EFFECT OF INDIGO (*Indigofera tinctoria* L.) GREEN MANURING ON THE PROPERTIES OF SOIL AND THE CONTROL OF ROOT-KNOT DISEASE OF JUTE CAUSED BY NEMATODE (*Meloidogyne javanica*)

A THESIS
BY

MD. ABU ZAFOR

Student No. 1505177
Semester: July-December, 2016
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MASTER OF SCIENCE (M.S.)
IN
SOIL SCIENCE

DEPARTMENT OF SOIL SCIENCE
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Submitted to the Department of Soil Science
Hajee Mohammad Danesh Science and Technology University, Dinajpur
in partial fulfilment of the requirements for the degree of

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DECEMBER, 2016

Dedicated

To my

Beloved parents

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The Author

ABSTRACT

A pot experiment was carried out in Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period from March 2016 to August 2016 to study the effect of indigo (*Indigofera tinctoria* L.) green manuring on the properties of soil and the control of root-knot disease of jute caused by nematode (*Meloidogyne javanica*). In this experiment jute plants were used as test crop and indigo (*Indigofera tinctoria* L.) as green manuring crop. The experiment was laid out with seven treatments having three replications. Indigo green manuring had significant effects on the soil properties, growth of the shoots and the roots of jute plants. Height of the jute plants were recorded before harvesting the plants and the length of the roots, their dry weights and the number of gall g^{-1} of roots were recorded. It was clearly found that the growth of shoots and roots were highest for the control treatment but reduced for the egg mass of root-knot inoculated jute plants. The highest plant height (78.00 cm) and the root length (50.00 cm) were found for the control treatment where no gall was formed. On the contrary, the lowest plant height and roots length were 23.17 cm and 20.50 cm respectively for the 400 eggs mass inoculated treatment. Application of indigo green manuring and furadan also increased the shoots and roots growth and decreased the gall numbers even having egg mass of root-knot inoculation. Same results were found for the shoot and root weights of jute plants. Maximum shoot and root weights of 39.17 g and 12.00 g respectively were found for the control treatment. Only in the 400 eggs mass inoculated treatment the shoot and root weights were 22.33 g and 6.17 g which increased after green manuring with indigo or application of furadan. 200 eggs pot^{-1} inoculated jute plants formed 77.00 galls g^{-1} of root which increased to 89.83 galls g^{-1} root due to 400 eggs pot^{-1} inoculation. Indigo green manuring markedly decreased the galls $g^{-1}$of root compared to those without indigo manuring. Furadan application also reduced the galls number but indigo green manuring reduced more galls than that of the chemical furadan application. The negative correlations between the galling incidence and the plant height and the root length of jute plants revealed that the indigo green manuring was effective in increasing the growth of the jute by suppressing the nematode activity.

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CHAPTER I

INTRODUCTION

Jute is the golden fiber of Bangladesh which is an important cash crop that belongs to the family Tiliaceae and genus *Corchorus.* There are two cultivated species of jute, namely *Corchorus capsularis* (deshi jute) and *Corchorus olitorious* (Tossa jute). It plays an important role in Bangladesh economy as the country earns about 12-13% of total foreign currency by exporting jute and jute goods (BJRI, 1998). Bangladesh, the second largest producer of jute, produces the best quality jute in the world and leads the export market. Jute covered 6.95% of the total cultivated area occupying 0.5 million hectares and producing 0.96 million metric tons fiber (AIS, 2003).

Jute is extensively used throughout the world because of its versatility, durability and eco-friendly nature. Its fiber is mainly used in manufacturing various types of industrial products such as hessian, sacking, carpet backing, cloths, mats, blankets, fabrics, packing materials, etc. The fiber is also used to prepare ropes and housing materials for domestic uses.

Recently, jute has entered the technical industry (non woven industry) where wood substitute furniture materials, ceiling goods, sanitary napkin, automobile things, fire proof fiber etc. are made instead of fabrics as it is one of the most cost effective high tensile natural fiber. Therefore, gradually the demand for jute has made its way into the automobile industry. Jute sticks are used as fuel and fence in rural areas. In recent years, green jute plants are being used as raw materials for paper pulp in the paper mills. It is also used for partex and geo-jute textile. Bangladesh Jute Research Institute has succeeded in research and development for using jute fiber as an alternative to cotton, wool and manufacturing fabrics (BJRI, 1987). Jute is bio-degradable, putting valuable nutrients back into the soil and eco-friendly. One hectare of jute plants consumes 15 tones of CO_2 and release 14 tones of O_2 which is several times higher than trees. Its young leaves are widely used as vegetables in many countries, its leaves also have been used as herbal medicine, have much advantage over synthetics and protect the environment and maintain the ecological balance (Tahsin, 2008). Present world demand of using the natural fiber instead of synthetic (to save the environment) is also regaining the past glory of Jute. Bangladesh government has also taken different steps for strengthening the jute sector.

But the production and quality of jute fiber is decreasing due to the various factors. Root-knot is one of them which is caused by nematode. Due to the attack of nematode growth of jute plant is stunted and plant becomes thinner. It also reduces the fiber production. It is necessary to control the nematode of jute for increasing fiber production.

Farmers of Bangladesh are controlling nematode by using chemicals which is very expensive, particularly for poor farmers of Bangladesh. In addition their harmful effect in the environment which is responsible for soil, air and water pollution. Although the researchers of Bangladesh have taken several biological measures to control the root-knot diseases caused in several crops like tobacco

(Hossain *et al.* 2011) but no information is available to control the root-knot disease of Jute using the indigo plants as green manure.

Indigo (*Indigofera tinctoria*) is a leguminous crop which adds organic matter to the soil and thereby improves the soil fertility (Barrios and Cobo, 2004). Farmers of the different parts of the world are cultivating indigo for different purposes such as improving organic matter content in soil as well as for green manuring. Farmers of Bangladesh under the districts of Nilphamari and Rangpur are cultivating indigo plants as green manure and to control nematode from the field (Ahmed, 2002).

Indigo is an important leguminous crop which improves and maintains the fertility of soil. In general, legumes are considered to be an important component of subsistence cropping systems because of their ability to convert atmospheric inert di-nitrogen (N_2) into available form of ammonia, to add substantial amount of organic matter to the soils and to grow better than many other crops with low inputs under harsh climatic and edaphic conditions.

Addition of organic residues in any form has become essential for Bangladesh soils because of very low content of usually less than 2% and in many cases even than 1% (BRAC, 1997). On the other hand, for satisfactory crop production, the maintenance of 2.5 to 3.0% organic matter in soils is desirable (Sun and Hrich, 1992). An established truth is that organic matter primarily determines the fertility of a soil where fertility indicates the abundance and unhindered availability of nutrients. In this regard, Bangladesh soils are conspicuously low in nutrients due to rapid decomposition of organic matter under congenial high temperature and humid conditions, losses of N due to volatilization and de-nitrification, considerable leaching and high removal by intensive cropping with modern varieties. The continuous application of chemical fertilizers has become detrimental for soil fertility and accelerator for environmental pollution.

As Bangladeshi soils are very deficient in organic matter, the key fertility factor inclusion of some ways of adding organic residues into soil has become essential. Intensive cropping for increasing food production in a desperate need for feeding the hungry millions leaves no space for green manuring. Other sources such as cow-dung, farmyard manures, composts etc. are not in enough supply. Inclusion of a cereal legume in the cropping pattern, inter or relay cropping of cereal legumes may come into picture to share the dire need of adding organic residues into soils. Indigo may contribute significantly to address this desperate situation. Farmers of three districts of Bangladesh have been cultivating indigo for three reasons-green manuring, controlling nematode incidence in tobacco and selling the dried stalks as fuel for hard cash. Nobody can deny the fact that farmers do not waste their time for anything nonsense. Indigo has already earned farmers acceptance although there had been no research activities on this important issue for finding out suitable cultivation technology.

