	33.93±3.79	33.08±3.38	0.82	1.19	0.43
50	43.45±4.41	42.50±4.49	0.95	0.94	0.39
60	48.85±4.31	49.70±5.73	0.54	0.72	0.31
70	55.25±4.95	55.15±5.16	0.64	0.55	0.04
80	61.60±4.84	61.15±5.15	0.64	0.60	0.16
90	69.55±5.34	64.30±5.72	0.80	0.32	1.73
100	77.85±5.77	68.30±5.69	0.83	0.40	3.04*
110	84.90±6.42	68.45±5.50	0.71	0.02	5.03*
120	94.85±7.90	67.60±5.45	1.00	0.09	7.35*
130	120.55±9.70	-	2.57	-	32.15*

*Mean of three replications

100 = Flowering and 110 to 130 = Seed release stage of *S. densiflora*

Table-27

Growth pattern (leaf length in cm) of control and treated sugarcane

Measurement after days of emergence	Leaf length in cm (Mean* with standard error)		Leaf length increase (cm/day)		't' value
	Control	Treated	Control	Treated	
10	3.32±1.01	2.70±1.08	0.33	0.27	1.09
20	6.52±0.79	6.58±1.06	0.32	0.39	0.12
30	12.70±1.58	12.20±1.49	0.62	0.56	0.60
40	22.85±3.36	21.85±2.74	1.02	0.97	0.60
50	32.90±2.38	31.20±3.12	1.01	0.94	1.12
60	40.40±2.15	38.35±3.39	0.75	0.72	1.32
70	46.50±2.80	44.45±2.82	0.61	0.61	1.33
80	52.70±4.18	49.65±3.25	0.62	0.52	1.52
90	57.65±4.78	53.30±3.58	0.50	0.39	1.88
100	63.35±5.37	53.55±4.36	0.57	0.03	3.92*
110	70.85±5.47	52.80±4.29	0.75	0.08	6.71*
120	76.80±5.27	52.40±4.01	0.60	0.04	9.31*
130	83.00±4.15	-	0.62	-	51.55*

*Mean of three replications

100 = Flowering and 110 to 130 = Seed release stage of *S. densiflora*

Table-28

Growth pattern (leaf breadth in cm) of control and treated sugarcane

Measurement after days of emergence	Leaf breadth in cm (Mean* with SE)		Leaf breadth increase (cm/day)		't' value
	Control	Treated	Control	Treated	
10	0.58±0.03	0.55±0.05	0.06	0.06	0.04
20	0.78±0.30	0.74±0.05	0.02	0.02	0.05
30	1.01±0.07	0.97±0.06	0.02	0.02	1.33
40	1.18±0.08	1.09±0.05	0.02	0.01	0.14
50	1.25±0.09	1.20±0.07	0.007	0.01	1.25
60	1.34±0.11	1.31±0.09	0.009	0.01	0.60
70	1.45±0.13	1.43±0.16	0.01	0.01	0.25
80	1.55±0.14	1.54±0.13	0.01	0.01	0.14
90	1.65±0.17	1.61±0.11	0.007	0.007	0.50
100	1.73±0.15	1.68±0.13	0.008	0.007	0.38
110	1.80±0.15	1.74±0.14	0.007	0.006	0.25
120	2.20±0.21	1.69±0.14	0.04	0.005	4.50*
130	2.90±0.19	-	0.07	-	8.55*

*Mean of three replications

120 to 130 = Seed release stage of *S. densiflora*

S. densiflora respectively. In case of leaf breadth, the significant ($P < 0.05$) difference between sugarcane of control and treated pots was found after 120 days at seed release stage of *S. densiflora* and at that time period treated sugarcane started to die (Table-28, Fig. 8).

It was also observed that sugarcane of treated pots started to die after 120 days of sugarcane emergence above the ground and after 130 days the treated sugarcane died. It was observed that environmental factors have tremendous role in growth rate (plant height, leaf length and leaf breadth) of both control and treated sugarcane. Growth rate of control sugarcane was measured to be the highest on the 130th day on wards after emergence, whereas *Striga*-parasitized sugarcane died at that time period (Table 26-28).

4.3.2 Leaf moisture and total solid substances

Leaf moisture and total solid substances content in *Striga*-infected sugarcane decreased significantly ($P < 0.05$) over control at the time of *Striga* emergence, at juvenile and at flowering stage of *S. densiflora*. The average decrease of leaf moisture content in *Striga*-infected sugarcane leaves was found to be 3.16, 3.25 and 15.26% and increase of total solid substances content was found to be 3.35, 3.21 and 15.32% over control at the time of *Striga* emergence, at juvenile and at flowering stage of *S. densiflora* respectively (Table-29).

4.3.3 Changes in chlorophyll contents

Changes in chlorophyll content (mg/g) of *Striga*-infected sugarcane leaves compared to their respective healthy check at different stages of growth of *S. densiflora* presented in Table-30. The amount of total chlorophyll, chlorophyll 'a' and chlorophyll 'b' in *Striga*-infected sugarcane leaves were found to be reduced 0.380, 12.797 and 4.081% at the time of *Striga* emergence above the ground and 63.496, 90.298 and 79.923% at flowering stage of *Striga* respectively. The decrease of total chlorophyll, chlorophyll 'a' and chlorophyll 'b' at the time of *Striga* emergence above the ground was non-significant ($P > 0.01$) but significant ($P < 0.05$) at flowering stage of *Striga*, when visible symptoms was observed.

Table-29

Mean* with standard error of moisture contents and total solid substances of control (healthy) and *Striga* infected sugarcane leaves at the three growth stages of *S. densiflora*

Time of estimation	Moisture %			Total solid substances %		
	Mean ¹ with SE		't' value	Mean ¹ with SE		't' value
	Control	Infected		Control	Infected	
At the time of the emergence of <i>Striga</i> above the ground	58.57±0.38	55.41±0.52	3.16	31.46±0.39	34.81±0.44	3.35
At juvenile stage of <i>Striga</i>	58.63±0.30	55.38±0.09	3.25	31.39±0.30	34.60±0.11	3.21
At flowering stage of <i>Striga</i>	58.18±0.24	42.92±0.22	15.26	31.82±0.46	47.14±0.21	15.32

¹= Mean of three replications

Table-30

Effect of *Striga* (mean* with standard error and 't' values) on chlorophyll contents in sugarcane leaves

Description	At the time of <i>Striga</i> emergence			At the time of flowering stage of <i>Striga</i>		
	Chl. a	Chl. b	Total Chl.	Chl. a	Chl. b	Total Chl.
Control	0.790±0.018	0.336±0.028	1.127±0.019	0.778±0.028	0.268±0.042	1.046±0.068
Infected	0.787±0.012	0.293±0.030	1.081±0.035	0.284±0.019	0.026±0.007	0.210±0.078
Decreased%	0.380	12.797	4.081	63.496	90.298	79.923
't' value	0.150	1.048	1.277	10.510*	7.562*	8.360*

*Mean of three replications

Table-31

Status of pH, organic and inorganic matter in the soil of *Striga* infected and control (healthy) sugarcane field

pH, name of organic and inorganic matter	% of pH, organic and inorganic matter (Mean* with SE)		Decreased/increased (%) over control	't' value
	Control	Infected		
PH	8.50±0.00	8.40±0.00	0.10	-
Total organic matter	8.65±0.05	8.91±0.00	-0.26	6.50*
N	1.32±0.03	1.44±0.03	-0.12	3.00
P	0.57±0.00	2.90±0.05	-2.33	58.25*
K	0.57±0.00	0.57±0.00	0.00	-
Ca	3.83±0.05	5.26±0.08	-1.43	15.89*
Mg	1.55±0.03	1.24±0.04	0.31	7.75*
S	3.10±0.06	1.65±0.03	1.45	24.17*
Fe	4.51±0.04	5.28±0.06	-0.77	12.83*
Cu	1.65±0.03	1.62±0.05	0.03	0.50
B	0.001±0.00	0.002±0.00	0.00	-
Mn	3.62±0.10	3.71±0.09	-0.09	0.69
Zn	0.57±0.00	0.57±0.00	0.00	-

*Mean of three replications. '-' refers to increase

4.3.4 Status of pH, organic and inorganic matter in the soil

Status of pH, organic and inorganic matters in the soil of *Striga*-infected and control (healthy) sugarcane field presented in Table-31. Mean pH in the soil of *Striga*-infected sugarcane field decreased non-significantly ($P>0.05$) compared to their control (in the soil of *Striga* free sugarcane field). The average decrease of pH in the soil of *Striga*-infected sugarcane field was found to be 0.10%. Total organic matter content in the soil of *Striga*-infected sugarcane field was increased significantly ($P<0.05$) compared to their control. The average increase of total organic matter in the treated soil was found to be 0.26%. Percentage of available phosphorus, calcium and iron in the soil of *Striga*-infected sugarcane field was increased significantly ($P<0.05$) compared to their control. On the other hand magnesium and sulfur in the soil of *Striga*-infected sugarcane field was decreased significantly ($P<0.05$). Available phosphorus, calcium and iron in the soil of *Striga*-infected sugarcane field was increased 2.33, 1.43 and 0.77% respectively. On the other hand available magnesium and sulfur in the soil of *Striga*-infected sugarcane field was decreased 0.31 and 1.45% respectively. Manganese and copper percentage in the soil of *Striga*-infected sugarcane field decreased non-significantly ($P>0.05$). Potassium, boron and zinc in the soil of *Striga*-infected sugarcane field were unchanged.

4.3.5 Changes in leaf nutrient contents of sugarcane

Changes in total leaf nutrient content of control sugarcane (in the leaves of *Striga* free sugarcane) and treated sugarcane (in the leaves of *Striga*-parasitized sugarcane) presented in Table-32. Percentage of total nitrogen, available phosphorus and potassium in the treated sugarcane leaves decreased significantly ($P<0.05$) compared to their control at the time of *Striga* emergence. The average decrease of total nitrogen, available phosphorus and potassium was found to be 2.56, 0.98 and 2.13% respectively. Available sulfur, calcium and magnesium increased non-significantly ($P>0.05$). The average increase of available sulfur,

Table-32

Mineral nutrient contents (%) of control and *Striga* parasitized sugarcane leaves at different growth stage of *S. densiflora*

Name of the elements	At the time of <i>Striga</i> emergence (Mean ¹ with SE)			't' value	At flowering stage of <i>Striga</i> (Mean ¹ with SE)			't' value
	Control	Treated	Decease/increase		Control	Treated	Decease/increase	
N	7.85±0.06	5.29±0.06	2.56	24.88*	6.63±0.07	4.05±0.07	2.58	23.67*
P	2.73±0.07	1.75±0.02	0.98	9.42*	2.68±0.10	2.06±0.08	0.62	5.17*
K	8.33±0.00	6.20±0.07	2.13	30.43*	7.99±0.06	7.42±0.06	0.57	7.13*
S	2.31±0.09	2.45±0.05	-0.14	1.56	2.09±0.06	2.75±0.07	-0.66	8.25*
Ca	4.68±0.05	4.74±0.06	-0.06	0.86	4.59±0.05	6.11±0.07	-1.52	19.00*
Mg	6.11±0.07	6.38±0.07	-0.27	2.70	5.55±0.08	5.93±0.08	-0.38	3.45

1= Mean of three replications. '-' refers to increase

calcium and magnesium was 0.14, 0.06 and 0.27% respectively. At flowering stage of *S. densiflora*, percentage of available sulfur and calcium in the *Striga*-infected sugarcane leaves increased significantly ($P < 0.05$) compared to their control. The average increase of available sulfur and calcium was found to be 0.66 and 1.52%. The increase of magnesium in the leaves of *Striga*-infected sugarcane was non-significant ($P > 0.05$).

4.3.6 Mineral nutrient contents in *Striga*-infected sugarcane leaves and *S. densiflora*

Mineral nutrient contents in the leaves of *Striga*-infected sugarcane and *S. densiflora* at the time of flowering stage of *S. densiflora* presented in Table-33. Percentage of total nitrogen, available phosphorus, potassium, sulfur, calcium and magnesium in *S. densiflora* increased significantly ($P < 0.05$) compared with *Striga*-parasitized sugarcane leaves. The average increase of total nitrogen, available phosphorus, potassium, sulfur, calcium and magnesium was found to be 2.64, 1.83, 5.65, 1.87, 1.41 and 1.48% respectively.

4.3.7 External morphology of *Striga* sugarcane root association

It was observed that several numbers of haustoria of *S. densiflora* penetrated into sugarcane root and formed a swollen structure and easily identified (Fig. 27). It was also observed that *Striga* root was devoid of root hairs and numbers of root branches were very few.

4.3.8 Internal structure of *Striga*-sugarcane root association

The microscopic examination of the internal structure of infected host root (sugarcane) revealed that the tip of multicellular haustorium penetrated through the epidermis and proliferated in the cortex. In the cortex haustorium grew independently, spread through the tissues and formed contacts with the vascular elements and found to establish connection between the vascular tissue of the host (sugarcane) and parasite (*S. densiflora*) (Fig. 28).

