

**YIELD, QUALITY AND SHELF LIFE OF JUTE (*Corchorus olitorius*)
SEED AS INFLUENCED BY POTASSIUM AND BORON**

A DISSERTATION

SUBMITTED

TO

**The Hajee Mohammad Danesh Science and Technology University
Dinajpur, in Partial Fulfillment of the Requirement for the Degree of**

DOCTOR OF PHILOSOPHY

BY

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Registration No. 0605055 (Session 2006-07)

Department of Soil Science

Hajee Mohammad Danesh Science and Technology University

Dinajpur

September, 2013

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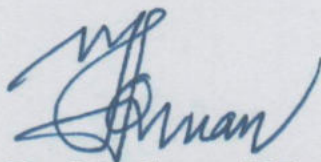
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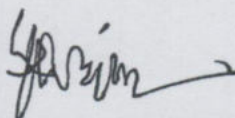
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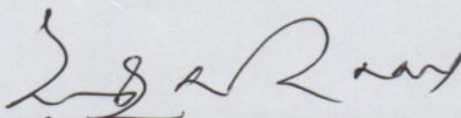
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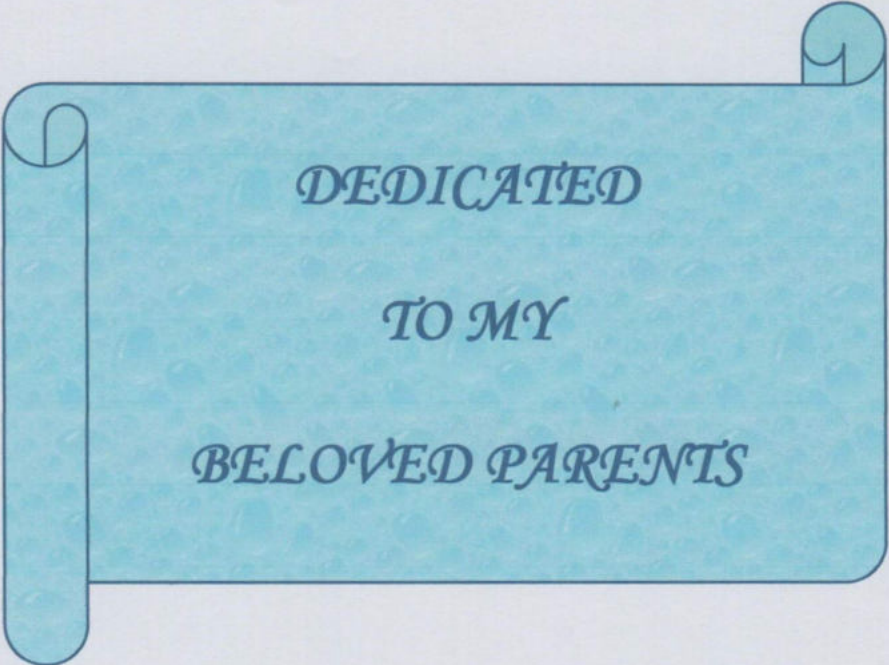
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September, 2013



DEDICATED
TO MY
BELOVED PARENTS

DECLARATION

I declare that, except otherwise stated, this dissertation is entirely my own work and has not been submitted in any form to any other university for my degree

The author

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First and foremost, I would like to express my gratefulness to the Almighty Allah, the Compassionate, the Omnipotent, the Omniscient, and the Merciful Being, for being so gracious to me all the way what I had to wade through during the period of this research work.

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September, 2013

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BIOGRAPHICAL SKETCH

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The author is married with Nasima Bari, Instructor (General), Primary Training Institute, Manikganj and blessed with two loving sons and a cute daughter.

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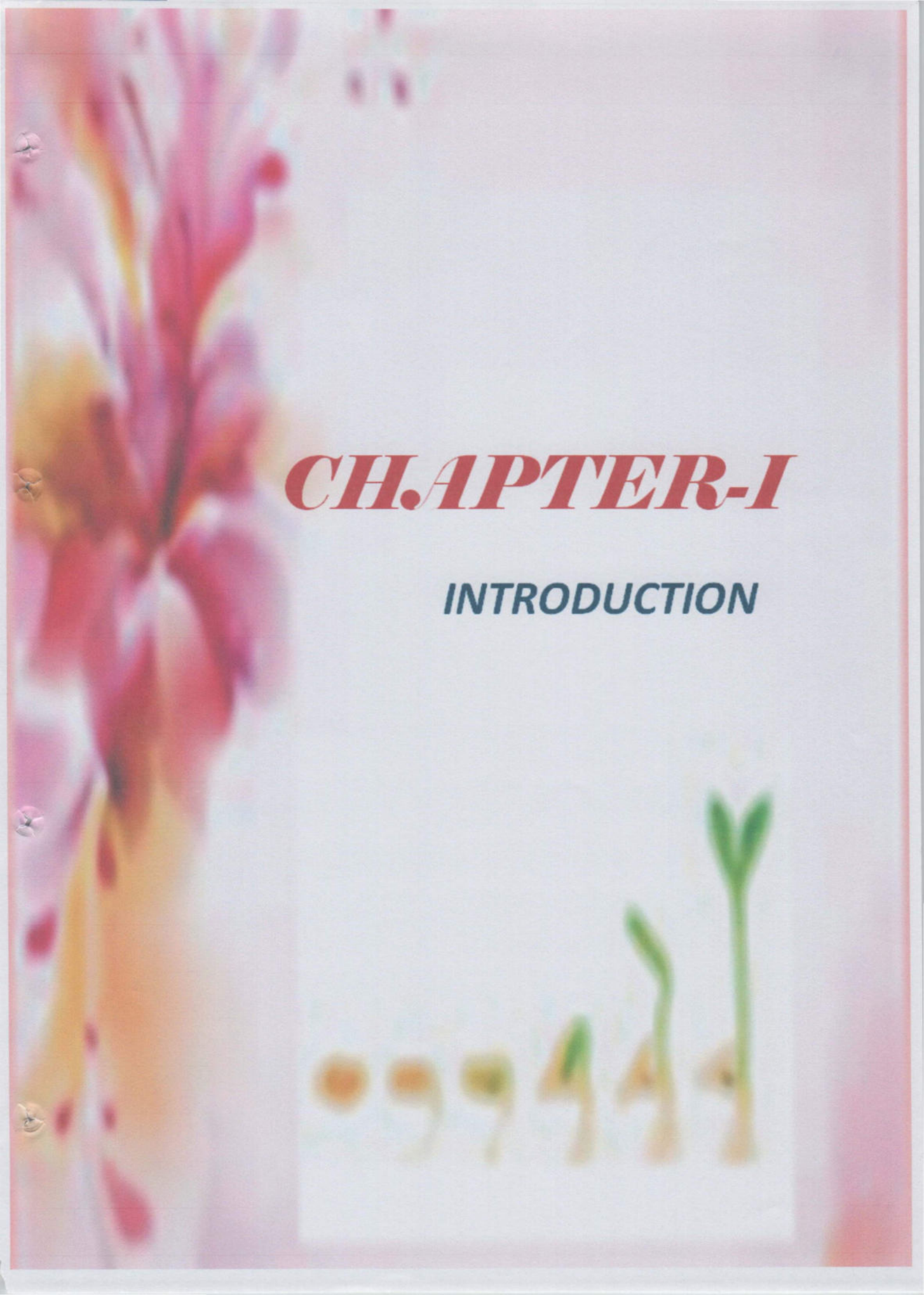
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YIELD, QUALITY AND SHELF LIFE OF TOSSA JUTE (*Corchorus olitorius*) SEED AS INFLUENCED BY POTASSIUM AND BORON

ABSTRACT

Acute shortage of quality jute seeds (*Corchorus olitorius*) accentuated conduction of this study in order to find out appropriate doses and proper application of potassium (K) and boron (B) in quest of increasing seed production and improving seed qualities for longer duration of storage. To achieve these objectives, a research plan was made with three experiments conducted at the Jute Seed Production and Research Center, Nashipur, Dinajpur during July 2007 to December 2008. First experiment had the target for selecting appropriate dose and methods for K application from amongst six levels of K (0, 30, 60, 90, 120 & 150 kg ha⁻¹) applied in three ways –(i) all K as basal at final land preparation, (ii) half as basal and rest half as top dressing at 30-35 days after sowing (DAS), and (iii) one- third as basal one third at 25 DAS and one- third at 45 DAS as top dressing. Of all the parameters studied, the following six –(i) shoot dry matter yield, (ii) seed yield, (iii) seed quality (viability, vigour, seedling dry matter, EC, soluble protein, soluble sugar), (iv) seed shelf life (deterioration of seed quality as in (iii)), (v) benefit cost ratio (BCR), and (vi) K and B, balance in soils, were used for selection of better treatments. Out of 16 treatments, only basal applications of 30, 60, and 90 kg K ha⁻¹ were selected from the first experiment. The second experiment was conducted parallel to first experiment with four levels of B (0, 1, 2, & 3 kg ha⁻¹) for application as – (1) basal (2) half as basal and half as top dressing at 35 DAS, (3) half as basal and half at 35 DAS as foliar spray, (4) one- third as basal, one third at 25 DAS and one- third at 45 DAS as top dressing, and (v) one- third as basal, one -third at 25 DAS and one- third at 45 DAS as foliar spray. Of the 16 treatments, basal applications of 1, 2 & 3 kg B ha⁻¹ were selected on the basis of their overall performances. The third experiment was carried out with 16 treatment-combination of K (0, 30, 60 and 90 kg ha⁻¹) and B (0, 1, 2 and 3 kg ha⁻¹) moduled from the finding of earlier two experiments. Basal application of K and B had significant positive effect on seed yield and seed qualities. They had beneficial effect on the degree of seed leachate conductivity, seedling dry weight and essaying vigour. Application of 60 or 90 kg K ha⁻¹ along with 1 or 2 kg B ha⁻¹ did not differ significantly in respect of increasing seed yield (62.2-69.0% increase), seed viability (97.5-99.0% germination), EC (317-354 μ S cm⁻¹), vigour (98.33-98.50), seedling dry weight (0.966-1.023 g plant⁻¹), % protein in seed (22.2-22.5%), % sugar in seed (13.4-13.6%) and BCR (1.24-1.36). Seeds stored in air tight plastic pot retained good germination (more than 90%) up to 9 months in place of only 6 months for no application of K and B. Use of 60 or 90 kg K ha⁻¹ with 1 or 2 kg B ha⁻¹ may ensure safe storage of seeds up to one year having only some deterioration like a decrease in seed germination (7.07-9.09%) vigour (5.95-7.70%), total soluble protein (4.41-8.42%) and total soluble sugar (5.16-7.95%). The highest seed yield and BCR (997.67 kg ha⁻¹ and 1.36, respectively) were recorded for the application of 60 kg K + 2 kg B per hectare with a negative balance of 32.6 kg K ha⁻¹ and a positive balance of 1.44 kg B ha⁻¹ with the corresponding values of 966.8 kg ha⁻¹ with 1.24 BCR, and a positive balance of K (1.32 kg ha⁻¹) and B (0.514 kg ha⁻¹) with the application of 90 kg K + 1 kg B per hectare. Therefore, it is inferred that basal application of 90 kg K ha⁻¹ + 1 kg B ha⁻¹ can be a recommendation for producing increased amounts of quality seeds of *Corchorus olitorius* leaving a positive balance of both K and B in soils.



CHAPTER-I

INTRODUCTION

INTRODUCTION

Bangladesh having a population of 150 million, with a growth rate of 1.59 per annum, comprises 9.98 million hectare of total cultivable land of which rice occupies 77.00 %, wheat 2.50%, jute 4.74%, pulses 1.70% and oils 2.50% under single, double and triple cropping pattern (BBS, 2011). Till to date, agriculture is the main stream of Bangladesh's economy and employment. The present contribution of agriculture to GDP is 19.95% employing 21.34% of the total national employment (BBS, 2011). The ever-increasing population of Bangladesh needs more food and fibre for mere survival, which has necessitated the uses of high input agricultural technologies and intensive cropping systems. Intensified production practices have let to use higher-than-traditional rates of nutrients to reach high yield goals of different crops.

Jute (*Corchorus* spp.), the largest natural fibre crop belonging to the family Tiliaceae, is an important cash crop of Bangladesh. Among jute growing countries, Bangladesh ranks second in respect of production. By exporting jute and jute goods the country earns about 2.39 % of total foreign currency. Jute sector as a whole accounts for 10% labour and 7% of GDP (BBS, 2010). Jute provides income to growers and employment for many workers throughout the year. At present 35% of the total population are directly or indirectly engaged in this sector. And it is noted that paddy and jute dominate the Bangladesh agriculture. Besides, jute fibre and jute sticks are largely used for different domestic purposes. In addition, jute plants improve soil productivity and also exert its positive role towards soil properties through its cultivation practices with residues viz., root, stubbles and litter fall and root proliferation in the field.

The seeds of different crops particularly those of winter crops (Late sowing jute seed crop is winter crop) have to pass away the unfavorable environmental conditions during the storage period in summer and monsoon of high temperature, high humidity and high rainfall. Hence, there is a dearth need of developing improve methods to produce high quality seed so that they do not deteriorate quickly under the prevailing unfavorable storage conditions and will perform better in the next sowing season.

Bangladesh needs more than 4000 metric tons of jute seed of which more than 50% of *Corchorus olitorius* seed is imported from our neighboring country by expending valuable foreign currency.

In Bangladesh, the availability of high quality seed is a great problem. During seed production less physiological and agronomic care is taken, and as well as during post harvest processing the farmers' do not take care of it as a crop. Moreover, hot and wet weather during seed production and storage affects seed quality adversely (Copeland and McDonald, 1995). At present, the system, which prevailing to supply jute seeds by the public sector, can meet only 5-7 % of the total demand of quality seeds (BJRI, 2005). We have world renowned jute varieties of high quality of fibre. It needs proper management practices to boost up adequate and qualitative seed production in this country. At present the vital problems associated with jute production are - (i) Less availability of the seeds (ii) Lower quality of the seeds, and (iii) Lower shelf life of seeds.

Jute seed production task is quite different from fibre production. Seed viability and vigour of cultivars mainly depend upon environmental factors; architecture of the inflorescence; seed crop husbandry including sowing date, plant density, the use of fertilizers, irrigation, disease and pest control; the maturity stage and weather at harvest; the length of time and environmental conditions between harvest, drying and threshing; post harvest processing, temperature at seed drying, methods and machines used for threshing and other processing methods (Woyke, 1997).

Roberts (1972) stated that longevity of seeds broadly depends on two major factors which are the inherent genetic quality of the seed and the effect of the environment on the seed. The environmental effect on the longevity of seed can be considered with respect to the four broad stages through which a seed passes. The main factors involved at each stages are as follows: (a) Pre-harvest environment: soil water, temperature, nutrition, photoperiod and disease, (b) Harvest environment: maturity of seeds, weather, harvesting method, threshing and cleaning and drying, (c) Storage environment: seed moisture, temperature, oxygen concentration, dormancy, micro flora and fauna, and (d)

Sowing environment: Soil type, soil moisture, temperature, oxygen, light and micro flora. All of these factors collectively determine the performance of a seed lot. Crop production and seedling performance in the field are the result of an adequate supply, distribution and accumulation of minerals, especially during seed formation (Liptay and Arevalo, 1998). Longevity and vigour of jute seeds like all other crop seeds depend on their maturity, size (large size) and freshness from abrasion since these factors provide valuable assistance to the growing embryo in terms of early nourishment, protection and strength to withstand unfavorable conditions (Talukder and Waseque, 1989). All the field factors and storage factors collectively determine the performance of a seed lot (Islam, 2007). However, the proposed research work is concerned with the maintenance of seed viability by controlling the pre-harvest environment i.e. nutrition only will be studied in detail.

Seed yield and yield contributing characters are directly related to the plant growth. The plant growth is directly related to availability of the plant nutrients. In fact 50% of the total increase in yield comes from the use of fertilizer and rest from all other factors combined together (Mukherjee, 1965). Norman Borlaug, who own the Nobel Prize in 1970 has rightly stated, if HYVs are the catalyst - fertilizer is the fuel of green revolution. Yield potentiality of a crop would not reach a maximum unless proper fertilizer management is made. Jute requires high amount of nutrients for its growth and development. As our land resources are limited, the increased target of production has to be mostly achieved raising the productivity of jute seed production per unit of land and improving its quality. Assessment of the fertilizer requirements of jute, both *C. olitorius* and *C. capsularis*, is very important.

Potassium is the most abundant cation inputs and is absorbed in large quantities by roots. Potassium is basic to plant and animal life. Unlike N and most of the other essential nutrients, K does not become a part of the chemical structure of the plants. Thus, its mobility in the plant allows it to influence almost all aspects of plant growth (PPIC, 1989). Marschner (1995) stated that potassium (K) is the element which is required

by all plant cells to conduct biosyntheses and to maintain cellular function in changing environments. Except for nitrogen, plants require more K than any other nutrient. Of the nutrients elements K is often described as the 'quality element' for crop production. Balanced nutrition with potash is of crop insurance. Its beneficial action on crop quality shows up in many ways including—better utilization of N and increased protein formation, size of kernels, seeds, fruits and tubers, shape of seeds and tubers, oil content of fruits and seeds, vit. C contents of fruits, vegetables and other crops. Moreover, K resists to bruising and physical breakdown in shipping and storage (i.e. longer shelf life), strength, length, fineness and colour of cotton (PPIC, 1989). Potassium has a crucial role in the energy status of the plant, translocation and storage of assimilates and maintenance of tissue water relations. Potassium is not an incorporated component of plant molecules, in opposite to N and P which are constituents of proteins, nucleic acids, phospholipids, ATP, etc. (Lindhauer, 1985).

Potassium activates more than 60 enzyme systems, aids in photosynthesis and favors high energy status. It maintains cell turgor, regulates opening of leaf stomata, promotes water uptake, regulates nutrients translocation in plant, favors carbohydrate transport and storage, enhances N uptake and protein synthesis, and promotes starch synthesis. Patra *et al.* (1996) described that K application maintained higher seed viability over longer period than where no K was applied in groundnut. Potassium application increased the yield of plants infested with fungal diseases by 42%, with bacteria by 57%, with insects and mites by 36% and viruses by 78% (Perrenoud, 1990).

Crop quality and high yields are often constrained due to insufficiency of K in soils (PPIC, 1989). Consequently, it is especially important in a multi nutrient fertilizer application (Brady, 1995). Potassium (K) mining from the soils is a serious problem of Bangladesh resulting substantial decrease in available K (Haque, 2012). Nutrient requirements of jute vary from place to place according to the soil and climatic conditions. Jute requires large amounts of K for optimum growth and yield. In fact, jute consumes K in the largest quantities (Alam *et al.* 1991) among the essential elements. But

literature pertaining to K fertilizer recommendation for jute is scarce and contains somewhat contradictory.

In plant nutrition, micronutrients are also important for plant growth, as plants require a proper balance of all the essential nutrients for normal growth and optimum yield. Micronutrient deficiency can cause serious yield limitations to crops. Moreover, many soils in the tropics are deficient in micronutrients especially Zn, B and Mo. In a structural role, boron confers stability to cell walls. In this role boron helps align and strengthen the cellulose fibre in cell walls of plant cells, and will accumulate there, bonding to cellulose fibres. The cell walls that form with insufficient boron are loose, brittle and weak. A deficiency of boron, shown by a positive response to boron application, has been reported in more than 80 countries and for 132 crops over the last 60 years (Shorrocks, 1997). Boron (B) deficiency has been reported a major cause of crop yield loss in China, India, Nepal and Bangladesh (Anantawiroon *et al.*, 1997). Boron is not a constituent of enzymes in plant, nor is there evidence that it directly affects enzyme activities. There is a long list of possible roles of boron (Parr and Loughman, 1983), including sugar transport, cell wall synthesis, lignifications, cell division, cell wall structure integrity, carbohydrate metabolism, RNA metabolism, respiration, indole acetic acid (IAA) metabolism, phenol metabolism, and as part of the cell membranes. Boron requires in lesser amounts for plant growth but is as essential as N, P and K. It plays an important role in absorption and translocation to some macronutrients like N, P, Ca and Mg (Bowen, 1981; Jones, 1972). Boron required in protein synthesis, important in cell division and development of normal root systems. Deficiencies affect flowering, fruiting and seed formation and regulates uptake of nitrogen and carbohydrate. It aids in the transfer of sugars and nutrients from leaves to fruit, and increases pollination and seed development.

Inclusion of B in cultivation practices produced higher yield by 31% in rice (Ahmed and Irshad, 2011), 53.9 % in wheat (Moeinian *et al.*, 2011), 19% in cotton seed (Pettigrew and Meredith, 1997), 24 % in Indian mustard (Rao *et al.*, 2006) and 53% in chickpea (Shil *et al.*, 2007). Rerkasem *et al.* (1993) reported that B deficiency depressed seed yield by 60% in

soybean, 45% in peanut and 93% in black gram. Its shortage induced 50% hollow heart in peanut. Seeds having lower B content are smaller and less viable. Boron is of interest in crop production both from the viewpoint of its effects in deficiency and excess. Fruit formation is impaired and yield depressions as high as 80% may occur compared to plants adequately supplied with B (Mengel and Kirkby, 2001). This is a consequence of high requirement of B for pollen germination, pollen tube growth and pollen viability (Dugger, 1983). Fruit and seed set may thus be depressed by inadequate B supply even when growth is optimal. Boron is required for normal development of reproductive tissues and deficiency results in low grain set or poor seed quality (Dell *et al.*, 2002). The importance of adequate B supply at the reproductive stage of growth is recognized in seed and fruit forming process (Shorrocks, 1997). Boron is involved in uracil synthesis and hence synthesis of protein is the most important process in meristematic tissues. If they are distributed by a lack of B, the entire processes of meristematic growth is impaired (Mengel and Kirkby, 2001).

The critical level of boron with reference to crops in general was reported to be 0.15 to 0.20 ppm depending on soil types (BARC, 2005). The intensive cropping with HYV, nutrient leaching due to monsoon rains and light textured soils are likely to favour the emergence of micronutrient deficiency (Abedin *et al.*, 1994). Application of B with rates of potassium resulted in small increases in yield, except at the highest B and K levels where yields were reduced (Hill *et al.*, 1975). Long term use of only nitrogenous fertilizer (> 70%) and simultaneous very limited use of phosphorus and potassium fertilizer (12 and 6% only) in crop production has led to potassium mining in soils. Moreover, cropping intensity has greatly increased with the introduction of high yielding varieties, irrigation facilities and better management practices. The intensive triple cropping system resulted in a 36% increase in potash removal over that of double cropping (Cereals) per year. Potassium depletion trend in soils over a period of last 12 years in rice cultivation indicated that 93-96% more potash was removed than applied (Miah *et al.*, 1996). Alim (2003) reported uptake of 371.62 kg K ha⁻¹ against application of 150 kg K ha⁻¹ in jute cultivation.

The critical limit of K for upland crops was found to be 0.17 me/100g soils through greenhouse experiment using sorghum as test plant (Islam and Miah, 1992). Based on critical potassium levels, about 50% of the cultivable land of Bangladesh is low in available K, 30% is medium (0.18-0.340 while the rest (20%) mostly in southern saline and low lying areas is high ($> 0.51\%$) in exchangeable potassium (Miah, 1991). In modern agriculture, the natural supply of K from soils is not adequate to sustain high yields. For this reason, soil supplies have to be supplemented by potash fertilization, which increases the amount of K readily available for crops uptake.

Boron is absorbed from the soil solution by roots mainly as undissociated boric acid. Its uptake in higher plants is closely related to the pH and boron concentration in the soil solution, and is probably a passive process. Its distribution in plants is primarily governed by the transpiration stream through the xylem (Raven, 1980), although it is also phloem mobile, and considerable amounts might be retranslocated (Shelp 1993; Brown and Shelp, 1997).

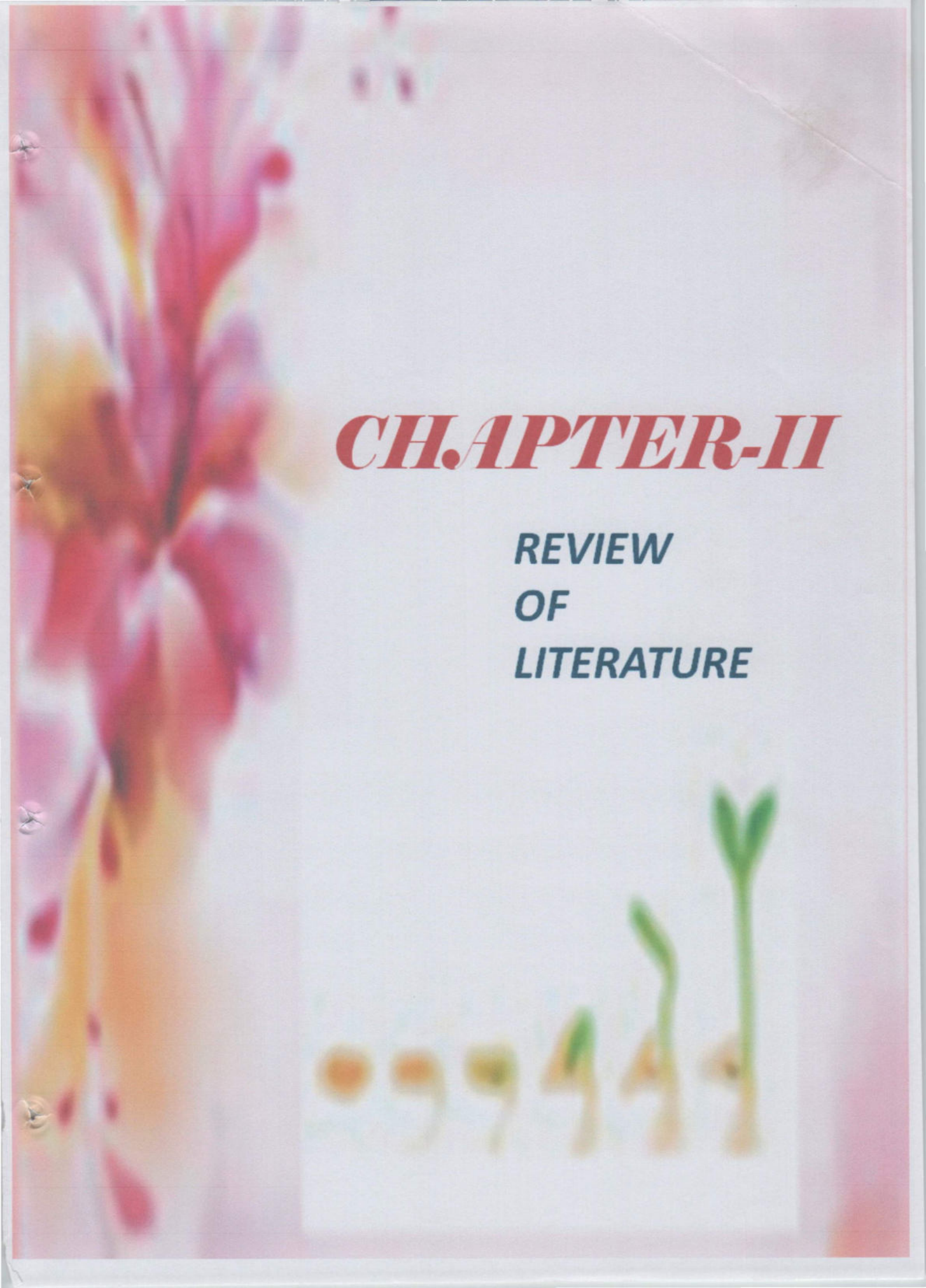
Continuous cropping without adequate restorative practices may endanger the sustainability of agriculture. A quantitative knowledge on the depletion of plant nutrients from soils helps understand the state of soil degradation and may be helpful in devising nutrient management strategies. Nutrient balance exercises may serve instruments to provide indicators for the sustainability of agricultural systems. The impact of nutrient balance can not be seen independently from actual soil fertility i.e. the nutrient stocks. A negative nutrient balance on a rich soil will not affect yield in the short term, while on a poor soil, crop yield may decline each year as a result of nutrient depletion. Less than adequate amount of fertilizer may cause severe depletion of soil reserve. The characteristics of soil related to retention and release of nutrients play a significant role on the positive or negative balance after harvest of each crop. Crop characteristics also have considerable influence on the balance of soil nutrients.

Plant species exhibit a wide range of responses to B. In general, dicotyledonous crops have higher B requirements than monocotyledonous crops. Soil and foliar application

methods are useful to prevent and control B deficiency. The method, rate and frequency of B fertilization depend on the crop, soil type and severity of deficiency. Many field and vegetable crops should receive B as broadcast application in soil prior to planting. Because a continuous supply of B is required by plants from germination to maturity, it is often necessary to split soil applications of B or sometimes to apply B as foliar spray (Joseph, 2000) whilst potassium has its role in electron (e^{-1}) transport the photosynthetic e^{-1} transport chain in supplying assimilates (Overnell, 1975 ; Suksri, 1998).

Poor people and poor soils co-exist. Depleted soils will refuse to deliver the goods if not handled properly (Tandon, 2007). Edaphic conditions present during mother plant and seed development can significantly influence the quality of the seed produced. The specific mother plant nutritional requirements for production of high quality jute seed have not been systematically investigated. Hence, it is the need of the time that experiments should be undertaken to ascertain and quantify the requirement of potassium and boron for yield maximization and quality seed production of jute. Moreover, improvement of shelf life of jute seeds is another dire need which may be ensured with K and B application. Considering the above circumstances, a research project was designed to study the role of K and B on yield, quality and shelf life of jute seeds. In addition, uptake of K and B by jute (*Corchorus olitorius*) seed crop as well as their amounts remained in soil will be determined to prepare a balance sheet to assess the possible impact on soil. The present investigation had the following objectives:

- i). To find out the effective dose, time, and method of K and B application for increasing jute (*C. olitorius*) seed yield and improving seed quality;
- ii). To assess the changes in chemical composition of jute seeds as influenced by K and B;
- iii). To evaluate the effects of K and B on storability or shelf life of the produced seeds; and
- iv). To prepare a nutrient balance sheet for K and B to ascertain their status in soil after crop harvest.



CHAPTER-II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Quality seed is the basic input for raising a good crop. The principal objectives of the science of seed production and seed technology are to improve the quality of propagating materials and to increase the performance of individual plants derived from them. Another important aspect of seed production is to multiply improved or high quality seed in sufficient amounts for satisfying the demands of growers. Nutrition plays an important role in increasing yield of crops as well as to maintain its quality to a great extent. Numerous researches on nutritional requirement of jute fibre growth or different parts of jute plant are carried out, but research is limited on nutritional requirement and its effect on seed yield and quality. In this chapter, literature pertinent to this research work has been reviewed, on different aspects of jute seed production.

2.1 Jute

Jute is the English version of the current Bengali word *pat*, a kind of natural fibre which is obtained from the species of the genus *Corchorus*, belonging to the family Tiliaceae. It is an annual plant and the fibre is procured from its bark. There are over 30 species which belong to the genus *Corchorus* but only two of them, *Corchorus olitorius* L. and *Corchorus capsularis* L. are cultivated for commercial purpose (Ahmed, 1966).

Jute has been the most widely used packaging material for more than 100 years. About 50% of raw jute is processed into gunny bags and sacks for transportation and storage of agricultural and industrial commodities. Other traditional products from jute include Hessian cloth, carpet backing, yarn, twine, cordage, felt and jute carpets. Whole jute stems are suitable as raw material for paper pulp. The leaves and tops are eaten as vegetables in many countries (Khandkar and Vossen, 2003).

Jute is usually propagated by seed. Seeds are sown directly in the field. Pre-monsoon showers in the months of February to April are essential for the preparation of land. Jute is mainly grown between 16 ° to 27 ° N, during the hot wet summer season. The daily temperature range for optimum growth is 22 to 34 ° C. Growth is retarded at temperature below 17°C and above 42°C. The annual rainfall should be 1000-1500 mm,

with 150 mm of pre- monsoon showers at sowing time in March to April, followed by a relatively dry period with a few light showers in May, and subsequently by the main monsoon rain. Jute can be grown on a range of soils from clays to sandy loams provided they are deep, free draining, fertile and with a pH range 5.0 to 8.0. The best soil is loam or sandy loam, which can quickly absorb rainwater and at the same time retain moisture. Jute is generally harvested between 100 to 120 days after sowing when most of the plants are flowered. Earlier harvesting will result in lower yield of immature, fine fibre, whereas later harvesting will produce higher yield of low quality fibre. Jute is usually harvested by hand with a sickle, being cut at the base of stem very close to the soil surface. Jute stems are retted in water for period of 12-20 days generally to free the fibres from the surrounding bark tissues by enzymatic action associated with microorganisms. The clean fibres are then dried in the sun over bamboo racks (Khandkar and Vossen, 2003).

Jute constitutes a major tropical fiber crop of considerable significance in view of the economic, social and environmental factors in Bangladesh. Jute is one of the main export and cash crops of Bangladesh that contributes approximately 2.50 % (BBS, 2011) to the national economy annually and provide livelihood to millions of rural and urban people.

2.2 Jute seed and its quality

2.2.1 Jute seed

In the genus *Corchorus* like most of the “closed seeded” plants (Angiosperm), it is the flower, fruit and seed, which concerned primarily with the maintenance of continuity from one generation to the other. Jute seed is a dormant embryo sporophyte (spore producing stage in the life cycle of the plant) with stored food and protective coats; food is supplied by the endosperm and protection provided by the seed coats formed by the integuments of the ovule.

Capsularis fruits are 1.0 to 1.5 cm in diameter and round in shape. The surface of the fruit is wrinkled, very rarely smooth. Seeds, 7 to 10 in number are arranged in two rows without transverse partition in each of 5 chambers. There are 35 to 50 seeds in each fruit.

In *olitorius* the fruit is an elongated capsule with 5 to 6 locules containing 25 to 40 seeds in each locule arranged in a single row having transverse partitions between the seeds. There are 125 to 200 seeds in each fruit of *olitorius*.

The colour of seed is normally chocolate brown in *capsularis* although bluish coloured seed has also been found, The seed colour of *olitorius* varies from bluish green or blackish to steel grey and brownish. In some strains of *olitorius* chocolate coloured seed has been found. Jute seeds are round. They are pyramidal shape having 4-5 faces. The *olitorius* seeds are smaller than *capsularis*. On the average 300 *capsularis* seed or 500 *olitorius* seed makes a gram (Talukder and Ali, 1989).

A jute seed consists of an immature, undeveloped plant (embryo), accompanied by a quantity of stored food (endosperm) available for its early nourishment and protective layers, the seed coats. Sun dried jute seeds contain moisture 10%, ash 6.0%, crude protein 26.6%, crude fibre 20.76%, free invert sugar 3.08% and sugar by inversion 5.95%, starch is found in trace. Jute seed contains 15% of oil including volatile oils (Talukder and Waseque, 1989).

Ghosh and Sen (1983) separated the bulk seeds of *Corchorus olitorius* L., variety JRO-632 into large, medium and small sizes and noted that the germination of small size seeds were slower and gave weak seedlings than the large sized ones. Ali (2011) reported that seedling from large seeds of *Corchorus olitorius* (var. O-9897) had much vigour than small and wrinkled seeds.

Bangladesh needs 6000 MT. of jute seeds of which 1600 kg is produced by BADC and some are produced by farmers' and the rest like 3000 MT. is imported from neighbouring country (DAE, 2012).

2.2.2 Jute Seed Quality

Islam *et al.* (1999) evaluated jute, kenaf and roselle on the basis of weight and volume and number of seeds per kg. Number of seed per liter, volume per kg, seeds, germination percentage, vigour value and moisture percent differed significantly among

all the crops studied. The quality characters like germination percent, vigour values and moisture should have 80% - 90%, 32-36 and 6.92% - 8.11%, respectively.

Talukder and Rahman (1989) developed jute seed purity standard. They showed the standard for registered jute seeds. National Seed Board (NSB) of Bangladesh approved in interim standard for jute seed (*Corchorus app.*) as follows: pure seed-96.00%, inert matter-3.00 %, Other crops seed - 0.05 %, Weed seed-0.05 % and other variety-1.00 %.

Islam (2007) reported that the seed quality and the relationship of viability and vigour have always been an important consideration in jute crop production. As jute seeds do not have any dormancy period in its life cycle, it can germinate at any time after harvest and if there is enough moisture it can germinate within the fruit also. He observed that higher the moisture content of jute seed lower and slower the germination. The relationship among germination, vigour index, purity, emergence, fibre and seed yields is highly significant and positive. Germination percentages after second day have positive relationship with total germination, vigour index and emergence.

ISTA (1976) has prescribed that seed should be counted for 5 days to assess germination in both jute species. Islam (2007) reported that jute seeds start to germinate within one day and more than 70 % was recorded on the second day. Patel and Dargan (1968) reported that dried matured jute seed had a germination range of 85-100% recorded in petridish when in the field it was about 70%. Islam (1994) reported that the petridish germination of jute seed has a very close correlation with the total germination ($r=0.83$) and pot germination ($r=0.71$). Khandker (1982) showed that nutrient loss in deteriorated jute seed could be as much as 10 times depending on the extent of deterioration which includes sugar and amino-acids.

In Bangladesh condition, the storage period of jute seed ranges from 5 to 7 months. Jute seed with excess moisture and high temperature (30°C or more) at storage loss viability very quickly. After middle February, day temperature starts rising and in March it goes up to 35°C or more and deteriorates the viability at a quicker rate (Hossain *et al.*, 1994a).