Indigo green manuring improves not only soil properties but also control the root-knot disease of Jute under the above circumstances, this pioneering research program was planned to test the following objectives-

1. To control the root-knot diseases and also to increase soil fertility for better production of jute.

2. To evaluate better growth and yield performance of jute using indigo as green manuring.

CHAPTER II

REVIEW OF LITERATURE

Nematodes are important group of plant pests and their effective management is an essential component of any crop improvement program. Chemical control of nematodes is neither sustainable nor economically viable. Therefore, the appraisal of nematode management with eco-friendly approaches and bio-components is an ideal subject in the present day environmentally conscious agriculture. There are many researches has been done on the effect of nematode on various crops but very few has been done on indigo green manure to control root knot nematode. However available literatures related with control of nematode in different crops and recent research activities on indigo are presented below:

Hossain *et al*. (2011) conducted a pod culture experiment during the period of June 2005 to December 2005 at the Soil Science Field Laboratory, Hajee Mohammad Danesh Science and Technology (HSTU), Dinajpur, Bangladesh to evaluate the effects of indigo green manuring on the root-knot disease caused by nematode (*Meloidogyne Javanica*). Tobacco (*Nicotiana tabaccum* L.) was used as test crop and Indigo (*Indigofera tinctoria* L.) as green manuring crop. Green manuring with indigo was found to give significant response in the growth and corresponding reduction in the number of galls in tobacco inoculated with *Meloidogyne Javanica*. The negative correlations between the galling incidence and the plant height and root length of tobacco revealed that the indigo green manuring was effective in increasing the growth of the tobacco by suppressing the nematode activity.

Isalam (2011) conducted an experiment to find out the efficacy of some biological means (BAU-Biofungicide, allamanda tablet and neem oil) on the control of root-knot (*Meloidogyne incognita*) of soybean. BAU-Biofungicide showed the best performance among those with the highest growth of shoot as well as weight of shoot; number of pods per plant, number of nodules per plant correspondingly with higher yield per plant as evident with higher weight of seeds consequently with decreased galling incidence and lower number of adult female, eggmass, j_2, j_3 and j_4 juveniles.

Sarker (2009) conducted an experiment with a newly developed bionematicide, BAU-Bionfungicide, bionematicide + BAU-Biofungicide and concentration under field conditions, most tested materials have significantly reduce second stage juveniles of *Meloidogyne incognita* in soil and roots of eggplants (*Solanum melongena*) cv. Baladi compared to oxamyl 24% L and the untreated check. Significant increase in weight of fruits/plant was also achieved by the most tested materials.

Hasan (2005) observed that the plant height, total number of branches, leaf area, total dry matter and seed yield of indigo significantly increased by the foliar application of 100 ppm GA_3 (121.5 cm, 55.2 cm, 1863 cm^2, 66.07 g and 11.4 g, respectively). Results concluded that application of foliar GA_3 at 45 days improved canopy structure and thereby increased total dry matter and seed yield.

Pratibha and Korwar (2005) conducted an experiment in the field during 1997-98 and 1998-99 in Hyderabad, Andhra Pradesh, India, to investigate the effect of harvest stages on biomass-yield, dye content and dye yield of indigo (*Indigofera tinctoria*). The treatments comprised 3 harvest stages, i.e. vegetative (45-50 days after sowing, DAS), flowering (60-90 DAS) and little pod stage (100-120 DAS). Harvesting indigo at little pod stage recorded 20% higher biomass and 46% higher dye content than that at flowering stage.

Khan (2004) was carried out a field experiment for three consecutive years with different nematicides, viz. carbofuran 3G at 2 kg a.i./ha, phorate 10G at 2 kg a.i./ha, sebuphos 10G at 2 kg a.i./ha, fenamiphos or benfuracarb 10G at 2 kg a.i./ha as soil applicants and carbosulfan 25 ST at 3% w/w as seed treatment, for controlling root-knot nematode, *Meloidogyne incognita* race 2, in jute. The only effective and economical approach was seed treatment with carbosulfan 25 ST at 3% w/w. However, soil applications of carbofuran and fenamiphos at 2 kg a.i./ha were also found effective in increasing fibre yield of jute. Good results were also obtained when seeds of jute were treated with carbosulfan 25 ST at 3% w/w followed by soil application of fenamiphos 10G, phorate 10G, or sebuphos 10G at 2 kg a.i./ha. A reduction of root galling was observed in plots treated with sebuphos at 2 kg a.i. /ha.

Pervin (2004) accomplished an experiment from May 2003 to March 2004 and seed were sown on 12 May, 2003 and the data were collected at 330 days after sowing (DAS). She also used three different levels of GA_3 (0, 100 and 150 ppm) on some canopy. Structures, dry mass and seed yield in *Indigofera tinctoria*. She also found that a dose of 100 ppm of GA_3 increased significantly the number of branches, racemes plant^{-1}, pods plant^{-1}, seed yield plant^{-1} and dry mass yield plant^{-1}.

Kabir (2003) executed two experiments with indigo (*Indigofera tinctoria*.) plant in the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh from May 2003 to November 2003 to investigate the effect of GA_3 and shoot clipping height on growth, morphological feature and yield contributing characters of indigo. Results of the hormone experiment showed that GA_3 at 100 ppm increased plant height, stem diameter, number of primary, secondary and tertiary branches, shoot fresh weight, total dry matter, number of raceme plant^{-1}, leaf number and leaf area. Cutting height at 60 cm resulted increased plant height, number of secondary and tertiary branches, number of leaf, leaf area, number of raceme plant^{-1} and nodule weight. He also concluded that 100 ppm GA_3 and 60 cm shoot clipping produced greater leaf and biomass yield.

Rokonuzzaman (2003) carried out an experiment at the Field Laboratory of the Department of Crop Botany, BAU, Mymensingh, during the period from April to October, 2003 to investigate the effect of shoot clipping (uncut and shoot cut at 60 cm height) and plant density (11, 16, 22 and 33 plants m^{-2}) on canopy structure, root growth and biomass yield in *Indigofera tinctoria* plant. Results revealed that shoot clipping at 60 cm height from ground level at 120 days after sowing promoted branch, leaf and root growth when compared with unclipped plant (control). Increasing density from 11 to 33 plants m^{-2} generally suppressed shoot and root growth with increased biomass yield at intermediate density. Results concluded that 60 cm shoot clipping and density of earlier 16 or 22 plants m^{-2} height be used for higher leaf and total dry mass yield.

An investigation was conducted by Patel and Patel (2001) to test the efficacy of sunhemp (*Crotalaria juncea*), periwinkle (*Catharanthus roseus*), and french marigoid (*Tagetes patula*) as green manure in the management of stunt (*Tylenchorhychus vulgaris*), root knot (*Meloidogyne incognita*) and reniform (*Rotylenchulus reniformis*) nematodes in bidi tobacco (*Nicotiana tabacum*) nursery. Sebufos and soil solarization with clear LLDPE plastic of 25 micro meters for l5 days during summer were also tested singly as well as in combination with the plants along with appropriate control. Bidi tobacco cv. Anand 119 was seeded in experimental area. Pooled results for 3 years revealed that all treatments reduced the nematode population at seeding over control. Root knot disease was significantly reduced until 63 DAS in- the treatments of sebufos alone and its combinations with sunhemp or French marigold and in green manuring of sunhemp followed by soil solarization.

Shrestha and Ladha (2000) carried out an experiment in rice-sweet pepper cropping system in farmers fields in the Philippines and found that significant amounts of NH_4-N accumulated in soil at 15 days after incorporation of residues of indigo *(Indigofera tinctoria*) alone (12 kg ha^{-1}) and indigo mixed with mung bean (*Vigna radiata*) residue (24 kg ha-^{1}), and at 60 days after incorporation of maize residue (8 kg ha^{-1}).

Augustin *et al*. (1999) executed a long term field experiment in Ilocos Norte, Philippines, to determine the effects of Indigo (*Indigofer tinctoria*) on the productivity of rain fed lowland rice based cropping systems: rice-tomato, rice-tobacco or soybean, rice-maize, and rice-garlic, with rice grown in the wet season and the other crops in the dry season. Indigo was grown as an intercrop during the dry season and incorporated as a green manure for wet season rice. Crop yields at dry season were not affected by the indigo intercrop but indigo green manure had a positive effect on rice yields.

Sarrazyn and Degroote (1999) conducted a spacing trial in indigo with the plant density of 11.1, 9.5, 8.2 and 6.2 plants m^{-2} compared with the normal plant density of 7.14 plants m^{-2} (35x40). The seeds were sown on 3 June, 1998 planted on 24 June and harvested on 26-27 August and 7 September. Wider spacing resulted in greater and heavier heads.