Table-33

Mineral nutrient contents (%) of *Striga* parasitized sugarcane leaves and *S. densiflora* leaves at flowering stage of *S. densiflora*

Name of the elements	Mineral nutrient content (%) (Mean* with standard error)		Increased (%) over cane leaves	't' value
	Cane leaves	<i>Striga</i>		
N	4.48±0.05	7.12±0.06	2.64	37.71*
P	2.04±0.06	3.87±0.05	1.83	26.14*
K	5.39±0.05	11.04±0.04	5.65	94.17*
S	2.38±0.05	4.25±0.07	1.87	23.38*
Ca	5.93±0.08	7.34±0.06	1.41	15.67*
Mg	6.11±0.07	4.63±0.07	1.48	16.44*

*Mean of three replications

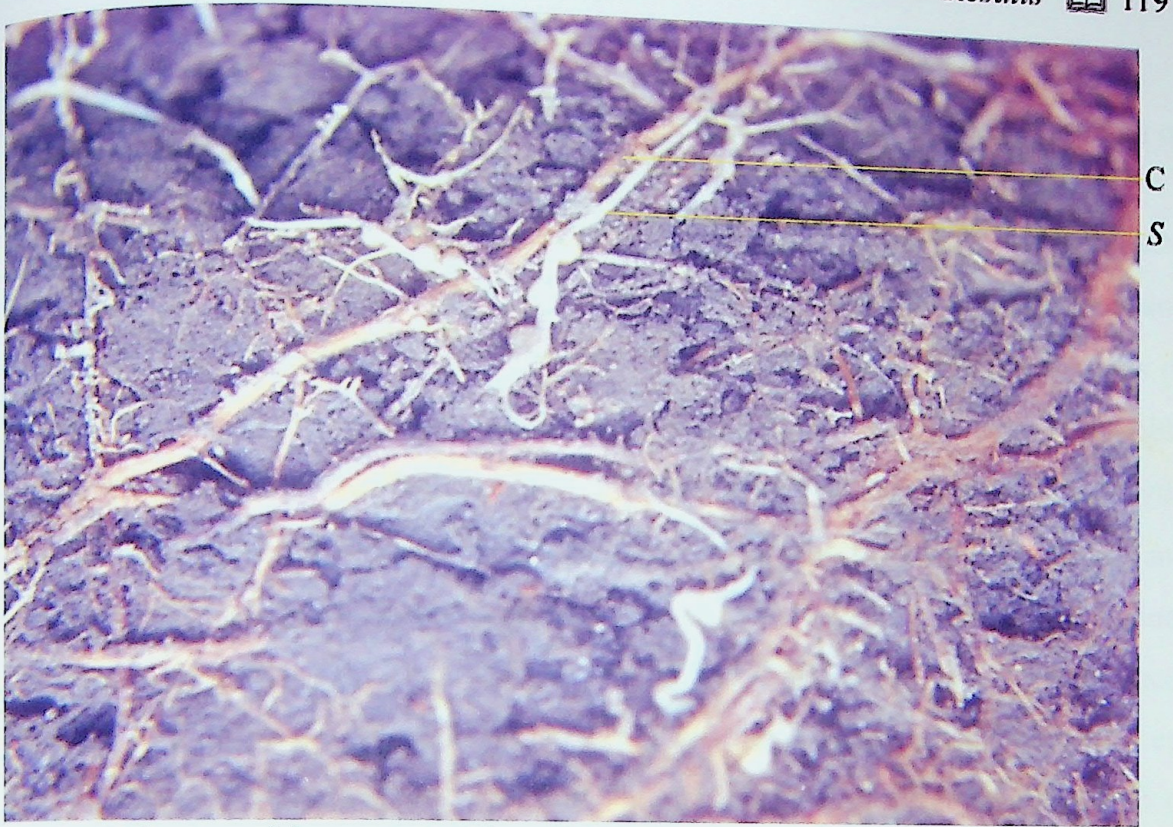


Figure-27 Photographic representation of external morphology of host root (sugarcane) and *Striga* root association (S= *Striga* root, C= Cane root)



Figure-28 Photographic representation of internal structure of host root (sugarcane) and *Striga* root association (H= Haustorium)

4.4 EFFECT OF *STRIGA* ON AGRONOMIC YIELD CHARACTERS OF SUGARCANE

Several economically important agronomic yield characters of control and *Striga*-infected sugarcane of the selected five locally cultivated improved cane varieties were presented in Table-34. Nine selected agronomic yield characters of the selected five improved cane varieties were studied, such as number of millable cane per square meter, stalk height, internode number, basal internode length, middle internode length, terminal internode length, stalk diameter at the base and at the top, unit stalk weight. Assessment of losses in *Striga* infected canes compared to control one (healthy) was made and significant ($P < 0.05$) differences were found in maximum yield characters of all the five selected varieties except basal internode length of Isd-2/54, Isd-25 and Bs-96; middle internode length of Isd-2/54; terminal internode length of Isd-18, Isd-2/54 and Isd-25; stalk diameter at the base of Isd-18 and Isd-2/54 and stalk diameter at the top of Isd-25 (Table-35).

Reduction percentage of agronomic yield characters of control and *Striga* infected sugarcane of the five selected varieties after 8 months of plantation and 4 months of *Striga* emergence above the ground were tabulated in Table-36. Number of millable cane reduced minimum 89.72% in Isd-16 while maximum 91.67% in Isd-2/54, but in case of stalk height in cm minimum 60.54% in Bs-96 and maximum 68.35% in Isd-25. The reduction of internode number, basal internode length, middle internode length and terminal internode length in cm were found to be minimum 0.27 in Isd-25, 18.57 in Bs-96, 1.83 in Isd-18 and 2.87% in Bs-96; maximum 28.77, 39.97, 28.47 and 19.60% in Isd-16 respectively. The reduction of stalk diameter at the base and at the top in cm was found to be minimum 18.42 and 80.08% in Bs-96; maximum 55.56 and 83.08% in Isd-18 respectively. Stalk weight in g reduced minimum 89.72% in Isd-16 while maximum 91.67% in Isd-2/54.

Table- 34

Mean* with standard error of agronomic yield characters of control and *Striga* infected sugarcane of the five selected varieties after eight months of plantation

Characters	Name of the varieties									
	Isd - 16		Isd - 18		Isd - 2/54		Isd - 25		Isd - 96	
	Control	Infected	Control	Infected	Control	Infected	Control	Infected	Control	Infected
Number of millable cane per sq. meter	12.65±0.50	1.30±0.16	13.40±0.45	1.20±0.17	13.20±0.54	1.10±0.02	13.35±0.46	1.15±0.17	13.1±0.53	1.25±0.19
Stalk height in cm	135.45±2.55	70.75±4.53	135.70±2.81	53.00±0.96	119.75±3.64	40.20±1.20	112.65±1.33	37.08±0.91	122.75±1.53	71.75±4.89
Internode number	12.85±0.36	4.90±0.27	12.65±0.28	4.35±0.11	13.10±0.41	4.35±0.15	11.85±0.31	3.75±0.10	13.05±0.25	5.15±0.26
Basal internode length in cm	8.62±0.14	6.14±0.19	11.86±0.13	11.12±0.18	7.30±0.23	7.28±0.21	9.20±0.20	8.20±0.20	5.61±0.14	5.24±0.24
Middle internode length in cm	12.91±0.30	7.75±0.20	12.76±0.17	9.78±0.15	10.80±0.17	8.76±0.17	9.99±0.12	7.34±0.13	9.48±0.08	7.72±0.21
Terminal internode length in cm	8.78±0.19	6.28±0.08	8.72±0.19	8.56±0.19	6.55±0.23	6.09±0.28	7.35±0.15	6.39±0.13	5.68±0.04	5.32±0.08
Stalk diameter at base in cm	1.99±0.05	1.60±0.06	1.63±0.06	1.52±0.06	1.68±0.04	1.62±0.03	1.93±0.01	1.73±0.11	2.09±0.03	2.03±0.04
Stalk diameter at top in cm	1.59±0.03	1.07±0.04	1.35±0.03	0.60±0.03	1.76±0.03	0.88±0.02	1.85±0.03	0.96±0.006	1.52±0.04	1.24±0.03
Stalk weight in g	444.85±16.32	86.70±7.90	418.15±30.71	70.75±6.20	400.06±20.81	69.90±3.41	424.15±14.57	72.50±2.75	438.50±15.66	87.35±7.71

*Mean of twenty replicates

Table-35

't' values for different agronomic yield characters of control and *Striga* infected sugarcane after eight months of plantation

Characters	Name of the varieties				
	Isd-16	Isd-18	Isd-2/54	Isd-25	Bs-96
Number of millable cane/sq. m	21.42*	25.42*	21.23*	24.90*	21.16*
Stalk height in cm	12.44*	27.87*	20.77*	47.05*	9.96*
Internode number	18.93*	27.67*	19.89*	25.55*	4.70*
Basal internode length in cm	10.33*	3.36*	0.06	2.00	1.32
Middle iternode length in cm	14.33*	13.55*	1.65	14.72*	8.00*
Terminal internode length in cm	12.5*	0.59	1.24	1.12	4.00*
Stalk diameter at the base in cm	4.44*	1.38	1.20	3.33*	1.20
Stalk diameter at the top in cm	10.40*	18.75*	1.49	3.18*	5.60*
Stalk weight in g	18.12*	11.09*	15.66*	23.73*	20.12*

Table-36

Reduction percentage of agronomic yield characters of control and *Striga* infected sugarcane of the five selected varieties after 8 months of plantation

Characters	Name of the varieties				
	Isd-16	Isd-18	Isd-2/54	Isd-25	Bs-96
Number of millable cane/sq. m	89.72	91.04	91.67	91.39	90.46
Stalk height in cm	47.77	65.96	66.43	67.08	41.55
Internode number	61.87	65.61	66.79	68.35	60.54
Basal internode length in cm	28.77	6.24	0.27	10.87	6.60
Middle iternode length in cm	39.97	23.35	18.89	26.53	18.57
Terminal internode length in cm	28.47	1.83	7.02	13.06	6.34
Stalk diameter at the base in cm	19.60	6.75	3.57	10.36	2.87
Stalk diameter at the top in cm	32.70	55.56	50.00	48.11	18.42
Stalk weight in g	80.51	83.08	82.53	82.91	80.08

4.4.1 Juice extraction percentage

It was evident from Table-37 that juice extraction percentage of all the 5 selected cane varieties decreased significantly ($P < 0.05$) in *Striga*-infected sugarcanes compared to control one (healthy). The decrease in juice extraction in selected cane varieties ranged from 6.14 to 8.60%.

4.4.2 Juice pH of control (healthy) and *Striga* infected sugarcane

Measurement of juice pH of control (healthy) and *Striga*-infected sugarcane were presented in Table-38. Juice pH decreased over control was found to be 3.85% in the juice of all the selected five improved cane varieties.

4.4.3 Fibre percentage of cane

Fibre content in *Striga*-infected sugarcanes of all the 5 selected cane varieties increased significantly ($P < 0.05$) compared to their control (healthy). The increase of fibre in *Striga*-infected sugarcanes ranged from 4.94 to 7.44% (Table-39).

4.4.4 Brix percentage in Juice

Mean brix percentage in juice of *Striga*-infected sugarcanes of all the 5 selected varieties decreased significantly ($P < 0.05$) compared to healthy canes (control). The decrease in brix in juice of selected cane varieties ranged from 32.46 to 36.82% (Table-40).

4.4.5 Pol percentage in juice

Mean pol percentage in juice of *Striga*-infected sugarcanes of all the 5 selected varieties was decreased significantly ($P < 0.05$) compared to healthy canes (control). The decrease in pol in juice of selected cane varieties ranged from 47.25 to 52.44% (Table-41).