2.3 Seed quality factors

Seed quality is determined by a number of genetic and physiological characteristics. The genetic component involves differences between two or more genetic lines, while differences between seed lots of a single genetic line comprise the physiological component. The genetic factors that can influence quality include (i) genetic make-up (ii) seed size and (iii) bulk density. The physical or environmental characteristics include: (i) injury during planting and establishment (ii) growing conditions during seed development (iii) nutrition of the mother plant (iv) physical damage during production or storage by machine or pest, (v) moisture and temperature during storage and (vi) age or maturity of seed.

Deterioration in seed quality may begin at any point in the plant's development stage from fertilization onward. Seed quality depends upon the physical conditions that the mother plant is exposed during its growth stages, as well as harvesting, processing, storage and planting. Temperature, nutrients and other environmental factors also affect seed development and influence seed quality. High quality seeds are the result of good production practices, which include: (i) proper maintenance of genetic purity (ii) good growing conditions (iii) proper timing and methods of harvesting (iv) appropriate processing during threshing; cleaning and drying (v) appropriate seed storage and seed distribution systems.

2.4 Effect of nutrients on seed yield, quality and shelf life

Nutrients play an important role to complete plant's life cycle. Crops require 16 essential nutrients to grow normally. Carbon (C), hydrogen (H), and oxygen (O) derived from the air comprise greater than 90 per cent of the fresh plant tissue. Macronutrients, needed in larger amounts, derived from the soil are nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), and magnesium (Mg). The remaining essential nutrients, derived from the soil, are referred to as micronutrients, because they are needed in

Lin (1955) commented nitrogen and phosphorus are needed for jute and jute is greedy for potassium. BJRI (1989) reported that crop quality and high yields of jute were often constrained by insufficiency of K in soils. Alam *et al.* (2000) observed significant effect of K on base diameter, plant height and weight of green plants with leaves of jute. They found the highest plant height with the application of 100 kg K ha⁻¹.

Sharma *et al.* (2003) conducted an experiment with pea cv. Arkel in Himachal Pradesh, India, with 3 fertilizer levels, i.e. 25 kg N+60 kg P+40 kg K; 35 kg N+75 kg P+50 kg K, and 45 kg N+90 kg P +60 kg K per hectare. The treatment 25 kg N+60 kg P +40 kg K per hectare recorded the maximum seed yield (1150 kg ha⁻¹), plant height, number of pods per plant, pod length and number of seeds per pod.

Alam *et al.* (2009a) conducted an experiment on the fertilizer requirement of transplanting method of jute plant cutting for jute seed production and reported that plant population was highest with K50 followed by K25 & K0. The number of pods plant⁻¹ increased with increasing doses of K fertilizer, but the number of seeds per pod remained almost same for all the treatments. Seed yield per plot was the highest (522.20 kg ha⁻¹) with K @ 50 kg ha⁻¹.

Tabbakh (2002) carried two field experiments in Egypt to investigate the influence of three irrigation treatments (fresh water, drainage water, and both) and four K fertilizer application times (one before sowing and three thereafter) on seed yield and fibre properties of two cotton cultivars (Giza 70 and TX-ORS-75C). There was a positive effect of potassium fertilization, when applied either at thinning or squaring, on seed yield, number of open bolls, boll weight (in both seasons) and seed index in the first season. Time of potassium application showed no significant effect on lint % and all fibre properties (in the two seasons) and seed index in the second season. Early K application, especially at the first irrigation, produced higher seed cotton yield, using the drainage water throughout the growing season.

Sarkar and Bandopadhyay (2000) reported that the plant height, basal diameter, K uptake and yield of jute increased with increasing rates of K application.

Alim (2003) conducted a field experiment at BSMRAU, Gazipur, Bangladesh to evaluate the effect of K on growth and yield of jute. The significant increase in green weight with leaves, total biomass, dry fibre and stick yield was recorded with 150 kg ha⁻¹ and the highest fibre (4.38 t ha⁻¹) was recorded with 150 kg ha⁻¹ which was 15.3 % higher over control (0 kg ha⁻¹).

Pettigrew *et al.* (1996) reported that Potassium deficiency reduced lint yield, boll mass, lint percentage, seed mass and some fibre quality traits of cotton. Sabino *et al.* (1995) reported that K increased the boll and seed mass of cotton. Das *et al.* (1996) reported that jute fibre and stick yield increased significantly with up to 2 ploughings and 40 kg K ha⁻¹. Chaudhury and Chattapadhyay (1998) reported that K at the rate of 40 kg per ha increased the harvest fibre yield 16% and 14% over no application of K in the first and second years, respectively.

Gormus *et al.* (2002) reported that K fertilizer application produced significant differences in seed cotton yield, lint yield and earliness. Potassium application in early planted cotton gave the highest boll weight while potassium deficiency related with the 0 kg K treatment produced the lowest boll weight. Averaged across years, soil applications of 150 kg K ha⁻¹ decreased the number of days required from planting to open first boll 1.8% compared with the no potassium control treatment.

2.4.2: Effect of potassium on seed quality

Bhattacharjee *et al.* (2000) reported increased the growth, seed yield and vigour of jute with progressive increasing in the level of NPK in West Bengal, India, in a sandy loam soil. The fertilizer treatments were N₁₀P₁₀K₁₀, N₂₀P₂₀K₂₀ and N₄₀P₄₀K₄₀ and N₆₀P₆₀K₆₀ kg ha⁻¹. The mode of N application was 50% as basal and rest 50% at 30 days after sowing as soil top dressing. Harvesting was done at full maturity. The study suggests that increasing in

the level of NPK increased the growth, seed yield and its vigour. Pod number, seed per pod, seed yield per plant, nutrient content and uptake were increased.

Nour *et al.* (2000) conducted a field experiment at Giza, Egypt, in 1996 ad 1997 to study the effects of planting date (15 March and 15 April) and potassium fertilizer rate (0, 24, and 48 kg K feddan⁻¹) on the yield, yield components, and quality parameters of cotton (*Gossypium barbadense*) cv. Giza 80. Potassium application increased the number of fruiting branches, total bolls, and open bolls per plant, boll weight, seed yield, earliness and lint percentage, seed index, micronaire reading, pressley index, and oil and protein contents, and favoured the formation of the initial fruiting branches at lower nodes. Potassium at 24 kg feddan⁻¹ (1 feddan = 0.42 ha) was the optimum rate.

Sawan *et al.* (2007) conducted field experiments during two successive seasons at the Agricultural Research Center, Giza, Egypt, on the cotton cultivar "Giza 86" (*Gossypium barbadense* L.) to study the effects of K fertilization (at 0.0 and 47.4 kg of K ha⁻¹) and foliar application of zinc (at 0.0 and 57.6 g of Zn ha⁻¹, two times, 70 and 85 days after planting, "during square initiation and boll setting stage") and phosphorus (at 0.0, 576, 1152 and 1728 g of P ha⁻¹, two times, 80 and 95 days after planting) on cotton seed. The application of K along with spraying plants with zinc and phosphorus caused an increase in cottonseed yield ha⁻¹, seed index, seed oil content, oil and protein yields ha⁻¹, seed oil unsaponifiable matter and total unsaturated fatty acids (oleic and linoleic).

Gadgil *et al.* (1989) studied seeds of seven cultivars of *C. olitorius* and four of *C. capsularis* were for protein, oil and ash content. Percentage oil and protein ranged between 11-16 and 16-20 respectively, while the ash content was 5%. No significant differences between olitorius and capsularis cultivars were found. The saponification number and iodine value for oil ranged between 163-175 and 116-121 respectively. In two cultivars, 'TJ- 40' and 'JRC-212' about 77% of the seed N was in protein.

Talukder and Waseque (1989) reported that longevity and vigour of jute seeds like all other seed crops depend on their maturity, size (large size) and freshness' from abrasion

since these factors provide valuable assistance to the growing embryo in terms of early nourishment, protection and strength to withstand unfavorable conditions.

2.4.3: Effect of potassium on nutrient content uptake and balance in seed production

Maitra *et al.* (1999) conducted an experiment at Barrackpore, India and stated that the effect of levels and time of application of potassium on the jute yield and potassium uptake by it. As a basal dressing, 40 kg K₂O-ha⁻¹ was the most effective in increasing the jute yield. A split application was better than full basal application. The highest fibre yield was observed 20 kg K₂O ha⁻¹ applied in two split doses. Potassium uptake was also affected by split application.

Singh *et al.* (1983) found that available K ranged from 0.45 to 4.15 me% in some soils of Haryana, India. They further noted that available K constituted only 0.03% of the total K. Islam *et al.* (1978) found that available soil K ranged from 0.096 to 3.74 me%. Chowdhury (1977) observed 0.26 me% available K in high land of Mirpur area of Dhaka district. Hasan (1994) working with 11 extensively cultivated different soil series found that available K ranged from 0.06 to 0.27 me% in Bangladesh.

Miah *et al.* (1996) opined that long term use of only nitrogenous fertilizer (> 70%) and simultaneous very limited use of phosphorus and potassium fertilizer (12 and 6% only) in crop production has led to potassium mining in soils. Moreover, cropping intensity has greatly increased with the introduction of high yielding varieties, irrigation facilities and better management practices. The intensive triple cropping system resulted in a 36% increase in potash removal over that of double cropping (Cereals) per year. Potassium depletion trend in soils over a period of last 12 years in rice cultivation indicated that 93-96% more potash is removed than applied.

Alam (2008) conducted a field trial at the Central Jute Research Station of BJRI, Manikganj, to determine the effect of Jute (*Corchorus olitorius* L.) included cropping patterns on crop performances and soil properties. The test crops were potato (*Solanum*

tuberosum), wheat (*Triticum aestivum* L.), Jute, broadcast aus rice and transplanted aman rice (*Oryza sativa* L.). Using nutrient uptake and nutrient addition data “nutrient balance sheets” for all the cropping patterns were prepared and compared. Jute plant harvested the lowest amount of nutrients (N, P, K and S) and added back the highest amount to the soil. Considering the crop performances and nutrient (N, P, K and S) balance in soil, Potato-Jute-T.aman was found as the best one, followed by Fallow-Jute-T.aman.

Alam (2007) conducted an experiment in two cropping patterns i.e. wheat-jute-transplanted aman and pulses-jute-transplanted aman under Tista Floodplain and Young Brahmaputra and Jamuna Floodplain (Agro-ecological zones 3 and 8 respectively) of Bangladesh to determine the effect of nutrient management on nutrient balance after completing the crop cycle. Nutrient mining was maximum where dry matter accumulation or grain/fibre/straw yield was higher. Balance sheet of nutrients showed apparent negative balance for nitrogen, phosphorus, and potassium but positive balance for sulfur. Nitrogen was in positive balance with integrated application of fertilizers. But soil balance at harvest showed surplus of N, P and K at the end of crop cycle in both patterns.

Alim (2003) conducted an experiment with seven levels of K comprising 0, 50, 100, 150, 200, 250 and 300 kg K ha⁻¹ and reported that higher the levels of potassium application, the higher were the content, and uptake of the nutrients in different parts of jute plant and the maximum uptake of 371.62 kg K ha⁻¹ were recorded against application of 150 kg K ha⁻¹ in jute cultivation leading the soil as depleted state.

2.4.4 Effect of boron on seed yield, quality and shelf life of seed

Craig (2009) described that boron, a micronutrient exerts a macro benefit. Since boron is non-mobile in plants (like calcium), a continuous supply from the soil is required in all plant growing points. In mineral soils, release of boron is usually quite slow. Much of the available soil boron is held rather tightly by soil organic material. As organic matter decomposition occurs, boron is released with a portion being absorbed by plants, some

leaching below the root zone area (especially in acid soil), or tied up under alkaline soil conditions.

As an essential micronutrient the mode of operation of boron differs considerably from that of other micronutrients. Metallic micronutrients such as Zn, Cu, Fe, Mn and Mo are effective as components or as activators or inhibitors of enzymes in the plant, but a similar function for boron has not been established (Sutcliffe and Baker, 1981; Bergmann, 1984), although its effect can be detected experimentally in various metabolic processes.

Boron has been considered to be functional in the transport of carbohydrates and translocation of sugar is thought to be enhanced by the formation of borate-sugar complexes (Katyal and Randhawa, 1983). In sugar beet the sucrose content of the storage roots tended to decrease in the same treatment at which limiting boron results lower yield (Tariq *et al.*, 1993).

The accumulation of auxins and phenols may be associated with leaf necrosis when boron is deficient (Mengel and Kirkby, 1982; Marcus-Wyner and Rains, 1982). Boron is presumably responsible for the metabolic changes and cell damage in boron deficient tissue (Marschner, 1986) and it is thought that boron complexes the phenolic compounds in plant cells, reducing their potential toxicity (Lee and Arnoff, 1967).

Boron is concerned with the water relations in cells and regulates the intake of water in to the cell (Wallace, 1961). In this connection Briggs (1943) in early work reported that boron deficient (*N. aquaticum* L.) plants showed decreased moisture percentage, less succulence, less metabolic activity and a lower growth rate, in comparison to boron-sufficient plants. This was confirmed many years later by Sharma and Ramchandra (1990) who also reported that boron deficient plants had low water potential, stomatal pore opening and transpiration.

Boron is required for proper development and differentiation of tissues (Katyal and Randhawa, 1983). Boron may affect the deposition of cell wall material by altering

membrane properties (Goldbach and Amberger, 1986) and the deficiency of boron causes the breakdown of the walls of parenchyma cells (Shorrocks, 1984). The responsive effect of boron deficiency on cell division causes slow down in root extension and followed by a degeneration of meristematic tissue in plants (Jackson and Chapman, 1975). Cohen and Lepper (1977) concluded that a continuous supply of boron is not essential for cell elongation of intact squash plants but is required for maintenance of meristematic activity. The evidence from the various literature review showed that boron is important in cell walls (Cohen and Lepper, 1977; Gupta *et al.*, 1985). Both boron deficiency and toxicity cause lower chlorophyll levels and net photosynthesis (Petracek and Sams, 1987). Boron may induce cell wall synthesis by an influence on the activity of the plasmalemma (Sutcliffe and Baker, 1981).

The role of boron in promoting pollen tube growth is well established but the mechanism of its action is still unknown (Sutcliffe and Baker, 1981). Thus a significant positive correlation could be found between boron in the plant and number of flowers, the proportion of flowers not aborted and the weight of fruit (Bergmann, 1984). In the case of rape, clover, alfalfa and beet, boron hinders abortion of the ovaries. Moreover, it reduces the proportion of sterile seeds in cotton, soybean, alfalfa, maize and sunflower (Bergmann, 1984).

Khandker *et al.* (2002) conducted an experiment at Jute Research Station, Rangpur and Manikganj to observe the effect of boron on the production of jute. They stated that application of boron showed an important role on the growth and yield of jute. The highest plant height, base diameter, green weight with leaves, green weight without leaves. Fibre weight and stick weight were found highest with 2 kg B ha⁻¹ at Rangpur and by 3 kg B ha⁻¹ at Manikganj over the control and recommended dose of fertilizer (RDF). Higher plant population was found with boron treated plots. The boron status of soil found enriched with boron application though the initial soil boron status was below critical level.

Alam *et al.* (2002) reported that boron @ 2 kg ha⁻¹ application along with other recommended dose of fertilizer gave the highest yield of jute seed (Variety O-72).

Pratima *et al.* (1999) described that 0.33 mg litre⁻¹ B concentration as foliar application gave the highest biomass and economic yield of sesame (*Sesamum indicum*). Sabino *et al.* (1996) reported that accumulation of B on soil after boron application increased boll and seed weight of cotton.

Alam *et al.* (2009a) conducted an experiment on jute seed production with fertilizer management. Boron in single and a combined doses of zinc and boron i.e. Zn @ 8 kg ha⁻¹ and B @ 4 kg ha⁻¹ (T₁₄) were applied. Positive effect of zinc and boron was observed in relation to seed yield.

Despite differences of opinion on its definition, there is general agreement that vigor measurements can be used to predict the potential performance of seed in the field. To achieve reliable results, dependence on a single vigor test is not reliable and therefore a number of tests should be conducted by the scientists in laboratory and under adverse soil conditions to determine the potential performance of the seed (Tekrony and Egli, 1991). The important tests for determining vigor in different seed lots are standard germination, accelerated aging, electrical conductivity, tetrazolium evaluation, seedling dry weight and field emergence.

Rathinavel *et al.* (1999) conducted field experiments during summer and winter 1996 at Coimbatore compared different Zn and B fertilizer treatments for cotton. Combined soil application of ZnSO (50 kg ha⁻¹) and borax (10 kg ha⁻¹) increased the number of sympodia plant⁻¹ (30.0%), number of bolls plant⁻¹ (39.2%), boll weight (49.8%), seed weight boll⁻¹ (36.8%), and number of seeds boll⁻¹ (10.8%). The seed cotton yield and seed yield were 47.1% and 19.2% higher for the same treatment, respectively, compared with controls. The quality of resultant seeds in terms of 100 seed weight, germination, speed of germination, seedling growth, dry matter production, vigour index, dehydrogenase enzyme activity and oil content were also significantly higher for the seeds from plants receiving both ZnSO and borax through soil or foliage.

Khandker *et al.* (2001) conducted an experiment at Rangpur regional station of Bangladesh Jute Research Institute to find out the effect of boron on growth and yield of jute seed. She stated that significantly highest pod per plant, 1000 seed weight and seed yield (0.998 kg ha^{-1}) were achieved with the application of boron @ 1 kg ha^{-1} as basal. Beyond this treatment capsule plant⁻¹ and seed yield were decreased.

2.4.5: Effect of boron on nutrient content uptake and balance in seed production

Jute produces huge green leaves, which are ultimately added to the soil (BJRI, 1999). As jute is a tap-rooted crop, it can absorb nutrients from a depth of 60 cm (Ghosh, 1983). Moreover, jute plant can add huge amounts of roots, which ultimately decompose in soil. Roots are the carriers of the carbon into the soil ecosystem (Fozel, 1985).

Gormus (2005) conducted an experiment to determine the effect of application rates of N and B on cotton yield and fibre quality. Suregrow 125 (*Gossypium hirsutum*) was grown on a clay soil having an average 0.38 mg kg^{-1} B concentration. Nitrogen was applied to the soil at rates of 0, 80 and 160 kg ha^{-1} , and B was applied to the foliage 3 times for totals of 0, 0.56 and 1.12 kg B/ha . Foliar-applied B significantly increased leaf blade B concentration, boll number, boll weight, seed cotton and lint yield. The application of 1.12 kg ha^{-1} B and 160 kg ha^{-1} N resulted in the highest number of bolls. B increased boll weight from 5.93 to 6.92 g boll^{-1} and boll bearing from 15.9 to 18.5 bolls per plant in 2003. Consequently, B application resulted in 15.5% increased crop yield over the control. This study demonstrated that cotton needed supplemental B when the soil B concentration was low.

Muhammad *et al.* (2007) conducted experiments in Pakistan to investigate the usefulness of boron (B) on cotton cultivar CIM-499 grown on silt loam (coarse silty, hyperthermic, typic haplocambids) soil. Boron at 0 (control), 1.0, 1.5 and 2.0 kg ha^{-1} was applied. The results revealed significant improvement in fruiting efficiency, leaf B concentration and seed cotton yield with B fertilizer application. The value cost ratio (VCR) was observed

and yield contributing characters such as plant population, plant height; base diameter, branch per plant etc were achieved with $N_{90} P_{10} K_{20} S_{20} B_2 Mg_{20}$ treatment combination. Sulphur and boron application were highly positive correlated with the seed production weight ($R^2 = 0.905$ and 0.913) and it was found at 3% significant level both. The nutrient content uptake and nutrient use efficiency were influenced by fertilization.

Silva *et al.* (2008) conducted In a long-term (12 year) field experiment in Brazil, K and B were applied annually to cotton at 0, 50, 100 and 150 kg K_2O ha⁻¹ and 0, 0.5, 1.0 and 1.5 kg B ha⁻¹, respectively. K increased yields consistently and significantly. Positive yield responses to B were associated with K applications, increasing with increasing rates of K. Fertilization increased both leaf K and B contents. Leaf K contents were related to yield increases. Leaf K and B concentration increased with soil K and B contents, respectively. Positive yield responses to B were associated with K applications, increasing with increasing rates of K. Fertilization increased both leaf K and B contents. Leaf K contents were related to yield increases.

Sarkar *et al.* (2000) reported that in a field experiment in Pundibari, West Bengal, India, *C. capsularis* cv. JRC-321 was given 30, 45, 60 kg k_2O and 0, 1.0 kg B ha⁻¹ and was harvested at 80,100,120 days after emergence. Plant height, basal diameter, K uptake and yield increased with increasing K rate, B application and delay in harvesting. Application of 45 kg K and 1.00 kg B ha⁻¹ produced fibres with a good combination of strength and fineness at 120 days.

CHAPTER-III

MATERIALS AND METHODS

3.3 Soil sample collection

Soil samples were collected before setting up of the experiments. Soils were collected from 10 spots and thoroughly mixed in a plastic bucket to make a composite sample. After air-drying the soil was ground in a mill and passed through a 0.5mm sieve. Finally 500 g of the composite soil sample was preserved for chemical analyses. Moreover, core sampling was done from the undisturbed soil for bulk density determination. In addition to that, soil samples were also collected from each experimental plot immediately after each crop harvest. These samples were dried, ground to pass through a 2-mm sieve and used for physical analysis. For chemical analysis, the samples were further sieved through a 0.5mm sieve. The initial status of the experimental plot soil is given in Table 3.1.

3.4 Test crop

The high yielding variety of jute (*Corchorus olitorius* L.) BJRI Tossa-4 (O-72) was used in the study. The variety was released by Bangladesh Jute Research Institute (BJRI) in 2005 and the percentage of the seed germination was 96.



Bangladesh

Fig. 3.1: Enlarged view of Dinajpur district showing experimental site (✧ sign)

Table 3.1: Physical and chemical properties of the initial soil of the experimental field

Soil properties	Analytical value	Critical value	Interpretation
Sand (%)	54.4	-	
Silt (%)	26.2	-	
Clay (%)	19.4	-	
Textural class	Sandy loam	-	
Bulk density	1.40 g/cm ³	-	
Particle density	2.52 g/cm ³	-	
pH	5.74	-	Moderately acidic
Organic matter (%)	1.33		Low
Total nitrogen (%)	0.08	0.12	Very low
Available phosphorus (ppm)	22.3	14.0	High
Exchangeable potassium (meq /100g soil)	0.10	0.12	Low
Available sulphur (ppm)	7.55	14.0	Very low
Available zinc (ppm)	2.33	2.0	Very high
Available boron (ppm)	0.18	0.2	Low
CEC (meq /100g soil)	14.17	-	

Experimental details: Three experiments were conducted which are as follows:

3.1 Experiment 1: Effects of different rates and methods of potassium application on yield, quality and shelf life of jute (*C.olitorius*) seed.

Potassium rates: 0, 30, 60, 90, 120 and 150 kg/ha along with recommended dose of all other nutrients.

Methods of potassium application:

- (i) As basal: All of potassium fertilizers were used in land at final land preparation
- (ii) Half as basal and the rest half at 35 days after sowing (DAS) as top dressing and

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- (i) As basal: All of potassium fertilizers were used in land at final land preparation
- (ii) Half as basal and the rest half at 35 days after sowing (DAS) as top dressing and

(iii) One- third as basal, one-third at 25 DAS and the rest one-third at 45 DAS as top dressing.

Design: RCBD

Replication: 4

Jute variety: O-72

3.1.1 Treatments

Treatments	Description
T1	0 kg K ha ⁻¹ : all as basal at final land preparation
T2	30 kg K ha ⁻¹ : all as basal at final land preparation
T3	30 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing
T4	30 kg K ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing
T5	60 kg K ha ⁻¹ : all as basal at final land preparation
T6	60 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing
T7	60 kg K ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing
T8	90 kg K ha ⁻¹ : all as basal at final land preparation
T9	90 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing
T10	90 kg K ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing
T11	120 kg K ha ⁻¹ : all as basal at final land preparation
T12	120 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing
T13	120 kg K ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing
T14	150 kg K ha ⁻¹ : all as basal at final land preparation
T15	150 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing
T16	150 kg K ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing

3.1.2 Fertilization

All of recommended dose of nutrients i.e. N (90 kg ha⁻¹), P (20 kg ha⁻¹), S (20 kg ha⁻¹), Zn (4 kg ha⁻¹) and B (1 kg ha⁻¹) as Urea, TSP, Gypsum, Zinc sulphate and Solubor respectively were used at final land preparation except nitrogen. Urea as the source of nitrogen was applied in three equal splits: one- third as basal, one- third at 25 DAS and rest one-third at 45 DAS. Potassium as muriate of potash was applied as per treatments designed in section 3.1.1.

3.1.3 Cultural operations

Land selection	Land preparation	Initial composite soil sample collection:	Date of sowing
07/8/2007	10/8/07-22/08/07	22/08/07	23/8/2007
Intercultural operations:			Pre harvest plant sample,
Weeding	Irrigation	Fertilization	Harvest and Post harvest soil sample collection
07/09/07, 16/9/07, 25/9/07	16/9/07, 26/9/07	17/9/07, 27/9/07	27.12.07

3.1.4 Data recording

3.1.4.1 Dry matter production

Ten randomly selected jute plants at maturity stage were collected from each plot and root, shoot (including pod) and leaves were separated and dried in the oven for 72 hours in 70°C after cutting into pieces. After drying dry matter accumulation by different plant parts was measured. Total dry matter was computed by summing up of dry matter of different parts of individual experiment.

3.1.4.2 Growth and yield contributing parameters

Number of plants in each plot at harvest was counted and plants population ha⁻¹ was calculated. Plant height (P.H.), number of branch plant⁻¹, number of pod plant⁻¹, pod length and seeds per pod of 10 randomly selected plants from each plot were taken and

heights, number of branch and number of pod of each plant was recorded and average of each item was calculated.

3.1.4.3 Seed Yield

Seeds produced plot⁻¹ was determined after harvesting all the plants of the plot. Seeds were then separated from the plants and were sun dried for 5 consecutive days covering a total sum drying period of at least 40 hours or more then seeds of each plot was weighed in an electric balance (Model-PC-180). Seed yield ha⁻¹ was computed from seed weight plot⁻¹.

3.1.4.4 Storing of seeds

Seeds produced from 18 treatments of potassium dose and split application in experiment 1 was collected. Then the seeds were stored in air tight plastic container. Each container contained about 250 g of seeds. All the containers were kept under a laboratory desk beside the wall in normal room temperature. Seeds were taken for different quality test in 3 months interval and the container was air tight with pasting with wax in the cork. All the windows of the laboratory remained open during day time of every working day and closed during night time and in the off days throughout the storage period.

3.1.4.5 Seed moisture content

Seed moisture was tested following the oven dry method (Khandakar, 1980). About 2 grams of seeds of each plot were taken and kept in the oven for 24 hours at 100 ° C. The ratio between the loss of seed weight and the original weight were found out and multiplied by 100 to estimate seed moisture content.

3.1.4.6 1000 seed weight

One thousand seeds of jute were randomly counted from each treatment and weighed in an electric balance (Model-PC-180). Thus 1000 seed weight representing the seed size were determined for two years.

3.1.4.7 Germination (%)

One hundred seeds with four replications were evenly distributed on the top of four filter papers placed in four glass petri-dishes. The seeds and filter papers were kept moist throughout the test period by adding distilled water. Seeds germinated were counted and recorded daily till fifth day. A seed was considered to be germinated as seed coat ruptured and radicle came out up to 0.2 cm or more length. Germination percentage was calculated using the following formula (Krishnasamy and Seshu, 1990).

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds tested}} \times 100$$

Thus seed germination was determined quarterly till 12 months.

3.1.4.8 Seed vigour (speed of germination)

The vigour performances were conducted in the laboratory with same procedure as that of laboratory standard germination test. Vigour (Vigour value) was calculated by following the method of Jain and Saha (1971).

$$V = \frac{a}{1} + \frac{b}{2} + \frac{c}{3}$$

Where, V = Vigour and a, b, c are the number of seeds that germinated after 1st, 2nd, and 3rd days from the start of germination test. The final count was made at the end of 5th day.

3.1.4.9 Electrical conductivity

For electrical conductivity test, 2 g seeds of each sample were taken in a conical flask containing 50 mL de-ionized water and incubated at 20° C for 20 hours. After 20 hours, water of the flask containing seeds was decanted in order to separate the seeds. The electrical conductivity of the decanted water containing seed leachate was measured

with a conductivity meter (Model-YSI 31 Conductivity bridge). Five replicates of measurements were made for each sample of seed.

3.1.4.10 Total soluble protein

Protein content of seeds was estimated quarterly by following Lowery *et al.* (1951) method. One gram of seed was soaked with distilled water for 4 hours and then after crushing, water was added up to a volume of 100 mL. Then filtrate was defatted by adding diethyl ether. Then 0.4 mL of the supernatant was pipetted in a test tube containing freshly prepared Folin-Ciocalteu Phenol reagent. The mixture of these three solutions was then shaken and allowed to stand for 30 minute. The optical density was measured in a spectrophotometer at 750 nm. Bovin Serum albumin was used to plot a standard curve for estimation of protein content in the solution. Each sample was replicated three times.

3.1.4.11 Total soluble sugar

Soluble sugar content in the seeds was quantified quarterly by following anthrone-sulphuric acid method of Shirlaw and Gilchrist (1967). One gram of seed was allowed to soak for 4 hours in distilled water and after crushing distilled water was added up to a volume of 100 mL. Crushed sample was then centrifuged and filtered through Whatman No. 1 filter paper. The filtrate was boiled for 20 minutes then centrifuged again for 20 minutes. The supernatant were washed twice with diethyl ether and 0.2 mL of elutes obtained was pipetted in a test tube containing 5 mL of ice-cold anthron ($\text{C}_6\text{H}_4\text{COC}_6\text{H}_4\text{CH}_2$) solution (0.2% in sulphuric acid). Elute and anthrone-sulphuric acid solution were mixed rapidly in a test tube and the sample was placed in a water bath for 10 minutes then cooled by running tap water. The optical density was measured at 625 nm. Glucose was used to plot a standard curve for the estimation of sugar content in the solution. Each sample was replicated three times.

3.1.5 Soil Sample Analysis

3.1.5.1 Particle size analysis

Particle size analysis was done for the samples collected initially i.e. before setting of the experiment. Bouyoucos (1962) hydrometer method was followed for analysis of the samples. The textural class of the initial soil was determined by triangular textural diagram suggested by USDA.

3.1.5.2 pH

Soil pH of the initial soil was determined by a pH meter (Horiba, Model No.M-8L) fitted with glass electrode using a soil-water ratio of 1: 2.5 (Hunter, 1984).

3.1.5.3 Organic matter

Organic matter of the initial was calculated by multiplying the percent organic carbon (determined by wet oxidation method) by Van Bemmelen factor, 1.724, as described by Piper (1942).

3.1.5.4 Total Nitrogen

Total nitrogen of the initial soil was extracted by Macro-Kjeldahl method and determined by alkali distillation as described by Black, 1965.

3.1.5.5 Available phosphorus

Extraction for available phosphorus in the initial soil samples was made with Bray and Kurtz (1945) dilute acid fluoride method described by Kuo (1996). Spectronic-21, Bausch and Lomb, Spectrophotometer was used to measure the colour intensity at wavelengths of 880 nm following the ascorbic acid blue colour method (Watanabe and Olsen, 1965).

3.1.5.6 Exchangeable potassium

Exchangeable potassium of initial and post harvest soil was extracted with neutral 1N NH_4OAc as described by Jackson (1973). Potassium was measured by flame photometer at 720 nm.

3.1.5.7 Available sulphur

Available sulphur of initial soil was extracted by 0.15% BaCl₂ extraction method and extractable S was determined by turbidity method. Turbidity was measured by spectrophotometer at 420 nm wavelength.

3.1.5.8 Available Zn

The initial soil sample was extracted by DTPA-TEA method as proposed by Lindsay and Norvell (1978) and the element was determined by atomic Absorption Spectrophotometer (AAS).

3.1.5.9 Available B

The boron content of the initial soil was extracted by hot water and determination was made by Azomethine H method. The colour intensity was measured by spectrophotometer.

3.1.5.10 Cation exchange capacity (CEC)

CEC of the initial soil was determined by saturating the soil with an excess of neutral 1N NaOAc and washing the excess salt with an electrolytic free solution as described by Jackson (1973). The exchangeable Na⁺ was replaced by NH₄OAc solution. The extractable Na⁺ was determined by flame photometer.

3.1.6 Plant samples analysis

Randomly selected 10 plants from each plot including root, stem and pod (without seed) and seed samples of each plot was dried in the oven and then crushed. The plant samples were sieved through 20 mesh sieve. The ground samples were kept in an airtight plastic container.

3.1.6.1 Total K

Total K was determined by nitric-perchloric acid digestion method followed by determination by flame photometer as described by Jackson (1973).

3.1.6.2 Apparent nutrient balance

The nutrient balance sheet was prepared from input and output of nutrients during the growing period. Applied nutrients were considered as input and nutrient taken up by plant was considered as nutrient output and expressed as kg ha^{-1} . The following terminologies were used in the balance sheet. Exchangeable nutrients in soil and nutrient uptake were taken into consideration. Apparent balance of nutrients was calculated from the difference between the added nutrient (fertilizer) and uptake of nutrients by crops. Amount of nutrients (ppm or percent) determined at the time of sowing was considered as initial soil balance. Amount of available nutrients (ppm or percent) found in the soil at the time of harvest of the crop as considered as soil balance at harvest.

3.1.6.3 Potassium use efficiency

Potassium use efficiency (KUE) was calculated as the ratio of jute seed yield (kg ha^{-1}) to the total K uptake (kg ha^{-1}) by the plants for a particular treatment.

3.1.7 Statistical analysis

Data were statistically analyzed by using MSTAT software (MSTAT, 2002).

3.1.8 Economic analysis

Benefit cost ratio was calculated using gross margin, additional benefit and total variable cost of the different produced.

3.2 Experiment 2: Effect of different rates and methods of boron application on yield, quality and shelf life of jute (*C.olitorius*) seed

Boron rates: 0, 1, 2 and 3 kg ha^{-1} with recommended dose of all other nutrients.

Methods of boron application:

- (i) As basal: All of boron fertilizer was used in land at final land preparation
- (ii) Half as basal and half at 35 days after sowing (DAS) as top dressing
- (iii) Half as basal and half at 35 days after sowing (DAS) as foliar spray
- (iv) One- third as basal, One-third at 25 DAS and rest one-third at 45 DAS as top dressing.

(v) One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as foliar spray.

Design: RCBD

Replication: 4

Jute variety: O-72

3.2.1 Treatments

Treatments	Description
T1	0 kg B ha ⁻¹ i.e. control i.e. no boron was applied
T2	1 kg B ha ⁻¹ : all as basal at final land preparation
T3	1 kg B ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing
T4	1 kg B ha ⁻¹ : Half as basal and half at 35 DAS as foliar spray
T5	1 kg B ha ⁻¹ : One third as basal, One-third at 25 DAS and rest one-third at 45 DAS as top dressing
T6	1 kg B ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as foliar spray
T7	2 kg B ha ⁻¹ : all as basal at final land preparation
T8	2 kg B ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing
T9	2 kg B ha ⁻¹ : Half as basal and half at 35 DAS as foliar spray
T10	2 kg B ha ⁻¹ : One third as basal, One-third at 25 DAS and rest one-third at 45 DAS as top dressing
T11	2 kg B ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as foliar spray
T12	3 kg B ha ⁻¹ : all as basal at final land preparation
T13	3 kg B ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing
T14	3 kg B ha ⁻¹ : Half as basal and half at 35 DAS as foliar spray
T15	3 kg B ha ⁻¹ : One third as basal, One-third at 25 DAS and rest one-third at 45 DAS as top dressing
T16	3 kg B ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as foliar spray

3.2.2 Fertilization

All of recommended dose of nutrients i.e. N (90 kg ha⁻¹), P (20 kg ha⁻¹), K (30 kg ha⁻¹), S (20 kg ha⁻¹) and Zn (4 kg ha⁻¹) as Urea, TSP, Muriate of potas, Gypsum and Zinc sulphate respectively was applied at final land preparation except N. Urea as the source of N was applied in three equal splits: one- third as basal, one third at 25 DAS and rest one-third at 45 DAS. Solubor as the source of B was applied as per treatments designed in section 3.2.1.

3.2.3 Cultural operations

Land selection	Land preparation	Initial composite soil sample collection:	Date of sowing
07/8/2007	10/8/07 -22/08/07	22/08/07	23/8/2007
Intercultural operations:			Pre harvest plant sample, Harvest and Post harvest soil sample collection
Weeding	Irrigation	Fertilization	
07/09/07, 16/9/07, 25/9/07	16/9/07, 26/9/07	17/9/07, 27/9/07	27.12.07

3.2.4 Data recorded

3.2.4.1 Dry matter production

Dry matter production was computed following the method stated under 3.1.2.1 in experiment 3.1.

3.2.4.2 Growth and yield contributing parameters

Growth and yield contributing characters like plant population, plant height (P.H.), number of branch plant⁻¹, number of pod plant⁻¹, pod length and seeds per pod were determined following the method as stated in section 3.1.4.2.

3.2.4.3 Seed Yield

Seed yield ha^{-1} was computed following the method stated in section 3.1.4.3.