The elaborate and comprehensive report of Garrity *et al*. (1994) claims that farmers use indigo primarily to reduce their expenses on chemical fertilizers. In the rice fields with no prior crop of indigo, farmers generally apply N fertilizers twice during the rice crop, but following indigo, they apply it only once at 45-53 days after transplanting. Thus they reduce N application, on average, by one-half or two-thirds when the rice is preceded by indigo i.e. 25-50 kg ha^{-1} compared with an average of 86-136 kg N ha^{-1}. The report concluded that indigo was a farmer-proven Green Manuring (GM) system in the Philippines and the technology has been spreading from farmer to farmer through personal contact which itself indicate that indigo deserves more attention than it has so far received.

Singh *et al.* (1990) observed the morphological characters of *Indigofera gerardiana* (height, average 1.37m, range 0.50-3.10 m; and crown area, average 3.66 m^2, range 0.57-20.42 m^2; based on data-from 200 plants), biomass production (stem, average 3.66 kg, range 0.88-2.23 kg; foliage, average 0.32 kg, range 0.20-0.54 kg; underground biomass, average 1.10 kg, range 0.55-1.43 kg; and total biomass, average 3.08 kg, range 1.67-4.20 kg; based on data from 50 plants), and shoot characteristics (based on data from 7 plants). Shoot length were 1.40-2.30 m (based on data from 7 plants). The stem contributed 53.8 % of the biomass, the roots 35.6% and leaves 10.4%.

Alam (1987) stated the pollution free control of plant parasitic nematodes by soil amendment with plant wastes. Results from the pot experiments proved that chopped plant leaves when incorporated into naturally infested soil effectively suppressed populations of plant parasitic nematodes and improved growth of tomato

Anon (1986) recorded under experimental conditions of the severity of root-knot and populations of females were directly correlated whereas growth of eggplant (*Solanum melongenum*) was reduced due to root-knot disease and as much as 53-62% losses in fruit yield.

Mian (1986) conducted a comprehensive survey throughout Bangladesh to find out host range of root-knot nematodes (*Meloidogyne* spp.). He found that the pests have wide host range causing severe root gall on their hosts.

Mian and Ali (1986) tested 97 crop species including few ornamentals commonly grown in Bangladesh and found that 44.33% crops were highly susceptible, 8.55% susceptible and 20.62% moderately susceptible hosts. Among the crops, jute, okra, Indian spinach, brinjal, tomato, cauliflower, pumpkin, papaya bottle gourd, radish, bitter gourd, green gram sponge gourd, cucumber, coriander, tobacco, chick pea pointed gourd, sweet gourd are highly susceptible. Carrot, cowpeas lentil, maize, pineapple, ridge gourd, snake gourd, rice, cabbage, sweet potato, amaranthus, banana, garlic were susceptible. Beteleaf, sugarcane red amaranth, linseed, rice, turnip, cauliflower, onion, wheat and green amaranth are moderately susceptible. Camellia, cosmos, ginger, chilli, sesame, moonflower and turmeric were resistant. Chrysanthemum, cotton, groundnut, marigold, pigeon pea sun-hemp, and water melon were not infected by the pest.

Duncan and Ferris (1983) noted that root-knot (*Meloidogyne incognita*) is a common disease of cowpea (*Vigna sinensis*). It causes severe growth retardation, decrease in pod setting and pod size and seed yield.

In a pot experiment Bora and Phukan (1982) found that fresh weight of jute (*Corchrorus capsularis*) increased appreciably and they opined that such growth increase might be due to hypertrophic and hyperplasic growth of roots during gall development. The reduction of root growth was observed when the inoculums level was more than 100 larvae pot^{-1}. It indicates that large number of larvae of the pest infects jute roots causing reduction in root proliferation and development.

Mian and Rodriguez-kabana (1982a) studied the nematicidal properties of 15 materials of plant origin in greenhouse experiments with a soil infested with *Meloidogyune arenaria* chit wood. Amendments of soil were most effective to reduce root galling caused by nematode on summer crookneck squash (*Cucurbita pepo* L.) The nematicidal efficacy of all the soil amendments in the study was directly correlated with their nitrogen content and inversely related to their C:N ratios. Amendments with material having C:N ratios in the ranges of 15-20 were the most efficacious against the nematode when all the amendments were applied at 1.0%.

Mian and Rodriguez-Kabana (1982b) studied the effect of soil amendments with oil cakes and chicken litter for control of *Meloidogyne spp*. in greenhouse experiments with squash (*Cucurbita pepo* L.). The amendments reduced root galling caused by nematode and stimulated plant growth. The degree of nematode control was dependent on the amount of material added.

Duke (1981) reported the use of indigo as green manuring in Southern India but so far, no other report on the issue has come out since then.

Yassin (1981) identified *Meloidogyne javanica*, *M. incognita* and *M. arenaria* as major namic pests of crop plants in Sudan. He found that *M. javanica* caused up to 70% loss of tomato (*Lycopersicon esculentum*) and tobacco (*Nicotiana tabacum*). Among the infected crop species tomato (*L. esculentum*), eggplant (*Solanum melongenum*) and papaya (*Carica papaya*) were severely affected.

Zeidan (1981) found that root-knot nematode is one of the major problems hindering tomato production throughout Sudan, especially in localities of light soil.

Chowdhury *et al*. (1981) found that the species most commonly found associated with banana (*Musa acuminata*) root-knot disease are *M. incognita* and *M. javanica*. The most obvious symptoms are galling on primary and secondary roots, causing them to bifurcate and distortion, reducing yield and quality of banana fruits.

In Bangladesh, root-knot nematodes (*Meloidogyne* spp.) can attack a wide range of crop species causing severe growth reduction and yield decrease (Haque and Choudhury 1980).

According to Gbuji (1979) groundnut (*A. hypogaea*) is common host of root-knot nematode (*M. incognita*) causing stunted vine, frequent flower abortion and decrease pod yield.

Bhatti and Jain (1977) found that root-knot nematode (*M. incognita*) was very detrimental to okra (*Abelmoschas esculentus*) causing decrease of plant growth, fruit setting, and fruit yield. Black pepper (*Piper nigrum*) has been recorded as a good host of root-knot nematodes (*Meloidogyne incognita*).

Hauonik *et al*. (1975) opined that reduction in plant growth and yield of tomato (*Lycopersicon esculentum*) and tobacco (*Nicotiama tabacum*) is a common occurrence due to attack of root-knot nematodes (*Meloidogyne* spp.).

In India root-knot disease has been identified as a detrimental disease of gram (*Acorus gramineus*). Under suitable conditions the crop heavily suffers from the disease. It causes reduction in plant growth; pod setting, pod size and seed yield (Srivastava *et al.* 1974).

Wallace (197I) reported that growth of plants was reduced and severity of root-knot increased due to increased population densities of root-knot nematode. The severity of root-knot and population of females were directly correlated whereas weight of shoot and root were inversely correlated with the increased population densities of root-knot nematode.

Minton (1963) reported that the pest is very detrimental to peanut (*Arachis hypogaea*) showing stunted growth, decrease shoots dry matter accumulation and more frequent flower abortion.

According to Bird and Millerd (1962) root-knot nematodes *M. incognita* is one the most destructive pests of tomato (*Lycopersicum esculentum*). It causes gall of knot causing a lower growth, reduction of shoot length and weight, root length and weight, resulting in a reduction of crop yield.

Root-knot was found to be very detrimental to soybean (*Glycine max*). Due to attack of root-knot the crop suffers heavily and causing retardation of plant growth, reduction in pod setting, pod size and ultimately decreases the yield (Dropkin and Nelson 1960).

Timm and Ameen (1960) reported that *Meloidogyne incognita* associated with almost all crops grown in Bangladesh and cause severe galls and crop damage.

The host of root-knot is amaranth, carrot, bottle gourd, black gram, bitter gourd, beet, barley banana, chickpea, chili, coriander, cowpea, cucumber, garlic, Indian spinach, jute, grass pea, lentil, lettuce, linseed, maize, mustard, pea, potato, pineapple, pumpkin, radish ribbed gourd, rice, sesame, soybean, sponge gourd, sugar-beet, sweet potato, tobacco, tomato and wheat.