Table-37

Juice extraction percentage of control (healthy) and *Striga* infected sugarcane stalk after 8 months of plantation

Name of the variety	Mean* with standard error		Decreased (%)	't' value
	Control	Infected		
Isd-16	47.05±0.17	44.16±0.19	6.14	12.04*
Isd-18	47.50±0.28	43.93±0.08	7.52	12.31*
Isd-2/54	48.54±0.23	44.64±0.25	8.03	11.82*
Isd-25	48.31±0.07	45.33±0.08	6.17	5.73*
Bs-96	48.00±0.21	43.87±0.14	8.60	17.21*

*Mean of three replications

Table-38

Measurement of Juice pH of control (Healthy) and infected sugarcane stalk

Name of the variety	Control	Infected	Decreased over control	Decreased%
Isd-16	5.20	5.00	0.20	3.85
Isd-18	5.20	5.00	0.20	3.85
Isd-2/54	5.20	5.00	0.20	3.85
Isd-25	5.20	5.00	0.20	3.85
Bs-96	5.20	5.00	0.20	3.85

Mean of three replications

Table-39

Fibre percentage of control (healthy) and *Striga* infected sugarcane stalk after 8 months of plantation

Name of the variety	Mean* with standard error		Decreased (%)	't' value
	Control	Infected		
Isd-16	22.46±0.15	24.07±0.08	4.94	12.67*
Isd-18	22.46±0.15	24.07±0.08	6.69	10.06*
Isd-2/54	22.27±0.16	23.99±0.11	7.17	10.12*
Isd-25	21.53±0.14	23.26±0.11	7.44	10.18*
Bs-96	21.53±0.10	23.08±0.11	6.72	11.07*

*Mean of three replications

Table-40

Brix (%) in juice of control (healthy) and *Striga* infected sugarcane stalk after 8 months of plantation

Name of the variety	Mean* with standard error		Decreased (%)	't' value
	Control	Infected		
Isd-16	23.89±0.04	15.19±0.13	36.42	62.14*
Isd-18	24.17±0.08	15.27±0.06	36.82	98.89*
Isd-2/54	24.12±0.07	15.56±0.05	35.49	107.00*
Isd-25	23.91±0.06	16.15±0.07	32.46	77.60*
Bs-96	23.92±0.02	15.56±0.04	34.95	104.50*

*Mean of three replications

Table-41

Pol (%) in juice of control (healthy) and *Striga* infected sugarcane stalk after 8 months of plantation

Name of the variety	Mean* with standard error		Decreased (%)	't' value
	Control	Infected		
Isd-16	22.25±0.06	10.68±0.01	52.00	105.18*
Isd-18	22.33±0.10	10.83±0.18	51.50	57.50*
Isd-2/54	22.33±0.12	11.78±0.14	47.25	52.75*
Isd-25	21.70±0.11	10.63±0.07	51.01	92.25*
Bs-96	21.89±0.04	10.41±0.12	52.44	114.80*

*Mean of three replications

4.4.6 Purity percentage of juice

It was evident from Table-42 that mean purity percentage of juice of *Striga*-infected sugarcane of all the 5 selected varieties decreased significantly ($P<0.05$) compared to healthy canes (control). The decrease in purity of juice of selected cane varieties ranged from 29.09 to 40.53%.

4.4.7 Commercial cane sugar (CCS) percentage in juice

It was found that commercial cane sugar (CCS) percentage in juice of *Striga*-infected sugarcane of all the 5 selected varieties decreased significantly ($P<0.05$) compared to healthy canes (control). The decrease in CCS in juice of selected cane varieties ranged from 57.09 to 75.08% (Table-43).

4.4.8 Germination percentage of ratoon cane groves

Germination percentage of ratoon cane groves of control and *Striga*-infected sugarcane in the pot experiment presented in Table-44. Hundred per cent ratoon cane grove of control (healthy) were germinated, whereas only 20% *Striga*-infected ratoon cane groves were germinated. Germination decreased in *Striga*-infected ratoon cane groves over control was found to be 80.00%.

4.4.9 Biochemical changes of *Striga* infected sugarcane

Total sugar, reducing sugar, non-reducing sugar and sucrose content in total tissue samples were taken from control (healthy) and *Striga*-infected sugarcane after 8 months of plantation and 4 months of *Striga* emergence above the ground are presented in Table-45. Total sugar, non-reducing sugar and sucrose percentage in *Striga*-infected sugarcane decreased significantly ($P<0.05$) compared to their control (healthy). Average decrease of total sugar, non-reducing sugar and sucrose in *Striga*-infected sugarcane over control was found to be 17.49, 19.41 and 19.32% respectively. On the other hand total reducing sugar increased significantly ($P<0.05$) compared to their control. Average increase of total reducing sugar was found to be 16.39%.

Table-42

Purity (%) of juice of control (healthy) and *Striga* infected sugarcane stalk after 8 months of plantation

Name of the variety	Mean* with standard error		Decreased (%)	't' value
	Control	Infected		
Isd-16	69.27±0.19	44.55±0.24	35.69	77.25*
Isd-18	67.78±0.21	45.25±0.18	33.24	86.65*
Isd-2/54	68.22±0.09	43.51±0.03	36.22	274.56*
Isd-25	58.50±0.08	41.48±0.06	29.09	141.83*
Bs-96	68.81±0.14	40.92±0.08	40.53	174.31*

*Mean of three replications

Table-43

Commercial cane sugar (CCS) (%) in juice of control (healthy) and *Striga* infected sugarcane stalk after 8 months of plantation

Name of the variety	Mean* with standard error		Decreased (%)	't' value
	Control	Infected		
Isd-16	15.79±0.05	5.11±0.05	67.64	178.00*
Isd-18	15.30±0.03	5.50±0.08	64.05	108.89*
Isd-2/54	15.45±0.09	6.63±0.07	57.09	73.50*
Isd-25	14.89±0.11	4.06±0.12	72.73	77.36*
Bs-96	15.53±0.11	3.87±0.12	75.08	83.29*

*Mean of three replications

Table-44

Germination percentage of ratoon cane groves of control and *Striga* infected pot

Characters	Mean* with standard error		
	Control	Infected	Decreased over control
No. of grove germinated	20±0.00	4±0.47	16±0.47
Percentage of grove germinated	100	20	80

*Mean of three replications

4.5 LIFE CYCLE OF *STRIGA DENSIFLORA*

The results of the study of life cycle of *S. densiflora* in the field and pot experiments were presented in Table-46. It was observed that *S. densiflora* started to emerge above the ground in May after early rain during the summer in the field and in earthen pots in April. It was also observed that 139.95 ± 0.71 days required for *S. densiflora* emergence above the ground after sowing of sugarcane setts in previously *Striga*-infested field and 111.20 ± 2.89 days in earthen pots. In the field 34.70 ± 0.74 days required for first flower appearance after emergence of *S. densiflora* and 20.85 ± 1.69 days in earthen pots. First fruit set after 37.70 ± 0.73 days of emergence in the field and 25.30 ± 1.76 days in earthen pots. Fruits matured and seeds were released after 55.05 ± 0.46 days of emergence in the field and 37.51 ± 1.80 days in earthen pots. In the field *S. densiflora* died after 85.05 ± 0.46 days of emergence and in earthen pots after 70.10 ± 2.31 days.

4.5.1 Growth pattern (seasonal plant height) of *S. densiflora*

It was observed that growth of *S. densiflora* was very rapid before first flower appearance (31.40 ± 2.09 and 23.43 ± 1.27 cm) in both the field and pot experiment. It was also observed that growth rate cm/day was very high at juvenile stage i.e. before first flower appearance (1.18 and 1.03) and very low at seed release stage i.e. maturing stage (0.30 and 0.43) in both the field and pot experiments (Fig. 25). The parasite releases its seeds within 55.05 ± 0.46 and 37.51 ± 1.80 days of emergence above the ground in both the environmental conditions (field and pot) respectively. The host plant (sugarcane) started to be stunt in growth i.e. visible symptoms appeared at flowering stage of *S. densiflora* in both the field and pot experiments.

It was also observed that, plant height of *S. densiflora* was higher in the field than that of pot experiment. Growth rate of *S. densiflora* was also higher in the field than that of pot experiment (Fig. 29). Higher growth rate of *S. densiflora* was found in the field due to its environmental conditions and supply of mineral nutrients.

Table-45

Estimation of total sugar, reducing sugar, non-reducing sugar and sucrose percentage of control (healthy) and *Striga* infected sugarcane stalk

Characters	Mean* with standard error		Decreased/Increased over control (%)	't' values
	Control	Infected		
Total sugar	16.30±0.16	11.35±0.12	30.37	24.80*
Reducing sugar	1.02±0.02	1.22±0.02	-16.39	9.35*
Non-reducing sugar	15.28±0.17	10.12±0.13	33.77	23.76*
Sucrose percent	14.52±0.17	9.62±0.12	33.75	23.76*

*Mean of three replications

Table-46

Observation of some selected plant characters related to life cycle of *S. densiflora* in the field and pot experiments

Selected characters	Duration (Mean* with SE)	
	Field experiment	Pot experiment
Date of plantation	5-1-99	1-1-2000
Date of the first emergence of <i>S. densiflora</i>	24-5-99	10-4-2000
Number of days required for emergence of <i>S. densiflora</i> after plantation	139.95±0.71	111.20±2.89
Number of days required for flowering of <i>S. densiflora</i> after emergence	34.70±0.74	20.85±1.69
Number of days required for first fruit seat of <i>S. densiflora</i> after emergence	37.70±0.73	25.30±1.76
Number of days required for release of seeds of <i>S. densiflora</i> after emergence	55.05±0.46	37.50±1.80
Number of days required for death of <i>S. densiflora</i> after emergence	85.05±0.46	70.10±2.31

* Mean of three replications

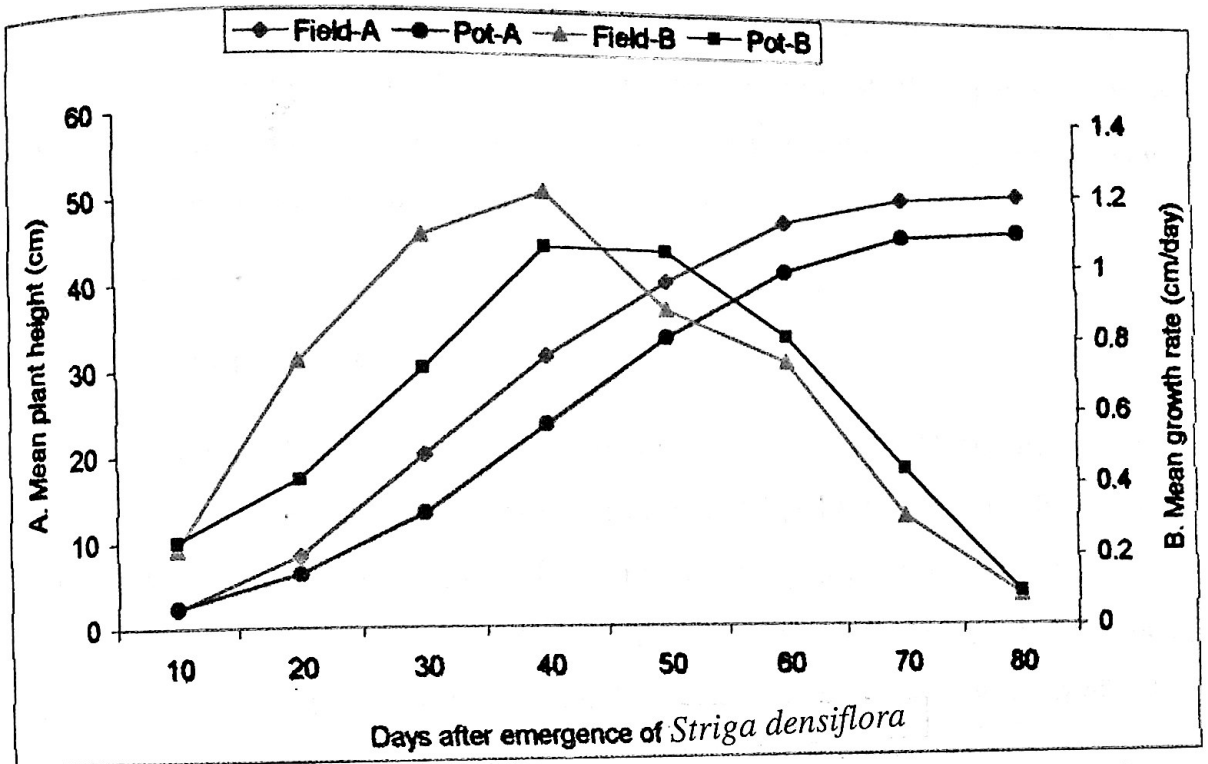


Figure-29 Graphic representation of the growth and development of *S. densiflora*

4.6 MANAGEMENT OF *STRIGA* PROBLEMS IN BANGLADESH

4.6.1 Eradication

It was observed from the *Striga* eradicated sugarcane planted pots that weeding was successful in early stages of growth of this parasitic weed (*Striga*). Within 3 months 9-12 weeding was needed and it is very costly, which makes this method discouraging to the growers, so this conventional practice was not found effective for *Striga* spp.

4.6.2 Effect of plant hormone (2,4-D)

For the control of *S. densiflora*, the plant hormone (2,4-D) has been sprayed on pot culture experiments. Ten concentrations of 2,4-D, such as 60, 70, 80, 100, 200, 300, 400, 500, 1000 and 2000 ppm were sprayed on pot experiment in the sunny day. Except 2000 ppm all showed negative result. Hundred per cent *S. densiflora* was dead after 3 days of application 2000 ppm concentration of 2,4-D at the juvenile stage of this parasitic weed (Table-47).

It was also evident from Table-47 that a few number of *S. densiflora* emerged from the same place within 10-15 days after the application of first hormone spray. It was found that the number of *S. densiflora* increased with the increase of duration but it decreased in second time of spray made after 30 days of first spray. Table-47 again showed that the application of 2000 ppm concentration of 2,4-D always inhibited (100%) both in second and third time of spray. Rest of the concentrations had no inhibition effect against *S. densiflora*.

4.6.3. Effect of urea solution

Four different concentrations of urea solution (1, 2.5, 5 and 7.5) were sprayed on pot culture experiments in the sunny day. It was observed that except 1% urea solution, all other concentrations showed positive results. Hundred per cent *S. densiflora* died after a day of application 2.5, 5 and 7.5% urea solution (Table-48, Fig. 30).