3.2.4.4 Storing of seeds

Seeds produced from 20 treatments of boron dose, methods and split application in experiment 2 was stored following the method stated in section 3.1.4.4.

3.2.4.5 Seed moisture content

Seed moisture was determined following the method as stated in section 3.1.4.5.

3.2.4.6 1000 seed weight

One thousand seeds of jute produced under experiment 3.2 were randomly counted from each treatment and weighed in an electric balance (Model-PC-180). Thus 1000 seed weight representing the seed size were determined.

3.2.4.7 Germination

Germination percentage was calculated using the method and formula as stated in section 3.1.4.7.

3.2.4.8 Seed vigour (speed of germination)

The vigour performances were determined following the sprocedure and formula as stated in section 3.1.4.8.

3.2.4.9 Electrical conductivity

Electrical conductivity was measured as per method as stated in section 3.1.4.9.

3.2.4.10 Soluble protein of jute seeds

Total soluble protein content was determined quarterly following the method and procedure as stated in section 3.1.4.10.

3.2.4.11 Soluble sugar content in seeds

Total soluble sugar content was determined quarterly following the method and procedure as stated in section 3.1.4.11.

3.2.5 Soil Sample Analysis

3.2.5.1 Available B

The available boron was determined following the method and procedure as stated in section 3.1.5.9.

3.2.6 Plant samples analysis

Plant samples analysis was done following the method and procedure stated in section 3.1.6.

3.2.6.1 Total B

Total B was determined as described by Hunter (1984).

3.2.6.2 Nutrient balance

The nutrient balance sheet was prepared following the method and procedure as stated in section 3.1.6.2.

3.2.6.3 Boron use efficiency

Boron use efficiency (BUE) was calculated as the ratio of jute seed yield (kg ha^{-1}) to the total B uptake (kg ha^{-1}) by the plants for a particular treatment.

3.2.7 Statistical analysis

Data were statistically analyzed by using MSTAT software (MSTAT, 2002).

3.2.8 Economic analysis

Benefit - cost ratio was calculated using gross margin, additional benefit and total variable cost of the different produced.

3.3 Experiment 3: Combined effect of potassium and boron application on yield, quality and shelf life of jute (*C.olitorius*) seed.

Potassium rates = 0, 30, 60 and 90 kg ha^{-1} and Boron rates = 0, 1, 2 and 3 kg ha^{-1} with recommended dose of all other nutrients.

Design: Two factor RCBD

Replication: 4

Jute variety: O-72

3.3.1 Treatments' combinations

Treatments	K rate (kg ha ⁻¹)	B rate (kg ha ⁻¹)
T1	0	0
T2	0	1
T3	0	2
T4	0	3
T5	30	0
T6	30	1
T7	30	2
T8	30	3
T9	60	0
T10	60	1
T11	60	2
T12	60	3
T13	90	0
T14	90	1
T15	90	2
T16	90	3

3.3.2 Fertilization

All of recommended doses of nutrients i.e. N (90 kg ha⁻¹) P (20 kg ha⁻¹), S (20 kg ha⁻¹) and Zn (4 kg ha⁻¹) were applied as Urea, TSP, Gypsum and Zinc sulphate at final land preparation except N, K and B. Urea was applied in three equal splits: one- third as basal, one- third at 25 DAS and the rest one-third at 45 DAS. Muriate of potash and Solubor were used as the source of K and B respectively and these were applied as per treatments designed in section 3.3.1.

3.3.3 Cultural operations

Land selection	Land preparation	Initial composite soil sample collection:		Date of sowing
05/08/08	07/08/08- 22/08/08	23/08/08		23/8/2008
Intercultural operations:				Plant sample collection, Harvest and Post harvest soil sample collection
Weeding	Gap filling	Fertilization	Drainage	
06/9/08, 16/9/08, 25/9/08	6/9/08, 16/9/08	17/9/08, 26/9/08	3/9/08, 16/9/08, 25/9/08	03.01.09

3.3.4 Data recorded

3.3.4.1 Dry matter production

Dry matter production was computed following the method stated under 3.1.2.1 in experiment 3.1.

3.3.4.2 Growth and yield contributing parameters

Growth and yield contributing characters like plant population, plant height (P.H.), number of branch plant⁻¹, number of pod plant⁻¹, pod length and seeds per pod were determined following the method as stated in section 3.1.4.2.

3.3.4.3 Seed Yield

Seed yield ha⁻¹ was computed following the method stated in section 3.1.4.3.

3.3.4.4 Storing of seeds

Seeds produced from 20 treatments of boron dose, methods and split application in experiment 2 was stored following the method stated in section 3.1.4.4.

3.3.4.5 Seed moisture content

Seed moisture was determined following the method as stated in section 3.1.4.5.

3.3.4.6 1000 seed weight

One thousand seeds of jute produced under experiment 3.2 were randomly counted from each treatment and weighed in an electric balance (Model-PC-180). Thus 1000 seed weight representing the seed size were determined.

3.3.4.7 Germination

Germination percentage was calculated using the method and formula as stated in section 3.1.4.7.

3.3.4.8 Seed vigour (speed of germination)

The vigour performances were determined following the sprocedure and formula as stated in section 3.1.4.8.

3.3.4.9 Electrical conductivity

Electrical conductivity was measured as per method as stated in section 3.1.4.9.

3.3.4.10 Soluble protein content of jute seeds

Total soluble protein content was determined quarterly following the method and procedure as stated in section 3.1.4.10.

3.3.4.11 Soluble sugar content in seeds

Total soluble sugar content was determined quarterly following the method and procedure as stated in section 3.1.4.11.

3.3.5 Soil Sample Analysis

3.3.5.1 Exchangeable potassium

Exchangeable potassium of initial and post harvest soil was measured following the method and procedrure as staed in section 3.1.5.6.

3.3.5.2 Available B

The available boron was determined following the method and procedure as stated in section 3.1.5.9.

3.3.6 Plant samples analysis

Plant samples analysis was done following the method and procedure stated in section 3.1.6.

3.3.6.1 Total K

Total K was determined by following the method and procedure as stated in section 3.1.6.1.

3.3.6.2 Total B

Total B was determined by following the method and procedure as stated in section 3.2.6.1.

3.3.6.3 Nutrient balance

The nutrient balance sheet was prepared following the method and procedure as stated in section 3.1.6.2.

3.3.6.4 Nutrient use efficiency

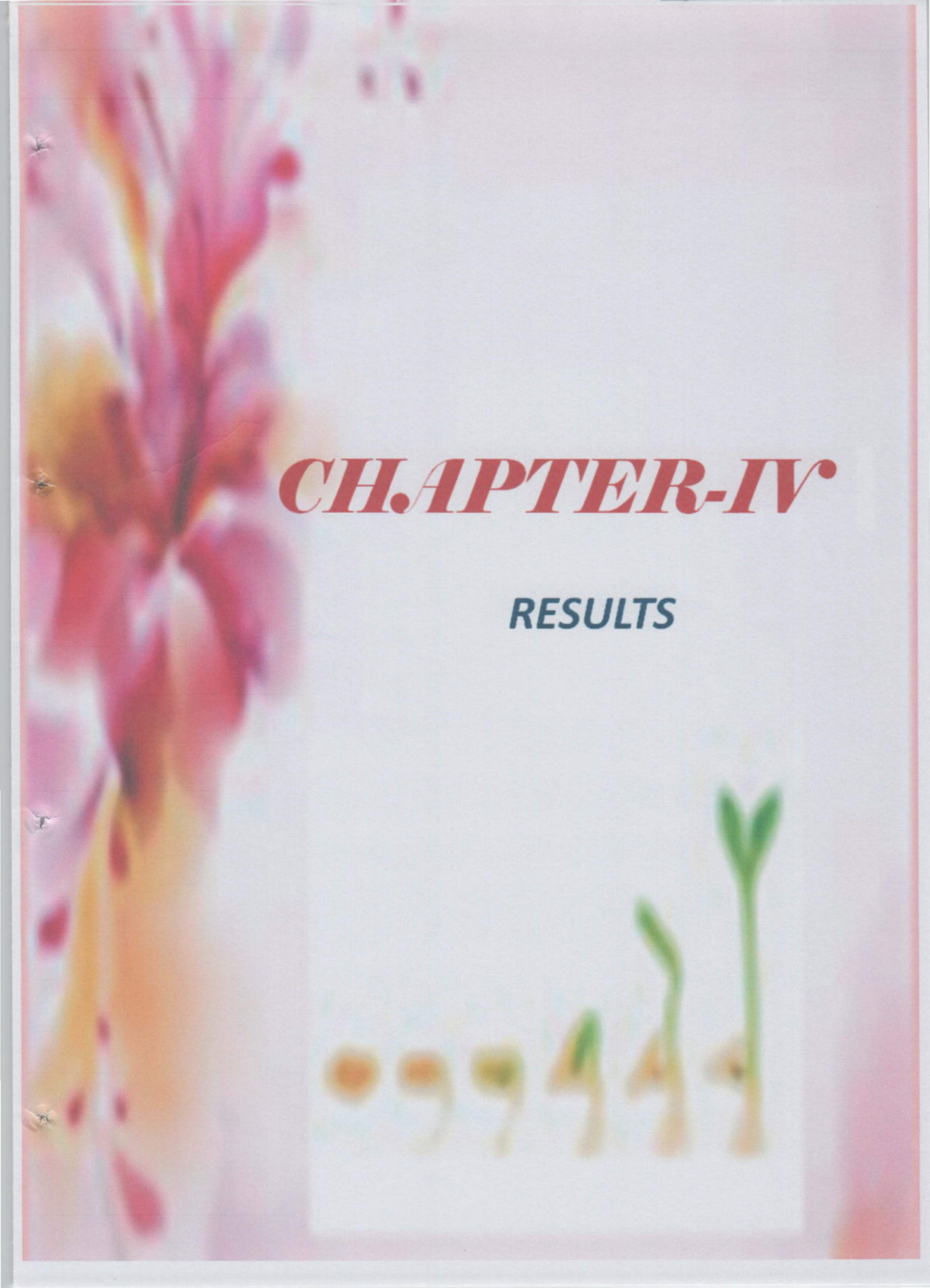
- (a) K use efficiency: Potassium use efficiency (KUE) was calculated as the ratio of jute seed yield (kg ha^{-1}) to the total K uptake (kg ha^{-1}) by the plants for a particular treatment.
- (b) B use efficiency: Boron use efficiency (BUE) was calculated as the ratio of jute seed yield (kg ha^{-1}) to the total B uptake (kg ha^{-1}) by the plants for a particular treatment.

3.3.7 Statistical analysis

Data were statistically analyzed by using MSTAT software (MSTAT, 2002).

3.3.8 Economic analysis

Benefit - cost ratio was calculated using gross margin, additional benefit and total variable cost of the different produced.



CHAPTER-IV

RESULTS

RESULTS

Experiment 4.1: Effect of dose and split application of potassium on yield, quality and shelf life of jute (*C. olitorius*) seed.

4.1.1: Growth and dry matter production

4.1.1.1: Plant population

With increasing rate of K application significant increase in plant population at harvest was recorded up to certain level then decreased. The highest plant population 4.24 Lacs ha⁻¹ was registered with treatment T₅, where 60 kg K ha⁻¹ (Table 4.1.1) was applied as basal. The lowest plant population 3.81 Lacs ha⁻¹ was recorded with 0 kg K ha⁻¹ i.e. at control plot (T₁). The plant population and the K fertilization were positively correlated ($r^2 = 0.215$) (Fig. 4.1.1).

4.1.1.2: Plant height

Plant height increased significantly and progressively reaching a maximum peak of 1.39 m with treatment T₈ where 90 kg K ha⁻¹ was applied as basal and the lowest (1.10 m) was recorded with treatment T₁ (control) (Table 4.1.1). The highest plant height was identical with all other treatments except control. Plant heights were significantly correlated ($r^2 = 0.593$) with K fertilization (Fig. 4.1.1).

4.1.1.3: Branch plant⁻¹

With increasing rate of K application up to certain level increased the number of branch per plant and then decreased. The significantly highest number of branch plant⁻¹ (4.44) was marked with the treatment T₅, which represents basal application of 60 kg K ha⁻¹ (Table 4.1.1).

4.1.1.4: Dry matter production

Fertilization showed significant effect on dry matter weight of jute plants. With increasing level of K fertilizer the dry weight also increased (Table 4.1.1). Dry weight

and K fertilization were significantly ($R^2 = 0.793$) correlated (Fig. 4.1.1). The highest dry matter weight (6.77 t ha^{-1}) with leaves was found with T₈ treatment where 90 kg K ha^{-1} was applied and the lowest dry matter weight (5.44 t ha^{-1}) was found with T₁ (control) treatment (Table 4.1.1).

Table 4.1.1: Growth characteristics of tossa jute seed production as influenced by potassium application

Treatments		Plant population (Lacs ha ⁻¹)	Plant height (cm)	Branch plant ⁻¹ (No.)	Total dry matter (t ha ⁻¹)
T1	(0 kg K ha ⁻¹ : all as basal at final land preparation)	3.81 d	1.10 b	4.11 bcde	5.44 g
T2	(30 kg K ha ⁻¹ : all as basal at final land preparation)	4.15 abcd	1.20 ab	4.22 abcd	5.81 ef
T3	(30 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	3.97 abcd	1.17 ab	3.98 cde	5.74 f
T4	(30 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	3.85 cd	1.18 b	4.33 ab	5.69 f
T5	(60 kg K ha ⁻¹ : all as basal at final land preparation)	4.24 a	1.24 ab	4.44 a	6.67 ab
T6	(60 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	4.10 abcd	1.20 ab	4.38 ab	6.45 bc
T7	(60 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	3.88 bcd	1.21 ab	4.16 abcd	6.15 d
T8	(90 kg K ha ⁻¹ : all as basal at final land preparation)	4.22 ab	1.39 a	4.43 ab	6.77 a
T9	(90 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	3.90 abcd	1.27 ab	4.29 abc	6.17 d
T10	(90 kg K ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing)	3.83 d	1.24 ab	4.41 ab	6.29 cd
T11	(120 kg K ha ⁻¹ : all as basal at final land preparation)	3.97 abcd	1.32 ab	4.20 ab	6.34 cd
T12	(120 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	3.92 abcd	1.31 ab	4.31 cde	6.36 cd
T13	(120 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	3.92 abcd	1.28 ab	4.42 ab	6.45 bc
T14	(150 kg K ha ⁻¹ : all as basal at final land preparation)	4.20 abc	1.19 b	3.95 de	5.77 ef
T15	(150 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	4.04 abcd	1.20 b	4.04 bcde	5.95 de
T16	(150 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	4.04 abcd	1.27 ab	4.19 abcd	6.04 d

Means followed by same small letters did not differ significantly by DMRT at 0.05 level

4.1.2: Yield and yield attributes

4.1.2.1: Pods plant⁻¹

Increasing level of K up to 60 kg ha^{-1} in basal application increased significantly the pods per plant (Table 4.1.2). Number of pod plant⁻¹ and seed weight were correlated ($r^2 =$

0.768, Table 4.1.3) as results showed in present studies. So, more pods were designated as, or seed yield. The highest number of pods plant⁻¹ (16.79) was observed with T₅ treatment which was identical with all other treatments except T₁ and T₁₄. The lowest pods plant⁻¹ (13.98) was found with T₁ (control) treatment. A positive but quadratic relationship (0.464) was observed between pods per plant and K fertilization (Fig.4.1.3a).

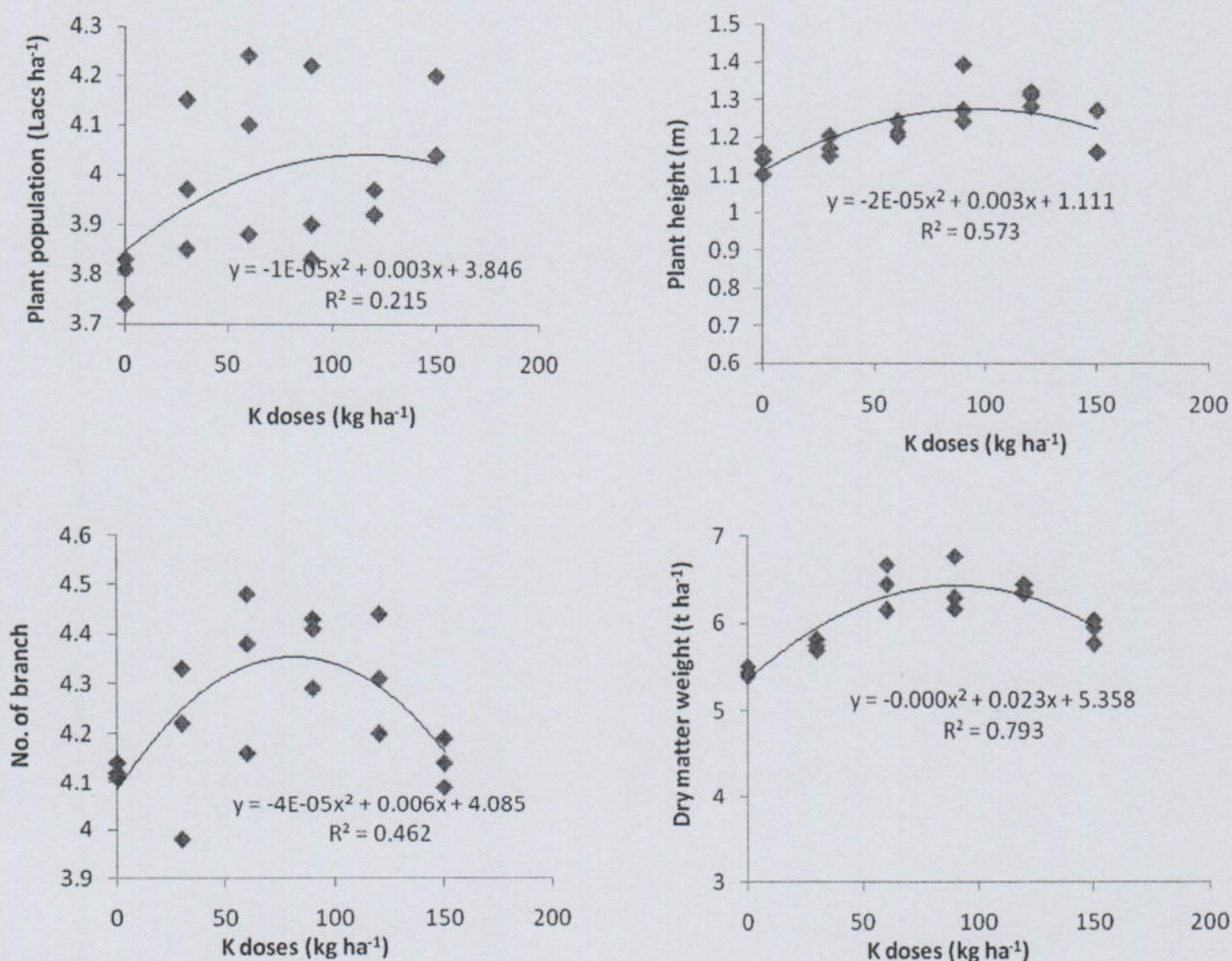


Fig.4.1.1: Relationship between growth characteristics of jute plants and K fertilizer management

4.1.2.2: Pod length

With increasing K fertilization pod length increased up to certain doses then decreased. There was a quadratic relationship ($R^2 = 0.935$) between pod length and K fertilizer management (Fig.4.1.3a). The maximum length of pod (6.29 cm) was observed in T₈ treatment i.e. 90 kg K ha⁻¹ with basal application. The minimum length of pod (5.26 cm)

was recorded in T₁ treatment where no K fertilizer was applied (Table 4.1.2). The present findings reveal that there is a strong quadratic relationship between the pod length and the number of seeds per pod (Fig. 4.1.2).

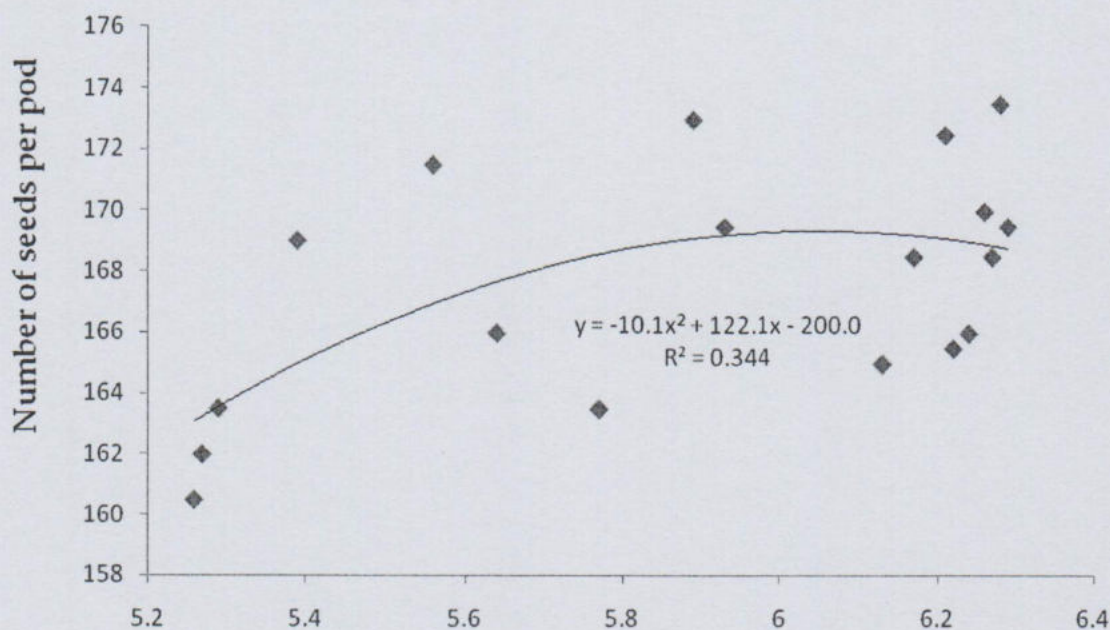


Fig.4.1.2: Relationship between pod length and number of seeds per pod of jute seeds obtained from K fertilizer management.

4.1.2.3: Seeds pod⁻¹

Potassium addition to soil has led to increase the number of seeds pod⁻¹ in jute plants and the highest value (173.5 seeds pod⁻¹) was recorded with T₁₀ (90 kg K ha⁻¹ in three splits), no significant variation was found among treatments except control (Table 4.1.2). The lowest value was 164.5 being documented in T₁ treatment (0 kg K ha⁻¹). There exists a positive but quadratic relationship ($r^2 = 0.401$) seeds per pod and K fertilization in this study (Fig.4.1.3a).

4.1.2.4: 1000 seed weight

With increasing level of K fertilizer application 1000 seed weight increased gradually up to certain levels then decreased. The maximum 1000 seed weight (2.149 g) was recorded with T₈ treatment i.e. 90 kg K ha⁻¹ applied as basal (T₁₀), which was statistically identical to all other treatments (Table 4.1.2). The lowest 1000 seed weight (1.916 g) of jute seed was noted from control plot (T₁). A positive but quadratic relationship ($r^2 = 0.467$) was found between 1000 seed weight and K fertilization (Fig.4.1.3a).

Table 4.1.2: Yield attributes and seed yield of tossa jute as influenced by potassium application

Treatment	Pods plant ⁻¹ (no.)	Pod length (cm)	Seed pod ⁻¹ (no.)	1000 seed wt. (g)	Seed yield (Kg ha ⁻¹)
T1 (0 kg K ha ⁻¹ : all as basal at final land preparation)	13.98 b	5.26b	164.5 b	1.916 a	766.50 i
T2 (30 kg K ha ⁻¹ : all as basal at final land preparation)	16.71 ab	5.64ab	166.0ab	2.034a	809.50 fghi
T3 (30 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	16.52 ab	5.56ab	171.5ab	2.096a	799.00 ghi
T4 (30 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	16.12 ab	5.39ab	169.0ab	2.112a	775.00 hi
T5 (60 kg K ha ⁻¹ : all as basal at final land preparation)	16.79 a	5.89ab	173.0 a	2.114a	914.00 a
T6 (60 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	16.25 ab	5.77ab	163.5ab	2.083a	871.50 abcd
T7 (60 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	15.60 ab	5.93ab	169.5ab	2.142a	815.50 efgh
T8 (90 kg K ha ⁻¹ : all as basal at final land preparation)	15.67 ab	6.29a	173.0 a	2.149a	901.00 ab
T9 (90 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	15.12 ab	6.22a	165.5ab	2.106a	875.50 abc
T10 (90 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	15.38 ab	6.28a	173.5a	2.008a	845.00 cdefg
T11 (120 kg K ha ⁻¹ : all as basal at final land preparation)	15.25 ab	6.24a	166.0ab	2.068a	833.50 cdefg
T12 (120 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	15.39 ab	6.27a	168.5ab	2.133a	856.00 bcdef
T13 (120 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	14.48 ab	6.21a	172.5ab	2.133a	859.50 bcde
T14 (150 kg K ha ⁻¹ : all as basal at final land preparation)	14.36 bc	6.13ab	165.0ab	2.026a	824.50 defg
T15 (150 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	15.16 abc	6.17ab	168.5ab	2.120a	850.00 cdef
T16 (150 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	15.24 abc	6.26a	170.0ab	2.007a	866.00 abcd

Means within column followed by common letters are not significantly different at 5% level of DMRT

4.1.2.5: Seed yield

Potassium application has created significant impact on jute seed yield and has led to increase seed yield with increased dose of K application up to 60 kg ha⁻¹ (T₅). The highest seed yield of 914 kg ha⁻¹ was recorded in T₅ treatment where all K fertilizer was applied as basal, which was 19.24 % higher than control treatment (T₁) where the minimum seed yield (766.5 kg ha⁻¹) was documented (Table 4.1.2) with no application of K. The role of basal application of K fertilization in increasing seed yield was more prominent as compared to that of split application. But the yield difference of split application of K

was insignificant to basal application. A positive but quadratic relationship ($r^2 = 0.880$) was observed between seed yield and added K (Fig.4.1.3b). From the quadratic response function, the optimum dose of K was calculated to be 104 kg ha^{-1} .

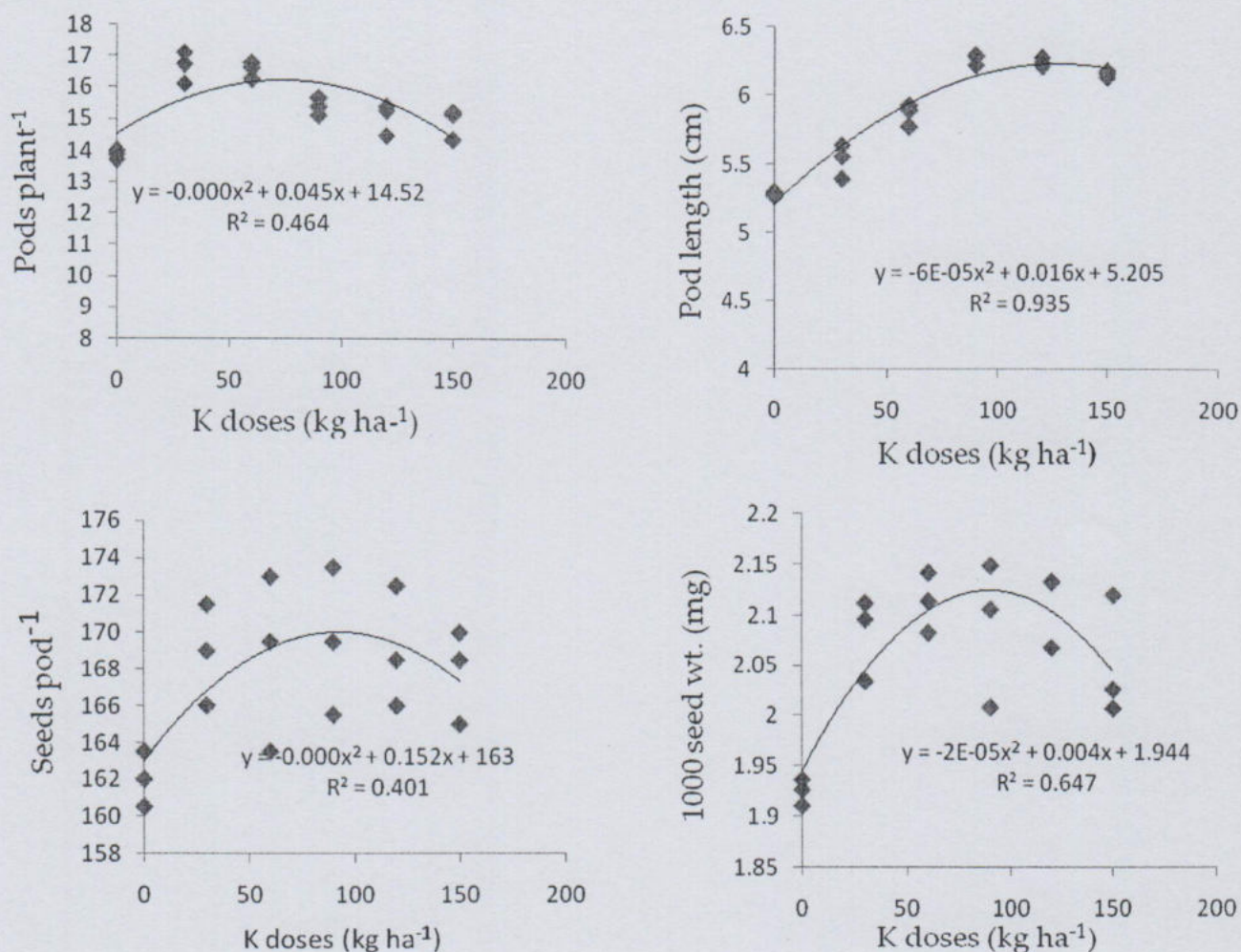


Fig. 4.1.3a: Relationship between yield characteristics of jute and K fertilizer management

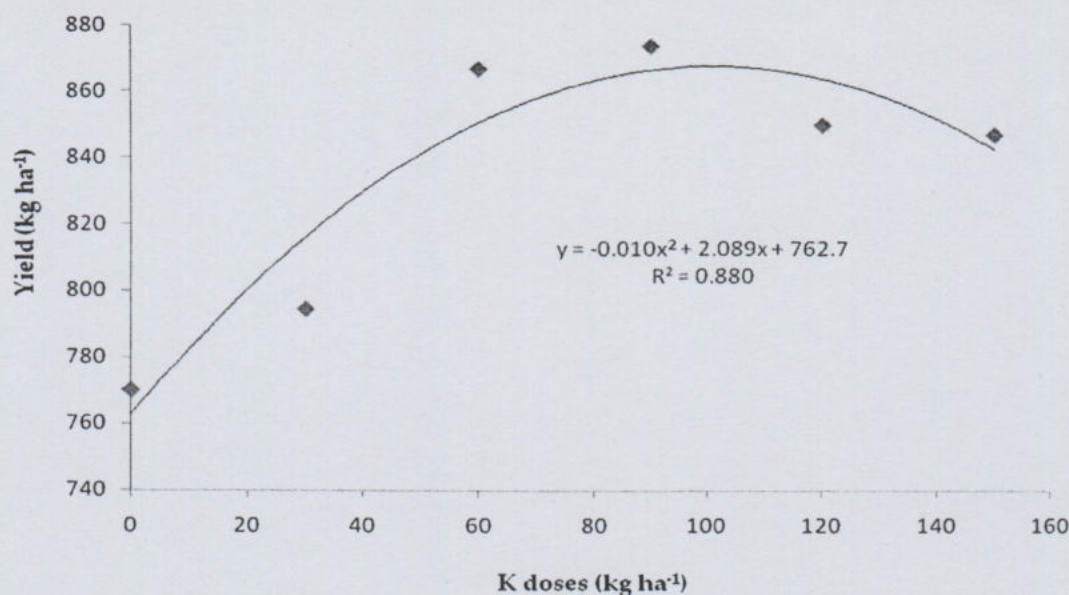


Fig. 4.1.3b: Response of jute to K fertilization in seed production

Table 4.1.3: Bivariate correlation analysis result of different yield contributing characters and yield of tossa jute seed influenced by K fertilization.

Parameters	PP	PH	Br/plant	TDM	Pods/plant	Seeds/pod
PH	0.589(*)					
Br/plant	0.419	0.783(**)				
TDM	0.651(**)	0.803(**)	0.840(**)			
Pods/plant	0.373	0.708(**)	0.887(**)	0.782(**)		
Seeds/pod	0.559(*)	0.761(**)	0.829(**)	0.857(**)	0.752(**)	
Seed yield	0.607(**)	0.893(**)	0.757(**)	0.842(**)	0.768(**)	0.860(**)

PP= Plant population, PH= Plant height, Br= Branch, TDM= Total dry matter

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Bivariate correlation analysis also revealed the similar phenomenon which showed that seed yield is directly correlated with plant population, plant height, branch number, pods per plant and seeds per pod (Table 4.1.3).

4.1.3: Seed quality attributes

4.1.3.1: Seed viability

Viability may be defined as the ability of seeds to germinate and produce a satisfactory crop under favorable conditions, provided dormancy if any is removed. Seeds possess maximum viability when they reach physiological maturity on the mother plant. Viability of a seed lot can be estimated by various laboratory methods such as the standard germination test, electrical conductivity test (Yaklich *et al.* 1979; Yaklich and Kulik, 1987) and estimation of jute seed viability in the two methods are cited below.

4.1.3.1.1: Seed germination

The germination of jute seed was not influenced profoundly by K fertilization. The highest germination percentage (99%) was achieved with T₁₀ treatment which was identical with all other treatments except control (Table 4.1.4). The results showed that split application of K in higher rates performed better in case of germination. The lowest germination (95%) was recorded in control treatment (T₁).

4.1.3.1.2: Seed leachate conductivity

Electrical conductivity differed among the different treatments (Table 4.1.4). The highest electrical conductivity (380 $\mu\text{S cm}^{-1}$) was recorded from control treatment i.e. where no K fertilizer was applied externally (T₁). The minimum electrical conductivity (330 $\mu\text{S cm}^{-1}$) was observed in the treatment T₁₀ where 90 kg K ha⁻¹ were applied in three split time which was identical with the treatment T₅ to T₁₆.

4.1.3.2: Seed vigour

The improvement in 1000 seed weight as under higher K, and with basal application also resulted in higher seed vigour. The higher level of K (90 kg ha⁻¹, treatment T₁₀) showed the highest vigour (97.83), which was statistically identical to all other treatments except T₃, where recorded the lowest vigour (91.50) at which 30 kg K ha⁻¹ was applied at two split (Table 4.1.4).

4.1.3.3: Seedling dry weight (SDM)

Seedling dry weight increased significantly by split application as well as increasing the dose of K addition to soil up to 90 kg ha⁻¹ (Treatment, T₈) exhibiting the maximum value of 0.97 mg plant⁻¹ (Table 4.1.4) which was statistically at par with the treatments T₅, T₉, and T₁₀. The lowest value 0.799 mg plant⁻¹ was recorded in the control plot (T₁).

Table 4.1.4: Quality attributes of jute seed as influenced by potassium application

Treatments	Germ* %	Vigour	E C* ($\mu\text{S cm}^{-1}$)	SDM (mg plant ⁻¹)	Soluble protein (%)	Soluble sugar (%)
T1 (0 kg K ha ⁻¹ : all as basal at final land preparation)	95 b	94.50 a	380 a	0.799 e	18.00 g	12.80 g
T2 (30 kg K ha ⁻¹ : all as basal at final land preparation)	95 b	97.00 a	360 abcd	0.840 d	18.20 efg	12.90 g
T3 (30 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	97 ab	91.50 b	367 abc	0.842 d	18.25 defg	13.10 efg
T4 (30 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	98 ab	97.33 a	369 ab	0.857 d	18.10 g	13.00 fg
T5 (60 kg K ha ⁻¹ : all as basal at final land preparation)	98 ab	97.50 a	339 de	0.963 a	20.39 a	14.40 ab
T6 (60 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	97 ab	96.50 a	343 bcde	0.904 c	19.35 bc	14.30 abc
T7 (60 kg K ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing)	98 ab	97.00 a	340 de	0.902 c	19.30 bc	13.60 def
T8 (90 kg K ha ⁻¹ : all as basal at final land preparation)	98 ab	96.83 a	333 e	0.970 a	20.45 a	14.50 a
T9 (90 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	98 ab	97.50 a	332 e	0.968 a	20.25 ab	14.40 ab
T10 (90 kg K ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing)	99 a	97.83 a	330 e	0.963 a	20.41 a	14.10 abcd
T11 (120 kg K ha ⁻¹ : all as basal at final land preparation)	96 ab	95.00 a	338 de	0.920 bc	19.20 cde	14.00 bcde
T12 (120 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	98 ab	96.83 a	342 cde	0.928 b	19.25 bcd	14.40 ab
T13 (120 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	98 ab	96.33 a	343 cde	0.931 b	19.25 bcd	14.30 abc
T14 (150 kg K ha ⁻¹ : all as basal at final land preparation)	97 ab	95.83 a	349 cde	0.909 c	19.05 cde	14.20 abcd
T15 (150 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	98 ab	97.00 a	347 cbde	0.904 c	18.85 cdef	14.10 abcd
T16 (150 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	98 ab	96.00 a	344 bcde	0.908 c	19.05 cde	14.00 bcde

Means within column following common letters are not significantly different at 5% level of DMRT

Germ. = Germination, EC= Electrical conductivity, SDM= Seedling dry matter

Correlations among seed quality attributes:

The relationship among different seed quality attributes was determined through the bivariate correlation analysis (Table 4.1.5). Seed size was positively correlated with viability percentage ($r = 0.864$), seedling dry weight ($r = 0.827$) and seed vigour ($r = 0.813$).