Dropkin (1954) noted that root-knot caused by *Meloidogyne incognita* is detrimental to cucumber (*Cucumis sativus*) and tomato (*Lycopersicon esculentum*). Due to attack of the pests crops suffer heavily from retardation of shoot and root growth fruit setting fruit size and yield.

Standifer and Perry (1951) reported that root-knot nematodes typically cause gall of plant roots causing a lower growth and early senescence of the plant, resulting in a reduction of crop yield. However, the damage was strictly related to nematode population densities in the soil and plant cultivar.

CHAPTER III

MATERIALS AND METHODS

A pot experiment was conducted in Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period from March 2016 to August 2016 to study the effect of indigo (*Indigofera tinctoria* L.) green manuring on the properties of soil and the control of root-knot disease of jute caused by nematode (*Meloidogyne javanica*). The materials used and methodologies followed for the study has been described in this chapter.

3.1 Site

Geographically the experimental site is located between 25.13^0 N latitude and 88.23^0 E longitudes and at an elevation of 37.5 m above the sea level. The land belongs to the Old Himalayan Piedmont plain (AEZ-1) (UNDP and FAO, 1988) (Table 1). The pot experiment was carried out in front of the Soil Science department, Hajee Mohammad Danesh Science and Technology University, Dinajpur (Appendix-I).

3.2 Weather and climate

The experimental area possesses sub-tropical climate. Usually the rainfall is heavy during kharif season (March-September) and scanty in rabi season (October-February). The atmospheric temperature was moderately low during the rabi season and increased as the season proceeds towards kharif season with occasional gusty winds. The weather, rainfall, temperature and relative humidity during the period is favorable for conducting the experiment (Appendix-II).

3.3 Soil

Generally the soil of the experimental pots was sandy loam and contains sand (%), silt (%), and clay (%) are 58, 28 and 14 respectively (Table 2). The soil of the pot experiment was sandy loam with pH 6.10. The initial soil (0-15 cm depth) test revealed that the soil contained 0.14% total nitrogen, 1.23% organic matter, 11.75 ppm available phosphorus, 0.68 meq/100g available potassium and 15.37 ppm available sulfur (Table 3).

Table 1 Morphological description of soil

Locality	**HSTU**
AEZ (UNDP, 1988)	AEZ-1: Old Himalayan Piedmont Plain.
Land type	High land
General soil type	Non-calcareous brow floodplain soils
Topography	Leveled
Drainage	Well drainage system
Flood level	Above flood level

Table 2 Physical Characteristics of soil

Location	HSTU
Particle size Distribution	Value
Sand (%)	58
Silt (%)	28
Clay (%)	14
Textural class	Sandy Loan

Table 3 Chemical characteristics of initial soil of pot experiment

Characteristics	Analytical data
pH	6.10
Organic matter (%)	1.23
Total N (%)	0.14
Available P (ppm)	11.75
Exchangeable K (meq/100g)	0.68
Available S (ppm)	15.37

3.4 Soil sample collection and pot preparation

Soil was collected from the arable land of Soil Science Field Laboratory Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur from a depth of l5 cm. The collected soil was sun dried for a week and weeds were removed. After drying and grinding the soil sample was passed through a 20-mesh sieve. The soil was then treated with 3% formalin solution for sterilization. Ten kilogram sterilized soil was taken into each pot. Earthen plate (20 cm) diameter was placed below each pot to retain excess fluid. Thus the pots were ready for seed sowing.

3.5 Setting of pots for the experiment

The pots were placed in the selected open space of Departmental compound of Soil Science of HSTU, Dinajpur in 7 rows and 3 columns. The row to row and column to column distance was maintained at 0.8 m and 0.8 m randomly and total pot number was 21.

3.6 Sowing of indigo seeds for green manuring

Indigo seeds were collected from the Ekarchali union under the Taragonj upozilla from the reliable farmer and the indigo seeds were sterilized and sown in each pot on 10 March 2016.

3.7 Germination of indigo seeds

Germination of seeds started from the third day of sowing. After one week nearly all plants came out of the soil.

3.8 Intercultural operation of green manuring crop

3.8.1 Weeding and watering of green manuring crop

Weeding was done after 15 days of sowing when the plants attained a height of about 10-12 cm. Second weeding was done after 30 days of sowing and watering was done at 3 days' interval with cool boiled water.

3.8.2 General observation of green manuring crop

The pots were frequently observed to notice any change in plant character and to prevent attack of crop by pests, diseases or any other predator.

3.8.3 Incorporation of indigo plants in soil

After a week, 90% seeds were germinated. The pots were watered with regular interval. After 45 DAS the indigo plants were cut into pieces and mixed with the soil (Appendix IV). The cut pieces of plants were incorporated in soil and kept for 2 weeks for well decomposition.

3.8.4 Experimental crop and sowing of jute seeds

The test crop used in this study was jute (*Corchorus olitorious*). The used seeds had 85% germination capacity. The seeds were sown in all the pots to mix with sand. It was sown 2-3 cm depth of the soil to ensure better germination.

3.9 Treatments under investigation

There were 7 treatments with 3 replications for conducting the whole experiments which were as follows.

T_1=control (no nematode + no indigo manure)

T_2= 200 egg mass

T_3= 200 egg mass + indigo green manuring

T_4= 400 egg mass

T_5= 400 egg mass + indigo green manuring

T_6= 200 egg mass + furadan

T_7= 400 egg mass + furadan

3.10 Experimental design

The experiment was laid out in a Complete Randomized Design (CRD) with 3 replications. There were 7 treatments. Therefore, twenty-one earthen pots were used in this experiment.

3.11 Inter cultural operations

3.11.1 Fertilizer application

The pot soil was fertilized with N, P and K @ 40, 25 and 38 Kg ha^{-1} as Urea, Triple super phosphate and muriate of potash, respectively.

3.11.2 Weeding

First weeding was done after 15 days of seeds sowing. 2nd and 3rd weeding were done after 30 days and 45 days after sowing seeds.

3.11.3 Thinning

First thinning was done after 15 days of seed germination. Second thinning was done after 30 days of sowing and 4 plants were kept in each plot. Final and 3rd thinning was done after 45 days after sowing and 2 plants were kept for conducting the experiment.

3.11.4 Irrigation

Due to heavy rainfall during the month of June-July no irrigation was done. But when no rainfall occurs, light irrigation was done at 4 days interval.

3.11.5 Furadan application

As treating the plant, furadan was applied at T_6 and T_7 pots respectively.

3.11.6 Inoculum preparation

Egg masses were collected from roots of jute plants, which were previously inoculated with a single egg mass of *Meliodogyne javanica*. Surface sterilization of the egg mass was done with 0.1 percent mercuric chloride solution for about one minute and then placed in small nylon sieves. The sieves were placed in watch glasses containing distilled water with the water level just touching the mesh. Egg masses were counted as 200 and 400 respectively. 200 egg masses were inoculated at T_2, T_3 and T_6 treatments and 400 egg masses were inoculated at T_5 and T_7 treatments of 20 days after sowing.

3.12 Parameters studied

Jute plants were uprooted from pots 70 days after inoculation to evaluate the following characters:

- Plant height
- Root length
- Air dry shoot weight
- Air dry root weight
- Number of root galls g^{-1}
- N content by shoot

3.13 Measurement of length of shoots and roots and fresh weight of shoots and roots

At first, the soil of the pot was watered to make it moist for easy uprooting of the plants. The whole plant along with the soil attached to the roots was lifted out from the pot and dipped into a bucket of water. Then with gradual and slow movement of roots in water, the roots were separated from the soil. It was further cleaned under gradually running tap water for careful washing out. The root portion was separated. Length of shoot and root was measured. After washing, the roots were stained in phloxin "B" and preserved in 5% formalin solution. The roots were cut into small pieces and randomly 1 g of root was taken from the bulk to count the number of galls formed. The shoots and roots were cut into small pieces and sun dried for 2 days. After drying the shoots and roots, their weights were taken. The cut pieces of shoots and roots were put into brown envelope and oven dried at 65°C for 3 days for mechanical analyses.

3.14 Soil sample analysis

Mechanical analysis of both initial and final soil was done by hydrometer method (Bouyoucos, 1927) and the textural class was determined by using the values of % sand, % silt and % clay to the Marshall's triangular co-ordinate following USDA system.