Table-47
Effect of plant hormone (2,4-D) on the inhibition of *S. densiflora*

Conc. in ppm	At the juvenile stage of <i>S. densiflora</i>					After 30 days of first spray					After 30 days of second spray				
	Mean* with SE			Percentage of death	Mean* with SE			Percentage of death	Mean* with SE			Percentage of death			
	No. of <i>Striga</i>	Dead <i>Striga</i>	No. of days req. for death		No. of <i>Striga</i>	Dead <i>Striga</i>	No. of days req. for death		No. of <i>Striga</i>	Dead <i>Striga</i>	No. of days req. for death				
60	4	0	-	-	10	0	-	-	12	0	-	-			
70	3	0	-	-	12	0	-	-	13	0	-	-			
80	4	0	-	-	17	0	-	-	18	0	-	-			
100	6	0	-	-	14	0	-	-	16	0	-	-			
200	5	0	-	-	16	0	-	-	17	0	-	-			
300	3	0	-	-	11	0	-	-	13	0	-	-			
400	5	0	-	-	14	0	-	-	15	0	-	-			
500	2	0	-	-	12	0	-	-	14	0	-	-			
1000	6	0	-	-	18	0	-	-	19	0	-	-			
2000	4	4	3	100	10	10	3	100	7	7	3	100			

*Mean of three replications

It was also evident from Table-48 that a few number of *Striga* emerged from the same place after the application of first spray of urea solution within 15-20 days. It was found that the number of *S. densiflora* increased with the increase of duration but it decreased in second time of spray after 30 days of first spray. Table-48 again showed that the application of 2.50, 5.00 and 7.50% urea solution always inhibited (100%) both in second and third time spray. Rest one had no inhibition effect against *S. densiflora*.

4.6.4 Application of chemical fertilizer (NPK) on inhibition of seed germination

Effect of chemical fertilizer (NPK) in different ratio on the inhibition of seed germination of *S. densiflora* was presented in Table-49. Seven different ratio of NPK were applied on the pot culture experiments at the time of plantation. Second time N:P 3:3 g/pot were applied except control during the month of April. In control pots (No chemical fertilizer were used) 4.80% seeds of *S. densiflora* were germinated. Significant ($P<0.05$) reduction of seed germination was found in all the treatments except where 5:5:5 g NPK was applied. The highest significant ($P<0.05$) reduction was observed where 40:0:0 g NPK was applied.

4.6.5 Cultivation of some plants for the suppression of seed germination of *S. densiflora* as crop rotation

Six rabi crops including 5 legumes were cultivated with the seeds of *S. densiflora* in pot culture experiments as suppressive crop rotation plants and the next year sugarcane was cultivated in those pots. Significant ($P<0.05$) inhibition in seed germination were observed in all the treatments. The highest significant ($P<0.05$) inhibition was found where *Cicer arietinum* was cultivated (Table-50).

Table-48
Effect of different concentration of urea solution on the inhibition of *S. densiflora*

Conc. of solution in %	At the juvenile stage of <i>S. densiflora</i>				After 30 days of first spray				After 30 days of second spray			
	Mean* with SE			Percentage of death	Mean* with SE			Percentage of death	Mean* with SE			Percentage of death
	No. of <i>Striga</i>	Dead <i>Striga</i>	No. of days req. for death		No. of <i>Striga</i>	Dead <i>Striga</i>	No. of days req. for death		No. of <i>Striga</i>	Dead <i>Striga</i>	No. of days req. for death	
1.00	5	0	-	-	12	0	-	-	19	0	-	-
2.50	4	4	1	100	12	12	1	100	4	4	1	100
5.00	6	6	1	100	7	7	1	100	3	3	1	100
7.50	5	5	1	100	9	9	1	100	5	5	1	100

*Mean of three replications



Figure30 Photographic representation of dead *Striga* after urea solution spray

Table-49

Application of chemical fertilizer (NPK) in different ratio on the inhibition of seed germination of *S. densiflora*

Fertilizer ratio (N:P:K)	No. of seed applied	No of <i>Striga</i> emergence (Mean* with SE)		Total No. of <i>Striga</i> (Mean* with SE)	Percentage of <i>Striga</i> emergence	't' value
		First time	Second time			
0:0:0	1500	45.00±2.09	23.33±2.20	68.33±1.86	4.53	-
5:5:5	1500	42.00±1.15	18.00±1.54	60.00±1.00	4.00	3.95
7:7:7	1500	40.33±1.46	17.67±0.89	58.00±0.58	3.87	5.32*
8:8:8	1500	39.00±1.15	16.33±1.20	55.33±1.86	3.69	4.96*
9:9:9	1500	32.00±1.53	11.67±0.88	43.67±1.77	2.91	8.85*
10:5:5	1500	28.67±1.77	8.67±1.53	37.33±2.34	2.49	10.40*
20:0:0	1500	17.33±2.19	6.33±0.88	27.00±0.58	1.80	21.30*
40:0:0	1500	11.00±1.16	3.67±0.33	14.67±0.88	0.98	26.18*

*Mean of three replications First time = Fertilizer applied at the time of plantation
Second time = Fertilizer applied during the month of March

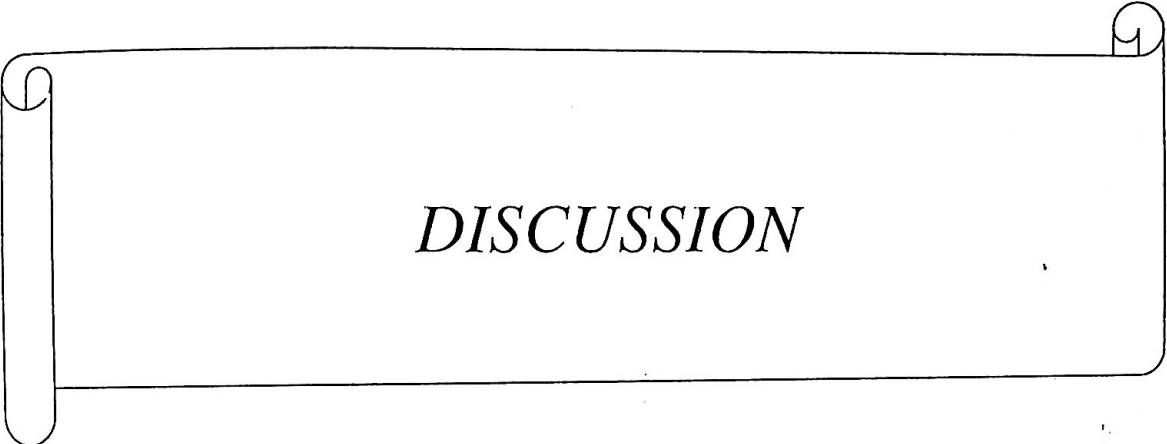
Table-50

Cultivation of some plants for the suppression of seed germination of *S. densiflora*

Name of the cultivated crops	No. of <i>Striga</i> seeds applied	No. (Mean* with SE) of <i>Striga</i> emergence	Percentage of germination of the seeds of <i>Striga</i>	't' value
Control	1500	68.33±1.86	4.53	-
<i>Vigna mungo</i>	1500	58.00±2.31	3.87	5.33
<i>Gossypium hirsutum</i>	1500	40.33±2.40	2.69	9.21*
<i>Pisum sativum</i>	1500	29.33±1.20	1.96	17.65*
<i>Lathyrus sativus</i>	1500	27.00±1.25	1.80	18.45*
<i>Lens esculenta</i>	1500	40.67±2.73	2.71	7.44*
<i>Cicer arietinum</i>	1500	24.00±2.31	1.60	14.98*

*Mean of three replications

CHAPTER V



DISCUSSION

DISCUSSION

Striga infestation of sugarcane (*Saccharum officinarum*) has directly been established as the most destructive and important problem for sugarcane growers in the northern part of Bangladesh (Ahmed and Mian, 1977; Zuberi and Biswas, 1986; Rahman *et al.*, 1988). So the damage of this cash crop positively affect the source of sugar and gour which ultimately affect the Food and Sugar Corporation of Bangladesh as well as our National Economy.

Symptoms

Symptoms of *Striga* infestation were similar to the report of Ahmed and Mian (1977) and Anon. (1979). Due to heavy *Striga* infestation in the field, most of the host plants (sugarcane) died and the whole field showed a burned appearance, which also confirmed the findings of Ahmed (1977) and Zuberi and Biswas (1986).

Incidence of *Striga* infestation

Incidence of *Striga* infestation of sugarcane fields was studied during three successive cropping seasons (1998-99 to 2000-2001). The highest *Striga* contamination was found at Nawdara (50), Mukterpur (65) and Solowa and Vatopara (60) and the lowest at Nalkala (20) and Varamara (25 and 20) during 1998-99, 1999-2000 and 2000-2001 cropping seasons respectively. Percentage of *Striga* infested plot was the highest at Askerpur (30) and Fakirpara (35 and 30) and the lowest at Dararchar (15) and Varamara (10) during 1998-99, 1999-2000 and 2000-2001 cropping seasons respectively. Incidence of *Striga* infestation of sugarcane was the highest at Dararchar (29.57), Solowa (18.38) and Nalkala (15.65) and the lowest at Nalkala (3.52 and Nawdara (3.46 and 1.46) during 1998-99, 1999-2000 and 2000-2001 cropping seasons respectively.

The soil of Nawdara, Mukterpur, Solowa and Vatopara were sandy-loam and the fields were high and medium high land than that of Dararchar and Varamara, which is suitable for the growth and development of *Striga* spp. The maximum plots of Dararchar and Varamara were low land, soil condition silty loam and the plots were under waterlogged condition where *Striga* spp. cannot survive. This observation and comment is also supported by the report of Anon. (1979). Singh (1983), Zuberi and Biswas (1986) and Matin *et al.* (1989) also reported that *Striga* was more common in light sand, sandy loam and loam soil than in heavy clay.

It was observed that percentage of *Striga* contamination, infested plot and *Striga* incidence differs from locality to locality during cropping season to cropping season. It was also observed that where the *Striga* incidence was higher during the first cropping season, it was the lowest during the next cropping season. Huge crop yield losses due to *Striga* infestation discourage the growers to cultivate sugarcane in newly *Striga* infested plots, and they wait for a certain period (3-4 cropping seasons) to cultivate sugarcane again. After waiting a certain period, the growers cultivate sugarcane in the previously *Striga* infested plots and the cane plots would be infested with *Striga* due to its long period of seed viability. For these reasons high variability of *Striga* infestation was observed within the localities during various cropping seasons.

Population density of *Striga* spp.

Population density of this parasitic weed per square metre was more or less equal in number in both the locations. Differences of population density of *Striga* among the visited areas were not remarkable which might be due to more or less similar land topography, soil texture and environmental conditions. This observation is in agreement with the findings of Zuberi and Biswas (1986).

Behaviour and distribution

During the present study maximum *Striga* infestation was found to occur in the months of July-August, when maximum predisposing environmental factors for the growth and development of *Striga* spp. were found (Anon. 2001). During the months of August-September, heavy rainfall was helpful for the dissemination of *Striga* seeds by rainwater. After this *Striga* plants died. Similar results were also reported elsewhere (Ahmed and Mian, 1977; Anon., 1979 and Zuberi and Biswas, 1986).

It was observed during the course of the visits that the parasite started to appear above the ground at the end of April after the early rain during the summer, continued to be present up to October. Even in the early June, population of the *Striga* consists of plants with mature fruits dispersing seeds, plants beginning to flower and plants, which are still in the juvenile stage of growth. During the months of June and July heavy occurrences were noticed. The cane areas where the parasite appeared comparatively earlier in the season were more affected which also confirmed the findings of Anon. (1979).

Anon. (1979) a preliminary survey was conducted to study the behaviour and distribution of *Striga* in the northern part of Bangladesh and reported that the parasite has covered an area of 400 square miles and is distributed in the region of Ishurdi, Natore, Puthia, Sardah and Krishna. During May, June and July heavy occurrences of *Striga* were noticed. The cane areas where the parasites appeared comparatively earlier were more affected.

Generally high and dry lands were infested, while in low lands where water logging conditions prevailed, were free from *Striga* infestation. The incidence was more on sandy and sandy loam soil than on heavy soil. These investigated results are in agreement with the report of Anon. (1979). Nelson (1958) working on *S. asiatica*, found that the weed was more common in light sand, sandy loam and loam soil than heavy clay.

In Barind region sugarcane is not cultivated because the soil is not fit for sugarcane cultivation. This region is free from *Striga* spp. due to non-availability of its host (sugarcane).

From the distribution and population density of this parasitic weed in Bangladesh, it appears that it is a localized problem. The parasitic weed has covered an area of 1300 sq. km. *Striga* is more prevalent between the region of Varamara to Joypurhat. This finding supported the report of Anon. (1979). It was also observed that three species of *Striga* are present in Bangladesh and among them *S. densiflora*, is more common and destructive. Rahman *et al.* (1988) reported that *Striga* covers an area of 450 square miles under the greater districts of Pabna, Rajshahi, Bogra and Kushtia causing lot of troubles in sugarcane cultivation. It has become alarming for sugarcane cultivation since it is spreading fast over new areas.