Table 4.1.5: Bivariate correlation analysis result of different quality attributes of tossa jute seed influenced by K fertilization

Variables	Germination	Vigour	EC	SDM	Soluble protein
Vigour	0.847(**)				
EC	-0.943(**)	-0.813(**)			
SDM	0.864(**)	0.731(**)	-0.940(**)		
1000 seed wt	0.864(**)	0.813(**)	-0.908(**)	0.827(**)	
Soluble protein	0.926(**)	0.849(**)	-0.879(**)	0.871(**)	
Soluble sugar	0.916(**)	0.764(**)	-0.780(**)	0.684(**)	0.845(**)

EC=Electrical conductivity, SDM= Seedling dry matter; ** Correlation is significant at the 0.01 level (2-tailed).

4.1.3.4: Total soluble protein

Total soluble protein of freshly harvested jute seed was significantly influenced by applied K fertilizers (Table 4.1.4). Total soluble protein increased with the increased levels and split application of K especially in higher doses and ranged from 18.00% to 20.45%. The highest total soluble protein (20.45%) was recorded in T_8 treatment (90 kg K ha^{-1} with basal application) which was closely followed by the treatments T_{10} (20.41%) and T_5 (20.39%). The lowest amount of soluble protein (18.0%) was noted in the treatment where no K was added to the soil (T_1). There was found a significant positive quadratic relationship ($r^2 = 0.737$) between total soluble protein and K fertilization (Fig. 4.1.4). It reveals from the present study that there exists a strong positive correlation ($r = 0.926$) between the total soluble protein content and germination percentage of jute seed (Table 4.1.5).

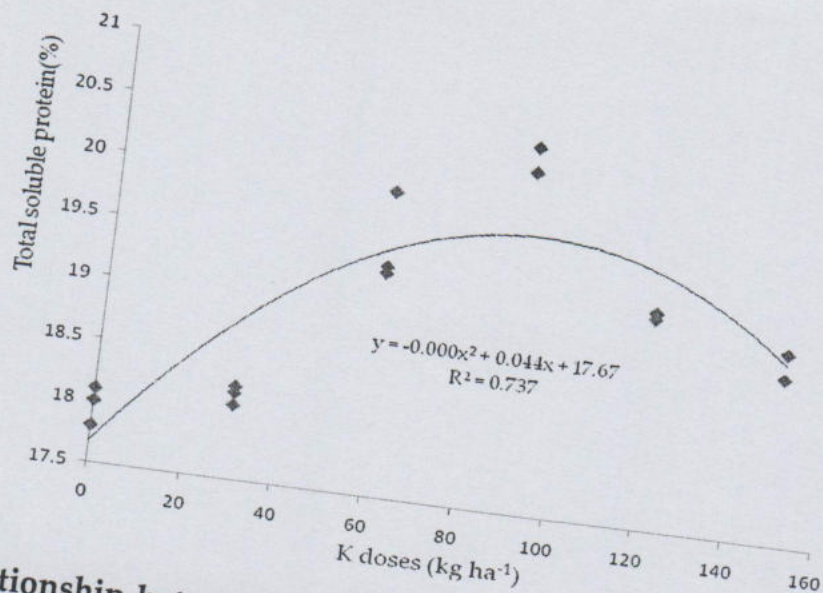


Fig.4.1.4: Relationship between total soluble protein of jute seed and K fertilizer management

4.1.3.5: Total soluble sugar

Total soluble sugar increased significantly with the increase of the levels of K and it increased from 12.80 to 14.50% (Table 4.1.4). The highest total soluble sugar was found from the seeds of the treatment with 90 kg K ha⁻¹ with basal application (T₈) and the lowest with control treatment (T₁). The total soluble sugar content and K fertilization was found significantly correlated ($r^2 = 0.737$) (Fig. 4.1.5).

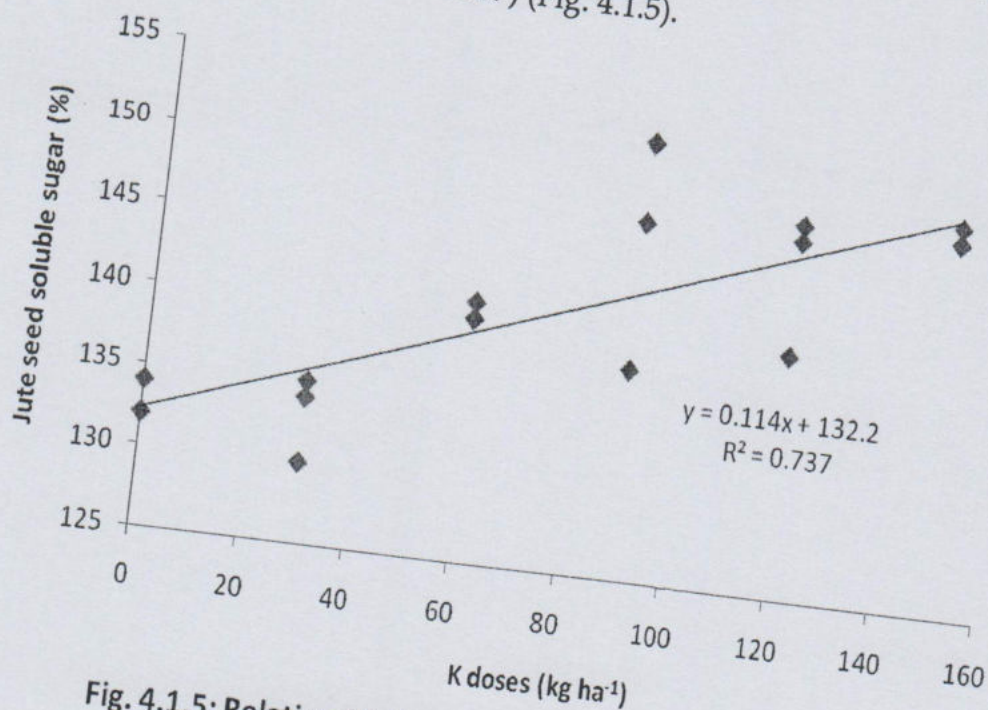


Fig. 4.1.5: Relationship between total soluble sugar of jute seed and K fertilizer management

There is strong positive correlation ($r = 0.916$) between the total soluble sugar content and germination percentage of jute seed (Table 4.1.5).

4.1.4: Seed shelf life study

4.1.4.1: Changes in seed moisture

A slight increase in seed moisture content was observed within early three months. Afterwards moisture content of jute seeds within the pot remained more or less steady as no moisture absorbed or released under air tight condition (Table 4.1.6). Application of K fertilizer slightly influenced on the moisture content of jute seed. Treatments with higher dose of K application have led to contain higher moisture in seeds. The variation of seed moisture was 0.78 % only.

Table 4.1.6: Moisture status at storage of jute seeds obtained from K fertilization

Treat.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	8.89	8.92	8.93	8.93	8.93
T2	8.89	8.89	8.9	8.90	8.90
T3	8.87	8.87	8.88	8.88	8.88
T4	8.88	8.88	8.89	8.89	8.89
T5	8.93	8.93	8.93	8.94	8.94
T6	8.91	8.91	8.92	8.92	8.92
T7	8.91	8.92	8.93	8.92	8.92
T8	8.94	8.94	8.95	8.95	8.94
T9	8.92	8.93	8.93	8.93	8.92
T10	8.93	8.95	8.95	8.94	8.94
T11	8.92	8.92	8.93	8.93	8.93
T12	8.93	8.93	8.95	8.94	8.94
T13	8.93	8.94	8.94	8.93	8.94
T14	8.93	8.95	8.94	8.94	8.94
T15	8.92	8.93	8.94	8.93	8.93
T16	8.94	8.94	8.95	8.95	8.95

Means within column have not significantly different at 5% level of DMRT

4.1.4.2: Changes in seed germination (viability)

Under K fertilization it was observed that jute seeds may be stored safely upto 9 months as seeds obtained from certain doses of K application maintained more than 90% germination at the end of 9 months of storing (Table 4.1.7). The germination performance increased with the increased K application. After 12 months of storage the best performance of germination exhibited (89%) with T₁₀ treatment where 90 kg K ha⁻¹ was applied as three split. The lowest germination (79.00 %) of jute seeds was noted from control treatment (T₁). The loss of germination percentage was minimum (9.18 %) at T₁₀ and maximum (16.84 %) in T₁ (Fig. 4.1.6)

Table 4.1.7: Germination (%) of jute seeds over storage obtained from K fertilization

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	95b	91b	88c	85cd	79d
T2	96b	93ab	92abc	88bcd	84abcd
T3	96ab	93ab	88c	85cd	80d
T4	95ab	93ab	87c	84d	80d
T5	97ab	95ab	92abc	90abc	87abc
T6	98ab	95ab	92abc	87bcd	82bcd
T7	98ab	94ab	91abc	86cd	82bcd
T8	98ab	96a	94ab	92ab	88ab
T9	98ab	94ab	90abc	87bcd	81cd
T10	99a	96a	95a	93a	89a
T11	96ab	92ab	90abc	86cd	83bcd
T12	98ab	95ab	90abc	86cd	81cd
T13	98ab	95ab	91abc	88bcd	83bcd
T14	97ab	95ab	88c	85cd	81cd
T15	98ab	94ab	91abc	86cd	82bcd
T16	98ab	95ab	89bc	85cd	81cd
Means within column followed by common letters are not significantly different at 5% level of DMRT					

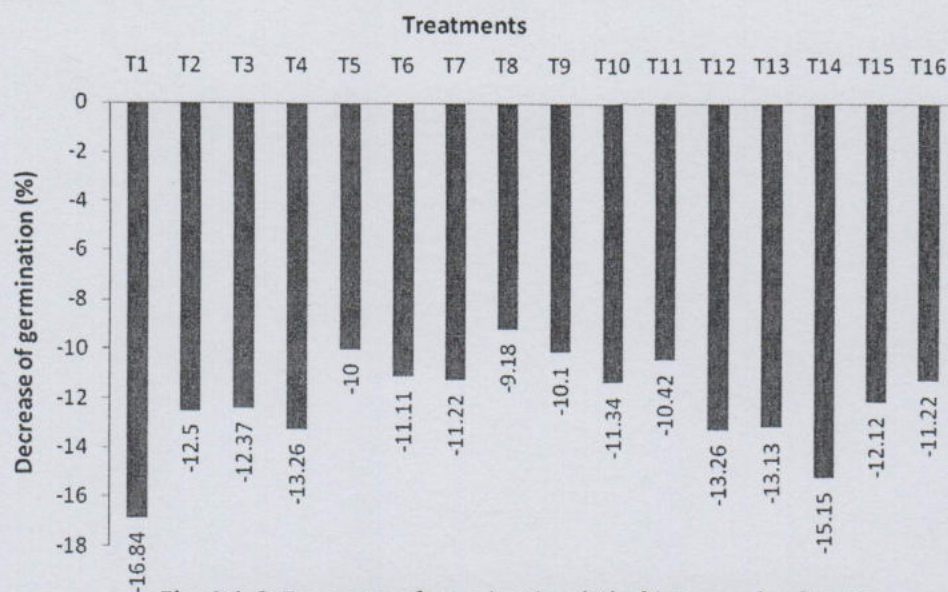


Fig. 4.1.6: Decrease of germination (%) of jute seeds after 12 months of storage obtained from K fertilizer management

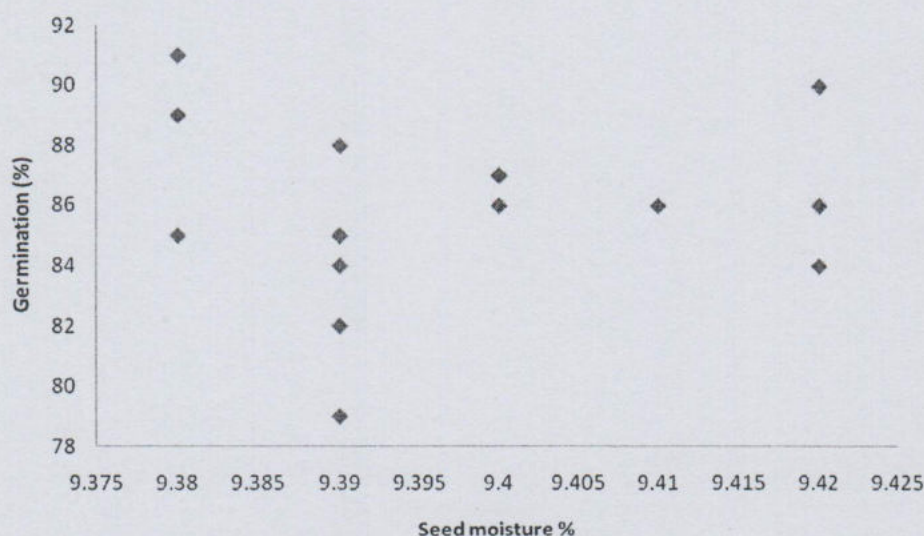


Fig.4.1.7: Relationship between seed moisture and seed germination at 12 months storage of jute seeds obtained from K fertilization

Relationship between seed moisture content and germination shown in scattered diagram (Fig.4.1.7) also indicated the same phenomena as diagrams are more scatteredly distributed. Such scatterly distribution in seed moisture and germination relationship might be due to application of different levels of K fertilizers during seed production.

4.1.4.3: Changes in seedling dry weight

The results showed that application of K had beneficial effect on seedling dry weight and higher level of K (90 kg ha^{-1} , T₈) showed the highest seedling dry weight ($0.901 \text{ mg plant}^{-1}$) after 12 months of storing (Table 4.1.8) and reduced only 7.08 % dry weight (Fig.4.1.8)

while the maximum decrease in seedling dry weight was 11.89 % in control treatment (T₁) where no K fertilizer was applied.

Table 4.1.8: Seedling dry matter (mg) at storage of jute seeds obtained from potassium fertilization

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	0.799 e	0.894 cde	0.876 cd	0.854 ef	0.820 cde
T2	0.840 d	0.883 e	0.887 bc	0.844 f	0.832 cd
T3	0.842 d	0.905 bcd	0.865 d	0.864 cde	0.808 e
T4	0.857 d	0.831 f	0.807 e	0.784 g	0.770 f
T5	0.963 a	0.826 f	0.805 e	0.781 g	0.756 f
T6	0.904 c	0.827 f	0.803 e	0.781 g	0.758 f
T7	0.902 c	0.831 F	0.807 e	0.784 g	0.770 f
T8	0.970 a	0.950 a	0.932 a	0.910 b	0.881 b
T9	0.968 a	0.893 cde	0.877 cd	0.857 def	0.822 cde
T10	0.963 a	0.892 de	0.870 cd	0.842 f	0.815 de
T11	0.920 bc	0.961 a	0.949 a	0.931 a	0.901 a
T12	0.928 b	0.958 a	0.941 a	0.919 ab	0.889 ab
T13	0.931 b	0.952 a	0.934 a	0.916 ab	0.877 b
T14	0.909 c	0.908 bcd	0.899 b	0.874 cd	0.831 cd
T15	0.904 c	0.911 bc	0.901 b	0.877 c	0.837 c
T16	0.909 c	0.916 b	0.902 b	0.877 c	0.839 c

Means within column followed by common letters are not significantly different at 5% level of DMRT

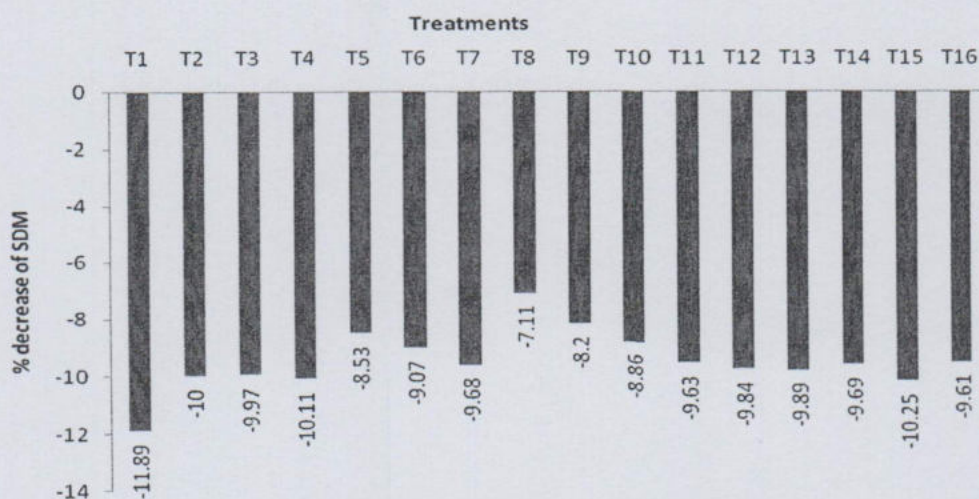


Fig.4.1.8: Decrease of seedling dry weight (%) after 12 months of storage of jute seeds obtained from K fertilization

4.1.4.4: Changes in seed vigour

Seed vigour decreased considerably after 12 months of storage (Table 4.1.9). Applied K contributed to a great extent to maintain better seed vigour of jute seeds after 12 months of storage.

Table 4.1.9: Vigour of jute seeds over storage obtained from K fertilization

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	94.50a	94.00ab	92.00ab	87.33c	77.23e
T2	97.00a	96.00ab	94.00ab	86.83d	82.33cd
T3	91.50b	91.00b	90.50b	87.00cd	83.00bc
T4	97.33a	97.00a	94.00ab	87.00cd	82.83bc
T5	97.50a	95.83ab	94.00ab	90.50ab	86.33ab
T6	96.50a	95.50ab	94.33ab	91.33ab	87.50ab
T7	97.00a	96.50a	95.50a	89.33ab	86.33b
T8	96.83a	96.00ab	95.00a	93.50ab	88.50a
T9	97.50a	96.00ab	95.00a	93.50a	86.83ab
T10	97.83a	96.33ab	95.00a	92.50ab	89.00a
T11	95.00a	94.33ab	93.50ab	89.33bc	84.33ab
T12	96.83a	96.33ab	95.50a	87.88c	82.50cd
T13	96.33a	95.50ab	94.00ab	89.00bc	83.33bc
T14	95.83a	94.83ab	94.00ab	88.00bc	81.33d
T15	97.00a	96.00ab	95.05ab	88.33bc	83.83c
T16	96.00a	95.50ab	92.50ab	87.83c	84.00c

Means within column followed by common letters are not significantly different at 5% level of DMRT

The maximum depletion of seed vigour (18.27%) was recorded in control treatment (T₁) and the minimum (8.08%) was observed in T₈ where 90 kg K ha⁻¹ was applied as basal which was statistically identical to T₇, T₁₃, and T₁₅ (Fig.4.1.9).

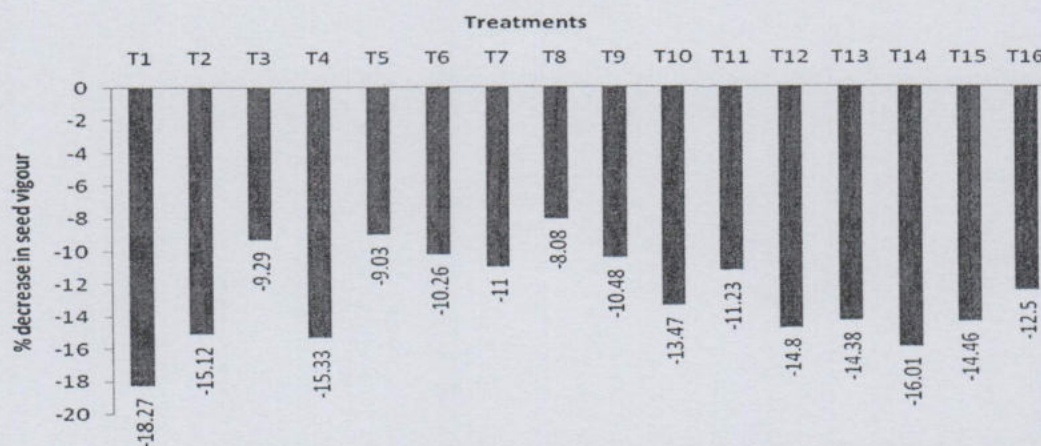


Fig.4.1.9: : Decrease of seed vigour (%) after 12 months storage of jute seeds obtained from K fertilizer application

4.1.4.5: Changes in seed leachate conductivity

Pattern of leachate conductivity differed widely over the applied K and the storage period. Jute seed harvested from lower levels of applied nutrients showed higher levels of electrical conductivity with the progressive of storage (Table 4.1.10). The minimum increase of electric conductivity (17.81%) was observed in the treatment T₈ where 90 kg K ha⁻¹ were applied as basal and the highest increase (29.30%) were recorded in control (T₁) treatment (Fig. 4.1.10).

Table 4.1.10: Electrical conductivity (μScm^{-1}) of jute seeds over storage obtained from K fertilization

Trt.	1 st month	4 th month	7 th month	10 th month	13 th month
T1	380a	445.0a	479.0 a	519.0 a	556.0 a
T2	360abcd	430.0b	441.0 b	477.0 b	497.0 b
T3	367abc	417.0c	433.0 b	465.0 b	493.0 b
T4	369ab	423.0bc	436.0 b	469.0 b	506.7 b
T5	339de	354.0gh	373.0 def	411.0 c	424.0 cd
T6	343bcde	365.0def	384.0 cd	421.0 c	418.0 cd
T7	340de	359.0efg	388.0 c	427.0 c	447.0 c
T8	320e	336.0 i	351.0 h	400.3 cd	428.3 cd
T9	332e	345.0 hi	360.0 gh	379.0 d	408.0 d
T10	330e	351.0 gh	372.0 ef	417.0 c	429.0 cd
T11	338de	347.0 h	365.0 fg	407.0 cd	416.0 cd
T12	342cde	358.0 fg	374.0 def	410.0 c	423.0 cd
T13	343cde	361.0 defg	377.0 cde	412.0 c	427.0 cd
T14	349cde	371.0 d	383.0 cde	424.0 c	429.0 cd
T15	347cde	369.0 de	384.3 cd	428.0 c	431.0 cd
T16	344bcde	366.0 def	379.0 cde	422.0 c	426.0 cd
Means within column followed by common letters are not significantly different at 5% level of DMRT					

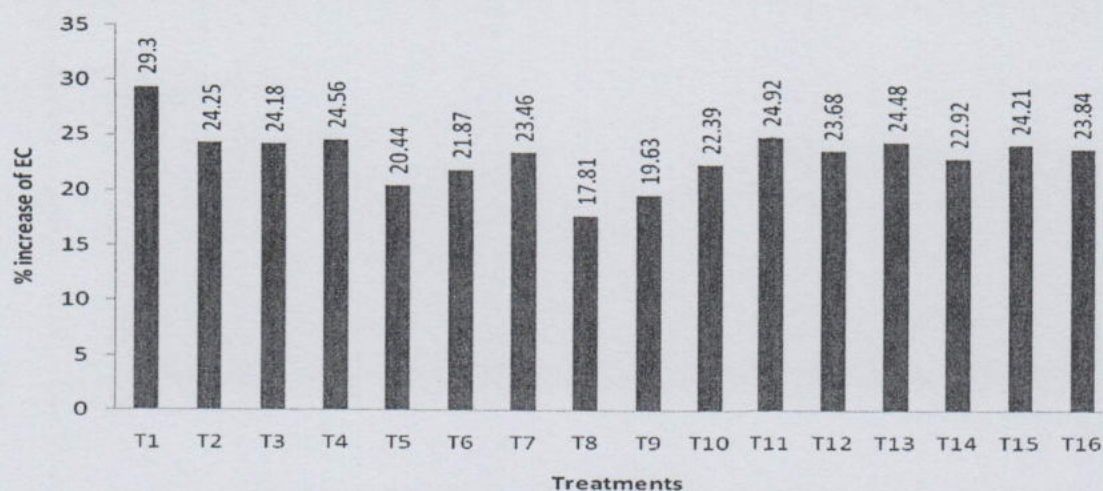


Fig. 4.1.10: Increase of EC (%) after 12 months of storage of jute seeds obtained from K fertilizer application

4.1.4.6: Changes in total soluble protein

Irrespective of the levels of applied K and its application time total soluble protein of jute seed decreased with the increase of storage period. Pattern of decrease of soluble protein however varied greatly over time and the applied K (Table 4.1.11).

Table 4.1.11: Changes in jute seed soluble protein over time as affected by potassium application

Treatment	1 st month	3 th month	6 th month	9 th month	12 th month
T1	18.00g	17.1 g	15.7 g	15.1 e	14.4 e
T2	18.20efg	17.5 fg	16.3 fg	15.5 de	14.8 de
T3	18.25defg	17.7 fg	16.2 fg	15.7 de	14.9 de
T4	18.10g	18.0 cdef	18.6 bcde	17.8 cd	16.4 cde
T5	20.39a	20.3 a	19.8 ab	18.5 bc	18.0 bc
T6	19.35bc	19.20 bc	18.7 bcde	18.2 bc	17.8 bc
T7	19.30bc	19.10 bc	18.7 bcde	18.3 bc	17.1 cd
T8	20.45a	20.35 a	20.19 a	20.00 a	19.8 a
T9	20.25ab	20.20 ab	19.4 bc	18.8 ab	18.5 b
T10	20.41a	20.10 ab	19.6 bc	19.0 ab	18.3 b
T11	19.20cde	19.00 bcd	18.9 bcd	18.3 bc	17.5 cd
T12	19.25bcd	19.05 bcd	18.8 bcd	18.2 bc	17.0 cd
T13	19.25bcd	19.10 bc	18.9 bcd	18.4 bc	17.0 cd
T14	19.05cde	18.89 bcd	18.5 cde	18.1 bcd	16.8 cde
T15	18.85cdef	18.55 cde	18.2 cdef	17.8 cd	16.8 cde
T16	19.05cde	18.75 cde	18.5 cde	18.0 bcd	16.6 cde

Means within column followed by common letters are not significantly different at 5% level of DMRT

In general, rate of decrease of soluble protein was higher (14.79%) in seeds of control (T_1) treatment. The rate of decrease of soluble protein was minimal (9.17%) in seed produced with 90 kg K ha⁻¹ in basal application (T_8) during the 12 months of storage (Fig.4.1.11).

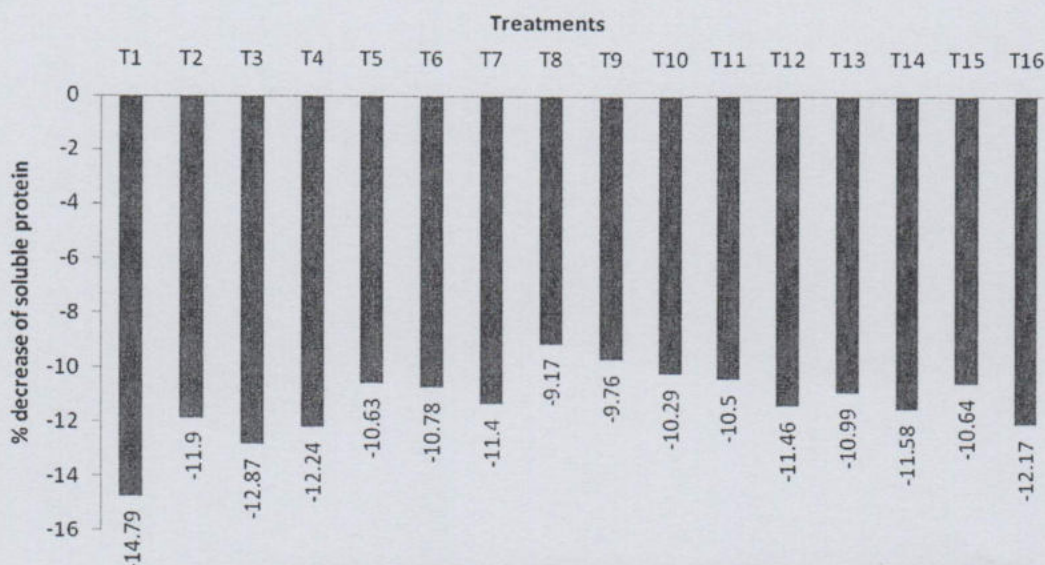


Fig.4.1.11:: Decrease of total soluble protein (%) after 12 months of storage of jute seeds obtained from K fertilizer application

The decline in viability (germination %) is associated with total soluble protein which exhibited through positive correlation between seed germination and total soluble protein of jute seeds obtained from different doses of K and its split application (Fig.4.1.12). Another observation was that seeds harvested from higher levels of K (90 kg ha⁻¹) maintained higher levels of soluble protein throughout the storage period and rate of protein degradation was minimal than that of other treatments.

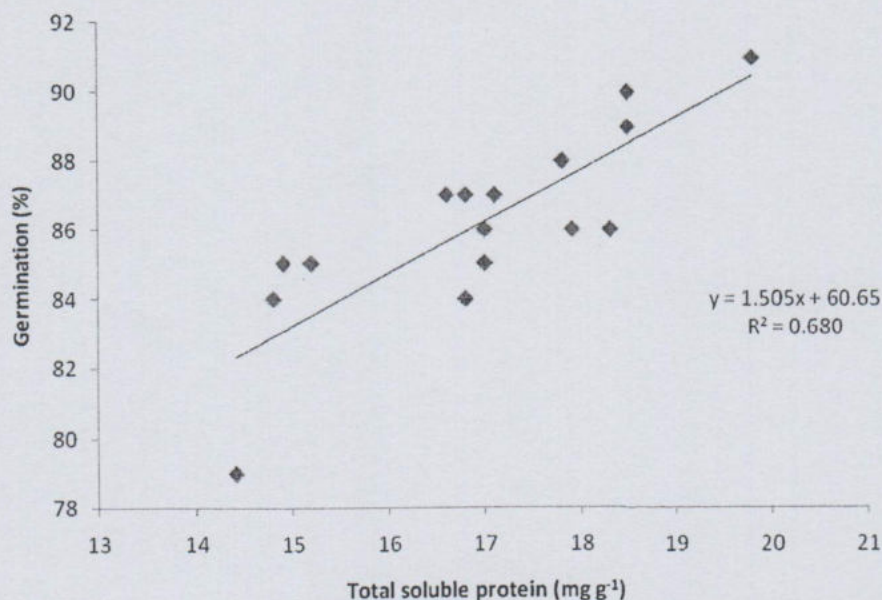


Fig.4.1.12: Relationship between total soluble protein and germination percentage of jute seeds obtained from K fertilization

4.1.4.7: Changes in total soluble sugar

The total soluble sugar of jute seed steadily declined with the increase of storage period irrespective K fertilizer dose and its split of application (Table 4.1.12).

Table 4.1.12: Total soluble sugar (%) over storage of jute seeds obtained from K fertilization

Treat	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	12.8g	12.6 d	12.2 d	11.7 d	10.9 e
T2	12.9g	12.7 cd	12.5 cd	12.2 bcd	11.2 de
T3	13.1efg	13.0 bcd	12.7 cd	12.2 bcd	11.5 de
T4	13.0fg	12.7 cd	12.4 cd	12.1 bcd	11.3 de
T5	14.4ab	13.9 bc	13.7 ab	13.3 ab	12.6 bc
T6	14.3abc	13.8 bc	13.6 ab	13.3 ab	12.4 bcd
T7	13.6def	13.3 bcd	13.1 bc	12.7 bc	12.2bcd
T8	14.5a	14.4 a	14.1 a	13.6 a	13.1 a
T9	14.4ab	14.1 ab	13.8 ab	13.5 a	12.8 ab
T10	14.1abcd	13.8 bc	13.4 abc	13.0 ab	12.6 ab
T11	14bcde	13.6 bcd	13.1 bc	12.7 bc	12.3
T12	14.4ab	14.3 a	14.0 a	13.6 a	13.0 a
T13	14.3abc	14.0 abc	13.7 ab	13.2 ab	12.6 bc
T14	14.2abcd	14.0 abc	13.5 abc	13.3 ab	12.5 bc
T15	14.1abcd	13.5 bcd	13.1 bc	12.6 bc	11.9 cd
T16	14.00bcde	13.6 bcd	13.0 bc	12.4 bcd	11.8 cd

Means within column followed by common letters are not significantly different at 5% level of DMRT

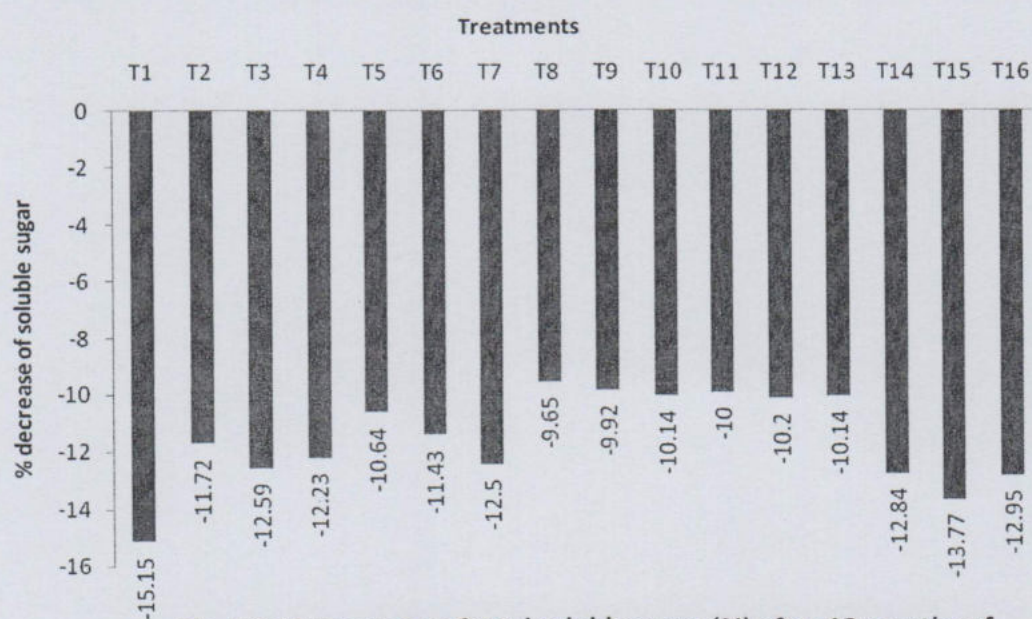


Fig.4.1.13: Decrease of total soluble sugar (%) after 12 months of storage of jute seeds obtained from K fertilizer application

The minimal (9.24%) deterioration of total soluble sugar was observed with T₈ treatment where 90 kg K ha⁻¹ were applied as basal and the maximum (15.15%) degradation was recorded with control (T₁) treatment (Fig.4.1.14). The decline on viability is associated with total soluble sugar which exhibited through positive correlation ($r^2 = 0.802$) between germination percentage and total soluble sugar (Fig.4.1.15).

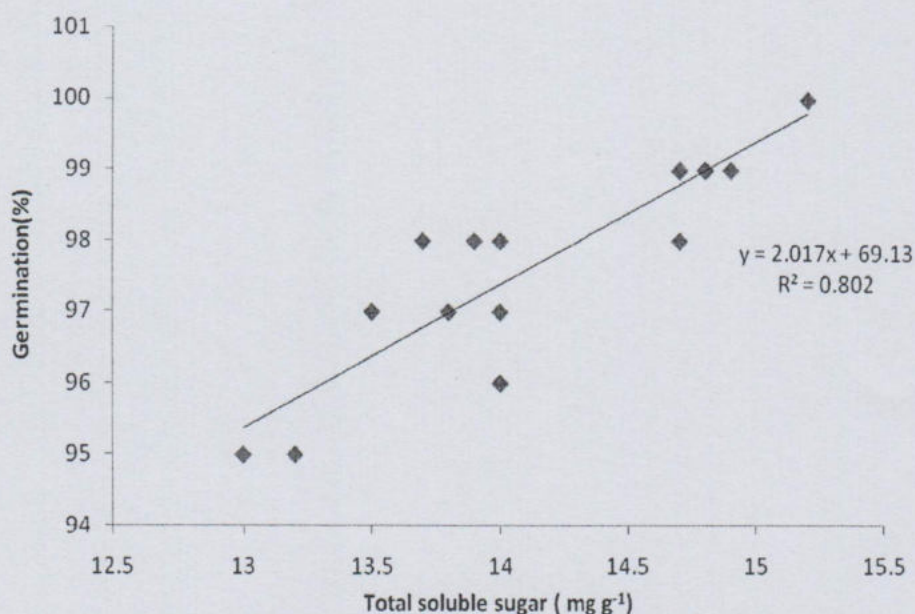


Fig.4.1.15: Relationship between total soluble sugar and germination percentage of jute seeds obtained from K fertilization

4.1.5: Potassium content, uptake and balance

4.1.5.1: Potassium content

The content of K in root, shoot, leaf and seed of jute exhibited marked variation due to variable level and split application of K fertilizer (Table 4.1.13). The content of K was 0.55 % (T₁)- 0.79 % (T₁₆), 0.610 % (T₁)- 0.775 % (T₁₆), 2.140 (T₁)- 2.675 (T₁₆) and 1.16 (T₁)- 1.41 (T₁₅) % in root, shoot, leaves and seed, respectively. At harvest leaves displayed the highest K content among the plant parts followed by root, seed and shoot. With increasing of K levels, K content increased significantly and linearly in different parts of jute plants except in seed production (Fig.4.1.16). The highest (2.675%, in leaves) and lowest (0.55%, in root) content of K was registered with 150 kg K ha⁻¹ with three split (T₁₆) and in control (T₁) treatment.