3.14.1 Soil pH

Soil pH was determined using a glass electrode pH meter at 1:2.5, soils: water ratio. The suspension was allowed to stand for one hour with occasional shaking before determination (Jackson, 1967).

3.14.2 Organic matter

Soil organic carbon content was determined by wet oxidation method using $K_2Cr_20_7$ and H_2SO_4 mixture and $FeSO_4$ solution was used for titration as outlined by Jackson (1967). The organic matter content was calculated by multiplying the percent organic carbon with the van Bemmelen factor of 1.724 (Piper, 1950).

3.14.3 Total nitrogen

Total nitrogen content was determined by Micro-Kjeldahl method where soil was digested with 3 ml concentrated H_2S0_4 and 1.1 g catalyst mixture (K_2S0_4: $CuS0_4$. $5H_20$: Se powder in the ratio of 100: 10: 1). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of distillate trapped in H_3BO_3 with 0.01 N H_2S0_4 (Page *et al.,* 1989).

3.14.4 Available phosphorus

Available phosphorus was extracted from the soil with 0.5 M sodium bicarbonate solution, pH 8.5 (Olsen *et al.,* 1954). Phosphorus in the extract was then determined by developing blue color with $SnCl_2$ reduction of phosphomolybdate complex and the color intensity was measured colorimetrically at 660 nm wave lengths (Page *et al.,* 1989).

3.14.5 Exchangeable potassium

Exchangeable potassium was determined from the ammonium acetate extract using flame photometer as described by Page *et al.* (1989).

3.14.6 Available sulfur

Available sulfur was determined by extracting the soil sample with 0.01M of $Ca(H_2P0_4)_2$. The S content in the extract was estimated turbid metrically and the intensity of turbid was measured by spectrophotometer at 420 nm wavelength.

3.15 Plant sample analysis

The shoots and roots of jute plants of all the treatments were powdered to 60 meshes separately using a Willey Mill and stored in desiccators for chemical analysis in the Soil Science Laboratory, HSTU.

3.16 Determination of total Nitrogen

Nitrogen content in plant samples (shoot) was determined by the standard micro-kjeldahl method (AOAC, 1980). Plant sample (0.1 g) was digested with 3 ml concentrated H_2S0_4, 1.1 g catalyst mixture (K_2S0_4: $CuS0_4$. 5 H_20: Se powder in the ratio of 100: 10: 1) and 2 ml H_20_2. Nitrogen in the digest was determined by distilling the digest with 10N NaOH followed by titration of the distillate trapped in H_3B0_3 indicator solution with 0.01 N H_2S0_4 (Bremmer and Mulvaney, 1982)

3.17 Statistical Analysis

Data obtained from the pot experiment were analyzed statistically following the ANOVA technique and the treatment means of different characters were compared following Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present research work was conducted to evaluate the effects of indigo green manuring on the properties of soil and also to control or reduction of nematode incidence of jute. The study regarding the control of root-knot by using indigo was compared with the chemical Furadan have been discussed.

4.1 Effect of indigo (*Indigofera tinctoria* L.) green manuring on the growth of jute

4.1.1 Plant height

There was a significant effect of indigo green manuring on the height of jute plant. The highest plant height (78 cm) was found in the control treatment T_1 which was significantly different from the other treatments (Table 4). The lowest height was found in the T_4 treatment. The use of 200 eggs pot^{-1} significantly reduced the plant heights of jute plants and the use of 400 eggs pot^{-1} caused further reduction. Indigo green manuring significantly increased the plant height even in presence of 200 or 400 eggs pot^{-1} to the treatment T_3 and T_5. Due to the Furadan application in the treatment T_6 which was inoculated with 200 eggs also increased the plant height. Plant height increased because of furadan application to the treatment T_6 which was statistically comparable to the control treatment T_1. Similar results were found by Hossain *et al.* (2011) in the case of tobacco plants treated with indigo green manuring.

4.1.2 Root length

The effect of different treatments on root length of jute was found significant (Table 4). The longest root was obtained for treatment T_1 which was statistically similar with treatment T_6. The longest and significantly superior root length (50.00 cm plant^{-1}) was observed for the control treatment T_1 which was followed by 200 eggs + furadan treatment (T_6) of root length. The lowest result was found in the T_4 treatment inoculated with 400 eggs which was statistically closed to the treatment T_5 and T_7 inoculated with 400 eggs+indigo and 400 eggs+furadan, respectively. No appreciable difference was found between the treatment T_2 inoculated with 200 eggs to the treatment T_3 inoculated with 200 eggs+indigo.

Table 4 Effect of indigo (*Indigofera tinctoria* L.) green manuring on the plant height and root length of jute plants

Treatments	Plant height (cm)	Root length(cm)
T_1=control (no nematode + no indigo manure)	78.00 a	50.00 a
T_2= 200 egg mass	38.00 cd	30.83 b
T_3= 200 egg mass + indigo green manuring	45.33 c	34.00 b
T_4= 400 egg mass	23.17f	20.50 c
T_5= 400 egg mass + indigo green manuring	27.83 ef	26.33 bc
T_6= 200 egg mass + furadan	56.67 b	44.83 a
T_7= 400 egg mass + furadan	33.57 de	27.67 bc
LSD at 5% level	7.928	7.805
CV %	10.31	13.12

In a column, figures having similar letter(s) do not differ significantly at 5% level of probability.

4.1.3 Shoot dry weight

The effect of indigo green manuring was significant for different treatments on the shoot dry weight of jute as shown in the table 5. The shoot dry weight ranged from 22.33 g to 39.17 g plant^{-1}. The maximum shoot dry weight was obtained in the control treatment T_1. The minimum shoot dry weight was found in the treatment T_4 which was treated with 400 egg mass of nematode. The lowest T_4 treatment was statistically similar to the T_5 treatment. No significant differences were found among the treatments T_2, T_3 and T_7. Hossain *et al*. (2011) showed the similar results for tobacco.

4.1.4 Root dry weight

Statistically significant difference was found in root weight among the treatments (Table 5). The control plant produced the highest root weight of 12.00 g plant^{-1} which was statistically superior to the weight of roots found in the rest treatments. The jute plants inoculated with eggs produced lower root weights compared to the control. Egg mass inoculated treatments having indigo green manuring produced higher root weights compared to treatment possessing egg inoculation. Pots treated with 200 egg mass+furadan showed the lower root weights compared to that of control but stayed higher over other treatments.

Table 5 Effect of indigo (*Indigofera tinctoria* L.) green manuring on the shoot weight and root weight of jute plants

Treatments	Shoot weight (g)	Root weight (g)
T_1=control (no nematode + no indigo manure)	39.17 a	12.00 a
T_2= 200 egg mass	29.67 c	8.50 cd
T_3= 200 egg mass + indigo green manuring	32.00 c	9.17 c
T_4= 400 egg mass	22.33 d	6.17 e
T_5= 400 egg mass + indigo green manuring	24.67 d	7.50 d
T_6= 200 egg mass + furadan	35.00 b	10.83 b
T_7= 400 egg mass + furadan	29.33 c	8.00 d
LSD at 5% level	2.609	0.958
CV %	4.84	6.06

In a column, figures having similar letter(s) do not differ significantly at 5% level of probability.

4.1.5 Gall number

The number of galls g^{-1} of root varied significantly due to the inoculation with eggs of root-knot nematode and also application of furadan and indigo green manuring (Fig. 1). No gall was found in the control treatment of jute plants. The jute plants inoculated with 200 eggs pot^{-1} had 77.00 galls g^{-1} root which increased to 89.83 galls g^{-1} root due to inoculated with 400 eggs pot^{-1} (Appendix III). Indigo green manuring significantly decreased the galls g^{-1} of root compared to those without indigo manuring. Application of furadan also reduced the galls g^{-1} root significantly but which was less than those of indigo green manuring. Similar results were recorded by Hossain *et al.* (2011) for tobacco.