Introduce and establishment

No information is available about the first appearance of *Striga* spp. in Bangladesh and adjoining region. It is thought that the place of first appearance of this parasitic weed was nearest to the oldest sugar mill of the country where the improved cane varieties were introduced as a seed cane from India and distributed among the growers. The parasite was recorded in India in the year 1912 (Luthra, 1921).

The North Bengal Sugar Mills Ltd. is the oldest sugar mill of Bangladesh situated at Azimpur (Gopalpur) near Ishurdi under Natore district. The Bangladesh Sugarcane Research Institute (BSRI) also situated at Ishurdi under Pabna district. In the past the *Striga* contaminated areas were under the North Bengal Sugar Mills Ltd. The seed of *Striga* is very minute and tiny. So it may be assumed that the locations around Azimpur and Ishurdi where the improved cane varieties were introduced as a seed cane from India, *Striga* seeds were also introduced along with the seed cane, multiplied day by day and disseminated in new locations i.e. the adjoining region of North Bengal Sugar Mills Ltd. This assumption was related to

Ahmed and Mian (1977) and Matin *et al.* (1989). From the report Sharma *et al.* (1955) it appears that *Striga* was not known in this region before 1940s. *Striga* established here after 1940s and multiplying year after year and spread to the adjoining region.

Investigation of different host plants of *Striga* spp.

From the previous report, in Bangladesh only two hosts were (sugarcane and rice) attacked by *Striga* spp. Sugarcane is more susceptible than that of rice crop. In the present study *Striga* spp. parasitizing five types of host plants such as *Saccharum officinarum*, *Oryza sativa*, *Cynodon dactylon* and two unidentified grass. This parasitic weed is getting a choice of rice plant as a host and there is a greater chance of its spreading to new locations of the country.

Three species of *Striga* viz., *S. densiflora*, *S. euphrasioides* and *S. lutea* have been reported in India on sugarcane, rice, sorghum and some grasses (Mehrotha, 1983; Singh, 1983). Zuberi *et al.* (1987) reported that in northern region of Bangladesh *S. densiflora* parasitizing rice plant. Singh *et al.* (1993) reported that two parasitic weed, *S. gesnerioids* and *Alectra vogelii*, causes heavy yield losses in cowpea (*Vegnia unguiculata*) throughout the semiarid regions of Sub-Saharan Africa.

Morpho-Taxonomic studies of *Striga* spp.

A fairly wide range of variability within species was observed for most of the characters studied. The mean with standard error greatly varied from species to species, which indicated that twenty-six characters under study were quantitative in nature and under polygenic control. Kamruzzaman *et al.* (2000) reported that there was pronounced variation in phenotypic, genotypic and environmental coefficient of variability for most of the characters in Tomato. For all characters the differences between phenotypic and genotypic coefficient of variability were found low except fruit weight. These indicate pronounced genetic control of these characters. A wide and pronounced range of variation

indicated that all the thirteen characters under study were quantitative in nature and under polygenic control. Kundu (1999) also studied on genetic variability in different phenotypic characters of neem trees and found similar results.

Statistically significant differences in variances were found among the three species of *Striga*. These significant inequalities in variance indicate that above mentioned characters showed high phenotypic variability, which may be due to environmental heterogeneity within population or due to the presence of genetic variation. The relative importance of these two cannot be determined here. These fields, which were used in this study were managed by the local cane growers and they have used different amounts of cowdung, other manures and chemical fertilizers. This along with differences in the host (various cane varieties were used) makes the analysis complicated.

On the whole, the maximum vegetative, floral, and reproductive characters exhibit much difference. Only two vegetative characters (straight hair length and gland length) were non-significant. However, comparatively higher degree of variations may be well expected, indicating genetic differences. Kundu *et al.* (1998) studied on neem in seedling characters that showed a wide range of variation in all the characters. Nahar and Khaleque (2000) also reported that the analysis of variance of biparental progenies in sugarcane the significant differences between families indicated that there were genetic differences among the families. Samad *et al.* (2002) studied on yield and yield contributing characters in cotton (*Gossypium* sp.) and reported that the variety item was highly significant for all the characters. It is indicated that the varieties were different genetically.

The qualitative characters such as root system, dry colour of the whole plant, underground scaly leaves, bract midrib, calyx tooth and its shape, flower colour and seed colour and its reticulation showed high variability, which also indicating genetic differences strongly. Though the structure of the flower and the relative position of their anthers and stigma of *Striga* spp. indicate self-pollination as the breeding system.

The genus *Striga* was first described in the Eastern and Northern Bengal (now Bangladesh) by Prain (1903). He described the morphology of *Striga* Lour. and identified three species of *Striga* on the basis of number of calyx-ribs. He first reported that *S. densiflora* was present in North Bengal; *S. lutea* in Chota, Nagpur, North Bengal and East Bengal; and *S. euphrasioides* found in Chota Nagpur, Bihar, North Bengal and East Bengal. However in India, it was reported by Hooker, (1885) who described the morphology of *Striga* and identified six species based on the rib number of calyx. Beel and Cottrell-Dormer (1932) reported several species of *Striga* in Queensland and other parts of Australia. Sharma *et al.* (1955) reported that three species of *Striga* were present in Bihar, Bombay and Western Himalayas.

Recently Ahmed and Mian (1977) reported only one species of *Striga* (*S. densiflora*) present in northern part of Bangladesh. Zuberi and Biswas (1986) reported that *S. densiflora* causing heavy infestation of cane-crop in northern part of Bangladesh. Matin *et al.* (1989) described the morphology of *S. densiflora*.

From the results of the present study it is apparent that in the northern districts of Bangladesh, sugarcane, rice and some grasses is parasitized by at least three different species of *Striga* namely *S. densiflora*, *S. lutea* and *S. euphrasioides*. Of these three, *S. densiflora* is more common and destructive than the others. Santapu (1952) on the basis of number of calyx-ribs has differentiated these three species of *Striga*. There being 10 calyx ribs in *S. lutea* and 15 in *S. euphrasioides*. Pennell (1943) placed all the species into two broad groups (I) 4-5 ribs in calyx and (II) 10-15 ribs in calyx and differentiated between two species on the basis of colour of corolla and branching of stem. According to him *S. lutea* and *S. euphrasioides* has respectively yellow and white corolla and the stem of the former is less branched than that of the latter. In Bihar both the species have white flowers and *S. lutea* is much more profusely branched than *S. euphrasioides* (Sharma *et al.*, 1955). *S. densiflora* was separated by Santapu (1952) from *S. gesneroides* and *S. orobanchioides* by its non-parasitic habit.

Since the number of calyx-ribs was regarded to be the basic diagnostic features for species identification of *Striga* by all previous workers. Twenty flowers of each of the phenotypically variable types were examined for this character. Number of calyx-ribs was found to show appreciable variation in at least three 'types' identified as three species. There were 10 to 15 calyx-ribs in *S. lutea*, 13 being more frequent and 14 to 18 in *S. euphrasioides* with 16 having higher frequency. In case of *S. densiflora* about 80.00% flowers had 5 calyx-ribs, showing a far greater consistency so far as this character is concerned.

Another qualitative character, which was not mentioned properly by Hooker (1885), Prain (1903) and other workers, is the bract. It was observed that two fairly prominent bracts are present in all three species of *Striga*. Present study revealed two distinct bracts, which were green and different in respect to their length and toothedness in the three different *Striga* species studied. Midrib present only in the bracts of *S. densiflora*. This character may also be used in intrageneric classification of *Striga*.

It may be concluded that appreciable phenotypic variation for metric characters was observed among *Striga* spp. The causes of this variation may be varied, such as heterogeneity of environment over space and or time, soil differences etc. Apart from these metric characters, some calyx-rib, bract and symmetry also exhibited variation.

On the basis of these characters the following key of identification for these three species is suggested.

- A. Calyx tooth lanceolate, calyx-ribs 4-6, 5 being more frequent, larger bract with midrib, larger plant body with smaller white flower, medium fruits with more coffee brown seeds, ovary bilobbed, under ground scaly leaves present, ill developed root system, black when dry. – *S. densiflora*.

- B. Calyx tooth linear. Calyx-ribs 10-15, 13 were more frequent, secondary ribs ending in sinus. Smaller plant body with large creamy flower. Smaller bract without midrib. Ovary rounded. Smaller fruit with more coffee brown seeds. Under ground scaly leaves present. Ill developed root system, dull brown depending on drying. – *S. lutea*.
- C. Calyx-midrib 14-18, 16 having higher frequency, secondary ribs continued into the extremity of calyx tooth. Larger plant body with larger white flower and few branches, flowers and fruits. Larger fruit with more darkish brown comparatively larger seeds. Underground scaly leaves absent with moderately developed root system, dull brown depending on drying. – *S. euphrasioides*.

Uddin *et al.* (2001), Uddin and Hassan (2001) and Ara *et al.* (2001) studied similar qualitative and quantitative characters for species identification of angiospermic plants.

Taxonomic position of *Striga* spp. are presented below (Conquist, 1968).

Division	Magnoliophyta
Class	Magnoliatae
Sub class	Asteridae
Order	Scrophulariales
Family	Scrophulariaceae
Genus	<i>Striga</i>
Species	<i>Striga</i> spp.

Host parasite relationship

During the investigation of cane field, in the 1st week of May *Striga* seedlings were shown in the base of sugarcane. At the seedling stage of *Striga* no remarkable difference between *Striga*-parasitized and control (healthy) sugarcane was visible. After a few weeks (at flowering stage of *S. densiflora*) parasitized-canes showed visible symptoms.

The seeds of *Striga* cannot germinate without the suitable host root exudates and it cannot survive without any living host. The root exudates of suitable host plants (sugarcane) stimulated *Striga* seed to germinate when came in contact with it and a parasitic relationship became established. Similar results also reported elsewhere (King, 1974; Singh, 1983; Matin *et al.*, 1989). Following germination the radicle of this parasitic weed penetrated into host root and formed a swollen structure. A multicellular haustorium formed at the point of attachment. Subsequently growth over a period of week leads to the development of a weakly branched, ill developed root system devoid of root hairs, but showing prominent haustoria practically everywhere it came in contact with the host roots and formed a common bridge. Such a linkage between the *Striga* and host roots has also been identified by Shaw *et al.* (1962), Ba (1983) and Matin *et al.* (1989).

The ill develop root system of this parasitic weed was not sufficient to absorb water and mineral nutrients from the soil and this parasitic weed bears several green leaves. In the microscopic examination *Striga* was found to penetrate their haustoria into the host root and uptake water and necessary mineral nutrients through their haustoria. By this process host plants (sugarcane) lost a quantity of mineral nutrients and water. King (1974) reported that *Striga* root could not absorb water and minerals from the soil possibly due to the absence of its root hair. Haustorium of *Striga* penetrated into sugarcane root and formed a common bridge. Matin *et al.* (1989) also observed that *S. densiflora* bear tap root system devoid of root hairs. Roots become swollen at the point of attachment to the sugarcane roots.

Haustorium developed from the tip of *Striga* root penetrated into epiblemma of host root and reached to xylem vessel of the latter passing through cortex and endodermis by mechanical pressure or secreting some chemicals. Shaw *et al.* (1962) and Rao (1987) reported that *Striga* root penetration appeared to be accomplished through chemical or enzymatic means rather than mechanical pressure.

This multicellular haustorium maintains connection between host and parasite and possibly absorbs minerals and water from the host resulting in huge crop yield losses. A phenomenon of transportation of minerals and water from host to parasite is also reported elsewhere (Shaw *et al.*, 1962; Egley, 1971 and Singh 1983, Matin *et al.*, 1989).

The growth rate of the specific host plant (sugarcane) which was parasitized by *S. densiflora* started to decrease over control at the time of attachment of the roots of host and parasite and this gradual decrease continued. This gradual decrease prominent at the flowering and seed release stage of *S. densiflora* and the specific host plant died after seed release.

After germination, the parasitic weed (*S. densiflora*) grew below the soil surface and produced underground stem and roots. The underground portion of the stem contains buds in the axil of scaly leaves. Singh (1983) found similar result. After emergence of the parasitic weed above the ground, green leaves appeared which fit for photosynthesis. These green leaves photosynthesize and prepare their own foods from the raw materials, which was drawn from the xylem vessels of the specific host roots (sugarcane) through haustoria, as a result host plants suffer physiological disorder. It has been shown by the radioactive tracer technique that both the subterranean and the green-leaved *Striga* seedlings obtained water and minerals from the host and photosynthesize (Okonkwo, 1964).

In the pot experiment host plants (sugarcane) were cut under the soil at seedling stage of *S. densiflora* and it was observed that the parasitic weed became stunted and died within a few days (the parasitic weed cannot survive). *S. densiflora* failed to absorb water and mineral nutrients without host roots.