Table 4.1.13: Effect of K on K content (%) of jute plants in seed production

Treatments		% K in different parts of jute plants in seed production			
		Root	Shoot	Leaves	Seed
T1	(0 kg K ha ⁻¹ : all as basal at final land preparation)	0.55 ab	0.610 b	2.140 c	1.16 a
T2	(30 kg K ha ⁻¹ : all as basal at final land preparation)	0.59 ab	0.650 ab	2.305 bc	1.26 a
T3	(30 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	0.59 ab	0.670 ab	2.320 bcf	1.27 a
T4	(30 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	0.57 ab	0.665 ab	2.333 bc	1.26 a
T5	(60 kg K ha ⁻¹ : all as basal at final land preparation)	0.58 ab	0.705 ab	2.485 abc	1.32 a
T6	(60 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	0.59 ab	0.725 ab	2.480 bcde	1.33 a
T7	(60 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	0.61 ab	0.729 ab	2.420 abc	1.32 a
T8	(90 kg K ha ⁻¹ : all as basal at final land preparation)	0.62 ab	0.740 a	2.550 abc	1.35 a
T9	(90 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	0.78 a	0.745 a	2.535 abc	1.36 a
T10	(90 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	0.70 ab	0.743 a	2.585 abc	1.37 a
T11	(120 kg K ha ⁻¹ : all as basal at final land preparation)	0.78 a	0.725 ab	2.550 abc	1.39 a
T12	(120 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	0.78 a	0.735 a	2.595 ab	1.37 a
T13	(120 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	0.78 a	0.745 a	2.510 abc	1.39 a
T14	(150 kg K ha ⁻¹ : all as basal at final land preparation)	0.77 a	0.760 a	2.661 ab	1.40 a
T15	(150 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	0.78 a	0.765 a	2.650 ab	1.41 a
T16	(150 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	0.79 a	0.775 a	2.675 a	1.40 a

Means within column followed by common letters are not significantly different at 5% level of DMRT

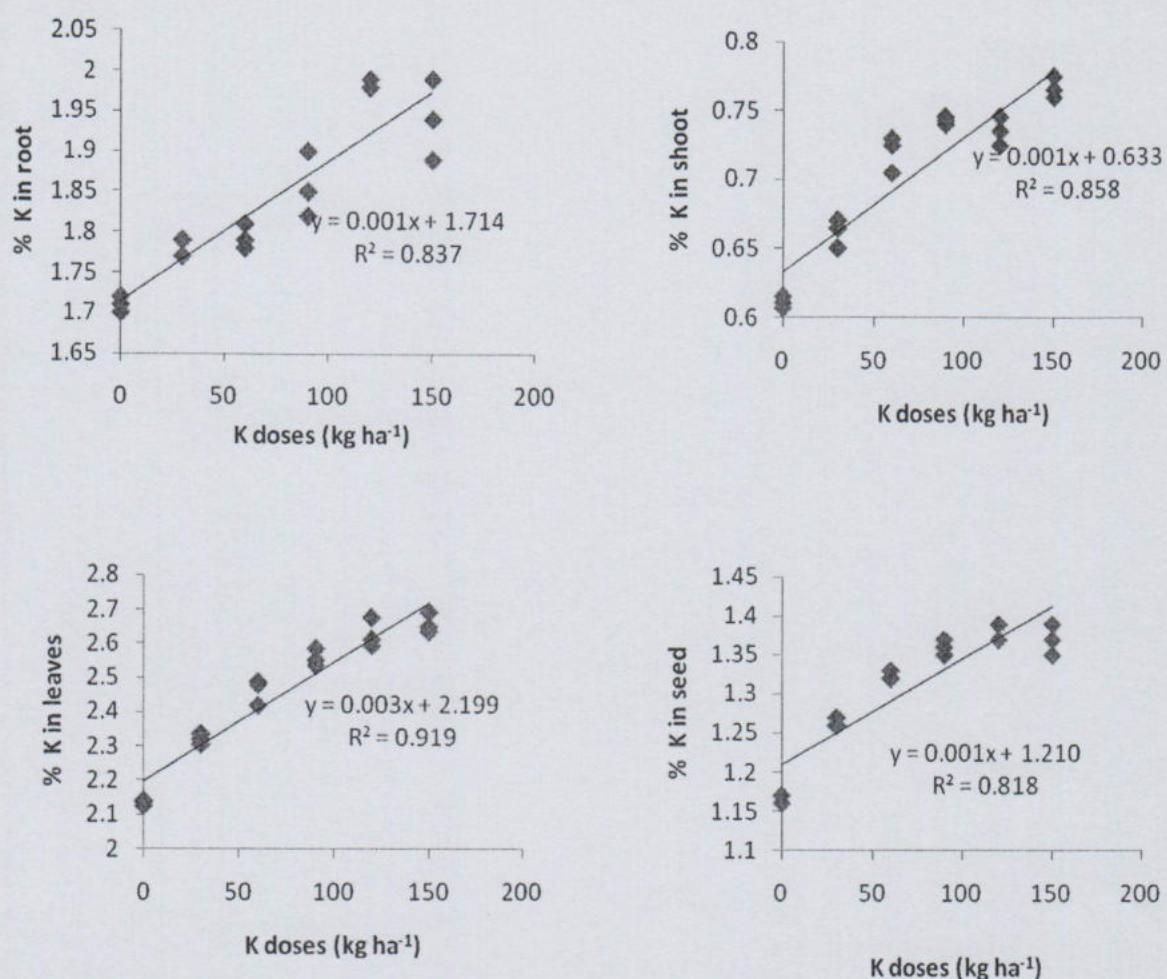


Fig.4.1.16: Relationship between K content and K doses in different parts of jute plant in seed production.

4.1.5.2: Potassium uptake

There was significant variation in uptake of K with K fertilization (Table 4.1.14). The uptake of K by different plant parts of jute in seed production ranged from 12.00 to 17.13 kg ha⁻¹ in root, 30.01 to 48.43 kg ha⁻¹ in shoot, 8.58 to 16.08 ka ha⁻¹ in leaf and 8.88 to 15.08 in seed. The highest total K uptake (96.72 kg ha⁻¹) was recorded where 90 kg K ha⁻¹ were applied as basal, which was 62.64 % higher compared to that of control.

Table 4.1.14: Effect of K on K uptake (kg ha^{-1}) of jute plants in seed production

Treatments		K uptake by different parts of jute plant in seed production				
		Root	Shoot	Leaves	Seed	Total
T1	(0 kg K ha^{-1} : all as basal at final land preparation)	12.00b	30.01e	8.58e	8.88d	59.47g
T2	(30 kg K ha^{-1} : all as basal at final land preparation)	13.96ab	35.41cde	11.33cde	10.24bcd	70.94def
T3	(30 kg K ha^{-1} : half as basal and rest half at 35 DAS as top dressing)	13.44ab	34.46de	11.13cde	10.18bcd	69.21ef
T4	(30 kg K ha^{-1} : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	12.92b	33.38de	10.80de	9.33cd	66.43fg
T5	(60 kg K ha^{-1} : all as basal at final land preparation)	16.98a	45.16ab	15.33ab	14.48ab	91.95ab
T6	(60 kg K ha^{-1} : half as basal and rest half at 35 DAS as top dressing)	14.56ab	40.41bcd	11.69cde	11.57abcd	78.23cde
T7	(60 kg K ha^{-1} : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing)	13.93ab	39.58bcd	12.89abcd	10.75abcd	77.15cde
T8	(90 kg K ha^{-1} : all as basal at final land preparation)	17.13a	48.43a	16.08a	15.08a	96.72a
T9	(90 kg K ha^{-1} : half as basal and rest half at 35 DAS as top dressing)	14.97ab	40.26bcd	12.27bcd	11.72abcd	79.22cd
T10	(90 kg K ha^{-1} : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as top dressing)	14.01ab	39.25bcd	12.19bcd	11.60abcd	77.05cde
T11	(120 kg K ha^{-1} : all as basal at final land preparation)	15.12ab	42.29abc	14.57abc	13.58abc	85.56bc
T12	(120 kg K ha^{-1} : half as basal and rest half at 35 DAS as top dressing)	15.05ab	38.06bcd	12.30bcd	11.88abcd	77.29cde
T13	(120 kg K ha^{-1} : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	15.04ab	38.28bcd	12.03bcd	11.94abcd	77.29cde
T14	(150 kg K ha^{-1} : all as basal at final land preparation)	15.11ab	40.42bcd	12.97abcd	12.48abcd	80.98c
T15	(150 kg K ha^{-1} : half as basal and rest half at 35 DAS as top dressing)	13.97ab	38.84bcd	12.91abcd	12.29abcd	78.01cde
T16	(150 kg K ha^{-1} : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	13.51ab	39.46bcd	13.36abcd	12.54abcd	78.87cd

Means within column followed by common letters are not significantly different at 5% level of DMRT

4.1.5.3: Potassium balance

Addition of K at different doses and split application showed different K balance in calculated amount from negative to positive trend (Fig.4.1.17). The negative balance was observed under lower amount of K application. With increasing the K doses the negative status was reduced gradually. The highest negative balance ($-59.47 \text{ kg ha}^{-1}$) was recorded with no application of K (T₁) and the highest positive balance (71.99 kg ha^{-1}) was observed when 150 kg K ha^{-1} was applied to soil in two split application (T₁₅). The minimum apparent negative balance (-6.72 kg ha^{-1}) of K was observed with T₈ where 90 kg K ha^{-1} was applied as basal. The minimum positive balances (10.78 kg ha^{-1}) of K was

observed with 90 kg K ha⁻¹ as two split application i.e. half at basal and rest half at 35 DAS as top dressing (T₉).

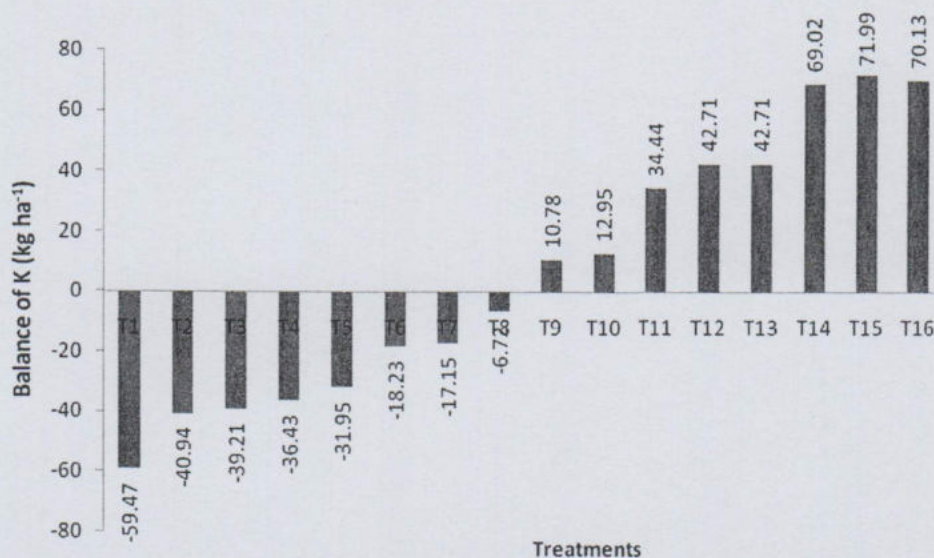


Fig.4.1.17: Apparent balance of K in jute seed production as influenced by K application

4.1.6: Benefit cost ratio (BCR)

Cultivation of any crop depends on its BCR and higher the BCR lower the risk of cultivation of the crops. Application of K has led to variation of the BCR among different doses and its split application in jute seed production. With increasing K doses increased BCR significantly and increasing it up to certain doses then it decreased (Fig 4.1.18). The highest BCR (1.31) was achieved with 60 kg K ha⁻¹ with basal application (T₅) which was identical with 90 kg K ha⁻¹ (BCR 1.28, T₈) application as basal and the lowest BCR (0.95) was recorded where no K was applied i.e. control treatment (T₁).

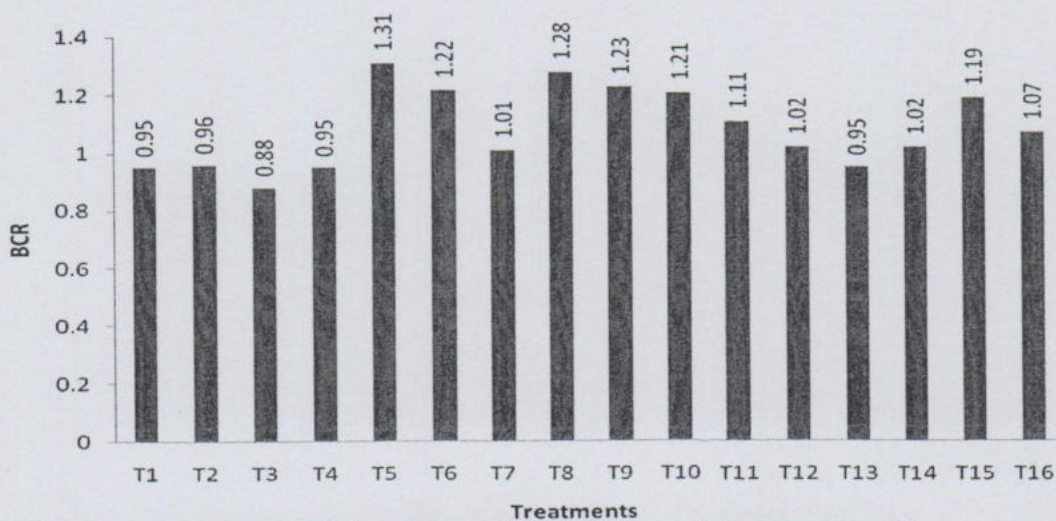


Fig.4.1.18: BCR in jute seed production as influenced by K application

4.1.7: Potassium use efficiency (KUE)

Potassium use efficiency expressed as the ratio of dry jute seed yield to total K uptake was found nonsignificant. At lower level of K, KUE was found higher compared to higher levels of K application (Table 4.1.15). KUE decreased with increase in K uptake through increased K application. The highest KUE (11.62 kg ha⁻¹/ kg K uptake) was found with 30 kg K ha⁻¹ application. At the highest level of K (150 kg ha⁻¹) KUE was found to be the lowest (9.93 kg seed/kg K uptake).

Table 4.1.15: Potassium use efficiency in jute seed production

Treatments		Potassium use efficiency (kg dry jute seed / kg K uptake)
T1	(0 kg K ha ⁻¹ : all as basal at final land preparation)	12.89
T2	(30 kg K ha ⁻¹ : all as basal at final land preparation)	10.95
T3	(30 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	10.78
T4	(30 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	11.62
T5	(60 kg K ha ⁻¹ : all as basal at final land preparation)	11.52
T6	(60 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	11.14
T7	(60 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	10.57
T8	(90 kg K ha ⁻¹ : all as basal at final land preparation)	11.12
T9	(90 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	10.55
T10	(90 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	11.23
T11	(120 kg K ha ⁻¹ : all as basal at final land preparation)	11.45
T12	(120 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	10.95
T13	(120 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	10.74
T14	(150 kg K ha ⁻¹ : all as basal at final land preparation)	9.93
T15	(150 kg K ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	11.41
T16	(150 kg K ha ⁻¹ : One- third as basal, one- third at 25 DAS and rest one-third at 45 DAS as top dressing)	10.53

Means did not significantly different at 5% level of DMRT

4.2 Experiment 2: Effect of dose and methods of boron application on yield, quality and shelf life of jute (*C.olitorius*) seed.

4.2.1: Growth and dry matter production

4.2.1.1: Plant population

In present studies B application was found to be effective on plant population but it was insignificant (Table 4.2.1). With increasing doses of B increased plant population up to 2 kg ha⁻¹ then it decreased. Highest plant population (4.35 lacks ha⁻¹) was noted with application of 2 kg B ha⁻¹ as basal (T₇) and the lowest value (3.81 lacs ha⁻¹) was recorded with T₁₂ where 3 kg B ha⁻¹ was applied as basal. In present study the plant population and B application was significantly correlated ($r^2 = 0.767$) (Fig. 4.2.1).

4.2.1.2: Plant height

Plant height increased progressively reaching a maximum of peak 1.28 m with treatment T₇ where 2 kg B ha⁻¹ were applied as basal which was statistically identical to all other treatments. The lowest plant height (1.05 m) was recorded in control treatment (T₁) (Table 4.2.1). In present studies the plant height and B application was found significantly correlated ($r=0.600$) (Fig. 4.2.1).

4.2.1.3: Branch plant⁻¹

The number of branches per plant increased significantly due to the application of boron (Table 4.2.1). With increasing rate of B application up to 2.0 kg ha⁻¹ increased the number of branch per plant and then declined. The maximum number of branch plant⁻¹ (4.47) was observed in T₇ treatment (2 kg B ha⁻¹ applied as basal) having the lowest value of 3.78 in T₁ with no application of B (Table 4.2.1). Branch per plant was positive but insignificantly correlated with B application (Fig.4.2.1).

4.2.1.4: Dry matter production

Significant variation among the different treatments (boron levels) was observed on dry matter production of jute plants in seed production. With increasing level of B fertilizer up to 2 kg ha⁻¹, the dry weight also increased (Table 4.2.1). The highest total dry matter

weight (6.59 t ha⁻¹) was found with T₇ treatment (2 kg B ha⁻¹ applied as basal) and the lowest (5.84 t ha⁻¹) was found with T₃ (control) treatment. TDM were strong but insignificantly correlated with B application (Fig.4.2.1).

Table 4.2.1: Growth characteristics of tossa jute in seed production as influenced by boron application

Treatments	P.P. (Lac ha ⁻¹)	P. H. (m)	Branch plant ⁻¹ (No.)	TDM (t ha ⁻¹)
T1 (0 kg B ha ⁻¹ : all as basal at final land preparation)	3.90 a	1.05 a	3.78 ef	5.92 c
T2 (1 kg B ha ⁻¹ : all as basal at final land preparation)	4.23 a	1.23 a	4.44 ab	6.52 ab
T3 (1 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	4.21 a	1.22 a	4.25 abcde	6.09 abc
T4 (1 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	4.06 a	1.09 a	4.43 abc	6.12 abc
T5 (1 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	4.02 a	1.09 a	4.33 abcd	6.03 abc
T6 (1 kg B ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as foliar spray)	4.02 a	1.02 a	3.94 cdef	6.01 bc
T7 (2 kg B ha ⁻¹ : all as basal at final land preparation)	4.35 a	1.28 a	4.47 a	6.59 a
T8 (2 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	4.22 a	1.19 a	4.03 abcdef	6.39 abc
T9 (2 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	4.25 a	1.23 a	3.61 f	6.48 abc
T10 (2 kg B ha ⁻¹ : One third as basal, One-third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	4.26 a	1.21 a	3.85 ef	6.54 ab
T11 (2 kg B ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as foliar spray)	4.30 a	1.24 a	3.79 ef	6.51 ab
T12 (3 kg B ha ⁻¹ : all as basal at final land preparation)	3.81 a	1.13 a	4.38 abcd	6.41 abc
T13 (3 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	3.83 a	1.17 a	4.36 abcd	6.47 abc
T14 (3 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	3.88 a	1.16 a	3.96 bcdef	6.51 ab
T15 (3 kg B ha ⁻¹ : One third as basal, One-third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	3.98 a	1.17 a	3.91 def	6.48 abc
T16 (3 kg B ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as foliar spray)	3.99 a	1.21 a	4.13 abcde	6.55 ab

Means followed in same column by same small letters did not differ significantly by DMRT at 0.05 level

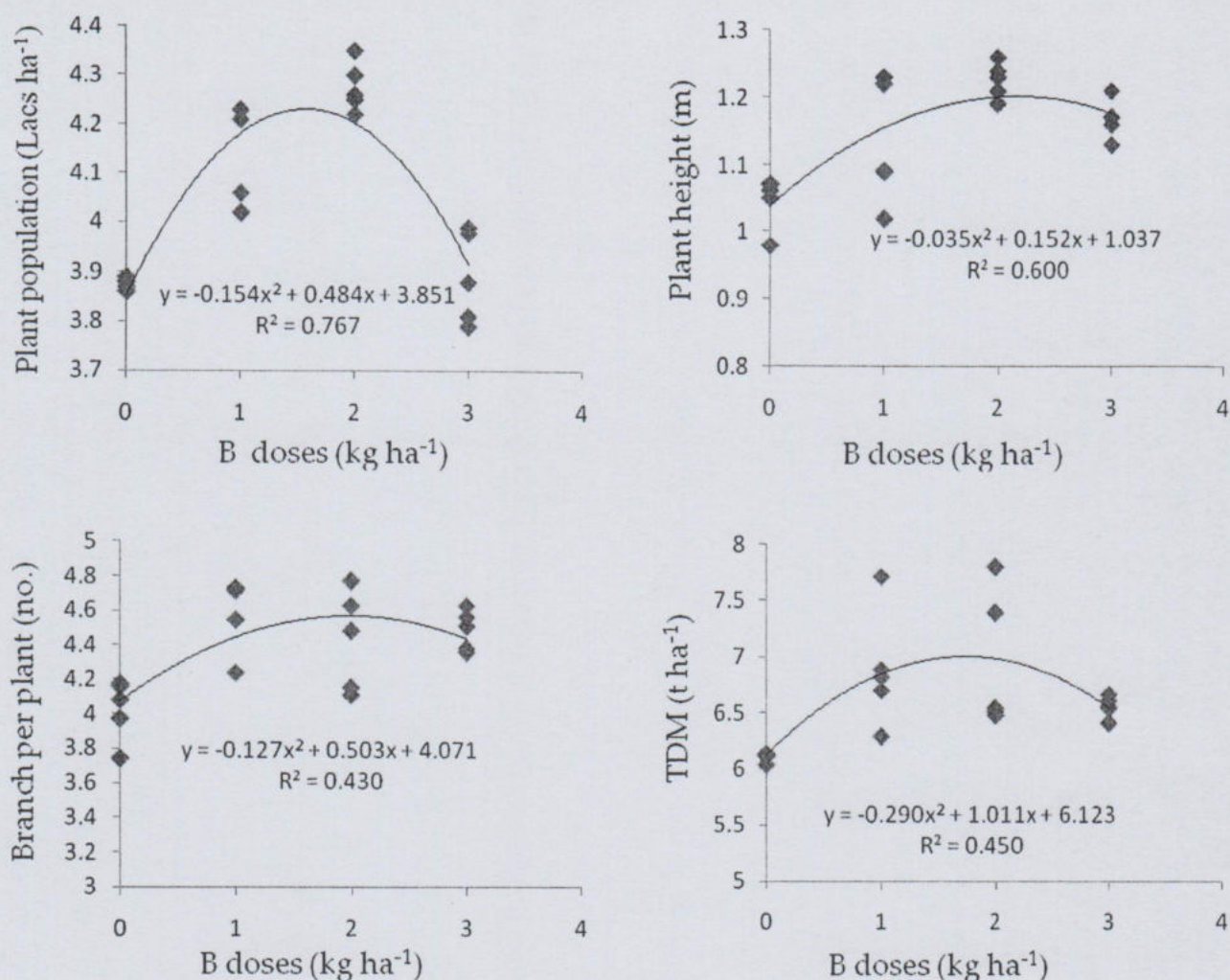


Fig.4.2.1: Relationship between growth characteristics of jute plant and B fertilizer management in seed production

4.2.2: Yield and yield attributes

4.2.2.1: Pods plant⁻¹

Significant variation was observed in respect of number of pods per plant due to boron application. The results showed that increasing level of B up to 2 kg ha⁻¹ in basal application increased the pods per plant (Table 4.2.2). A positive and quadratic relationship between pods per plant and B fertilization was observed (Fig. 4.2.2a). Numbers of pods plant⁻¹ and seed weight were significantly correlated ($r^2 = 0.855$, Table 4.2.3). The lowest number of pods plant⁻¹ (14.00) was counted with no boron application (control, T₁). The highest number of pods plant⁻¹ (21.77) was observed with T₇ treatment which was statistically identical with T₂ and T₈. Above 2 kg B ha⁻¹ caused a significant decrease in pod yield.

Table 4.2.2: Yield attributes and seed yield of tossa jute as influenced by boron application

Treatments		Pods plant ⁻¹	Pod length (cm)	Seeds pod ⁻¹	1000 seed wt. (g)	Seed yield (kg ha ⁻¹)
T1	(0 kg B ha ⁻¹ : all as basal at final land preparation)	14.00 e	6.08 abc	170.25 a	1.933 c	754 c
T2	(1 kg B ha ⁻¹ : all as basal at final land preparation)	20.45 ab	6.60 a	184.75 a	2.165 abc	965 ab
T3	(1 kg B ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	18.14 bcd	5.97 bc	180.11 a	2.288 a	930 ab
T4	(1 kg B ha ⁻¹ : Half as basal and half at 35 DAS as foliar spray)	17.46 d	6.53 a	181.00 a	1.985 bc	881 abc
T5	(1 kg B ha ⁻¹ : One third as basal, One-third at 25 DAS and rest one-third at 45 DAS as top dressing)	17.51 d	6.10 abc	174.00 a	1.938 c	901 ab
T6	(1 kg B ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 40-45 DAS as foliar spray)	16.66de	6.44 ab	182.10 a	2.115 abc	885 abc
T7	(2 kg B ha ⁻¹ : all as basal at final land preparation)	21.77 a	6.49 ab	183.15 a	2.327 a	985 a
T8	(2 kg B ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	20.24 abc	6.33 abc	181.25 a	2.229 ab	958 ab
T9	(2 kg B ha ⁻¹ : Half as basal and half at 35 DAS as foliar spray)	16.66 de	5.91 c	172.01 a	2.007 bc	873abc
T10	(2 kg B ha ⁻¹ : One third as basal, One-third at 25 DAS and rest one-third at 45 DAS as top dressing)	17.74 cd	6.15 abc	174.40 a	2.117 abc	910 ab
T11	(2 kg B ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as foliar spray)	16.41de	6.09 abc	173.45 a	2.158 abc	912 ab
T12	(3 kg B ha ⁻¹ : all as basal at final land preparation)	17.14 d	6.45 ab	170.05 a	2.223 ab	856 bc
T13	(3 kg B ha ⁻¹ : half as basal and rest half at 35 DAS as top dressing)	16.22de	6.26 abc	179.20 a	2.011 bc	859 bc
T14	(3 kg B ha ⁻¹ : Half as basal and half at 35 DAS as foliar spray)	16.22de	6.41 abc	182.00 a	2.016 bc	857 bc
T15	(3 kg B ha ⁻¹ : One third as basal, One-third at 25 DAS and rest one-third at 40-45 DAS as top dressing)	16.25 de	5.89 c	173.13 a	2.024 bc	849 bc
T16	(3 kg B ha ⁻¹ : One- third as basal, one-third at 25 DAS and rest one-third at 45 DAS as foliar spray)	17.00 d	6.37 abc	176.00 a	2.112 abc	869 abc

Means followed in same column by same small letters did not differ significantly by DMRT at 0.05 level

4.2.2.2: Pod length

With increasing B fertilization up to 2.0 kg ha⁻¹ increased pod length and reached the maximum length of 6.60 cm in T₂ treatment where 1.0 kg B ha⁻¹ was applied as basal. The minimum length of pod (5.89 cm) was recorded in T₁₅ treatment where 3 kg B ha⁻¹ was applied in three split (Table 4.2.2). There was found a positive and quadratic relationship between pods length and B fertilization in this study (Fig. 4.2.2a).

4.2.2.3: Seeds pod⁻¹

With B fertilization increased seeds pod⁻¹ was recorded in present study. The highest number of seeds pod⁻¹ (184.75) was marked with the application of B @ 1 kg ha⁻¹ as basal (T₂) which was insignificantly different from all other treatments (Table 4.2.2). The lowest number of seeds per pod (170.25) was recorded in T₁ treatment where no B fertilizer was applied. Quadratic relationship between seeds per pod B fertilization was found in the study (Fig. 4.2.2a). Numbers of seeds pod⁻¹ and seed weight were significantly correlated, as result showed in present study (Table 4.2.3).

4.2.2.4: 1000 seed weight (g)

Increased 1000 seed weight (g) was observed with fertilization. The maximum 1000 seed weight (2.327 g) was recorded with treatment T₇ i.e. 2 kg B ha⁻¹ being applied as basal, which was statistically dential to with all other treatments except T₁, T₄, T₅, T₉, T₁₃, T₁₄ and T₁₅ (Table 4.2.2). The lowest weight (1.933 mg) of jute seed was achieved from the control plot. A quadratic and significant relation ($r^2 = 0.685$) was observed between 1000 seed weight and B application (Fig. 4.2.2a).

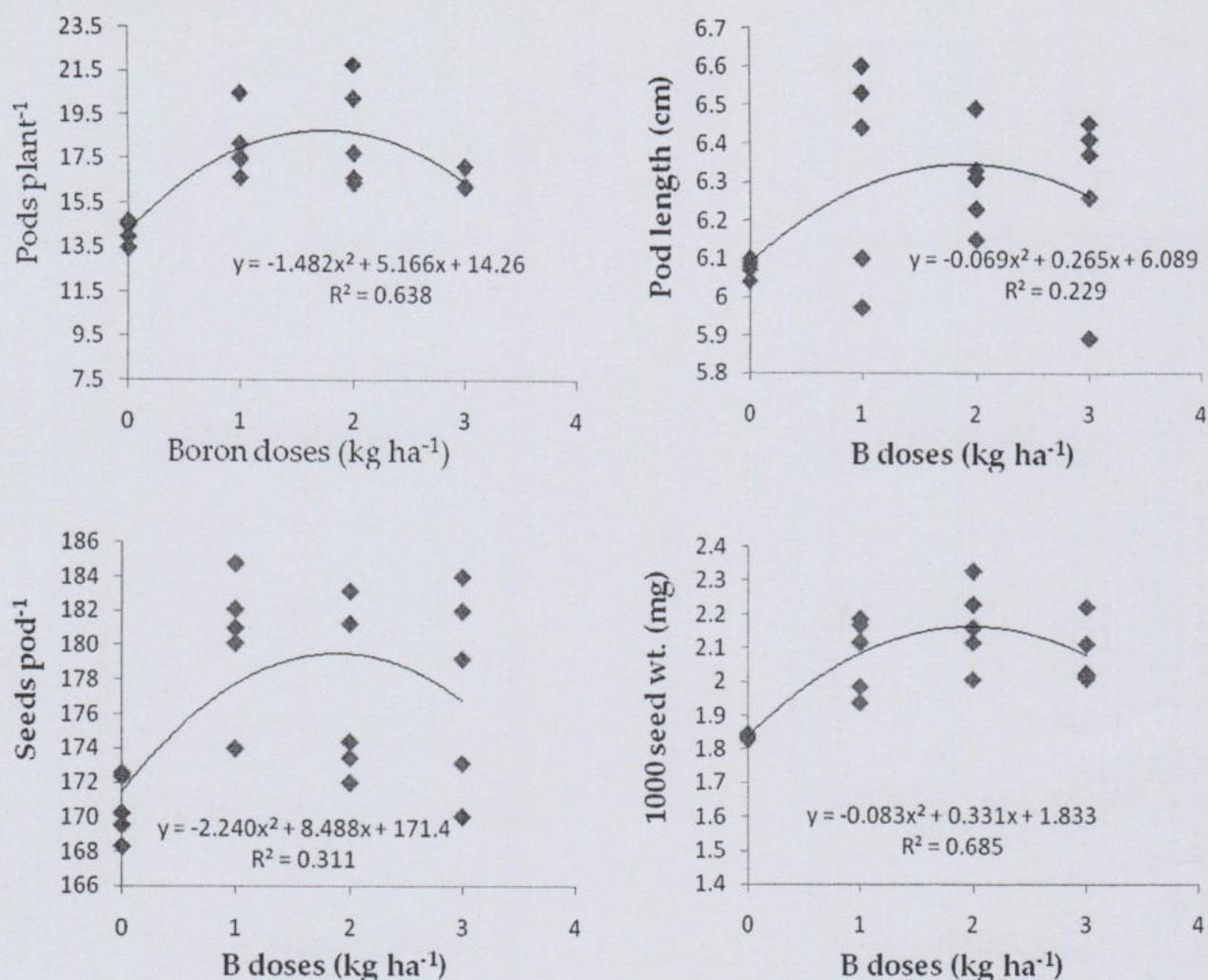


Fig.4.2.2a: Relationship between yield attributes and B fertilizer management in jute seed production

4.2.2.5: Seed yield

Jute seed production was significantly influenced by B fertilization. The results of the study reflected that increasing boron levels increased seed yield up to 2 kg B ha⁻¹ as basal application and then decreased (Table 4.2.2). At higher dose of above 2 kg B ha⁻¹ yield might be decreased due to significant decrease in pod, which might be attributed to injurious effect of high concentration of B in pods as well as leaves and resultant effect was observed on seed yield. In case of seed yield the split application of B was not pronounced as basal application. The highest seed yield (985 kg ha⁻¹, 34.93% higher over control) was recorded with the treatment T₇ and it was statistically identical with all other treatments except T₁, T₁₂, T₁₃, T₁₄ to T₁₅ and the lowest seed yield (754 kg ha⁻¹) was recorded with no application of B (T₁) (Table 4.2.2). A positive but quadratic relationship

was observed between seed yield and added B (Fig.4.2.2b). From the quadratic response function, the optimum dose of B was calculated to be 1.70 kg ha⁻¹.

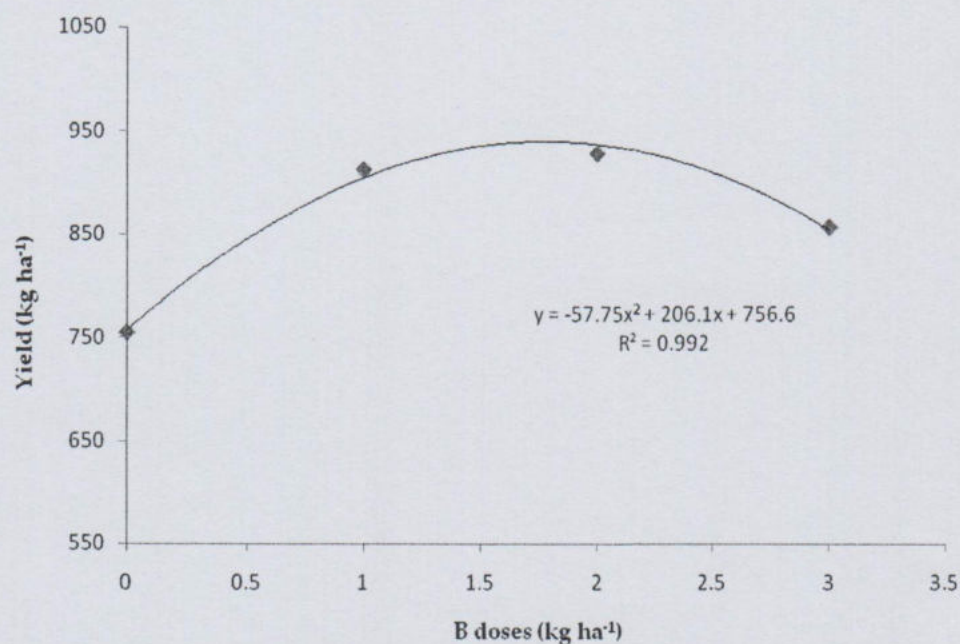


Fig.4.2.2b: Responso of jute to B fertilization in seed production

Table 4.2.3: Bivariate correlation analysis result of different yield contributing characters and yield of tossa jute seed influenced by B fertilization

Variables	PP	PH	Br/plant	TDM	Pod/plant	Seed/pod
PH	0.709(**)					
Br/plant	0.551(*)	0.699(**)				
TDM	0.758(**)	0.648(**)	0.707(**)			
Pod/plant	0.620(**)	0.793(**)	0.735(**)	0.662(**)		
Seed/pod	0.644(**)	0.868(**)	0.722(**)	0.725(**)	0.755(**)	
Seed yield	0.507(*)	0.753(**)	0.720(**)	0.667(**)	0.855(**)	0.865(**)

PP= Plant population, PH= Plant height, Br= Branch, TDM= Total dry matter

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Bivariate correlation analysis revealed the similar phenomenon which showed that seed yield is directly correlated with plant population, plant height, branch number, pods per plant and seeds per pod (Table 4.2.3).

4.2.3: Seed Quality attributes

4.2.3.1: Seed viability

Estimation of jute seed viability in the two methods is cited below.

4.2.3.1.1: Seed germination

The germination of jute seed was influenced by B fertilization (Table 4.2.4). The highest germination percentage (99%) was achieved with T₇ treatment where 2 kg B ha⁻¹ were applied as basal. The lowest germination (94%) was recorded in control (T₁) treatment.

4.2.3.1.2: Seed leachate conductivity

Seed leachate conductivity differed among the different treatments (Table 4.2.4). The highest electrical conductivity (430 $\mu\text{S cm}^{-1}$) was recorded from control (T₁) treatment i.e. where no B fertilizer was applied externally. The minimum electrical conductivity (320 $\mu\text{S cm}^{-1}$) was observed in the treatment T₇ where 2 kg B ha⁻¹ were applied as basal which was statistically identical with treatment T₂, T₈ and T₉.