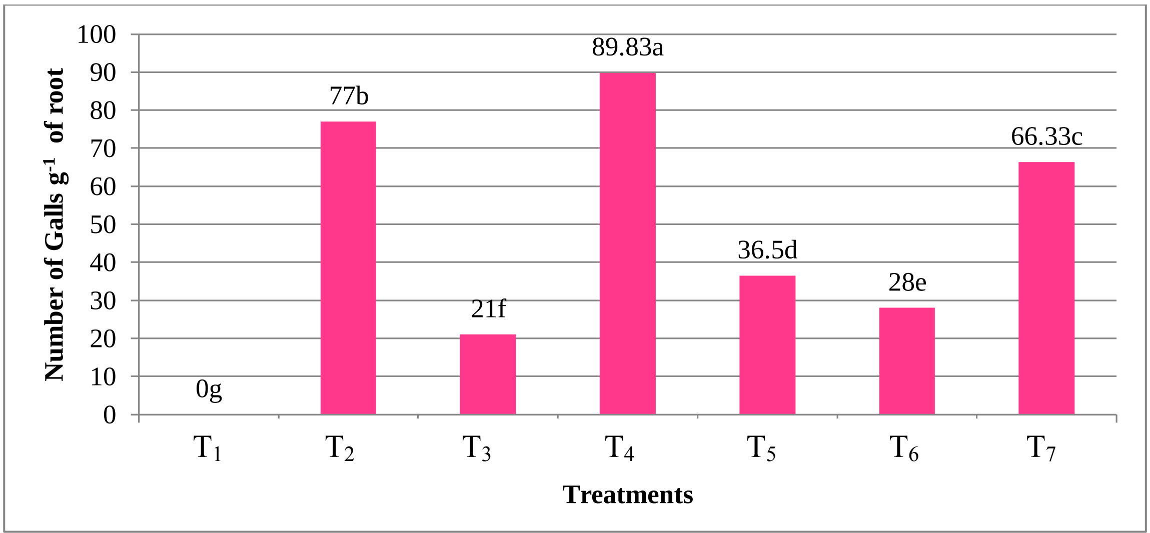


Fig. 1: Effect of indigo (*Indigofera tinctoria* L.) green manuring on number of galls g^{-1} of root

T_1= Control (no nematode + no indigo manure) T_2= 200 egg mass

T_3= 200 egg mass + indigo green manuring T_4= 400 egg mass

T_5= 400 egg mass + indigo green manuring T_6= 200 egg mass + furadan

T_7= 400 egg mass + furadan

4.2 Chemical properties of the soil collected after harvesting the crops

4.2.1 Soil pH

The post-harvest soil was around neutral, soil pH ranged from 6.10 to 6.35 (Table 6). The control treatment T_1 showed slightly increases in soil pH than the initial soil pH (6.10) (Table 6). Treatments T_2, T_3, T_4, T_5, T_6 and T_7 were statistically identical with the control treatment T_1. The study proved that soil reaction remained more or same after post harvesting soil compared with initial soil.

4.2.2 Organic matter

The effect of indigo green manuring increases the organic matter content of the soil. Organic matter (OM) content of the post-harvest soil was balanced proportional to the initial soil. Control treatment T_1 was statistically analogous with the treatments T_2, $T_{4,}$ T_6 and T_7. Green manuring treatments T_3 and T_5 were significantly alike (Table 6).

Table 6 Soil pH and organic matter of post-harvest soil

Treatments	pH	OM (%)
T_1=control (no nematode + no indigo manure)	6.35	2.09 a
T_2= 200 egg mass	6.30	2.08 a
T_3= 200 egg mass + indigo green manuring	6.31	3.23 b
T_4= 400 egg mass	6.10	2.23 a
T_5= 400 egg mass + indigo green manuring	6.35	3.20 b
T_6= 200 egg mass + furadan	6.20	2.20 a
T_7= 400 egg mass + furadan	6.23	2.09 a
LSD at 5% level	0.5954	0.3328
CV %	4.60	6.61

In a column, figures having similar letter(s) do not differ significantly at 5% level of probability.

4.2.3 Soil nitrogen

Indigo plants have a momentous effect of the nitrogen content of the soil which increases by fixing atmospheric nitrogen. This nitrogen subsequently used by the jute plants and also reduced the urea requirement for that plant. Effect of indigo on nutrient content in different parts of jute plants was pronounced than the initial soil. The highest result was found in the T_3 treatment which was incorporated with indigo plants (Table 7). The other treatments were significantly similar with the T_3 treatment.

4.2.4 Available phosphorus in soil

Phosphorus content in the post harvest soil was affected by the different treatments (Table 7). The maximum phosphorus content was found in the treatment T_7 that was identical with those of the treatments T_2 and T_4. Other treatments i.e. T_1, T_5 and T_6 were statistically similar and Treatment T_3 was followed by them.

4.2.5 Exchangeable potassium in soil

The exchangeable potassium content of the post-harvest soil was influenced by the different treatments. The values of the exchangeable potassium were traveling around from 0.20 to 0.34 me/100 g soil (Table 7). The highest value was observed in the T_3 treatment that was incorporated with indigo green manuring. Statistically analogous relations were found among the treatments T_4, T_5 and T_7 and also in the treatments T_2 and T_6.

4.2.6 Available sulfur in soil

The available S in soil was significantly affected by the different treatments. The available S content in the soil ranged from 2.02 to 6.13 ppm (Table 7). The highest S content was found in the treatment T_7 and lowest was in the treatment T_4.

Table 7 Total N, Available P and S and Exchangeable K in post-harvest soil

Treatments	Total N (%)	Available P (ppm)	Exchangeable K (me/100g)	Available S (ppm)
T_1=control (no nematode + no indigo manure)	0.15	86.02 bc	0.20 c	2.85 b
T_2= 200 egg mass,	0.14	101.3 a	0.26 b	2.20 bc
T_3= 200 egg mass + indigo green manuring	0.16	74.00 c	0.34 a	2.98 b
T_4= 400 egg mass	0.16	91.25 ab	0.32 ab	2.02 c
T_5= 400 egg mass + indigo green manuring	0.11	80.14 bc	0.31 ab	2.48 bc
T_6= 200 egg mass + furadan	0.11	86.91 bc	0.27 b	2.62 bc
T_7= 400 egg mass + furadan	0.15	103.0 a	0.28 ab	6.13 a
LSD at 5% level	0.05626	13.51	0.05626	0.7182
CV %	14.62	8.54	9.65	13.28

In a column, figures having similar letter(s) do not differ significantly at 5% level of probability.

4.3 Nitrogen content by the shoots of jute plants

Nitrogen content by the jute plants were markedly influenced by the different treatments (Table 8). The content of nitrogen of the jute plants differs from 0.67 to 1.96%. The highest content of nitrogen was found in the control treatment T_1 and lowest was found in the T_4 treatment. Egg added treatments appeared to be lower content of nitrogen than the control treatment T_1. Indigo green manuring greatly increased the content of nitrogen by the shoots even having the inoculation 200 or 400 eggs pot^{-1}. Egg mass inoculated treatments T_2, T_5 and T_7 were statistically resembled with each other. Hoisted of nitrogen was also increased when furadan was applied even in presence of 200 or 400 eggs pot^{-1}.

Table 8 Nitrogen content by the shoots of jute plants

Treatments	N content by Shoot (%)
T_1=control (no nematode + no indigo manure)	1.96 a
T_2= 200 egg mass,	1.05 d
T_3= 200 egg mass + indigo green manuring	1.20 c
T_4= 400 egg mass	0.67 e
T_5= 400 egg mass + indigo green manuring	0.95 d
T_6= 200 egg mass + furadan	1.82 b
T_7= 400 egg mass + furadan	1.04 d
LSD at 5% level	0.1378
CV %	6.12

In a column, figures having similar letter(s) do not differ significantly at 5% level of probability.

4.4 Correlation results:

The correlation results among the different parameters are shown in the Fig. 2.1 and 2.2. The plant height was positively correlated with the shoot weight (a) and was negatively correlated with the galls g^{-1} of root (b). When shoot weight increases then plant height increases but with the increasing of gall g^{-1} of root decreases plant height.