Host leaf moisture and leaf chlorophyll deficit started due to absorption of raw materials from the host plants by the parasite (*Striga*), when the radicle of this parasitic weed penetrated the specific host roots and gradual deficit continued. Ghosh (1996) found higher amount of moisture contents in healthy leaf samples in comparison with leaf spot diseased leaf of *Morus* sp.

Chlorophyll is the most important and essential photopigments present in the sugarcane leaves, which directly associated with the photosynthetic activity of plant. Gradual reduction in leaf moisture and leaf chlorophyll contents possibly reduced the photosynthetic activities of the leaves of *Striga* infected sugarcane and the affected cane plants became weak. Host plants suffered from physiological disorders due to gradual deficit of leaf moisture and chlorophyll content, as a result of parasitization. Due to this physiological disturbance, the parasitized cane plants became stunted and attacked by different types of diseases. Finally the cane plants died, resulting huge crop yields losses.

Wu *et al.* (1969) and Chen and Chen (1974) found about 92.35% reduction in total chlorophyll content in white leaf disease infected sugarcane leaves. Reduction in chlorophyll content up to 60.90% in pigeon pea plants affected with sterility mosaic an MLO was reported by Narainswamy and Ramakrishnan (1966). Marked decrease in chlorophyll content in the diseased leaves suggested that the etiologic agent was perhaps interfering in the biosynthesis of chlorophyll (Shukla *et al.*, 1988). According to Benson (1964) infected molecule of chlorophyll must be present for proper development of chloroplast lamellae. Chen and Chen (1974) and Shukla *et al.* (1984) reported about the poor development of lamellae or irregular and distorted chloroplast in the leaves of sugarcane infected by MLO indicating the interruption of chlorophyll biosynthesis in the leaves of diseased plant.

Talukder (1994) found that total chlorophyll, chlorophyll 'a' and chlorophyll 'b' significantly decreased in WLD cane leaf compared to healthy one. Kaley and Nagaich (1977) found drastically reduced quantity of chlorophyll 'a' and chlorophyll 'b' in potato plants affected with purple top roll disease caused by MLO. Kaley and Nagaich (1977) found drastically reduced quantity of chlorophyll 'a' and chlorophyll 'b' in potato plants affected with purple top roll disease caused by MLO, when compared with healthy ones.

Siddramaiah and Hedge (1990b) found decreased amount of total chlorophyll, chlorophyll 'a' and chlorophyll 'b' with the increased disease intensity in mulberry. Neema (1991) found reduction in total chlorophyll as well as chlorophyll 'a' and chlorophyll 'b' content in highly susceptible cultivars of betel vine.

Borah *et al.* (1978) found the changes of chlorophyll contents in the leaves when infected with *Cephaleurus parasiticus*. They also found considerable reduction in chlorophyll 'a' and chlorophyll 'b' as a result of destruction of chloroplast.

Brekdown of chlorophyll is brought about by the enzyme chlorophyllase, resulting in the formation of chlorine ring containing the magnesium (chlorophyllide) and phytol, the chain alcohol (Goodman *et al.*, 1967). Dhumal and Nimbalkar (1982) reported that loss of chlorophyll content in the GSD infected leaves of sugarcane may be due to lower concentration of Mg in the diseased plants. Peterson (1931) observed a high degree of chlorophyllase activity in tobacco varieties where tobacco mosaic virus caused maximum loss of chlorophyll. Mazzolini *et al.* (1982) also described that chlorosis is related primarily to an imbalance of elements particularly the ratio of P and Fe. Chlorosis of leaf due to MLO infection was reported in other crops also by many workers (Kuske and Kirkpatrick, 1992; Martha *et al.*, 1989; Thompson and Pietersen, 1988).

Striga plants were eradicated before green leaf appeared in the pot culture experiments and found that the growth of host plant (sugarcane) became stunted. Number of parasite (*Striga*) per host (sugarcane) was very few. The height of the host plant was very higher than the parasitic weed. A few numbers of host roots attacked by the ill develop *Striga* root. It was suspected that the parasitic weed not only suck water and mineral nutrients from the host root but also secrete some toxic substance into the host protoplasm, which inhibited the growth of host plants resulting in stunted growth and finally the host plants died. Further research is essential in this line to confirm and identify this toxic substance. Edgerton (1959) has suggested that though this has not been proved, the parasite produced a substance toxic to the cane. The host plants usually stunted and frequently killed.

Percentage of total organic matter in the soil of *Striga*-infected sugarcane field increased significantly ($P < 0.05$) due to the death of host plant (sugarcane). Total nitrogen in the soil of *Striga*-infected sugarcane field increased significantly ($p < 0.01$). Available phosphorus, calcium and iron percentage in the soil of *Striga*-infected sugarcane field increased significantly ($P < 0.05$) over control due to the death of specific host plant (sugarcane). In the control field healthy sugarcane uptake a large amount of total nitrogen, available phosphorus, calcium and iron from the soil for their normal growth and development and these elements were essential for the growth and development of sugarcane. As a result in the soil of control field total nitrogen, available phosphorus, calcium and iron deficit was found. This finding supported by the analysis of leaves both control and *Striga*-parasitized host plant (sugarcane). On the other hand magnesium and sulfur percentage decreased significantly ($P < 0.05$) in the soil of *Striga*-infected sugarcane field. *S. densiflora* uptake these elements from the host root through haustoria. These elements were essential for the growth and development of this parasitic weed. This finding also supported by the analysis of leaves both control and *Striga*-parasitized host plant and parasitic weed (*S. densiflora*).

Total nitrogen, available phosphorus and potassium percentage in the *Striga*-infected host (sugarcane) leaves started to decrease and sulfur and calcium percentage in the same host leaves started to increase when the radicle of this parasitic weed (*S. densiflora*) penetrated the specific host roots (sugarcane) and gradual decrease/increase continued.

Striga infestation alters the morphology of sugarcane. Disturbed mineral nutrition is one of the most common effects of plant disease (Huber, 1978). This may reflect an imposed mineral deficiency some where in the plant, impaired utilization of toxicity from abnormal accumulation around the site of infection.

Dhumal and Nimbalkar (1982), Rao (1984) and Gupta *et al.* (1988) reported that grassy shoot diseased leaves of sugarcane contained significantly reduced quantity of nitrogen. Decrease in nitrogen contents in the diseased leaves was also reported by many other workers (Ghorpade and Joshi, 1981; Hegde and Mungal, 1971; Singh and Verma, 1973). This reduction may be due to utilization of nitrogen by the pathogen (Hegde and Mungal, 1971). The reduction in nitrogen may be due to blockage of protein synthesis (Goodman *et al.*, 1967). Reduction in nitrogen content has also been reported in maize and sugarcane infected by *Ustilago maydis* and sugarcane mosaic virus (SCMV) respectively (Petho, 1966; Ghorpade and Joshi, 1981).

Total nitrogen, available phosphorus, potassium, sulfur, calcium and magnesium percentage in *S. densiflora* increased significantly over *Striga*-infected sugarcane leaves at flowering stage of *S. densiflora*. *Striga* plants absorb these elements through haustoria from their specific host (sugarcane) roots for their metabolic activities and growth and development, as a result the host plants (sugarcane) suffered from physiological disorders and attacked by the different types of diseases and finally died.

A pathogen induced an increase in respiration may be responsible for this higher accumulation of phosphorus (Akazawa and Uritani, 1955). The higher rate of respiration in WLD and GSD affected plants has been reported, respectively by Chen and Kong (1976) and Shukla *et al.* (1988) may be attributed to the increased quantity of P in diseased leaves. The greater P content in diseased leaves may also be due to increased metabolic activity at the infection site (Fucikousky, 1966; Shaw and Somborski, 1956).

Potassium plays an important role in plant metabolism and is found in high concentration wherever high energy transformations take place (Humbert, 1963). Accumulation of K by *S. densiflora* may serve as a defence mechanism. Talukder (1994) worked on WLD of sugarcane and found that WLD affected sugarcane accumulate higher rate of phosphorus and potassium due to higher rate of respiration and metabolic activities and defence mechanism of the pathogen.

Effect of *Striga* on agronomic yield characters of sugarcane

In the beginning, the fields parasitized by *Striga* usually do not show any specific diagnostic features apart from the occurrence of the parasitic weed itself. The damage to the cane crop even within one field was often variable. Sometimes there was minor damage due to stunting of the canes whereas severe parasitization kills all the canes in large areas of the field. Affected cane plants were stunted with reduced height and internodes, and losses of cane weight, juice and CCS content.

Assessment of agronomic yield losses of *Striga*-infected sugarcane compared to healthy one. Samples were collected from the same source. Nine important agronomic yield characters were studied such as number of millable cane, stalk height, internode number, basal internode length, middle internode length, terminal internode length, stalk diameter at the base, stalk diameter at the top and stalk weight. Statistically significant differences were found on all the selected agronomic yield characters of the selected 5 improved cane varieties, which were locally cultivated.

Visser (1987) working on *S. asiatica* reported that infected plants (sugarcane) had attained the same length after 27 weeks of parasitization. DM yields were significantly lower in heavily infected cultivars variety of sugarcane.

Juice extraction percentage of all the selected 5 improved cane varieties, which were parasitized by *Striga* compared to healthy one were found to decrease significantly in all the selected varieties, subsequently fibre percentage increased in *Striga*-infected sugarcane. Juice percentage and fibre percentage in sugarcane was co-related. It was also observed that juice extraction decreased over control 11.04%, subsequently fibre increase in *Striga*-infected sugarcane 12.40%. Juice pH of *Striga*-infected sugarcane of all the selected varieties was significantly lower than their control.

Present findings are in agreement with the findings of Beniwal *et al.* (1989) in red rot diseased cane sample. They reported minimum reduction of 4.97% in resistant clone Co 7314 while the maximum reduction of 40.79% in susceptible clone CoL 29 due to red rot infection. Mckaing and Fort (1936) also reported that reduction in the quality and quantity of juice extracted from the sugarcane varieties PoJ 36-M, PoJ 213, PoJ 234 and Co 281 due to red rot attack. Reduction in juice extraction percentage in smut (*Ustilago scitaminea* Sydow) infected cane has been reported by many researchers (Goyal *et al.*, 1982; Bachchav *et al.*, 1979; Kumar *et al.*, 1989; Rahman, 1995). A significant reduction in juice extraction percentage has been reported in grassy shoot disease (Singh, 1974) and white leaf disease (Talukder, 1994) both of which are caused by mycoplasma. Talukder (1994) found that the mean fibre content in healthy canes of Isd 16 and Isd 20 was 16.80 and 17.22% when the corresponding WLD infected canes showed 16.93 and 17.47% fibre, respectively. Other researchers (James, 1973; Goyal, 1980, Rahman, 1995) have also reported similar increase in fibre content in smutted canes.

Brix, pol, purity and commercial cane sugars (CCS) percentage of *Striga*-infected sugarcane was also decreased significantly over control of all the selected varieties. A few percentage of *Striga*-infected ratoon cane grove were germinated.

Brix percentage reduction in *Striga*-infected sugarcane were also similar with the findings of Beniwal *et al.* (1989), in red rot diseased cane sample. They found 7.03 to 32.94% reductions in brix in different varieties. The resistant clone Co 7314 showed the lowest reduction, while the highly susceptible clone S 78/560 showed the highest reduction in brix. Sandhu *et al.* (1969) also recorded the reduction in brix of juice from 2.70 to 21.70% in diseased canes. Like *Striga* parasitization, reduction in brix in juice was reported due to smut disease of sugarcane (Bachchav *et al.*, 1979; Goyal *et al.*, 1982; Padmanaban *et al.*, 1988; Kumer *et al.*, 1989; Rahman, 1995). Grassy shoot disease (GSD) decreased the brix in juice of sugarcane (Singh and Rao, 1967; Singh, 1974). Talukder (1994) also found the reduction of brix in juice due to white leaf disease (WLD) ranging from 24.53 to 29.69% compared to control.

Pol percentage reduction in *Striga*-infected sugarcane was also in agreement with the results of Beniwal *et al.* (1989) in red root diseased cane sample. They reported that the decrease in pol ranged from 7.43 to 38.70% in the diseased cane where minimum reduction was found in the resistant variety Co 7314 and maximum in the susceptible variety S 78/560. Similar observations on reduction of pol percentage in juice were also recorded in other systemic disease like GSD, WLD and smut of sugarcane (Singh and Rao, 1967; Talukder, 1994; Rahman, 1996).

Purity percentage of *Striga*-infected sugarcane juice was also reduced and it is in conformity with the finding of Beniwal *et al.* (1989) in red rot diseased cane sample. They reported that the purity varied from 0.45 to 8.26% in red rot infected canes of different varieties. Reduction in purity of juice of the red rot infected canes has also been reported by various workers (Kamal *et al.*, 1981; Singh and Waraitich, 1981). Like *Striga* parasitization, reduction in purity percentage in juice has been reported due to some systemic diseases like smut, GSD and WLD (Padmanaban *et al.*, 1988; Singh, 1974; Talukder, 1994).