4.2.3.2: Seed vigor

The improvement in 1000 seed weight under higher B (2 kg B ha⁻¹, T₇) with basal application also resulted in higher seed vigour (98.33) while it was lowest vigour (90.50) at no B application (T₁) (Table 4.2.4).

4.2.3.3: Seedling dry weight (SDM)

Seedling dry weight was affected by B through its rate and method or split application. Results indicated that the effects were induced by increasing B rate (Table 4.2.4). The highest seedling dry weight (0.984 mg plant⁻¹) was recorded from the seeds obtained from the treatments having 2 kg B ha⁻¹ through basal application (T₇) which was statistically identical to seedling dry weights observed from T₂, T₁₀ and T₁₁. Increase in seedling dry weight at higher levels of B was associated ($r^2 = 0.764$) with increased 1000

seed weight (Table 4.2.5). Conversely, the seed produced from lower level of B (0 kg ha⁻¹, T₁) showed lower seedling dry weight (0.797 mg).

Table 4.2.4: Quality attributes of jute seed as influenced by boron application

Treatments	Germ* (%)	Vigour	EC (μS cm ⁻¹)	SDM (mg plant ⁻¹)	Soluble protein (%)	Soluble sugar (%)
T1 (0 kg B ha ⁻¹ : all as basal at final land preparation)	94 d	90.50 gh	430 a	0.797 j	18.0 f	13.1 g
T2 (1 kg B ha ⁻¹ : all as basal at final land preparation)	99 a	97.50 ab	340 def	0.970 abc	20.6 abc	14.5 ab
T3 (1 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	99 a	95.33 bc	395 abcde	0.835 hi	19.5 de	14.0 def
T4 (1 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	97 abc	92.50 fg	391 abcde	0.844 h	19.3 e	13.8 f
T5 (1 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	95 cd	89.33 h	380 abcdef	0.822 i	19.3 e	14.0 def
T6 (1 kg B ha ⁻¹ : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	97 abc	94.33cd	395 abcde	0.847 gh	19.4 e	13.9 ef
T7 (2 kg B ha ⁻¹ : all as basal at final land preparation)	99 a	98.33 a	320 f	0.984 a	21.0 a	14.7 a
T8 (2 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	99 a	97.50 ab	337 ef	0.964 bc	20.9 a	14.6 ab
T9 (2 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	98 ab	96.50 b	335 ef	0.958 c	20.5 abc	14.6 ab
T10 (2 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	99 a	97.00 b	380 abcdef	0.973 abc	20.4 bc	14.4 abc
T11 (2 kg B ha ⁻¹ : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	97 abc	92.33 ef	395 abcde	0.977 ab	20.3 bc	14.5 ab
T12 (3 kg B ha ⁻¹ : all as basal at final land preparation)	98 ab	93.50de	410 ab	0.891 ef	19.6 de	13.8 f
T13 (3 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	99 a	96.33 b	408 ab	0.898 ef	19.7cde	13.9 ef
T14 (3 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	96 bcd	93.33de	404 abc	0.883 f	20.0 cd	14.1 cdef
T15 (3 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	98 ab	92.83ef	402 abc	0.903 e	20.0 cd	14.0 def
T16 (3 kg B ha ⁻¹ : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	99 a	90.50 gh	400 abcd	0.921 d	20.1c	13.8 f

Means followed in same column by same small letters did not differ significantly by DMRT at 0.05 level

4.2.3.4: Total soluble protein

Total soluble protein of freshly harvested jute seed was influenced significantly by applied B fertilizers (Table 4.2.4). Total soluble protein increased with the increase of the

significant correlation between the total soluble sugar content and germination percentage of jute seed (Fig. 4.2.4).

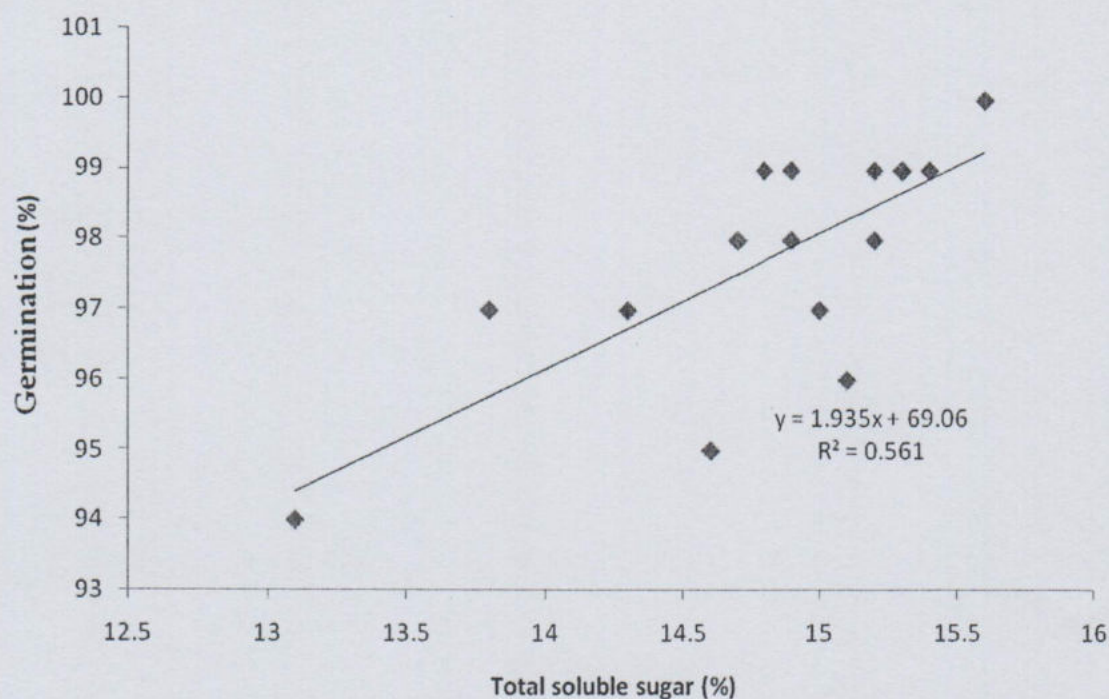


Fig. 4.2.4: Relationship between total soluble sugar and germination percentage of jute seeds obtained from B fertilizer management

Correlations among seed quality attributes:

The relationship among different seed quality attributes was determined through the Bivariate correlation analysis (Table 4.2.5). Seed size was positively correlated with viability (germination) percentage ($r = 0.832$), seedling dry weight ($r = 0.764$) and seed vigour ($r = 0.700$).

Table 4.2.5: Bivariate correlation analysis result of different quality attributes of tossa jute seed influenced by B fertilization

Variables	Germination	Vigour	EC	SDM	Soluble protein
Vigour	0.857(**)				
EC	-0.604(**)	-0.711(**)			
SDM	0.842(**)	0.875(**)	-0.666(**)		
1000 seed weight	0.832(**)	0.700(**)	-0.433	0.764(**)	
Soluble protein	0.687(**)	0.516(*)	-0.500(*)	0.706(**)	
Soluble sugar	0.584(**)	0.428	-0.621(**)	0.698(**)	0.858(**)

EC=Electric conductivity, SDM= Seedling dry matter; ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

The negative relationship between electrical conductivity with viability ($r = -0.604$), Seedling dry weight ($r = -0.666$), seed vigour ($r = -0.711$) and seed size ($r = -0.433$) indicated that more leachates were escaped from poor quality seeds obtained from lower levels of B fertilizers and lowered the viability and the seed vigour (Table 4.2.5).

4.2.4: Seed shelf life study

4.2.4.1: Changes in seed moisture

At the time of storing, initial moisture content varied from 8.87 to 8.99 % in different treatments (Table 4.2.6). A slight increase in seed moisture content was observed within early three months of storage which might be due to absorption of moisture from adjacent free space of plastic pot where there is every possibility to prevail higher vapour pressure gradient than the seed. Application of B fertilizer influenced on the moisture content of jute seed. Jute seed contained higher amount of moisture in the seeds harvested from higher levels of B fertilizers. Difference in seed moisture content in lowest (0 kg B ha^{-1}) and highest level of nutrition (2 kg B ha^{-1}) was 1.35 % and 1.24% at initial and after 12 months of storage respectively.

Table 4.2.6: Moisture (%) of jute seeds at storage obtained from B fertilization

Treat.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	8.87	8.88	8.89	8.89	8.88
T2	8.88	8.90	8.90	8.90	8.89
T3	8.90	8.90	8.91	8.91	8.90
T4	8.90	8.91	8.91	8.91	8.91
T5	8.89	8.90	8.9	8.9	8.90
T6	8.90	8.90	8.91	8.91	8.90
T7	8.99	8.99	9.00	9.00	8.99
T8	8.98	9.00	9.00	9.00	8.99
T9	8.97	8.98	8.98	8.98	8.98
T10	9.00	8.99	9.00	9.00	9.00
T11	8.99	9.00	9.00	9.00	9.00
T12	8.98	8.99	8.99	8.99	8.99
T13	8.99	8.99	8.99	9.00	9.00
T14	8.98	9.00	9.00	9.00	9.00
T15	8.98	8.99	8.99	8.99	8.99
T16	8.98	9.00	9.00	8.99	8.99
Means within column did not differ significantly at 5% level of DMRT					

4.2.4.2: Changes in seed germination (viability)

Fresh jute seeds maintaining 95-99 % germination was stored for future study. It was observed that jute seeds may be stored safely up to 3 months as seeds maintained more than 90% germination whether B is applied or not. But at the end of 6 months of storing, the seeds grown under certain dose of B fertilization showed more than 90% germination (Table 4.2.7). After 12 months of storage, germination of jute seeds obtained from control treatment was lowest (74.00%) and 2 kg B ha⁻¹ recorded highest germination percentage (91%) as its initial stage.

The minimal decrease in germination (8.08%) was observed in the seeds where 2 kg B ha⁻¹ were applied (T₇) and the maximum germination depletion (21.27%) was recorded in control treatment (T₁) where no B fertilizer was applied (Fig.4.2.5). Relationship between seed moisture content and germination is shown in scattered diagram (Fig. 4.2.6).

Table 4.2.7: Germination (%) of jute seeds over storage obtained from B application

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	94 d	92 d	86 f	79 f	74 f
T2	99 a	98 ab	95 b	91 b	87 bc
T3	99 a	98 ab	95 b	90 bc	86 bc
T4	97 abc	98 ab	93 bcd	89 bc	85 bc
T5	95 cd	95 cd	91 cde	87 bcd	82 cd
T6	97 abc	97 ab	92 cd	87 bcd	84 bcd
T7	99 a	99 a	97 a	94 a	91 a
T8	99 a	98 ab	95 b	92 ab	89 ab
T9	98 ab	98 ab	91 cde	89 bc	86 bc
T10	99 a	98 ab	92 cd	88 bc	86 bc
T11	97 abc	96 bcd	91 cde	87 bcd	85 bc
T12	98 ab	98 ab	94 bc	89 bc	84 bcd
T13	99 a	98 ab	94 bc	89 bc	86 bc
T14	96 bcd	95 cd	91 cde	87 bcd	85 bc
T15	98 ab	97 abc	92 cd	86 cd	84 bcd
T16	99 a	98 ab	95 b	90 b	87 bc
Means within column followed by common letters are not significantly different at 5% level of DMRT					

only 5.38 % seedling dry weight over time by the application 2 kg B ha⁻¹ as basal (T₇). In same condition, the maximum decrease in seedling dry weight was 13.80 % in control treatment (T₁) where no external B fertilizer was applied.

Table 4.2.8: Changes in SDM (mg plant⁻¹) in storage as influenced by boron fertilization

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	0.797 j	0.781 h	0.752 g	0.724 h	0.687 i
T2	0.970 abc	0.853 efg	0.840 cd	0.817 e	0.782 fg
T3	0.835 hi	0.823 fg	0.810 e	0.784 ef	0.747 fg
T4	0.844 h	0.832 fg	0.818 e	0.794 ef	0.755 fg
T5	0.822 i	0.811 g	0.797 f	0.776 ef	0.741 fg
T6	0.847 gh	0.835 fg	0.819 de	0.799 ef	0.761 fg
T7	0.984 a	0.975 a	0.963 a	0.949 a	0.931 a
T8	0.964 bc	0.954 bc	0.939 bc	0.921 b	0.897 bc
T9	0.958 c	0.952 bcd	0.936 bc	0.917 b	0.878 cd
T10	0.973 abc	0.958 bc	0.944 bc	0.928 ab	0.890 cd
T11	0.977 ab	0.965 ab	0.955 ab	0.937 ab	0.901 bc
T12	0.891 ef	0.879 ef	0.859 cd	0.838 cd	0.800 de
T13	0.898 ef	0.886 ef	0.874 cd	0.856 cd	0.814 cde
T14	0.883 f	0.872 ef	0.858 cd	0.842 cde	0.800 de
T15	0.903 e	0.891 ef	0.879 cd	0.863 cd	0.821 cde
T16	0.921 d	0.912 e	0.894 c	0.874 c	0.846 d

Means within column followed by common letters are not significantly different at 5% level of DMRT

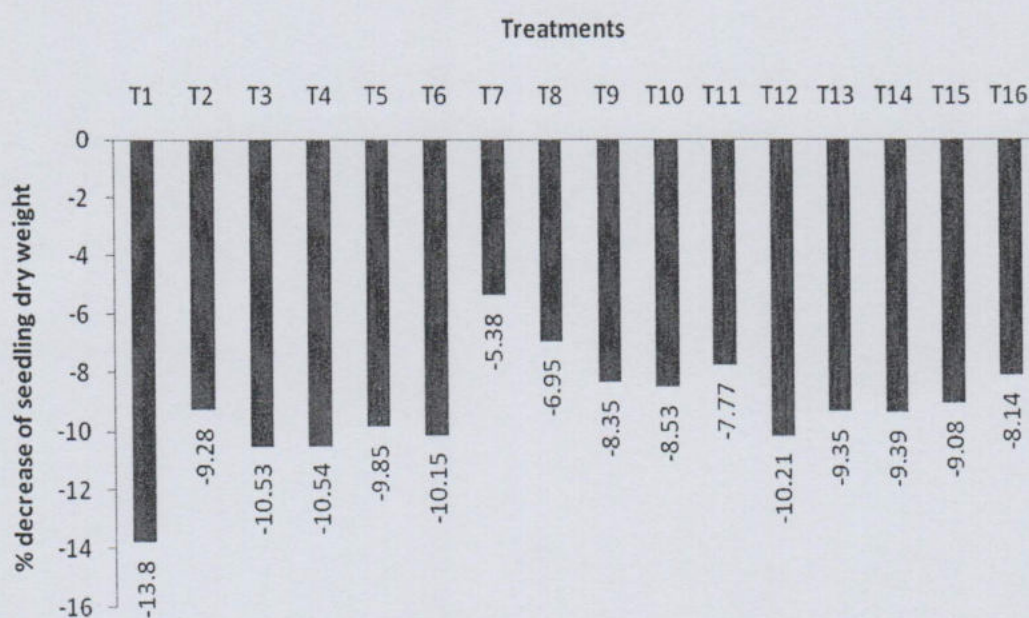


Fig.4.2.7: Decrease of seedling dry weight (%) after 12 months of storage of jute seed obtained from B fertilization

4.2.4.4: Changes in seed vigour

Irrespective of fertilizer management jute seed vigour progressively decreased (Table 4.2.9). The minimum depletion (6.64%) in seed vigour was observed in T₇ where 2 kg B ha⁻¹ was applied as basal being statistically identical to T₈, T₉, T₁₁ and T₁₆. The maximum depletion (15.86%) was recorded with control treatment (T₁), where no B fertilizer was applied (Fig.4.2.8). Changes in seed vigour corresponded well to that of seedling dry weight where seed vigour decreased considerably after 12 months of storage. Like seedling dry weight, decrease in seed vigour indices varied with doses of applied B at 12 months storage (Fig. 4.2.8).

Table 4.2.9: Vigour of jute seeds obtained from varying levels and splitting of B fertilization

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	90.50 gh	88.50 g	85.50 h	80.33 fg	77.83 g
T2	97.50 ab	96.50 ab	93.33 bc	91.00 c	88.33 bc
T3	95.33 bc	95.33 bc	94.00 b	91.83 b	87.50 cd
T4	92.50 fg	94.50 ab	92.83 c	90.33 d	86.50 de
T5	89.33 h	92.83 d	89.83 de	88.00 g	84.50 f
T6	94.33cd	94.33 bc	90.83 d	88.50 e	86.33 de
T7	98.33 a	96.83 a	95.83 a	93.83 a	91.33 a
T8	97.50 ab	94.83 b	93.00 bc	90.33 cd	88.83 bc
T9	96.50 b	94.33 bc	93.33 bc	91.33 bc	87.83 cd
T10	97.00 b	95.50 ab	92.50 cd	90.83 cd	87.50 cd
T11	92.33 ef	93.83 c	92.33 cd	92.00 b	87.50 cd
T12	93.50de	93.50 c	92.33 cd	90.33 d	87.00 cd
T13	96.33 b	94.83 b	93.33 bc	91.33 bc	87.50 cd
T14	93.33de	93.33 cd	92.00 cd	90.33 cd	86.83 d
T15	92.83ef	94.00 bc	92.83 c	90.83 cd	86.33 de
T16	90.50 gh	95.50 ab	93.33 bc	91.83 b	89.00 bc

Means within column followed by common letters are not significantly different at 5% level of DMRT

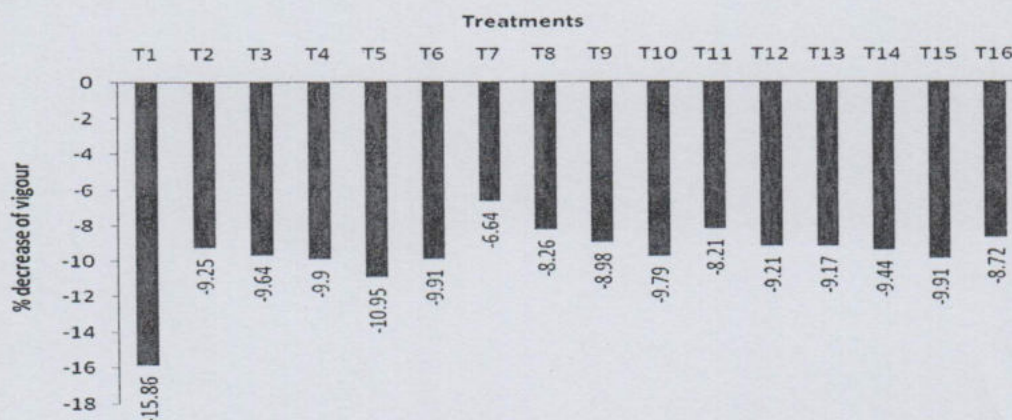


Fig.4.2.8: Decrease of vigour (%) of jute seeds after 12 months of storage obtained from B fertilization

4.2.4.5: Changes in seed leachate conductivity

Irrespective of fertilization the leaching of solutes from the imbibed seed increased with the increase of storage period as it is exhibited by the increase of electrical conductivity of seed electrolytes (Table 4.2.10). This is an indication of seed deterioration with passing of storage time.

Table 4.2.10: Electrical conductivity ($\mu\text{S cm}^{-1}$) in storage of jute seeds at varying levels and splitting of B fertilization

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	430 a	454 a	477 a	510 a	556 a
T2	340 def	391 bcd	406 d	427 bc	452 d
T3	395 abcde	408 bc	424 cd	445 bc	467 cd
T4	391 abcde	401 bc	421 cd	447 bc	470 cd
T5	380 abcdef	388 c	411 cd	444 bc	467 cd
T6	395 abcde	362 cde	396 de	429 bc	479 cd
T7	320 f	326 f	335 g	346 e	377 f
T8	337 ef	380 cd	391 de	404 c	422 de
T9	335 ef	420 bc	433 cd	445 bc	477 cd
T10	380 abcdef	420 bc	436 c	452 bc	477 cd
T11	395 abcde	409 bc	421 cd	439 bc	459 d
T12	410 ab	344 ef	360 f	379 cd	401 de
T13	408 ab	360 cde	379 ef	404 c	422 de
T14	404 abc	380 cd	393 de	413 bc	430 de
T15	402 abc	347 ef	363 f	384 cd	418 de
T16	400 abcd	342 ef	359 f	385 cd	405 de
Means within column followed by common letters are not significantly different at 5% level of DMRT					

Jute seeds harvested from lower levels of applied B like 0 kg B ha⁻¹ showed higher levels of electrical conductivity (29.30%) after 12 months of storage (T₁). The seeds produced by 2 kg B ha⁻¹ as basal application electrical conductivity of seed leachates were also affected significantly being minimum (17.81 %, T₇) after 12 months of storage (Fig. 4.2.9). There existence a negative relationship ($r = - 0.433$) between seed size (1000 seed weight) and electrical conductivity (Table 4.2.5), indicating that smaller the seed size higher is the electrical conductivity.

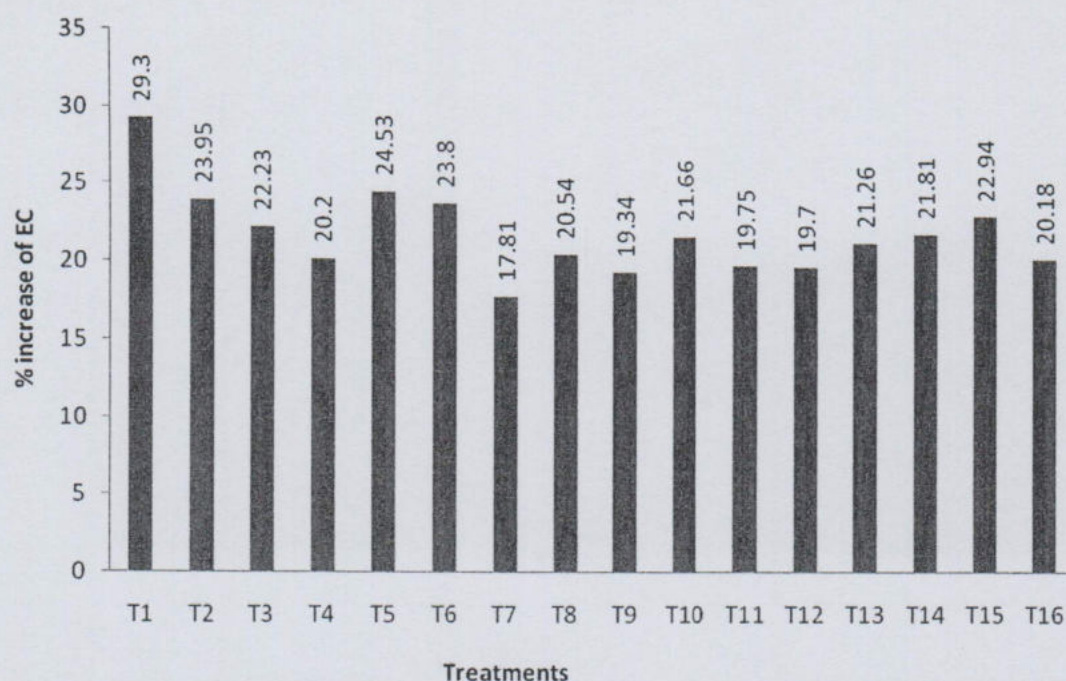


Fig.4.2.9: Increase of EC (%) of jute seeds after 12 months storage obtained from B fertilization

4.2.4.6: Changes in total soluble protein

Irrespective of the levels of applied B and its application methods total soluble protein of jute seeds decreased with the increase of storage period. Pattern of decrease of soluble protein however varied greatly with storage period and the applied B (Table 4.2.11).

Table 4.2.11: Total soluble protein (%) at storage of jute seeds obtained from B fertilization

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	18.0 f	17.8 f	17.4 g	16.7 h	15.0 i
T2	20.6 abc	19.3 de	19.0 d	18.4 de	17.5 ef
T3	19.5 de	19.3 de	19.0 d	18.3 de	17.3 f
T4	19.3 e	19.0 e	18.6 de	18.2 ef	17.2 f
T5	19.3 e	19.1 e	18.8 de	18.3 de	17.3 f
T6	19.4 e	19.1 e	18.9 de	18.4 de	17.2 f
T7	21.0 a	20.9 a	20.6 a	20.1 a	19.6 a
T8	20.9 a	20.6 ab	20.5 a	20.3 a	19.1 ab
T9	20.5 abc	20.0 bc	19.7 cd	19.3 cd	18.5 bc
T10	20.4 bc	19.8 cd	19.5 cd	19.1 d	18.3 c
T11	20.3 bc	20.0 bc	19.7 cd	19.1 d	18.5 bc
T12	19.6 de	19.4 d	19.1 d	18.6 de	18.0 cd
T13	19.7cde	19.2 de	19.0 d	18.4 de	17.9 de
T14	20.0 cd	19.5 d	19.1 d	18.5 de	18.2 cd
T15	20.0 cd	19.7 cd	19.2 d	18.4 de	17.8 de
T16	20.1c	19.9 cd	19.3 cd	18.5 de	18.0 cd

Means within column followed by common letters are not significantly different at 5% level of DMRT

After 12 months of storage the decrease of soluble protein was higher (16.67%) in seeds of control treatment (T₁) and minimal (6.67%) in seeds produced with 2 kg B ha⁻¹ in basal application (T₇) (Fig. 4.2.10).

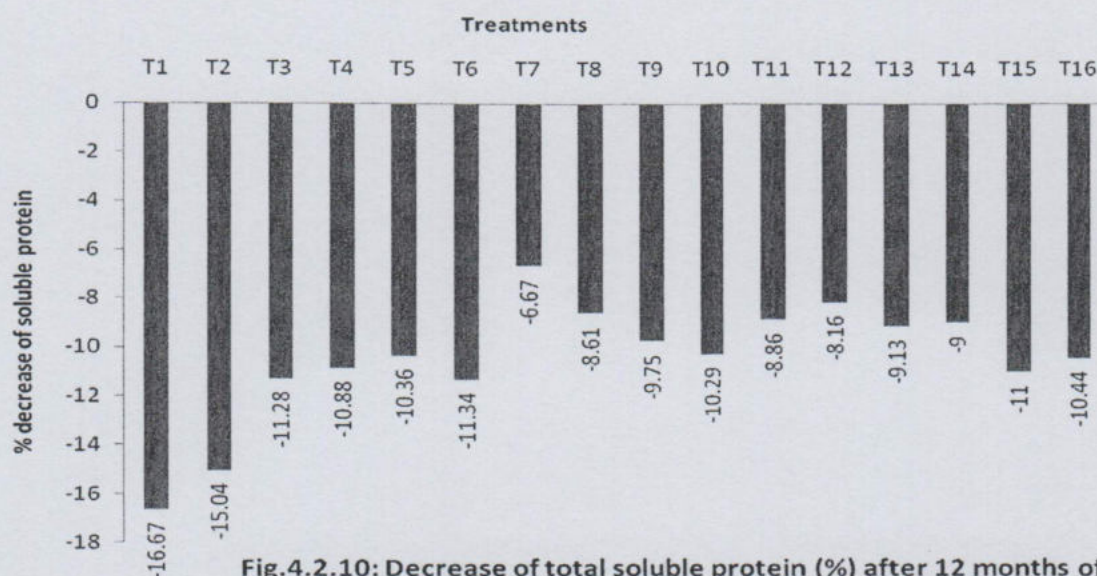


Fig.4.2.10: Decrease of total soluble protein (%) after 12 months of storage of jute seeds under different level and splitting of B

The decline on viability is associated with total soluble protein being exhibited through positive correlation between germination percentage and total soluble protein (Fig. 4.2.11).

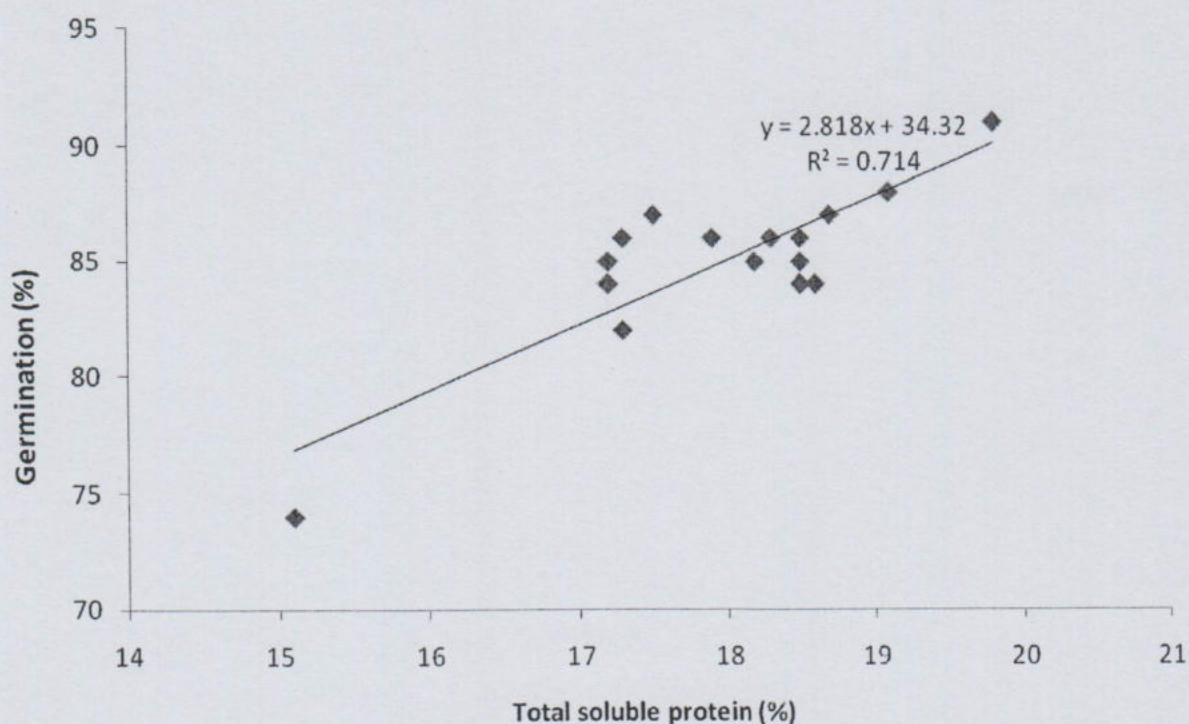


Fig.4.2.11: Relationship between total soluble protein and germination of jute seeds after 12 months of storage

Another observation was that seeds harvested from higher levels of B (2 kg ha⁻¹) maintained higher levels of soluble protein throughout the storage period and the protein degradation was minimal than that of other treatments (Table 4.2.11).

4.2.4.7: Changes in total soluble sugar

Irrespective of B fertilizers' dose and its methods of application total soluble sugar of jute seed steadily declined with the increase of storage period (Table 4.2.12).

Table 4.2.12: Total soluble sugar (%) at storage of jute seeds obtained from B fertilization

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	13.1 g	12.8 h	12.4 i	11.9 j	11.2 k
T2	14.5 ab	13.8 cde	13.3 de	12.8 fg	12.6 ef
T3	14.0 def	13.8 cde	13.2 e	12.6 fg	12.5 fg
T4	13.8 f	13.7 cde	13.4 de	13.1 cde	12.5 fg
T5	14.0 def	13.8 cde	13.3 de	13.0 cde	12.4 fg
T6	13.9 ef	13.7 cde	13.5 d	13.1 cde	12.7 ef
T7	14.7 a	14.6 a	14.4 a	14.0 a	13.7 a
T8	14.6 ab	14.4 ab	14.2 ab	13.9 ab	13.6 ab
T9	14.6 ab	14.3 ab	13.6 cd	13.1 cde	12.9
T10	14.4 abc	14.1 bc	13.8 cd	13.5 cde	13.1 bcd
T11	14.5 ab	14.2 bc	14.0 bc	13.8 abc	13.5 ab
T12	13.8 f	13.6 bc	13.4 de	13.0 cde	12.7 ef
T13	13.9 ef	13.7 cde	13.4 de	13.0 cde	12.6 ef
T14	14.1 cdef	14.0 cd	13.7 cd	13.2 cd	12.7 ef
T15	14.0 def	13.8 ccde	13.6 cd	13.3 cd	13.0 bcd
T16	13.8 f	13.5 cdef	13.3 de	13.0 cde	12.4 fg
Means within column followed by common letters are not significantly different at 5% level of DMRT					

Application of B in jute seeds production varied the declining trend in total soluble sugar and the minimal was (6.80%) where 2 kg B ha⁻¹ were applied as basal (T₇) and pronounced in control (T₁) treatment (14.50%) (Fig.4.2.12). Decline on viability is associated with total soluble sugar which was exhibited through positive correlation ($r^2 = 0.713$) between germination percentage and total soluble sugar (Fig. 4.2.13).

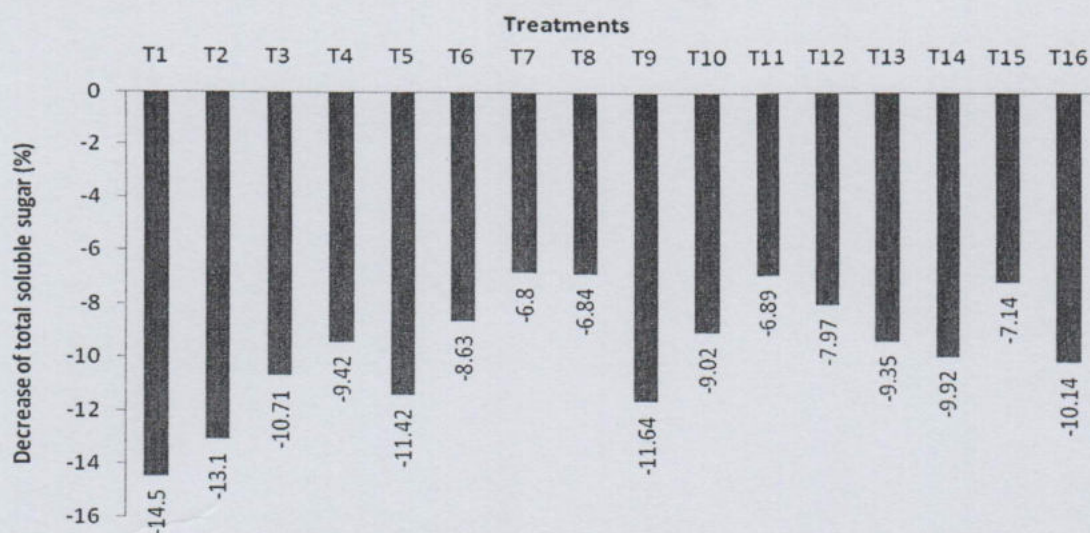


Fig.4.2.12: Decrease of total soluble sugar (%) of jute seeds after 12 months of storage obtained from B fertilization

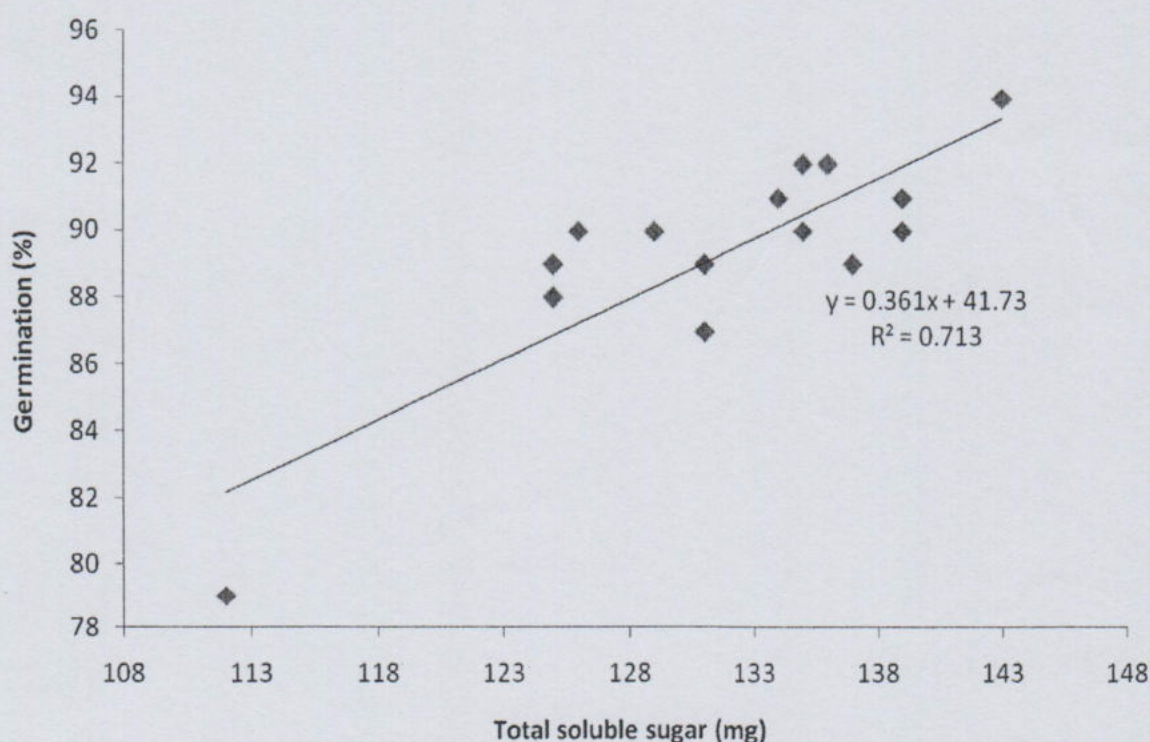


Fig.4.2.13: Relationship between total soluble sugar and germination (%) after 12 months of jute seed storage obtained from B fertilization

4.2.5: Boron content, uptake and balance

4.2.5.1: Boron content

The level of B increased the B content in jute (O-72) plant (Table 4.2.13) up to 2 kg ha⁻¹. The content of B was 28 ppm (T₁) – 35ppm (T₉), 18 ppm (T₁) - 30 ppm (T₁₁), 32 ppm (T₁) - 45 ppm (T₈) and 15 ppm (T₁) – 29 ppm (T₇) in root, shoot, leaves and seed respectively.