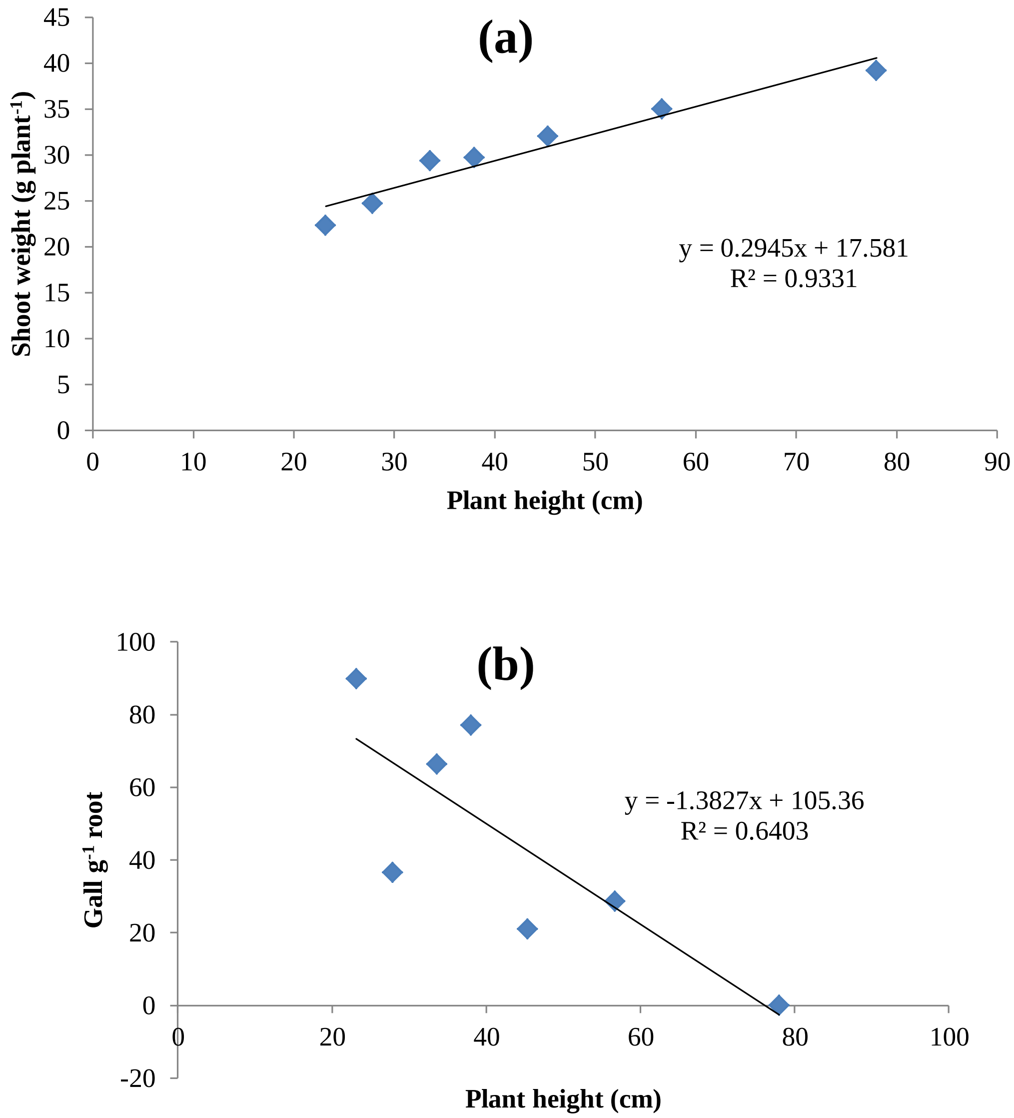


Figure 2.1: Relationship between (a) Plant height and shoot weight, (b) Plant height and gall number

The shoot weight was positively correlated with the root weight (c) and was negatively correlated with the galls g^{-1} of root. In addition, the shoot weight was positively correlated with the N content by the plants (d). With the increasing of gall number g^{-1} of root decreases the root length (e). But when no gall was applied then soot weight increases which also increases nitrogen content of shoot.

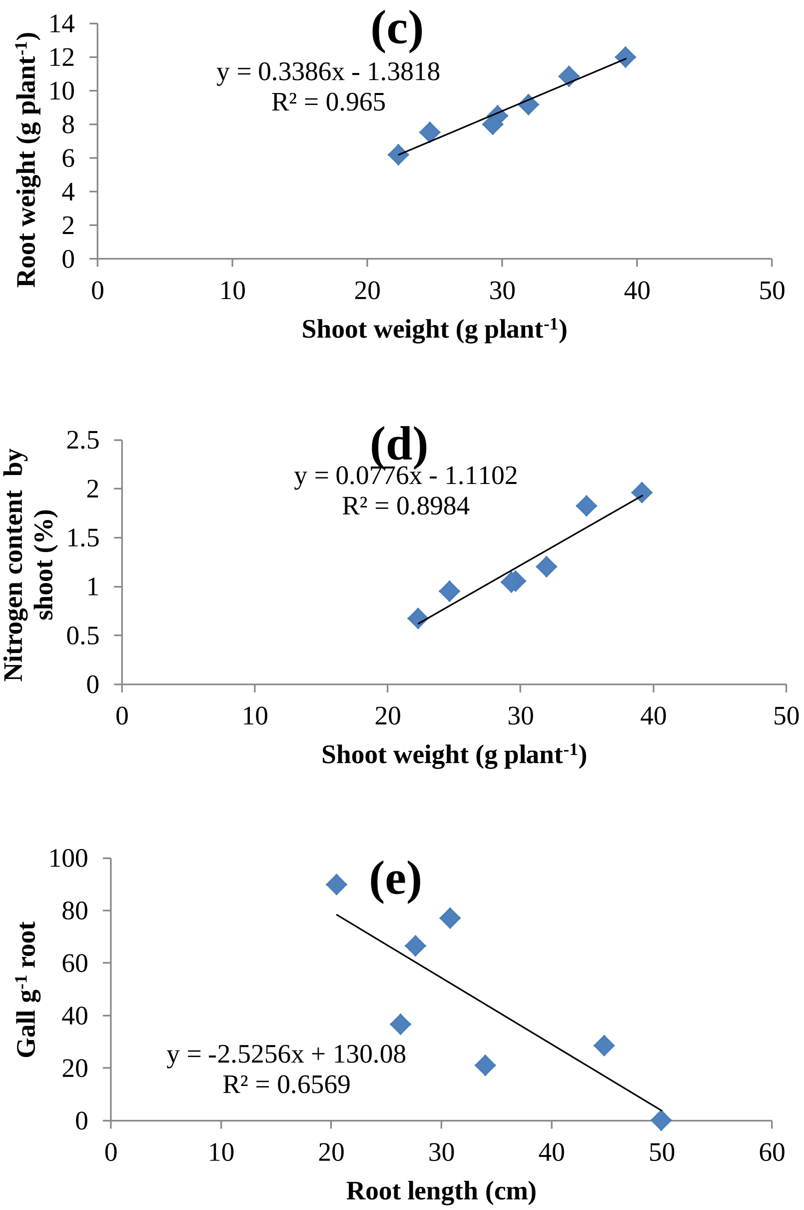


Figure 2.2: Relationship between (c) Shoot weight and Root weight, (d) Shoot weight and nitrogen content by the jute plants (e) Root length and gall number inoculated with *Meloidogyne javanica*.

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment was conducted in open space in front of the Soil Science Department, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during the period from March to August, 2016 in kharif season to study the effect of indigo (*Indigofera tinctoria* L.) green manuring on the properties of soil and the control of root-knot disease of jute caused by nematode (*Meloidogyne javanica*). The experiment was laid out in the Complete Randomized Design (CRD) with 7 treatments and three replications.

The experiment was carried out with seven treatments viz. T_1=control (no nematode + no indigo manuring), T_2= 200 egg mass, T_3= 200 egg mass + indigo green manuring, T_4= 400 egg mass, T_5= 400 egg mass + indigo green manuring, T_6= 200 egg mass + furadan. T_7= 400 egg mass + furadan. Intercultural operations were done as and when necessary. Data on plant height, root length, shoot weight, root weight and gall g^{-1} of root was recorded. The results on the physical and chemical properties of the initial and post harvest soil were analyzed statistically and mean differences were adjusted by Duncan's Multiple Range Test (DMRT).

The results of the experiment revealed that the plant height significantly influenced by the indigo green manuring. The plant height ranged from 23.17 cm in T_4 treatment to 78.00 cm in T_1 treatment. Egg inoculated jute plants attained greater height for the incorporation of indigo green manuring than the only egg inoculated jute plants. Control treatment T_1 showed higher plant heights where no egg mass was inoculated.