CCS percentage in *Striga*-infected sugarcane was highly reduced which is supported by the findings of Beniwal *et al.* (1989) in red rot diseased cane sample. They reported that reduction in CCS were 7.84 and 43.81% in the red rot infected canes of the resistant clone Co 7314 and susceptible clone 78/560 respectively. Rao *et al.* (1984) recorded a decrease in commercial cane sugar (CCS %) and recovery of Jaggery (Gur), in the red rot infected cane varieties CoC 671 and B 3364. Like *Striga* parasitization, significant decrease of CCS has been reported in other systemic disease infected canes like smut and WLD. Kumar *et al.* (1989) reported reduction in CCS ranging from 8.26 to 18.30% in smutted canes. Talukder (1994) reported the decrease in CCS by 30.05 to 39.06% in the WLD infected cane.

The high significant value between control and *Striga*-infected sugarcane in yield components of all the selected 5 improved cane varieties indicate that all the selected varieties were highly susceptible to *Striga* spp.

The number of millable canes, stalk height, internode number, stalk weight, commercial cane sugar percentage and germination percentage of ratoon cane groves were reduced by 90.87, 57.79, 64.57, 81.78, 89.08 and 80.00% respectively due to *Striga* parasitization. Due to this huge crop yield losses growers were economically looser and discouraged to cultivate sugarcane in the previously *Striga* infested cane fields. As a result total national product decreased which affected the food and Sugar Corporation, as well as our national economy.

Yield losses depend on *Striga* population and severity of infestation. Yield losses were reported by Rao (1983), which was confirmed by the findings of the present investigation. Due to heavy *Striga* infestation in the field, most of the plants died and the whole field showed a burned appearance, which confirmed the findings of Ahmed (1977) and Rahman *et al.*, 1988.

Biochemical changes in *Striga*-infected sugarcane

In the present study, total sugar content in total tissue samples of sugarcane decreased significantly in *Striga*-infected sugarcane after 8 months of plantation and 4 months of *Striga* emergence above the ground compared to control (healthy) one. Similar observations were recorded by Singh and Waraitch, (1981) in red rot diseased cane sample. They reported that sucrose (%) decreased gradually in red rot diseased sugarcane. Sandhu *et al.* (1969) found decrease in sucrose content from 12.20 to 31.31% due to red rot. Like *Striga* parasitization, total sugar in cane was found to be reduced in smutted canes in the clones I. 291/87 and I. 31/88 by 45.53 and 25.66% respectively (Rahman, 1995). Sankpal and Nimbalkar (1979) also reported reduction of total sugar content in smut infected cane by 15.90% than that of healthy checks. Ghorpade and Joshi (1981) reported that in sugarcane mosaic virus infected tissue sample, total sugar decreased also. Talukder (1994) recorded the reduction of total sugars by 62.22 and 90.00% in the variety Isd 16 and Isd 20 respectively due to WLD infection in sugarcane.

It was found that total reducing sugar in total tissue sample of sugarcane increased due to *Striga* parasitization after 8 months of plantation and 4 months of *Striga* emergence above the ground compared to their control. Like *Striga* parasitization, reducing sugar (%) in cane was found to be increased in GSD affected sugarcane, (Dhumal and Nimbalkar, 1983). Cane mosaic virus infected sugarcane also showed increase in reducing sugar (Ghorpade and Joshi, 1981). Talukder (1994) reported that increase in reducing sugars by 62.22 and 90.00% in the variety Isd 16 and Isd 20 respectively due to WLD infection over their respective healthy checks. Rahman (1995) reported an increase in reducing sugars by 22.50 and 8.97% in the clone I. 291/87 and I. 31/88 respectively in smutted canes compared to their healthy checks.

In *Striga*-infected sugarcane, mean non-reducing sugars in total tissue sample decreased significantly after 8 months of plantation and 4 months of *Striga* emergence above the ground compared to their control. Like *Striga* parasitization, similar results were found in red rot diseased sugarcane (Edgerton, 1959; Shandhu *et al.*, 1969; Singh and Waraitch, 1977, 1981, 1981; Rao *et al.*, 1984). Agnihotri *et al.* (1989) reported that out of 8 varieties, decrease in amount of total carbohydrates (which includes non-reducing sugars) was greater in red rot susceptible varieties like Colk 8002, Colk 7810 and Co 997 than in the resistant varieties Cos 767, Co 1158 and Colk 8001. Reduction of non-reducing sugars also occurred due to other diseases. Non-reducing sugars (%) was reduced in GSD infected sugarcane (Singh and Rao, 1967; Singh, 1974; Dhumal and Nimbalkar, 1983). Ghorpade and Joshi (1981) reported that in sugarcane mosaic virus infected cane sample, non-reducing sugars decreased. Talukder (1994) reported a significant decrease in non-reducing sugars in the WLD infected canes in Isd 16 and Isd 20 by 28.07 and 35.74% respectively.

It was also found that sucrose contents in *Striga* infected total tissue samples decreased significantly after 8 months of plantation and 4 months of *Striga* emergence above the ground compared to their control. Like *Striga* parasitization similar results were found in red rot diseased sugarcane (Edgerton, 1959; Singh and Waraitch, 1981; Agnihotri *et al.*, 1989). Edgerton, 1959 also reported that sucrose content of *Striga* affected cane plants was very low.

Life cycle of *Striga densiflora*

Seeds of *Striga* germinate below the soil surface when come in contact with suitable host root. After germination, plumule and radicle of this parasitic weed grow below the soil surface and produce under ground stems and roots respectively. The underground stem contains buds in the axil of leaves, and the roots form haustoria, which penetrates the host roots from which this parasitic weed draws water and mineral nutrients, eventually wasting and destroying the host. Similar observations were also reported elsewhere (Singh, 1983).

It was observed that *S. densiflora* emerged after 139.95 ± 0.71 days in the field and 111.20 ± 2.89 days in pot experiment. These investigations were in agreements with the findings of Matin *et al.*, 1989; Mbogo and Osoro, 1991. This delay in emergence of parasitic weed has been explained by many workers (Shaw *et al.*, 1962; Singh, 1983; Rao, 1987).

Seasonal plant height (growth pattern) of *S. densiflora* was increasing progressively up to the first flower appeared. Later on plant height increased very little as the parasitic weed approached maturity. This parasitic weed attained one-third of its final height before flowering stage and more than two-thirds of the final height before fruit setting stage of *S. densiflora*. Final plant height was attained at seed release stage beyond which there occurred practically no growth of this parasitic weed, which gradually died. These observations were in agreement with the findings of Matin *et al.* (1989).

The growth pattern recorded as plant height (cm/day) of *S. densiflora* was faster at juvenile stage, after which increased slowly and coinciding with fruit setting time. There after increase in plant height fell rapidly, when seed release started approaching practically to nil beyond seed release and finally died. Matin *et al.* (1989) worked on "Association of *S. densiflora* with sugarcane" and obtained similar result. It was also observed that *S. densiflora* completed its life cycle very quickly and produced a large amount of very minute tiny seeds and the seed viability was very long. Sing (1983) reported that *Striga* produced a very minute seeds in great abundance. The viability of these seeds has been reported to be from 12-40 years by different workers.

Parasite completed its life cycle very quickly. Growth rate of parasite is very quick at juvenile stage i.e. before reproductive stage and produces large amount of tiny reproductive unit (seeds/spores), which is viable for a long time. These characters also present in *S. densiflora*. It was observed that *S. densiflora* completed its life cycle within 55.05 ± 0.46 days in field and 37.50 ± 1.80 in pot experiment. This findings were similar to the findings of Shaw *et al.*, 1962; Matin *et al.*, 1989.

It was also observed that in pot culture experiments *S. densiflora* complete its life cycle quickly compared to field experiment. It was also observed that growth and development including growth rate (Seasonal plant height cm/day) were higher in field experiment than pot culture experiments. This variation was found due to environmental factors and host growth.

Management of *Striga* problem in Bangladesh

The best way to manage this parasitic weed is by destroying it before seed formation. If the seeds have formed and shed on the soil it becomes very difficult to eradicate this parasitic weed for several years due to its long seed viability and dormancy. Long dry periods especially summer may help in reducing the soil population of seeds. It is an old and conventional practice, which was used for weed

control. *Striga* is a parasitic weed. More than 9 weeding is needed to manage it and it is very costly, which makes this method discouraging to the growers. Singh (1983) and Talukder and Rahman (1989) reported that eradication is an old and expensive method and it is not effective for *Striga* spp. as it is discouraging to the growers.

The seeds of *Striga* spp. are very minute and produce in great abundance. The viability of these seeds has been reported to be from 12 to 40 years by different workers (Singh, 1983). *Striga* spp. reproduced within short distance disseminating seeds. Due to its short distance dissemination of seeds it is a localized problem in Bangladesh. It was suggested that long distance dissemination of this parasitic weed would be checked by plant quarantine.

Chemicals have been recommended for direct killing of *Striga* or for stimulating its seed germination. Soaking the soil up to a depth of 4-6 inches with 2-3% copper sulphate solution was once recommended for killing the parasite (Singh, 1983). Copper sulphate is very harmful for soil environment.

Control of *Striga* plants using Agroxone (MCPA) and fernoxone (80% sodium salts of 2,4-D) have been reported elsewhere (Singh, 1983; Mehrotha, 1983 and Rangaswamy, 1972). However, these chemicals are very costly, to some extent toxic, low concentrations were not suitable for *Striga* control and also not available in the market. Considering these difficulties, management of *Striga* problem by using urea solution (2.5% at juvenile stage of *Striga*) and high dose of urea fertilizer applied at the time of sugarcane plantation. The results above do indicate that application of chemical fertilizer (NPK) with high doses of urea inhibited seed germination of *S. densiflora* significantly ($P < 0.05$) but not 100% suppression.

Talukder and Rahman (1989) reported that control of *Striga* by using urea solution (1:20, w/v) would be suitable as it is fairly available, less costly and also less toxic to sugarcane plants as well as mammals. Sawyer (1925) reported that close row spacing, good cultural practices, fertilizer use, burning of stubble, crop rotation demonstrated benefits in sorghum against *S. asiatica*. Watt (1936) published similar recommendations for *S. hermonthica* control in Kenya.

An agronomic practice for *Striga* control is the use of “false host crops” such as cotton, soybean and groundnuts. These crops induce *Striga* seed germination but do not support the growth of this parasitic weed. Thus the population of the parasite is gradually reduced in few years (Singh, 1983). Dejongh *et al.* (1993) observed that cowpeas, cotton and soybean in order to quantitatively identify non-host germination that will stimulate *S. hermonthica* seed germination.

Cultural and chemical control methods have gradually been ineffective due to the close ecological and physiological relationship between host and parasite. Cultivation of legume crops especially *Cicer arietinum* as crop rotation for the suppression of *Striga* seed germination significantly ($P < 0.05$) but not 100% suppression and it will be suitable, less costly and also not toxic. Subsequently these crops increase soil fertility due to atmospheric free nitrogen fixation into nodule and these are also economic rabi crops. From the above findings it may be suggested that crop rotation with legume crops especially *Cicer arietinum* and burning of stubble are the best solution for *Striga* problem. It is a preliminary observation and more studies are needed to establish it to manage *Striga* problem. It may be noted that non-graminaceous crops especially legumes and jute is recommended for the *Striga* infested plots to avoid crop loss.

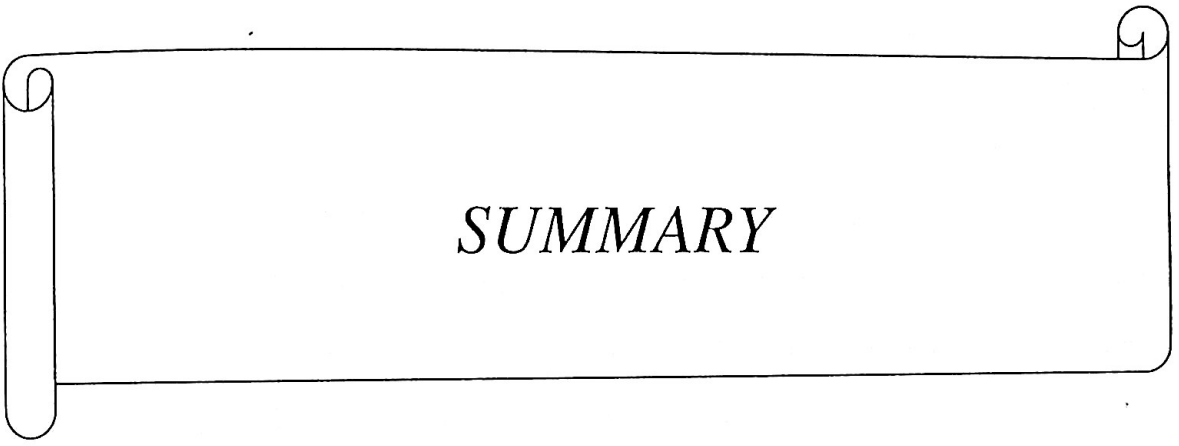
Khan *et al.* (2001) reported that a habitat management strategy for minimizing damage due to stemborer and *Striga* weed has been developed in maize-based farming system for small and medium scale farmers of eastern Africa. The two most successful trap crop plants Napier grass, *Pennisetum purpureum* and Sudan grass, *Sorghum vulgare sudanesis* attracted greater oviposition by stem borers, than cultivated maize. The intercrops giving maximum repellent effect were molasses grass, *Melinis minutiflora* and a legume species, silverleaf, *Desmodium uncinatum*. ‘Push-pull’ trials using the trap crops and repellent plants, reduced stemborer on protected plants, resulting in significant increase in maize yield. The plant chemistry responsible for stemborer control involves release of attractant semiochemicals from the intercrops. Intercropping

maize with *D. uncinatum* not only reduced parasitization of maize but also reduced parasitization of maize by *S. hermonthica*. More than six hundred farmers in different agro-ecologies in Kenya have adopted this technology resulting in increased maize and milk production.