Table 4.2.13: Boron content (ppm) in different parts of jute seed plant as influenced by boron application

Treatments		Root	Shoot	Leaves	Seed
T1	(0 kg B ha ⁻¹ : all as basal at final land preparation)	28ab	18f	32cde	15d
T2	(1 kg B ha ⁻¹ : all as basal at final land preparation)	29ab	26abcd	38abcde	27ab
T3	(1 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	34ab	27abcd	42abcd	28ab
T4	(1 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	34ab	27abcd	39abcde	26abc
T5	(1 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	33ab	26abcd	42abcd	27ab
T6	(1 kg B ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as foliar spray)	33ab	28abc	41abcde	28ab
T7	(2 kg B ha ⁻¹ : all as basal at final land preparation)	32ab	24bcde	42abcd	29 a
T8	(2 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	33ab	23cdef	45 a	27ab
T9	(2 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	35a	22def	42abcd	28 ab
T10	(2 kg B ha ⁻¹ : One third as basal, One-third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	34ab	23cdef	41abcde	24abc
T11	(2 kg B ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as foliar spray)	33ab	30 a	43abc	23bc
T12	(3 kg B ha ⁻¹ : all as basal at final land preparation)	33ab	27abcd	44ab	29a
T13	(3 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	32ab	28abc	43abc	24abc
T14	(3 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	34ab	26abcd	42abcd	26abc
T15	(3 kg B ha ⁻¹ : One third as basal, One-third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	33ab	26abcd	44ab	27ab
T16	(3 kg B ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as foliar spray)	32ab	27abcd	42abcd	26abc

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level

At harvest leaves exhibited the highest B content among the plant parts followed by root, seed and shoot. The highest (45 ppm) and lowest (15 ppm) B content was recorded with 2 kg B ha⁻¹ in leaves and 0 kg B ha⁻¹ in seed, respectively. The B treatment and B content in different parts of jute plants in seed production were significantly correlated (Fig. 4.2.14).

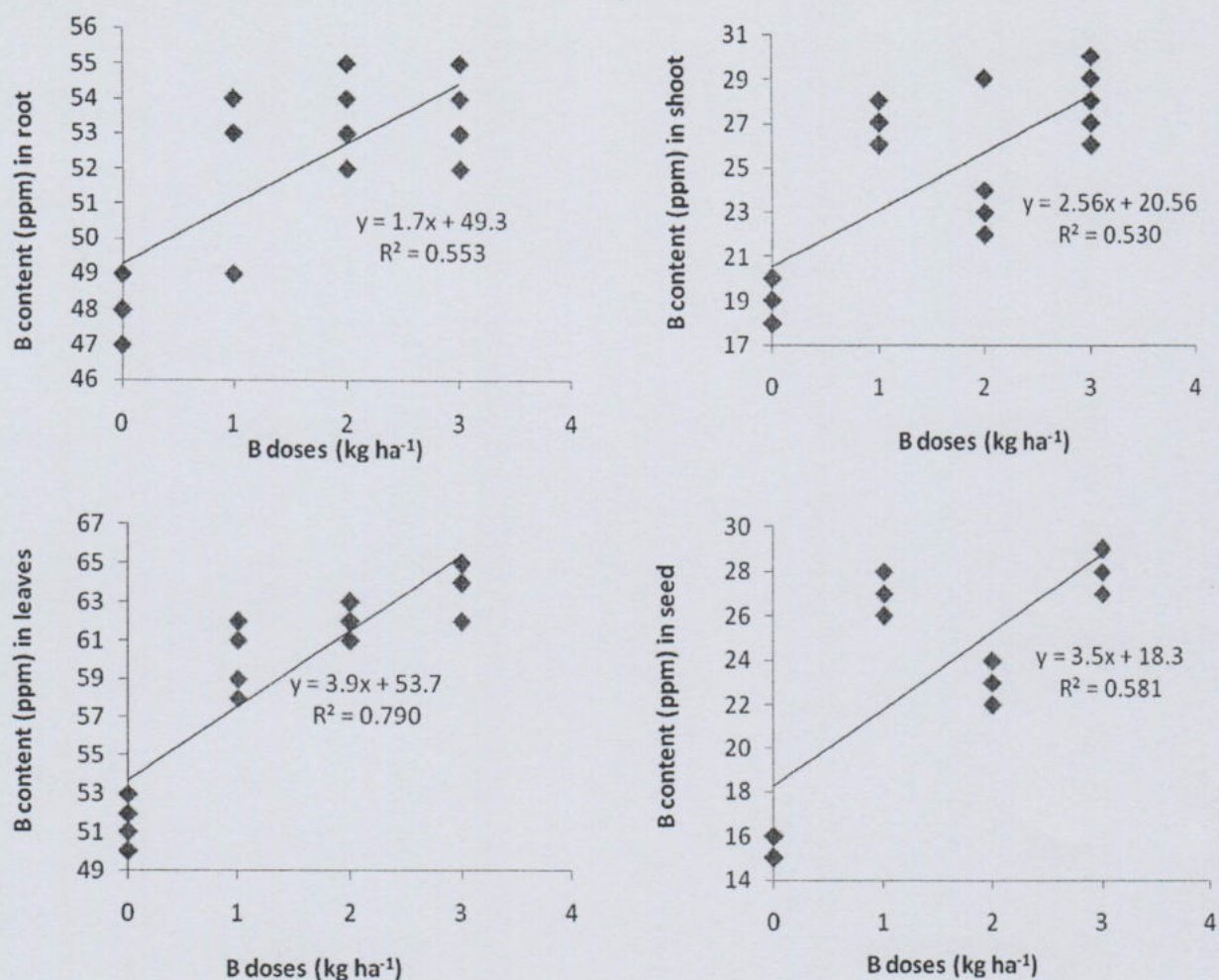


Fig. 4.2.14: Relationships between B doses and content of B in different plant parts of jute in seed production

4.2.5.2: Boron uptake

There was significant variation in uptake of B with B fertilization (Table 4.2.14). The uptake of B by different plant parts of jute for seed production ranged from 47.07 to 68.92 g ha⁻¹ in root, 174.50 to 340.68 g ha⁻¹ in shoot, 34.35 to 51.84 g ha⁻¹ in leaf and 18.83 to 38.63 g ha⁻¹ in seed. The highest total B uptake (497.71 g ha⁻¹) was recorded where 2 kg B ha⁻¹ was applied as basal (T₇) which was 81.14 % higher compared to that of control i.e. 0 kg B ha⁻¹. Boron uptake was increased with increasing rates of B application and the shoot removed the highest amount of B than that of roots, leaves and seeds.

4.2.5.3: Apparent B Balance

Data on B balance, as affected by different treatments of B, has been exhibited by Fig. 4.2.15. It has been found that B uptake by jute plants in seed production depended upon doses and split application of B. The negative balance was observed under no

application of B application and with increasing the B doses the negative status was reduced gradually (Fig. 4.2.15). The highest negative balance of B ($-0.275 \text{ kg ha}^{-1}$) was recorded with 0 kg B ha^{-1} (T_1) the highest positive balance (2.600 kg ha^{-1}) was observed with 3 kg B ha^{-1} applied as half at basal and rest half at 35 DAS as top dressing (T_{13}) and a difference between the calculated and the measured final amounts of B was observed which indicated unaccounted gain.

Table 4.2.14: Effect of B on B uptake (g ha^{-1}) of jute plants in seed production

Treatments		B uptake (g ha^{-1}) by different parts of jute plant in seed production				
		Root	Shoot (including pod)	Leaves	Seed	Total
T1	(0 kg B ha^{-1} : all as basal at final land preparation)	47.07de	174.50g	34.36b	18.83e	274.76h -
T2	(1 kg B ha^{-1} : all as basal at final land preparation)	64.07ab	311.08bc	51.84a	35.71ab	462.7ab (68.40)
T3	(1 kg B ha^{-1} : half as basal and rest half at 30-35 DAS as top dressing)	61.49abc	285.20cd	42.89ab	35.42ab	425bcde (54.68)
T4	(1 kg B ha^{-1} : Half as basal and half at 30-35 DAS as foliar spray)	61.37abc	269.23de	47.22ab	33.90bc	411.72cdefg (49.85)
T5	(1 kg B ha^{-1} : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	51.27cde	287.98cd	46.24ab	33.26bc	418.75bcdef (52.41)
T6	(1 kg B ha^{-1} : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	47.80de	274.90de	45.41ab	32.16bcd	400.27efg (45.67)
T7	(2 kg B ha^{-1} : all as basal at final land preparation)	68.92a	339.41ab	50.75a	38.63 a	497.71a (81.14)
T8	(2 kg B ha^{-1} : half as basal and rest half at 30-35 DAS as top dressing)	64.16ab	340.68a	46.82ab	36.13ab	487.79a (77.53)
T9	(2 kg B ha^{-1} : Half as basal and half at 30-35 DAS as foliar spray)	54.44bcde	325.62ab	39.84ab	28.84d	448.74abcd (63.32)
T10	(2 kg B ha^{-1} : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	50.97cde	292.12cd	42.60ab	30.90cd	416.59bcdef (51.62)
T11	(2 kg B ha^{-1} : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	55.59bcd	326.69ab	41.75ab	30.12cd	454.15abc (65.29)
T12	(3 kg B ha^{-1} : all as basal at final land preparation)	47.90de	288.57f	44.99ab	35.74ab	417.2g (51.84)
T13	(3 kg B ha^{-1} : half as basal and rest half at 30-35 DAS as top dressing)	48.14de	280.64d	38.27ab	33.41bc	400.39defg (45.57)
T14	(3 kg B ha^{-1} : Half as basal and half at 30-35 DAS as foliar spray)	54.18bcde	276.16def	39.43ab	32.42bcd	402.19efg (46.40)
T15	(3 kg B ha^{-1} : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	51.88cde	286.94ef	42.62ab	33.15bcd	414.59fg (50.89)
T16	(3 kg B ha^{-1} : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	52.17cde	293.51cd	46.27ab	34.23 bc	426.18bcde (55.11)

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level;

*The parenthesis indicates percent increase over control.

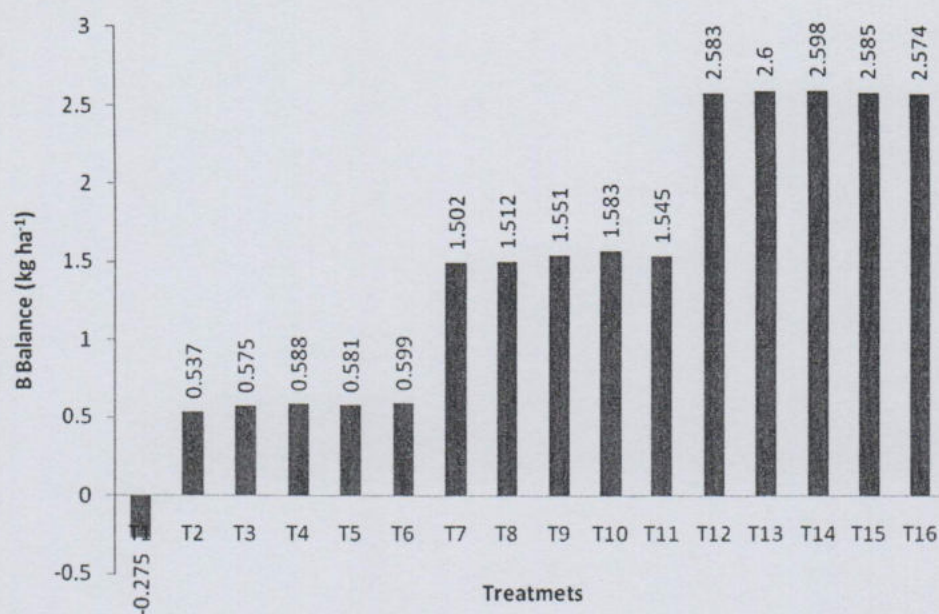


Fig.4.2.15: Effect of B fertilization on apparent balance of B (kg ha⁻¹) in jute seed production

4.2.6: Benefit cost ratio (BCR)

The treatments of B have led to variation of BCR (Fig. 4.2.16). With increasing B doses up to certain level BCR increased and then it decreased. The highest BCR (1.34) was achieved with 2 kg B ha⁻¹ with basal application (T₇), which was statistically at par with T₂ (BCR, 1.31) and T₈ (BCR, 1.28). The lowest BCR (0.87) was recorded with T₁ i.e. 0 kg B ha⁻¹.

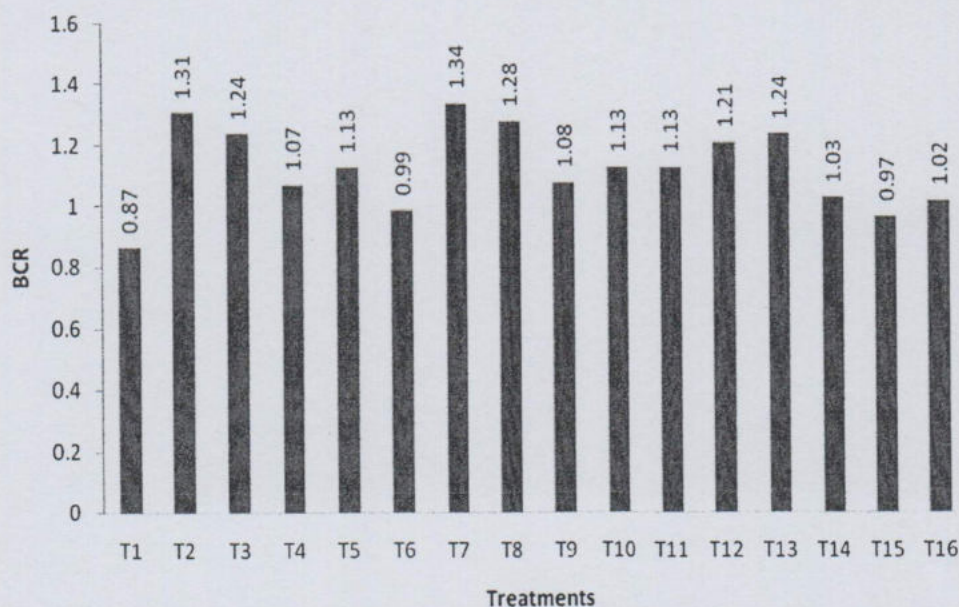


Fig.4.2.16: Effect of B fertilizer management on BCR in jute seed production

4.2.7: Boron use efficiency (BUE)

At lower level of boron BUE was found higher compared to higher B levels (Table 4.2.8). BUE decreased with increase in B uptake through increased B application. Application of B @ 1 kg ha⁻¹ applied half as basal and half as top dressing at 35 days after sowing (DAS) recorded the highest applied boron use efficiency (2188.24 kg seed/kg B uptake). At the higher level of B (2 kg ha⁻¹) as half as basal and half as foliar spray at 35 DAS, BUE was found to be the lowest (1944.32 kg seed/kg B uptake).

Table 4.2.15: Boron use efficiency in jute seed production

Treatments		Boron use efficiency (kg dry jute seed / kg B uptake)
T1	(0 kg B ha ⁻¹ : all as basal at final land preparation)	2741.82a
T2	(1 kg B ha ⁻¹ : all as basal at final land preparation)	2084.23ig
T3	(1 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	2188.24e
T4	(1 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	2089.81f
T5	(1 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	2150.36ef
T6	(1 kg B ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as foliar spray)	2112.50ef
T7	(2 kg B ha ⁻¹ : all as basal at final land preparation)	1997.97h
T8	(2 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	1975.26h
T9	(2 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	1944.32h
T10	(2 kg B ha ⁻¹ : One third as basal, One-third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	2182.25e
T11	(2 kg B ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as foliar spray)	2008.81h
T12	(3 kg B ha ⁻¹ : all as basal at final land preparation)	2051.18 fg
T13	(3 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	2130.56 ef
T14	(3 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	2130.83 ef
T15	(3 kg B ha ⁻¹ : One third as basal, One-third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	2047.81 fg
T16	(3 kg B ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as foliar spray)	2039.04 fg

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 levels.

4.3 Experiment 3: Combined effect of potassium and boron on yield, quality and shelf life of jute (*C. olitorius*) seed

4.3.1. Main effect of K on growth, yield and quality of jute seed

The main effect of K showed that the seed yield of jute was increased significantly and linearly up to 60 kg ha⁻¹ (Table 4.3.1). Potassium contributed the highest yield with 60 kg ha⁻¹ which was statistically identical to 90 kg ha⁻¹. Other growth and yield contributing characters like plant population, plant height, branch per plant, pods per plant, pod length, seed no, 1000 seed weight and total drymatter production were significantly increased over control by potassium application (Table 4.3.1). The seed quality like germination, vigour, seedling dry matter, total soluble protein and total soluble sugar were significantly increased with K application except germination which was statistically at par with all other treatments (Table 4.3.2). The electrical conductivity was significantly reduced with K application and was found minimum with 60 kg K ha⁻¹ application. Regression analysis showed a positive but quadratic relationship between K and yield (Fig. 4.3.1). From the quadratic response function the optimum dose of K was calculated to be 92 kg.

Table 4.3.1: Main effect of K on growth and yield of jute in seed production

K levels (kg ha ⁻¹)	PP* (Lacs ha ⁻¹)	PH (m)	BR (no.)	TDM (t ha ⁻¹)	Pod (no.)	PL (cm)	Seed No.	1000 seed wt. (g)	Seed yield (kg ha ⁻¹)
0	3.52 b	0.96b	3.51b	4.97c	15.92b	5.98b	192b	1.863c	710.51c
30	3.88 a	1.21 a	3.84a	6.13b	16.80b	6.17ab	204a	1.974b	805.71b
60	3.99 a	1.32 a	4.18a	6.69a	19.74a	6.41a	207a	2.173a	923.74a
90	4.00 a	1.28a	4.19a	6.47ab	18.98a	6.22a	207a	2.228a	918.46a

PP=Plant population, PH= Plant height, BR=Branch, TDM= Total dry matter, PL= Pod length

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level

Table 4.3.2: Main effect of K on jute seed quality

K levels (kg ha ⁻¹)	Germination (%)	Electric Conductivity (μScm^{-1})	Vigour (%)	Seedling dry weight (mg)	Total soluble protein (%)	Total soluble sugar (%)
0	95a	402a	94.62c	0.799d	18.72c	13.22c
30	97a	393a	96.00b	0.901c	19.05b	13.72b
60	98a	350b	97.12a	0.957a	20.38a	14.10a
90	98a	357b	96.83a	0.939b	20.37a	14.25a

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level

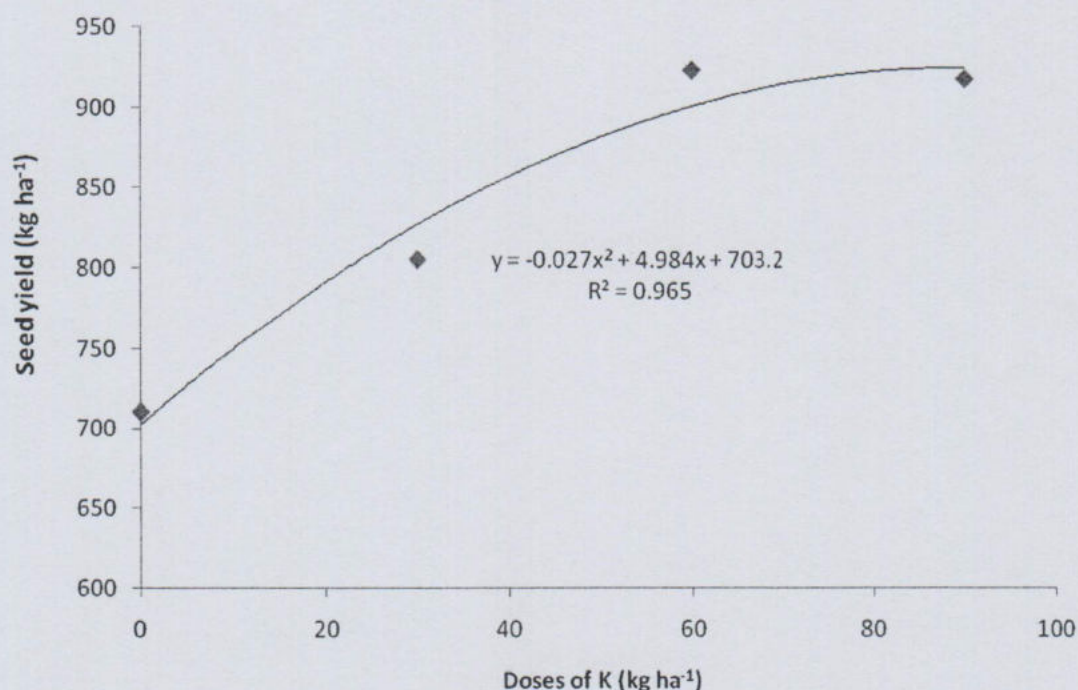


Fig.4.3.1: Response of K to jute seed production

4.3.2. Main effect of B on growth, yield and quality of jute seed

The main effect of B showed the highest and significant increase of jute seed yield with 2 kg ha⁻¹ (Table 4.3.3). All other growth and yield contributing characters like plant population, plant height, branch per plant, pods per plant, pod length, seed no, 1000 seed weight and total drymatter production were significantly increased over control by B fertilization and was statistically identical to 1 kg ha⁻¹ including seed yield (Table 4.3.3). The seed quality like germination, vigour, seedling dry matter, total soluble protein and total soluble sugar were significantly increased with B application which was statistically at par with all other treatments (Table 4.3.2). The electrical conductivity was significantly reduced with B application and showed the minimum with 2 kg B ha⁻¹ application.

Regression analysis showed a positive but quadratic relationship between B and yield (Fig. 4.3.2). From the quadratic response function the optimum dose of B was calculated to be 1.80 kg.

Table 4.3.3: Main effect of B on growth and yield and quality of jute in seed production

B levels (kg ha ⁻¹)	PP* (Lacs ha ⁻¹)	PH (m)	BR (no.)	TDM (t ha ⁻¹)	Pod (no.)	PL (cm)	Seed No.	1000 seed wt. (g)	Seed yield (kg ha ⁻¹)
0	3.66b	1.11a	3.74b	5.17c	14.57c	5.81b	193b	1.949b	748.59c
1	4.02a	1.21a	4.10ab	6.74a	19.35a	6.51a	204a	2.106a	926.08ab
2	3.98a	1.25a	4.18a	6.48a	20.08a	6.54a	208a	2.139a	956.51a
3	3.78ab	1.20a	3.70b	5.91b	17.43b	6.13b	205a	2.033ab	873.35b

PP=Plant population, PH= Plantheight, BR=Branch per plant, TDM= Total dry mateer, PL= Pod length

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level

Table 4.3.4: Main effect of B on jute seed quality

B levels (kg ha ⁻¹)	Germination (%)	Electric Conductivity (μScm^{-1})	Vigour (%)	Seedling dry weight (mg)	Total soluble protein (%)	Total soluble sugar (%)
0	95b	397a	93.75c	0.824c	18.51c	13.17c
1	98a	365b	97.33a	0.931a	19.79b	14.03b
2	98a	364b	97.62a	0.924a	20.12a	14.22a
3	97a	377ab	95.87b	0.908b	20.10a	13.87b

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level

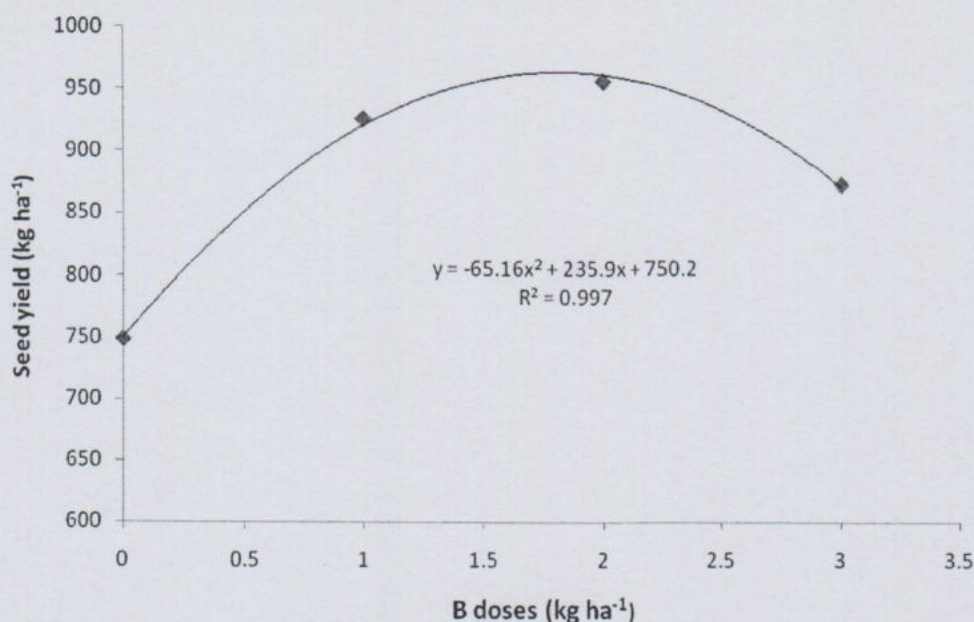


Fig.4.3.2: Response of B to jute seed production

4.3.3: Interaction effect of K and B on growth and dry matter production

4.3.3.1: Plant population

In the present studies it was observed both of the elements individually or in combination played a positive role on plant population. With increasing doses of the elements increased plant population up to certain levels and then decreased. Highest plant population (4.22 lacs ha⁻¹) was marked by 60 kg K ha⁻¹ and 1 kg B ha⁻¹ treatments and the lowest (3.40 lacs ha⁻¹) was observed with control treatment i.e. without external application of K and B, plant population decreases alarmingly (Table 4.3.5).

Table 4.3.5: Interaction effect of K and B on plant population (Lacs ha⁻¹) of tossa jute in seed production

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	3.40aB	3.65aA	3.70aA	3.42aB
30	3.56aB	4.13aA	3.83aA	3.99aA
60	3.85aA	4.22aA	4.15aA	3.74aA
90	3.83aA	4.06aA	4.15aA	3.95aA

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.3.2: Plant height

Plant height increased progressively and significantly over control reaching a maximum of peak 1.42 m with the treatment where 60 kg K and 2 kg B ha⁻¹ were applied and it was statistically identical with all other treatments except control (Table 4.3.6). The lowest plant height (0.89 m) was recorded in control treatment. Plant heights were positively correlated with treatment combination, but not significantly.

Table 4.3.6: Interaction effect of K and B on the plant height (cm) of jute in seed production

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	0.89aB	0.99aA	0.97aA	0.99aA
30	1.07aA	1.23aA	1.29aA	1.24aA
60	1.26aA	1.32aA	1.42aA	1.29aA
90	1.22aA	1.31aA	1.32aA	1.26aA

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.3.3: Branch plant⁻¹

The interaction effect of K and B application on number of branches plant⁻¹ was significant and positive (Table 4.3.7). The maximum number of branches (4.49) was recorded under application of 60 kg K along with 2 kg B ha⁻¹ and it was statistically in consonance with all other treatments except control and 0 kg K + 3 kg B ha⁻¹. The lowest value (3.34 branches plant⁻¹) was recorded from the plots where no K and B (K0B0) were applied.

Table 4.3.7: Interaction effect of K and B on branch plant⁻¹ of tossa jute in seed production

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	3.34bC	3.64aB	3.73aB	3.33bC
30	3.63aB	3.86aB	4.12aA	3.74aB
60	4.00aB	4.44aA	4.49aA	3.78aB
90	3.99aB	4.45aA	4.38aA	3.95aB

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.3.4: Dry matter production

With increasing level of K and B fertilizers the dry matter weight increased. The combined effect of K and B application on dry matter weight plant⁻¹ was significant (Table 4.3.8). The highest dry matter weight (7.554 t ha⁻¹) was found with application of 60 kg K + 2 kg B and it was statistically at par with 60 kg K + 1 kg B ha⁻¹ and 90 kg K + 1 kg B⁻¹. The lowest dry matter weight (4.133 t ha⁻¹) was registered with control treatment i.e. with 0 kg K + 0 kg B application.

Table 4.3.8: Interaction effect of K and B on dry matter yield (t ha⁻¹) of tossa jute in seed production

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	4.133bG	5.316eE	5.356dE	5.068cE
30	5.280aE	6.814bB	6.273cC	6.326aC
60	5.589aD	7.374aA	7.554aA	6.245aC
90	5.664aD	7.441aA	6.751bB	6.026aC

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.4: Yield and yield attributes

4.3.4.1: Pods plant⁻¹

Significant variation was observed in respect of number of pods per plant due to K and B addition to soil (Table 4.3.9). The results showed that increasing level of K and B up to certain levels increased the number of pods per plant. The highest pods plant⁻¹ (22.48) were observed with 60 kg K + 2 kg B application which was statistically identical to 60 kg K + 1 kg B, 60 kg K + 3 kg B, 90 kg K + 1 kg B and 90 kg K + 2 kg B treatment. The lowest pods plant⁻¹ (13.13) was counted with no potassium and no boron application (i.e. in control treatment).

Table 4.3.9: Interaction effect of K and B on the number of pods per plant of tossa jute in seed production

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	13.13aC	16.42bB	18.35aAB	15.79aB
30	14.21aB	17.48bB	18.55aAB	16.94aB
60	15.52aB	21.68aA	22.48aA	19.27aA
90	15.43aB	21.82aA	20.95aA	17.72aB

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.4.2: Pod length

Combined application of potassium and boron influenced significantly on pod length of tossa jute in seed production. The highest length of pod (6.65cm) was recorded with 60 kg K + 2 kg B ha⁻¹ application, which was statistically identical to all other of K and B combination treatments except control (Table 4.3.10). The shortest pod length (5.26 cm) was recorded with control treatment i.e. 0 kg K + 0 kg B ha⁻¹ which were similar to 30 kg K ha⁻¹ + 0 kg B ha⁻¹.

Table 4.3.10: Interaction effect of K and B on pod length (cm) of tossa jute in seed production

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	5.26bB	6.42aA	6.45aA	5.79aA
30	5.41bA	6.48aA	6.55aA	6.24aA
60	6.12aA	6.61aA	6.65aA	6.27aA
90	6.43aA	6.52aA	6.49aA	6.22aA

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.4.3: Seeds pod⁻¹

With increasing level of K and B fertilization up to certain level increased number of seeds pod⁻¹ (Table 4.3.11). The highest number of seeds pod⁻¹ (212.16) was marked with

60 kg K + 2 kg B treatment which was at par with all other treatments except control and 1 kg B ha⁻¹. The lowest seeds per pod (161.88) were recorded in control treatment where no K and B were applied. Numbers of seeds pod⁻¹ and pod length and number of seeds and seed weight were positively correlated ($r = 0.349$ and 0.809 , Table 4.3.10), respectively.

Table 4.3.11: Interaction effect of K and B on the number of seeds pod⁻¹ of tossa jute in seed production

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	161.88bB	194.96bB	203.77aB	206.25aB
30	203.49aB	203.04aB	203.79aB	207.24aB
60	203.74aB	208.37aA	212.16aA	202.81aB
90	203.18aB	211.33aA	210.53aA	202.77aB

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.4.4: 1000 seed weight

Increased 1000 seed weight was observed with increased K and B application. The maximum 1000 seed weight (2.351 mg) was noted with 60 kg K + 2 kg B treatment (Table 4.3.12). The lowest seed weight (1.807 mg) of jute seed was documented from control plot.

Table 4.3.12: Interaction effect of K and B on 100 seed weight (mg) of tossa jute in seed production

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	1.807bC	1.858bC	1.892bB	1.856bC
30	1.903bB	1.926bB	1.973bB	2.092aB
60	2.012aB	2.322aA	2.351aA	2.008aB
90	2.074aB	2.319aA	2.341aA	2.176aA

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.4.5: Seed yield

The results of the study reflected that increasing potassium and boron levels up to 60 kg K and 2 kg B ha⁻¹ increased seed yield significantly and then decreased (Table 4.3.13).

Table 4.3.13: Interaction effect of K and B on the seed yield (kg ha⁻¹) of tossa jute

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	590.24gG (-)	713.54eE (20.89)	794.36dD (34.61)	743.88dE (26.03)
30	638.23eF (8.13)	927.78bB (57.19)	936.50aB (58.66)	916.33aB (58.72)
60	919.56aB (55.79)	976.23aA (65.40)	997.66aA (69.03)	921.50aB (56.12)
90	926.34aB (56.94)	966.78aA (63.79)	977.50aA (65.41)	911.23aB (54.38)

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels; * Parenthesis indicates % increase over control

The highest seed yield (997.66 kg ha⁻¹, 69.03 % higher over control) was recorded with combined application of 60 kg K + 2 kg B ha⁻¹ which was statistically identical with 60 kg K + 1 kg B, 90 kg K + 1 kg B and 90 kg K + 2 kg B and the lowest (590.24 kg ha⁻¹) was remarked with control treatment.

Table 4.3.14: Bivariate correlation analysis result of different yield contributing characters and yield of tossa jute seed influenced by K and B fertilization

Variables	PP	PH	Br	TDM	Pod	Seed No.
PH	0.777(**)					
Branch	0.822(**)	0.880(**)				
TDM	0.930(**)	0.832(**)	0.805(**)			
Pod	0.719(**)	0.749(**)	0.823(**)	0.763(**)		
Seed No.	0.562(*)	0.715(**)	0.673(**)	0.580(*)	0.783(**)	
Seed yield	0.785(**)	0.926(**)	0.842(**)	0.786(**)	0.813(**)	0.809(**)

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Bivariate correlation analysis also revealed the similar phenomenon which showed that seed yield is directly correlated with plant population, plant height, branch number, pods per plant and seeds per pod (Table 4.3.14).

4.3.5: Seed quality attributes

4.3.5.1: Seed viability

The viability of a seed sample is usually measured to assess the suitability of a seed lot for its field planting value. Here, standard germination test (viability test) and electric conductivity test were performed to evaluate the seed quality.

4.3.5.1.1: Germination percentage

The germination of jute seed was influenced significantly by combined application K and B over control. The highest germination percentage (99%) was achieved with combined application of 60 kg K and 1 or 2 kg B ha⁻¹ (Table 4.3.15). The lowest germination (92%) was recorded with control treatment i.e. in K0B0 treatment.

Table 4.3.15: Interaction effect of K and B on the seed viability (% germination) of tossa jute

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	91.00bB	97.25aA	96.5 0aB	96.25aB
30	96.00aB	97.25aA	97.50aA	97.25aA
60	96.50aB	99.00aA	99.00aA	96.75aA
90	96.25aB	98.25aA	97.50aA	98.00aA

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.5.1.2: Seed leachate conductivity

Electrical conductivity differed among the different treatments widely. The highest electrical conductivity (455 $\mu\text{S cm}^{-1}$) was recorded from control treatment (Table 4.3.16) i.e. where no K and B was applied externally.

Table 4.3.16: Interaction effect of K and B on seed leachate conductivity (μScm^{-1}) of tossa jute

Potassium levels (kg ha^{-1})	Boron levels (kg ha^{-1})			
	0	1	2	3
0	455cD	381aB	384bB	389aB
30	391bB	387bB	394bB	399bC
60	380aB	349aA	317aA	353aAB
90	362aB	342aA	359bB	366aB

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

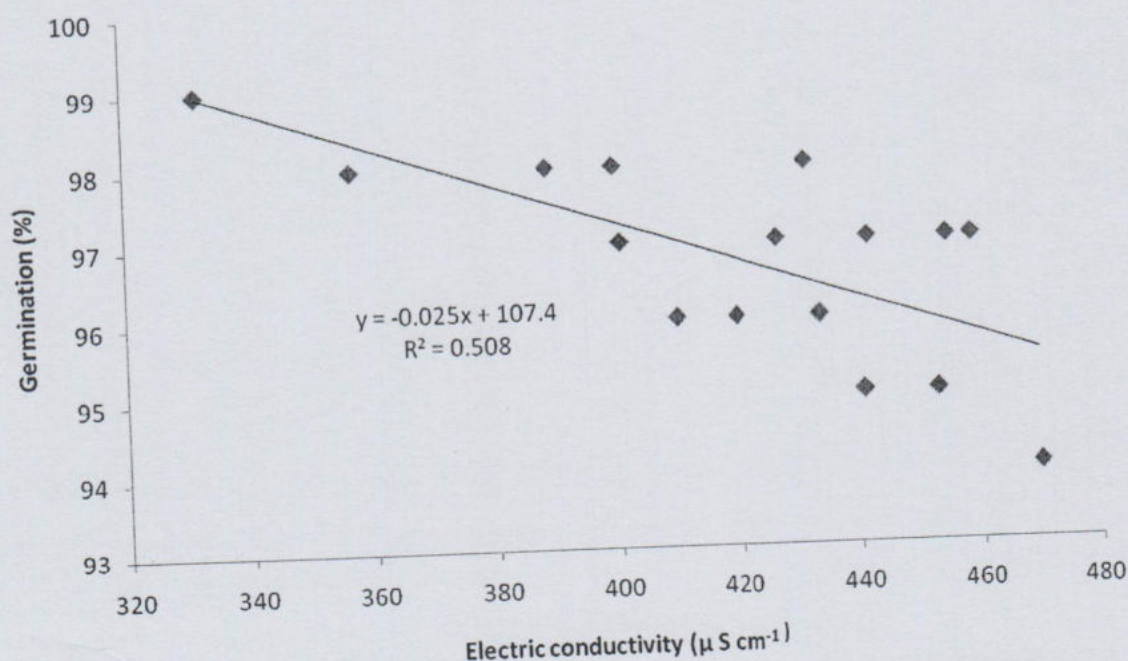


Fig.4.3.3: Relationship between electric conductivity and germination (%) of jute seeds obtained from K and B fertilizers management

The minimum electrical conductivity ($317 \mu \text{S cm}^{-1}$) was observed in the treatment where $60 \text{ kg K} + 2 \text{ kg B ha}^{-1}$ were applied which was identical with treatment $60 \text{ kg K} + 1 \text{ kg B ha}^{-1}$ and $90 \text{ kg K} + 1 \text{ kg B ha}^{-1}$. The significantly inverse relationship was found between electrical conductivity and seed viability (germination) in this study (Fig.4.3.3).