The root length of the jute plants was highest at the control treatment. The root length ranged from 20.50 cm to 50.00 cm. Treatments containing 200 eggs mass and 400 eggs mass attained less plant height than the treatments containing similar egg mass and incorporated with indigo plants attained higher plant height.

Data on dry weights of shoots and roots gave clear pictures on the jute plants for the different treatments. Maximum dry weights of the shoots (39.17 g) and roots (12.00 g) were recorded for the control treatment (T_1). Indigo green manuring treatments T_3 and T_5 were found better even those having egg mass of root-knot. In the T_2 and T_4 treatments only inoculated with egg mass of root-knot were observed less shoots and roots weight than those had similar egg mass and indigo green manuring treatments T_3 and T_5.

Effects of indigo green manuring on the jute plants clearly showed corresponding reduction in the number of galls g^{-1} of root. No gall was found in the controlled treatment of jute plants. The jute plants inoculated with 200 eggs pot^{-1} had 77.00 galls g^{-1} root which increased to 89.83 galls g^{-1} root due to inoculated with 400 eggs pot^{-1}. But for the similar treatments only added indigo green manuring significantly decreased the galls number from 21.00 to 36.50 g^{-1} of root. This experiment undoubtedly proved that indigo plants suppressed the activity of the nematode allowing better metabolism of the host plants.

In the case of post harvest soil various factors like pH, organic matter, nitrogen, phosphorus, potassium and sulfur were nearly similar like the pre harvested soil. Indigo plants not only reduced the gall numbers but also increased the organic matter of the soil and other nutrients kept balanced.

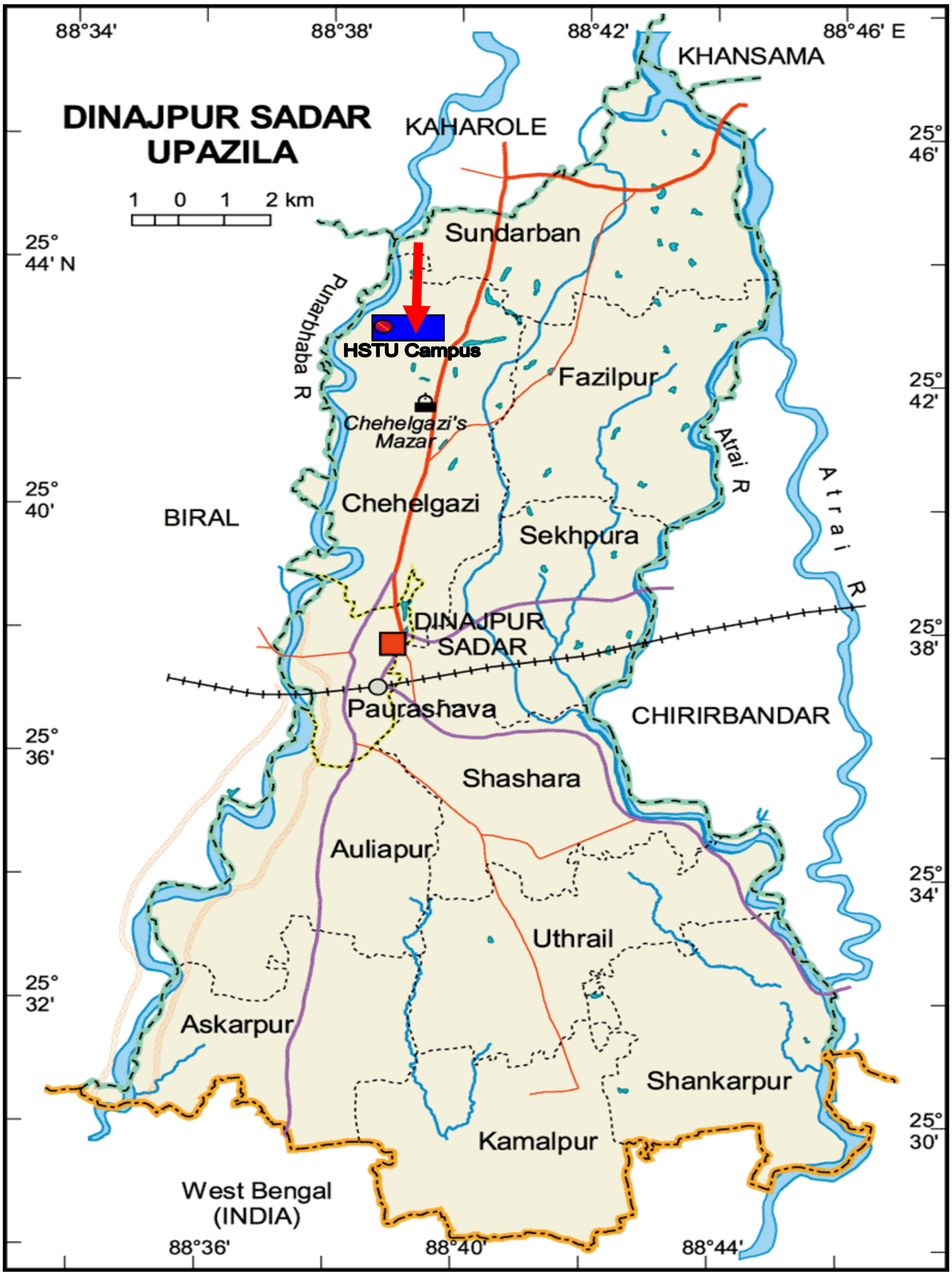
Nitrogen content by the jute plants were significantly influenced with the incorporation of indigo green manuring. It was found that the nitrogen content by the jute plants was highest (1.96%) for the controlled treatment T_1. The exhibition of jute plants treated with eggs mass of nematode with indigo green manuring viz. treatments T_3 and T_5 were greater content of nitrogen than the jute plants only treated with eggs mass of nematode viz. treatments T_2 and T_4.

The correlation and regression study showed significant and negative correlation between galling incidence of roots and shoots weight of jute plants. The findings of the present experiment indicate clearly that the indigo plants revealed the better performance in increasing the growth characters of the jute plants by suppressing the nematode activity.

Green manuring with indigo plants (*Indigofera tinctoria* L.) which was incorporated in the pots of jute plants helped to reduce the incidence root knot disease in jute and thereby increased the yield. Further research in the field level at the different AEZs (Agro-ecological zones) of Bangladesh should be carried out before making any recommendation.

APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research plot).



Appendix II. Weather data of the experimental site during the period from March to July, 2016.

Month	** Air Temperature (^0C)			*Rainfall (mm)	**Relative Humidity (%)
	Minimum	Maximum	Average		
March	16.9	30.7	23.80	25.5	74.0
April	20.1	31.0	25.55	66.0	70.0
May	22.6	32.7	27.65	331.5	76.0
June	24.7	32.1	28.40	282.0	85.0
July	25.0	32.8	28.90	255.0	80.0

***** = Monthly total

****** = Monthly average

Source: Meteorological Station, Wheat Research Center, Nosipur, Dinajpur-5200 (2016).

Appendix III. Effect of indigo (*Indigofera tinctoria* L.) green manuring on number of galls g^{-1} of plant

Treatments	**Galls g^{-1}root**
T_1=control (no nematode + no indigo manure)	0.0 g
T_2= 200 egg mass	77.00 b
T_3= 200 egg mass + indigo green manuring	21.00 f
T_4= 400 egg mass	89.83 a
T_5= 400 egg mass + indigo green manuring	36.50 d
T_6= 200 egg mass + furadan	28.50 e
T_7= 400 egg mass + furadan	66.33 c

Appendix IV. Sowing the photographs of research pots of (*Indigofera tinctoria* L.) green manuring

(a)

(b)

(c) T_1 = Control (no neatode + no indigo manure)

(d) T_2 = 200 egg mass of root-knot

(e) T_3 = 200 egg mass of root -knot + indigo green manuring

(f) T_4 = 400 egg mass of root-knot

(g) T_5 = 400 egg mass of root-knot + indigo green manuring

(h) T_1 = Control (no neatode + no indigo manure)

(i) T_2 = 200 egg mass of root-knot

(j) T_3 = 200 egg mass of root-knot + indigo green manuring

(k) T_4 = 400 egg mass of root-knot

(l) T_5 = 400 egg mass of root-knot + indigo green manuring