Berner and Williams (1998) reported that the crop rotation with non-host cultivars, selected to stimulate *Striga* and seed germination, is being used successfully to control other *Striga* spp. and may have potential to control *S. gesnerioides*. Little information has been available on non-host of *S. gesnerioides* that are capable of stimulating germination of parasite seed. Genotype of all *Vigna* spp. tested stimulated parasite seed germination. Some genotype of the non-host species *Cajanus cajan*, *Lablab bicolor* also stimulated parasite seed germination.

The traditional control measures were economically not viable. The complexity of *Striga* problem demanded an integrated control approach with solutions that were flexible enough to match the diversity and variability of the sugarcane cultivation. A better understanding of the parasite's biology by the cane growers would encourage them to appreciate the current complex and time consuming *Striga* control measures. Though a picture supported group extension program would be developed, which was characterized by a shift from a teaching centre to learner-centre extension approach in Northern Bangladesh. The cost for developing the felt picture course and the manual were low. Field extension staff of the respective sugar mills of *Striga* affected region may play a vital role in these learner centre for their industrial benefit. Similar suggestions were suggested by Feil *et al.* (1997).

CHAPTER VI



SUMMARY

SUMMARY

A brief survey of *Striga* (Scrophulariaceae), an angiospermic root parasite of sugarcane in the northern part of Bangladesh was carried out during three successive cropping seasons (1998-99 to 2000-2001). Due to heavy *Striga* infestation in the field, most of the host plants (sugarcane) died and the whole field showed a burned appearance. Incidence of *Striga* infestation of sugarcane fields was the highest in sandy loam than that of loam soil and clay. In the low lands *Striga* cannot survive due to its waterlogged condition. *Striga* incidence differs from locality to locality during cropping seasons to cropping season. Growers generally prohibit sugarcane cultivation in the newly *Striga* infested fields for a certain period (3-4 cropping seasons). After a certain period the growers cultivate sugarcane in previously *Striga* infested plots and the cane plots were infested with *Striga* due to its long period of seed viability. For these reasons high variability of *Striga* infestation was observed among the localities during various cropping seasons.

Striga spp. started to appear above the ground from the end of April after early rain during summer continued to be present up to October. Even in the early June population of the *Striga* consists of plants with mature fruits, dispersing seeds, plants beginning to flower and plants still in juvenile stage of growth. During the months of June and July heavy occurrences were noticed when maximum predisposing environmental factors for the growth and development of *Striga* spp. were found. During the months of August and September, heavy rainfall is helpful for the dissemination of *Striga* seeds. In the cane areas where the parasitic weed appeared comparatively earlier in the season was more affected.

The population density of this parasitic weed (*Striga*) per square meter was more or less equal in number in all the visited areas due to more or less similar land topography, soil texture and environmental conditions. This parasitic weed covered an area of 1300 sq. Km and is more prevalent between the regions of Varamara to Joypurhat. It was observed that three species of *Striga* present in Bangladesh and among them *S. densiflora* is more common and destructive. From the distribution and population density of this parasitic weed in Bangladesh, it appears that it is a localized problem.

No information is available about the first appearance of *Striga* spp. in Bangladesh and adjoining region. It is suspected that the place of first appearance of this parasitic weed was nearest to the oldest sugar mill of the country (North Bengal Sugar Mills Ltd.) where the improved cane varieties were introduced as seed cane from India and distributed among the growers.

The seeds of *Striga* spp. is very minute and tiny, so it may be assumed that *Striga* seeds were introduced here along with the seed cane, multiplied day by day and disseminated the adjoining region of North Bengal Sugar Mills Ltd.

In the present study, it was observed that *Striga* spp. parasitizing five types of host plants such as *Saccharum officinarum*, *Oryza sativa*, *Cynodon dactylon*, and two unidentified grasses.

Comparatively higher degree of variation was observed for maximum quantitative characters of vegetative, floral and reproductive parts of *Striga* spp. Maximum qualitative characters of vegetative, floral and reproductive parts of *Striga* spp. showed high variability. Such variations may be well expected, indicating genetic differences.

From the result of the present study it is apparent that in the northern part of Bangladesh, sugarcane, rice and some grasses are parasitized by at least three types of *Striga*. Number of calyx rib was regarded to be the basic diagnostic features for species identification of *Striga* by all the previous workers. On the basis of this diagnostic feature above three types identified as three species. There were 4-6 calyx-ribs in *S. densiflora*, 5 being more frequent, 10-15 in *S. lutea*, 13 is more frequent and 14-18 in *S. euphrasioides* with 16 having higher frequency.

Seasonal plant height (growth pattern) of *S. densiflora* was increasing progressively up to first flower appeared. Later on plant height increased very little as the parasitic weed approached to maturity. This parasitic weed attained one-third of its final height within juvenile stage and more than two-thirds of the final within fruit setting stage of *S. densiflora*. Final plant height was attained at seed release stage beyond which there occurred practically no growth of this parasitic weed and gradually died.

The growth pattern recorded as plant height (cm/day) of *S. densiflora* was faster at juvenile stage after which increased slowly coinciding with fruit setting time. There after increase in plant height fell rapidly, when seed release started approaching practically to nil beyond seed release and finally to die. Quick lifecycle and quick growth rate (cm/day) at juvenile stage (before fruit seat) of this weed approached its parasitic nature.

It was observed that *S. densiflora* completes its life cycle quickly in pot culture experiment compared to field experiment. It was also observed that growth and development including growth rate (seasonal plant height) cm/day was higher in field experiment than pot culture experiment due to its environmental factors and host growth.

During the investigation of cane field in the 1st week of May *Striga* seedlings were shown at the base of sugarcane. At the seedling stage of *Striga* no remarkable differences between *Striga*-parasitized and control (healthy) sugarcane was visible. After a few weeks (juvenile stage of *Striga*) parasitized canes showed visible symptoms.

The root exudates of suitable host plants (sugarcane) stimulated *Striga* seed to germinate when came in contact with it and a parasitic relationship became established. Following germination the radicle of this parasitic weed penetrated into host root and formed a swollen structure. A multicellular haustorium formed at the point of attachment penetrated into epiblema of host (sugarcane) root and reached xylem vessel of the latter passing through cortex and endodermis by mechanical pressure or secreting some chemicals. Subsequently growth over a period of weeks leads to the development of a weakly branched ill developed root system devoid of root hairs, but showing prominent haustoria practically every where it came in contact with the host roots and formed a common bridge.

The ill-developed root system of this parasitic weed is less efficient to absorb water and mineral nutrients from the soil and it bear several green leaves. Multicellular haustorium maintains connections between host and parasite and possibly absorbs minerals and water from the host root and prepares their own foods. By this process host plant (sugarcane) lost a quantity of mineral nutrient and water, as a result leaf moisture and leaf chlorophyll deficit started in *Striga* parasitized cane leaves when the radicle of this parasitic weed penetrated the specific host roots and gradual deficit continued. Subsequently growth and development including growth rate (cm/day) of the specific host plant (sugarcane) which was parasitized with *S. densiflora* started to decrease over control at the same time and gradual decrease continued. These gradual decrease prominent at the juvenile and flowering stage of *S. densiflora*.

Uptake rate of water and mineral nutrient specially nitrogen, phosphorus, potassium, calcium and sulfur by *S. densiflora* from the specific host roots through haustoria for their normal growth and development was higher. As a result *Striga* parasitized sugarcane died and water and mineral nutrient, specially nitrogen, phosphorus, calcium, iron and boron of that soil were not used. On the other hand control sugarcane take up a large amount of water and mineral nutrient specially nitrogen, phosphorus, calcium, iron and boron from the soil for their normal growth and development. Due to this, nitrogen, phosphorus, calcium, iron and boron percentage increased and potassium and magnesium percentage decreased significantly in the soil of *Striga* parasitized sugarcane field over control.

Due to this loss of water and minerals from specific host roots (sugarcane) through haustoria of *S. densiflora*, the host plants suffering from physiological disorder. As a result parasitized cane plants were stunted and attacked by different types of diseases. Finally the cane plants died when *Striga* plants released its seeds, resulting huge crop yields losses.

In the beginning, the fields parasitized by *Striga* usually do not show any specific diagnostic features apart from the occurrence of the parasitic weed itself. The damage to cane crop even within one field was often variable. Sometimes there was minor damage due to stunting of the canes whereas canes there showed major damage i.e. death of the canes. Severe parasitization kills all the canes in large areas of the field. Affected cane plants were stunted with reduced height, internode number, stalk weight, juice extraction percentage and CCS percentage in all the selected 5 improved varieties. Number of millable cane and germination of ratoon cane groves were also reduced in higher percentage. The high significant value between control and *Striga*-parasitized sugarcane in yields components of all the selected 5 improved varieties indicate that all the selected varieties were highly susceptible to *Striga* spp. Yield losses depends on *Striga* population and severity of infestation.

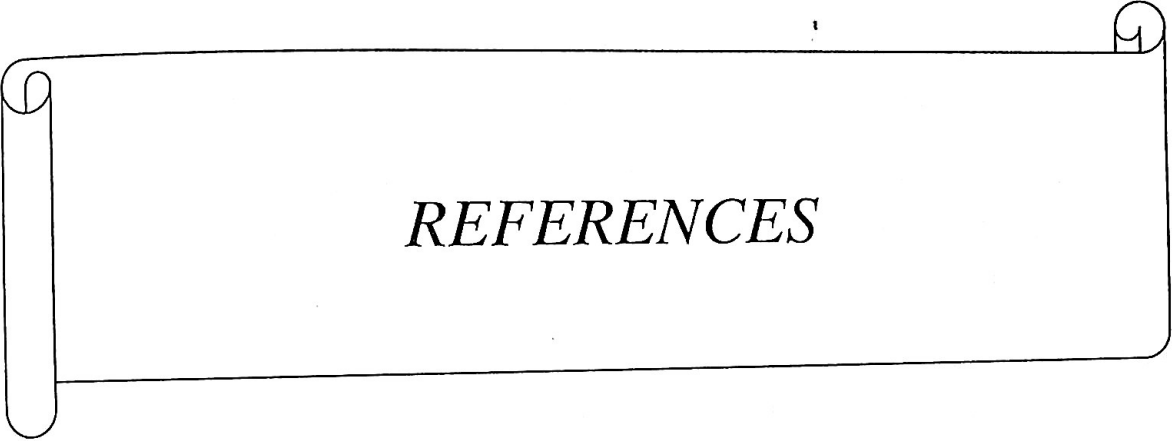
In the present study, total sugar content in total tissue samples decreased significantly in *Striga*-parasitized sugarcane after 8 months of plantation and 4 months of *Striga* emergence above the ground compared to control one. Reducing sugar in total tissue samples also increased due to *Striga* parasitization and non-reducing sugar in total tissue samples decreased significantly compared to their control.

The best way to manage this parasitic weed is to eradicate it before fruit set and more than 9 weeding^s are needed. It is very costly, which makes this method discouraging to the growers. It is a localized problem in Bangladesh. Long distance dissemination may be controlled by plant quarantine.

Chemicals (80% sodium salts of 2,4-D and 2-3% copper sulphate solution) have been recommended for direct killing of *Striga* or for stimulating its seed germination. These chemicals are very costly, to some extent toxic, not available in the market and very much harmful for soil environment. Considering these difficulties, management of *Striga* problem by using urea solution (2.5%) at juvenile stage of *Striga* and high dose of urea fertilizer applied at the time of sugarcane plantation. Urea solution killed the *Striga* plants and high dose of urea fertilizer inhibited seed germination of *S. densiflora*. It is fairly available, less costly and also less toxic to sugarcane plants as well as mammals.

Cultural and chemical control methods have gradually been ineffective due to the close ecological and physiological relationship between host and parasite. Cultivation of legume crops especially *Cicer arietinum* as crop rotation and burning of stubble is the best solution for *Striga* problem. Legume crops suppressed *Striga* seeds germination, it is less costly and also not toxic. Subsequently these crops increase soil fertility due to fixation of atmospheric free nitrogen into nodule and these are also economic rabi crops. It is a preliminary observation and more studies are needed to establish it to manage *Striga* problems. Non-graminaceous crops especially legumes and jute is recommended for the *Striga* infested plots to avoid crop loss.

CHAPTER VII



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