4.3.5.2: Seed vigour

The improvement in seed vigour with any level of K and B fertilization was observed over control (without K and B application) and the highest seed vigour (98.83) was registered with 60 kg K + 2 Kg B ha⁻¹ which was statistically identical with 60 kg K + 1 Kg B ha⁻¹, 90 kg K + 1 Kg B ha⁻¹ and 90 kg K + 2 Kg B ha⁻¹ (Table 4.3.17). The lowest seed vigour (90.83) was recorded with 0 kg K + 0 Kg B ha⁻¹ i.e. in control treatment.

Table 4.3.17: Interaction effect of K and B on vigour of tossa jute seed

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	90.83cC	95.50bB	96.83bA	95.33aB
30	94.33aC	96.83aA	96.50bB	96.33aB
60	95.83aB	98.50aA	98.83aA	95.33aB
90	94.00aB	98.50aA	98.33aA	96.50bB

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.5.3: Seedling dry weight

Significant influence on seedling dry weight was observed by the application of K and B. Results indicated that the effects was induced by increasing K and B rates (Table 4.3.18). The highest seedling dry weight (1.023 mg plant⁻¹) was found from the seeds obtained from the treatments 60 kg K ha⁻¹ + 1 kg B ha⁻¹ which was statistically identical to seedling dry weights resulted from 60 kg K ha⁻¹ + 2 kg B ha⁻¹, 90 kg K ha⁻¹ + 1 kg B ha⁻¹ and 90 kg K ha⁻¹ + 2 kg B ha⁻¹. Conversely, the seed produced from lower level of K and B i.e. K0B0 showed the lower (0.762 mg plant⁻¹) seedling dry weight.

Table 4.3.18: Interaction effect of K and B on seedling dry weight (mg plant⁻¹) of jute

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	0.762bE	0.798dD	0.808dD	0.826cD
30	0.838aD	0.912bB	0.937aB	0.917aB
60	0.862aC	1.023aA	0.984aA	0.956aB
90	0.834aD	0.992aA	0.966aA	0.932aB

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels.

4.3.5.4: Total soluble protein

Total soluble protein of freshly harvested jute seeds was significantly influenced by combined application of K and B (Table 4.3.19). Total soluble protein ranged from 17.60% to 21.05 %. The highest total soluble protein (21.05 %, 19.58% higher compared to control), was estimated from the seeds harvested from 60 Kg K + 1 kg B ha⁻¹ treatment followed by the treatments 60 Kg K + 2 kg B ha⁻¹, 60 Kg K + 3 kg B ha⁻¹, 90 Kg K + 1 kg B ha⁻¹, 90 Kg K + 2 kg B ha⁻¹ and 90 Kg K + 3 kg B ha⁻¹. The lowest total soluble protein (17.60 %) was found from the seeds of control treatment i.e. with no K and B application.

Table 4.3.19: Interaction effect of K and B on soluble protein content (%) of tossa jute seed

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	17.6dg (-)	17.88cf (1.59)	19.94bD (13.29)	19.46cD (10.57)
30	17.97cf (2.10)	19.28eD (9.55)	19.11eD (8.58)	19.83bC (12.67)
60	19.09aD (8.47)	21.05aA (19.60)	20.86aA (18.52)	20.50aA (16.47)
90	19.37aD (10.05)	20.95aA (19.03)	20.55aA (16.76)	20.60 aA (17.99)

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels ; *Parenthesis indicates percent increase over control.

In present study, growth processes is increased, there also exists positive and significant correlation between the total soluble protein content and germination percentage of jute seed (Fig. 4.3.4).

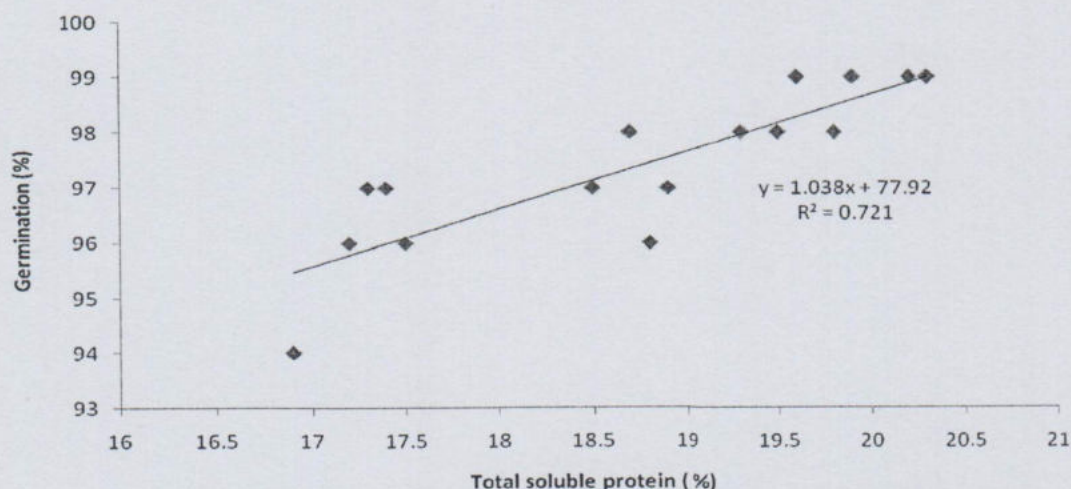


Fig.4.3.4: Relationship between total soluble protein and germination of jute seeds obtained from K and B fertilizers management

4.3.5.5: Total soluble sugar

Total soluble sugar of tossa jute seeds was significantly influenced by the application of K and B. Total soluble sugar increased with the increased levels of K and B and it increased from 12.72 to 14.71 % (Table 4.3.20). This agrees well to Begum (1977) who found 12-13% soluble sugar from Olitorius jute seed. The highest total soluble sugar (14.71%, 15.64% higher compared to control), was observed from the seeds of the treatments with 60 kg K + 2 kg B ha⁻¹ which was statistically at par with 60 kg k + 1 kg B ha⁻¹, 90 kg K + 1 kg B ha⁻¹, 90 kg K + 2 kg B ha⁻¹ and 90 kg K + 3 kg B ha⁻¹.

Table 4.3.20: Interaction effect of K and B application on soluble sugar content (%) of tossa jute seed

Potassium levels (kg ha ⁻¹)	Boron levels (kg ha ⁻¹)			
	0	1	2	3
0	12.72cE (-)	13.09dD (2.90)	13.71bB (7.78)	13.37bC (5.11)
30	13.08bC (2.83)	14.04bB (10.37)	13.96bB (9.75)	13.79aB (8.41)
60	13.36aC (5.03)	14.44aA (13.52)	14.71aA (15.64)	13.87aB (9.04)
90	13.52aC (6.29)	14.54aA (14.31)	14.51aA (14.07)	14.44aA (13.52)

Means in a column followed by same small letter and in a row by same capital letter did not differ significantly by DMRT at 0.05 levels; * Parenthesis indicates percent increase over control

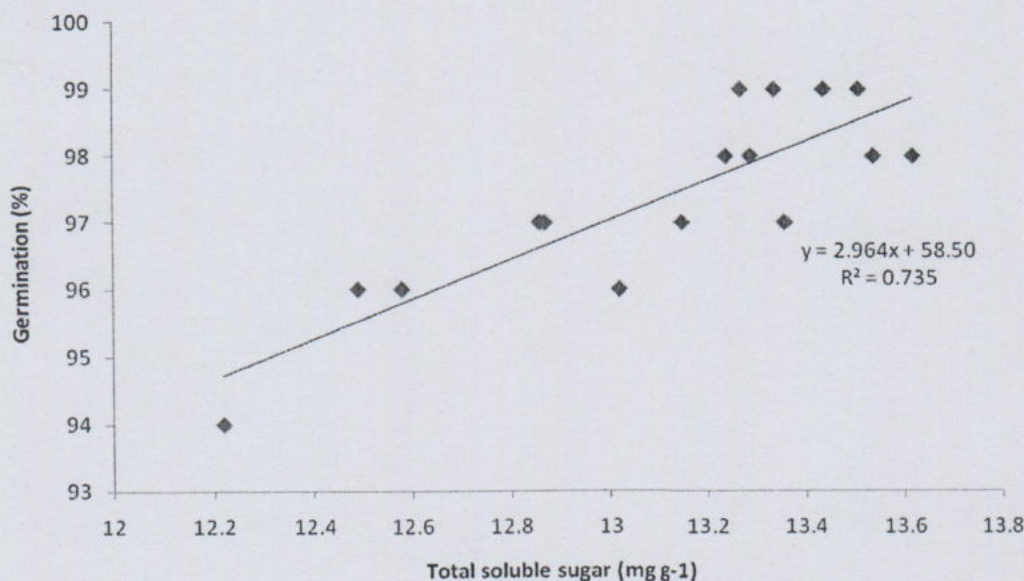


Fig.4.3.5: Relationship between total soluble sugar and germination of jute seeds obtained from K and B fertilizers management

Presence of soluble sugar in seed has great implication on seed quality as there is significant positive correlation between the total soluble sugar content and germination percentage of jute seed (Fig. 4.3.5).

Correlations among seed quality attributes:

Bivariate correlation analyses (Table 4.3.21) were done for determining the relationship among different seed quality attributes. Seed size was positively and significantly correlated with viability percentage ($r = 0.504$), seedling dry weight ($r = 0.703$) and seed vigour ($r = 0.514$).

Table 4.3.21: Bivariate correlation analysis result of different quality attributes of tossa jute seed as influenced by the interaction of K and B fertilization

Parameters	Germination	Vigour	EC	Seed size	SDM	Soluble protein
Vigour	0.945(**)					
Electric conductivity	-0.616(*)	-0.609(*)				
Seed size	0.504(*)	0.514(*)	-0.754(**)			
SDM	0.617(*)	0.729(**)	-0.674(**)	0.703(**)		
Soluble protein	0.446	0.522(*)	-0.590(*)	0.749(**)	0.892(**)	
Soluble sugar	0.566(*)	0.638(**)	-0.739(**)	0.667(**)	0.896(**)	0.899(**)

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed). EC=Electric conductivity, SDM= Seedling dry matter;

The negative relationship (Table 4.3.21) between leachate conductivity with viability percent ($r = -0.616$), Seedling dry weight ($r = -0.674$), seed vigour ($r = -0.609$) and seed size ($r = -0.754$) indicated that more leachates were escaped from poor quality seeds obtained from lower levels of K and B fertilizers and lowered the viability and the seed vigour.

4.3.6: Seed shelf life

4.3.6.1: Changes in seed moisture

At the time of storing, initial moisture content varied from 8.87 to 8.92 % in different treatments (Table 3.4.22). A slight increase in seed moisture content was observed within early three to six months of storage which might be due to absorption of moisture from adjacent free space of plastic pot where there is every possibility to prevail higher vapour pressure gradient than the seed.

Table 4.3.22: Moisture (%) at storage of jute seeds obtained from combined application of K and B

Treat.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	8.90	8.92	8.92	8.91	8.90
T2	8.89	8.89	8.90	8.90	8.89
T3	8.87	8.88	8.89	8.89	8.89
T4	8.90	8.91	8.91	8.91	8.90
T5	8.88	8.88	8.89	8.89	8.89
T6	8.90	8.90	8.91	8.90	8.89
T7	8.89	8.89	8.90	8.90	8.90
T8	8.87	8.88	8.89	8.89	8.88
T9	8.89	8.90	8.90	8.90	8.89
T10	8.97	8.97	8.99	9.00	9.00
T11	8.99	9.00	9.00	9.00	8.99
T12	9.00	9.00	9.01	9.01	9.00
T13	9.00	9.00	9.00	8.99	8.99
T14	8.96	8.98	8.97	8.97	8.97
T15	8.98	8.99	9.00	9.00	9.00
T16	8.97	8.98	8.99	8.99	8.98
Means in same column did not differ significantly by DMRT at 0.05 level					

Combined application of K and B fertilizers influenced on the moisture content of jute seeds. Jute seed contained higher amount of moisture in the seeds harvested from higher levels of K and B fertilizers. Difference in seed moisture content in lowest and highest level of K and B nutrition was 0.45 % after 12 months of storage. The highest and lowest moisture percentages recorded at all the period of storage were in the treatment of 90 kg K + 0 kg B ha⁻¹ and 90 kg K + 3 kg B ha⁻¹ respectively.

4.3.6.2: Changes in seed germination (viability)

Fresh jute seeds maintained more than 90 % germination is stored for future study. It was observed that jute seeds obtained from certain combination of K and B fertilizers may be stored safely up to 9 months as seeds maintained more than 90% germination at the end of 9 months of storing (Table 4.3.23).

Table 4.3.23: Germination (%) at storage of jute seeds obtained by combined application of K and B

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	91 e	89 e	84 g	80 h	71 i
T2	95 cd	96 bcd	94 cd	92 cd	85 e
T3	96 bcd	96 bcd	94 cd	92 cd	87 d
T4	97 abc	96 bcd	94 cd	92 cd	85 e
T5	94 d	94 d	92 e	88 e	79 h
T6	98 ab	98 ab	96 abc	95 a	91 ab
T7	99 a	97 abc	96 abc	94 ab	90 abc
T8	97 abc	96 bcd	95 bcd	94 ab	89 bcd
T9	95 cd	95 cd	94 bcd	89 e	83 f
T10	99 a	99 a	98 a	95 a	92 a
T11	99 a	99 a	98 a	95 a	91 ab
T12	97 abc	97 abc	95 bcd	93 abc	90 bcd
T13	96 bcd	95 cd	94 cd	92 cd	87 d
T14	99 a	98 ab	97 ab	94 ab	90 bcd
T15	98 ab	97 abc	98 a	94 ab	91 ab
T16	98 ab	97 abc	95 bcd	94 ab	91 ab
Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level					

After 12 months of storage, the highest and lowest germination of jute seeds were 92% and 71.00% (Fig. 4.3.6) which were recorded with combined application of 90 kg K + 1 kg B ha⁻¹ and 0 kg K + 0 kg B ha⁻¹, respectively. The decrease in germination from its initial value was more pronounced in control treatment i.e. in A₀B₀, which was 21.98% lower than its initial value. Lowest decrease of germination (7.07 %) were found with 90 kg K + 1 kg B ha⁻¹ and it was statistically identical with 60 kg K + 1 kg B ha⁻¹, 60 kg K + 2 kg B ha⁻¹, 90 kg K + 2 kg B ha⁻¹.

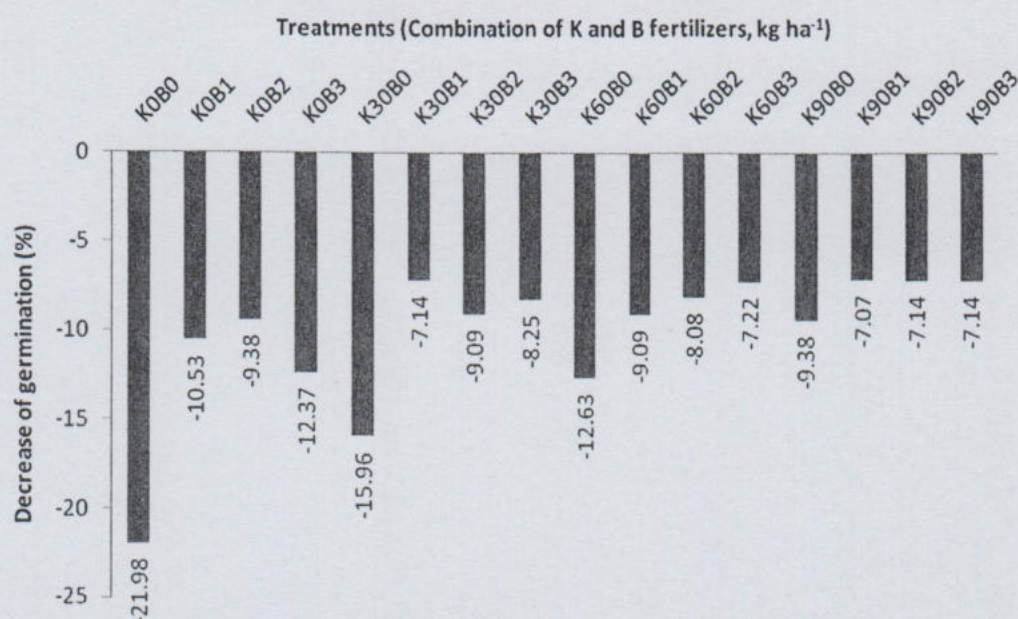


Fig.4.3.6: Decrease of germination (%) after 12 months of storage of jute seeds obtained from combined application of K and B

4.3.6.3: Changes in seedling dry weight

Decrease of seedling dry weight was more profound in control treatment than the fertilized one (Table 4.3.24).

Table 4.3.24: Seedling dry weight (%) of jute seeds over storage obtained from K and B fertilization

Trt.	1 st month	4 th month	7 th month	10 th month	13 th month
T1	0.762 f	0.723 h	0.673 m	0.612 g	0.539 h
T2	0.798 e	0.760 fg	0.715 hij	0.648 ef	0.569 gh
T3	0.808 de	0.767 fg	0.713 hij	0.649 ef	0.571 fg
T4	0.826 cd	0.784 f	0.729 hi	0.664 def	0.584 efg
T5	0.838 cd	0.796 e	0.740 h	0.673 de	0.592 ef
T6	0.912 bcd	0.866 de	0.805 f	0.733 cde	0.645 cde
T7	0.937 bc	0.890 de	0.827 def	0.753 cd	0.662 cd
T8	0.917 bcd	0.871 de	0.810 ef	0.737 cde	0.648 cde
T9	0.862 cd	0.818 ef	0.761 g	0.693 d	0.609 def
T10	1.023 a	0.981 a	0.913 a	0.829 a	0.733 a
T11	0.984 ab	0.939 bc	0.879 cd	0.796 bc	0.681 bcd
T12	0.956 abc	0.908 bcd	0.844 cde	0.768 cd	0.676 bcd
T13	0.834 cd	0.792 ef	0.736 h	0.670 de	0.590 ef
T14	0.992 ab	0.942 bc	0.876 cd	0.797 bc	0.701 abc
T15	0.966 abc	0.917 bcd	0.853 cde	0.776 bcd	0.683 bcd
T16	0.932 bc	0.885 de	0.823 def	0.749 cde	0.659 cd

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level

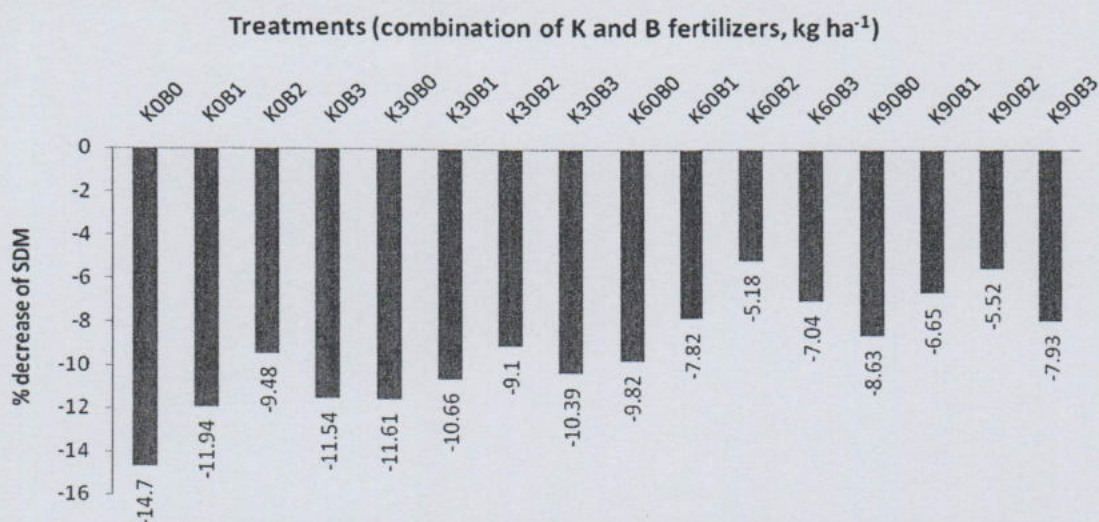


Fig.4.3.7: Decrease of seedling dry weight (%) of jute after 12 months of storage of the seeds obtained from varying levels of K and B application

The results showed that application of applied K and B had beneficial effect on seedling dry weight. Higher level of K (60 kg ha⁻¹) and boron (2 kg ha⁻¹) showed the minimum reduction of dry weight only 5.18 % as compared to that has led to be the maximum reduction of as much as 14.70 % in control treatment where no K and B was applied (Fig. 4.3.7).

4.3.6.4: Changes in seed vigour

Irrespective of fertilization with progressive of storage period the seed vigour decreased steadily and gradually and it was more pronounced in control than any other treatments (Table 3.4.25). Applied K and B contributed to great extent to maintain better seed vigour of jute after 12 months of storage. The maximum depletion of seed vigour (22.51%) was recorded from the seeds of the plots where no K and B were applied (Fig. 4.3.8). The minimum depletion in seed vigour (7.42%) was observed in 60 kg K + 2 kg B ha⁻¹ fertilizer application which was statistically identical to 60 kg K + 1 kg B ha⁻¹, 90 kg K + 1 kg B ha⁻¹ and 90 kg K + 2 kg B ha⁻¹.

Table 4.3.25: Vigour of jute seeds over storage obtained from K and B application

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	88.83 j	87.33 k	81.33 k	78.50 l	68.83 p
T2	94.33 fg	93.00 ghi	91.00 fg	90.33 ef	81.50 jk
T3	95.50 e	94.33 fg	92.50 ef	90.83 ef	84.33 ghi
T4	95.33 ef	94.33 fg	93.00 def	91.00 def	84.00 hi
T5	93.33 g	92.83 fg	92.00 efg	86.83 hi	79.83 kl
T6	96.83 d	95.83 de	94.83 bc	94.00 ab	89.50 cd
T7	97.83 bc	96.50 cd	94.50 bcd	93.00 bcd	88.50 de
T8	96.33 de	95.33 def	94.33 bcd	93.00 bcd	87.00 fg
T9	93.83 d	93.33 gh	92.00 efg	90.33 ef	81.33 jil
T10	98.50 ab	98.00 ab	96.50 a	93.83 abc	89.00 d
T11	98.83 a	98.33 a	96.50 a	94.33 a	91.50 a
T12	96.33 de	96.00 cde	93.50 def	92.83 d	89.33 cde
T13	95.33 ef	93.33 gh	91.83 fg	91.00 def	85.83 gh
T14	97.83 bc	97.33 bc	94.83 bc	91.50 de	90.00 bc
T15	96.83 d	96.00 cde	94.00 cde	93.50 bc	90.33 abc
T16	97.00 bcd	95.50 de	94.00 cde	92.33 de	89.33 cde

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level

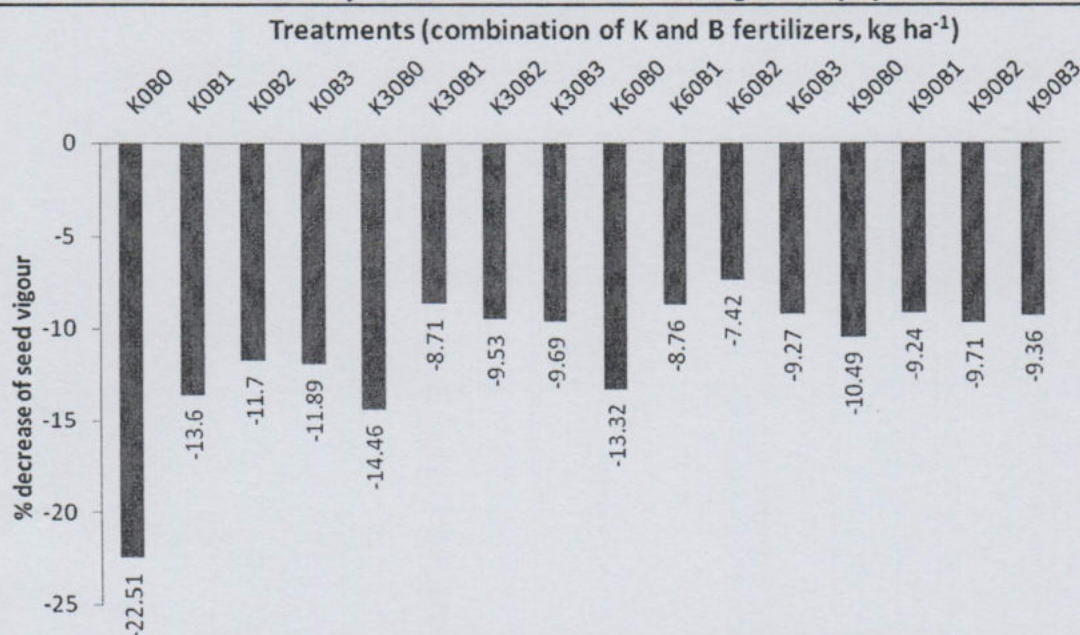


Fig.4.3.8: Decrease of seed vigour after 12 months of storage of jute seeds obtained from K and B fertilizer management

4.3.6.5: Changes in seed leachate conductivity

Pattern of leachate conductivity differed widely over the applied nutrients and the storage period. Jute seeds harvested from the lowest levels of applied nutrients (control, K₀B₀) after 12 months of storage showed highest levels (626 $\mu\text{S cm}^{-1}$) of electrical conductivity (Table 4.3.26), which was 37.58 % higher than its initial status (Fig. 4.3.9). The lowest level of electrical conductivity (371 $\mu\text{S cm}^{-1}$), which was 17.03 % higher than

its initial status, was recorded from the treatment where 60 kg K + 2 kg B ha⁻¹ were applied.

Table 4.3.26: EC ($\mu\text{S cm}^{-1}$) of jute seeds over storage obtained from K and B application

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	455 a	476 a	502 a	558 a	626 a
T2	381 bcde	402 cde	431 bcd	471 bcd	505 bc
T3	384 bcd	404 bcd	434 bcd	472 bcd	496 bcd
T4	389 bcd	407 bcd	437 bcde	474 bcd	510 bc
T5	391 bcd	414 bc	441bcd	474 bcd	502 bc
T6	387 bcd	407 bcd	435 bcd	475 bcd	488 bcd
T7	394 bc	411 bc	442 bcd	483 bc	503 bc
T8	399 bc	416 bcd	450 abcd	492 bc	508 bc
T9	380 bcde	404 cde	428 bcde	464 bcd	476 bcd
T10	342 ef	358 efg	371 ef	391 ef	418 de
T11	317 f	330 g	342 f	351 f	371 e
T12	353 cde	369 efg	392 cde	429 cde	450 d
T13	362 cd	384 cde	408 bcde	447 bcd	474 cd
T14	349 cde	366 efg	394 cde	423 def	447 cd
T15	359 cd	376 def	401 bcdef	435 bcde	455 cd
T16	366 bcdef	381 cdef	410 bcde	451 bcd	468 cd

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level

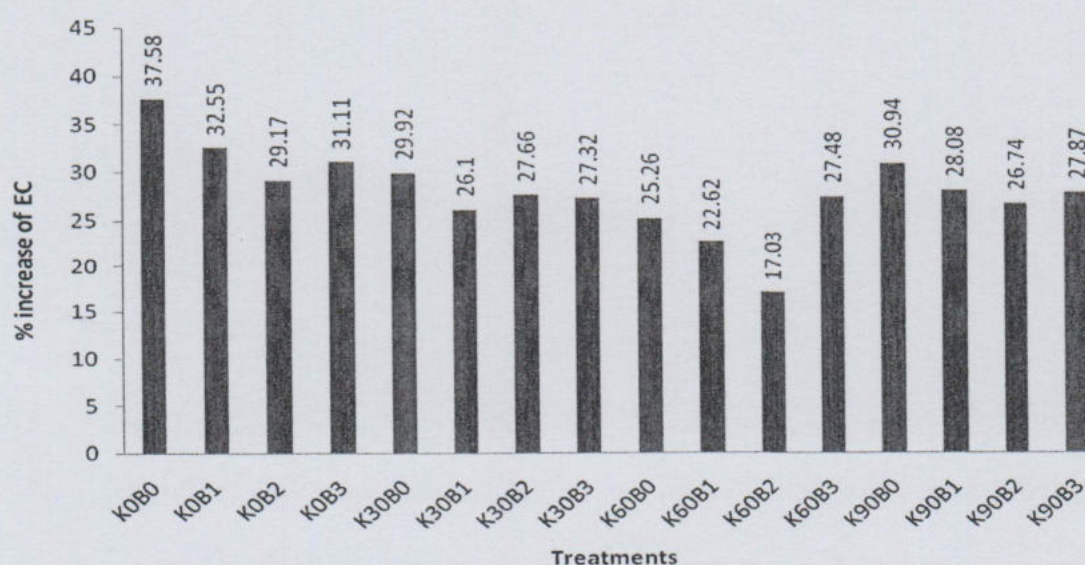


Fig.4.3.9: Increase of leachate conductivity (%) after 12 months storage of jute seeds obtained from varying levels of K and B application

The negative relationship between seed size and electrical conductivity of present study (Fig. 4.3.10), confirms that smaller is the seed size higher is the electrical conductivity.

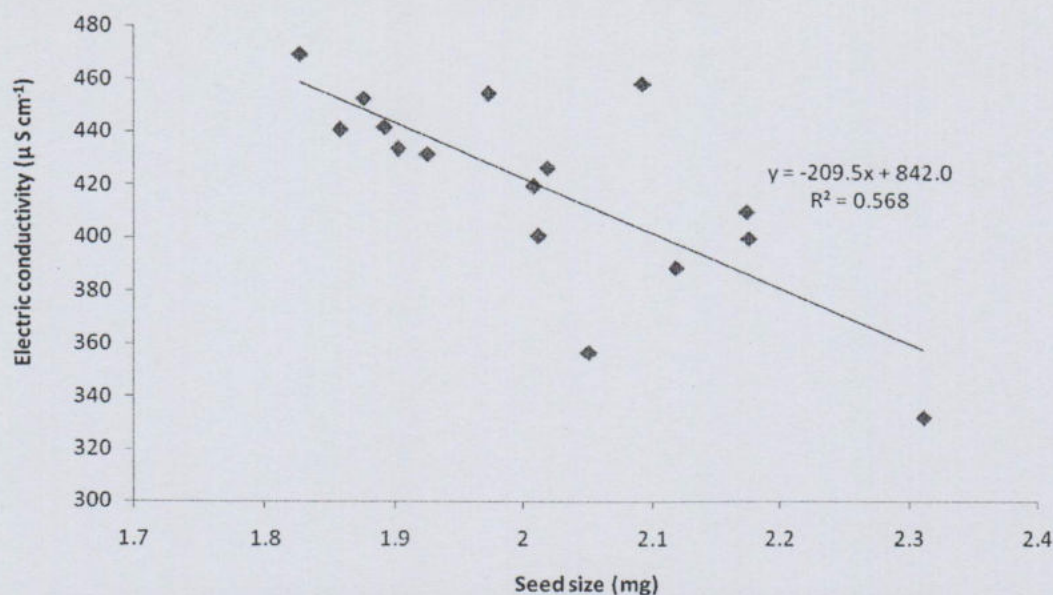


Fig.4.3.10: Relationship between seed size and electric conductivity of jute seeds obtained from combine application of K and B fertilizers

4.3.6.6: Changes in total soluble protein

Irrespective of the levels of applied nutrients the total soluble protein of jute seeds decreased with the increase of storage period. Pattern of decrease of soluble protein, however varied greatly over time and the applied nutrients (Table 4.3.27).

Table 4.3.27: Total soluble protein content (%) of jute seeds over storage obtained from K and B application

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	17.60 g	17.00 j	16.30 h	15.50 k	14.56 j
T2	17.88 fg	17.68 hi	17.38 efg	16.40 hij	15.95 fghi
T3	19.94 cd	19.64 cde	19.25 bcd	18.77 de	18.11 de
T4	19.46 cde	19.16 efg	18.30 def	17.80 fgh	17.59 ef
T5	17.97 fg	17.77 h	17.17 fg	16.70 hi	15.99 fgh
T6	19.28 def	19.08 efg	18.78 cd	17.70 fgh	17.63 ef
T7	19.11 def	19.01 fg	18.61 cde	18.00 efg	17.59 ef
T8	19.83 cd	19.63 cde	19.23 bcd	18.20 ef	17.98 def
T9	19.09 ef	18.89 fg	18.39 de	17.50 fghi	17.17 efg
T10	21.05 a	20.85 a	20.45 a	19.90 ab	19.65 ab
T11	20.86 ab	20.68 ab	20.48 a	20.17 a	19.94 a
T12	20.50 b	20.20 bcd	19.80 bc	19.30 bcd	18.98 bcd
T13	19.37 def	19.07 ef	18.67 cde	17.82 efgh	17.62 ef
T14	20.95 ab	20.55 ab	20.15 b	19.93 ab	19.71 ab
T15	20.30 bc	19.90 cd	19.50 bcd	19.10 cde	18.59 cd
T16	20.60 ab	20.30 bc	19.80 bc	19.10 cde	18.76 cd

Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level

Rate of decrease of soluble protein was higher (17.27%) in seeds of control treatment (K0B0) (Fig.4.3.11). The rate of decrease of soluble protein was minimal (4.41 %) in seed produced with 60 kg K + 2 kg B ha⁻¹ after 12 months of storage.

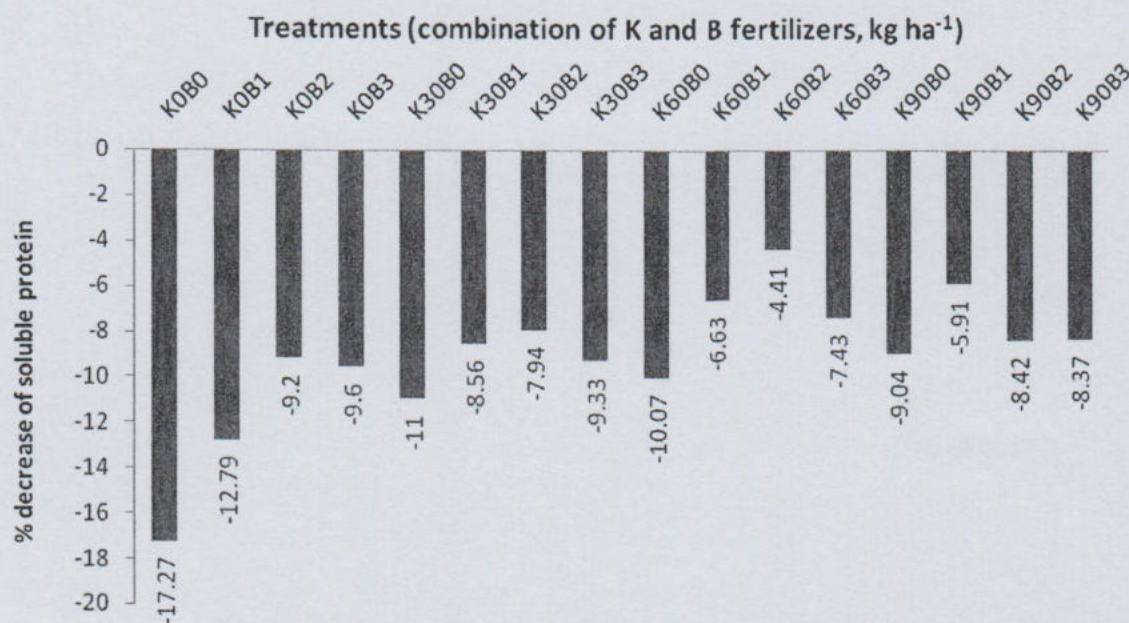


Fig.4.3.11: Decrease of total soluble protein (%) of jute seeds after 12 months of storage obtained from combined application of K and B

The decline in viability is associated with total soluble protein which showed positive correlation between germination and total soluble protein after 12 months of storage (Fig.4.3.12). Another observation was that seeds harvested from the combined application of 60 kg K and 2 kg B ha⁻¹, maintained higher levels of soluble protein throughout the storage period and rate of protein degradation was minimal than that of other treatments.

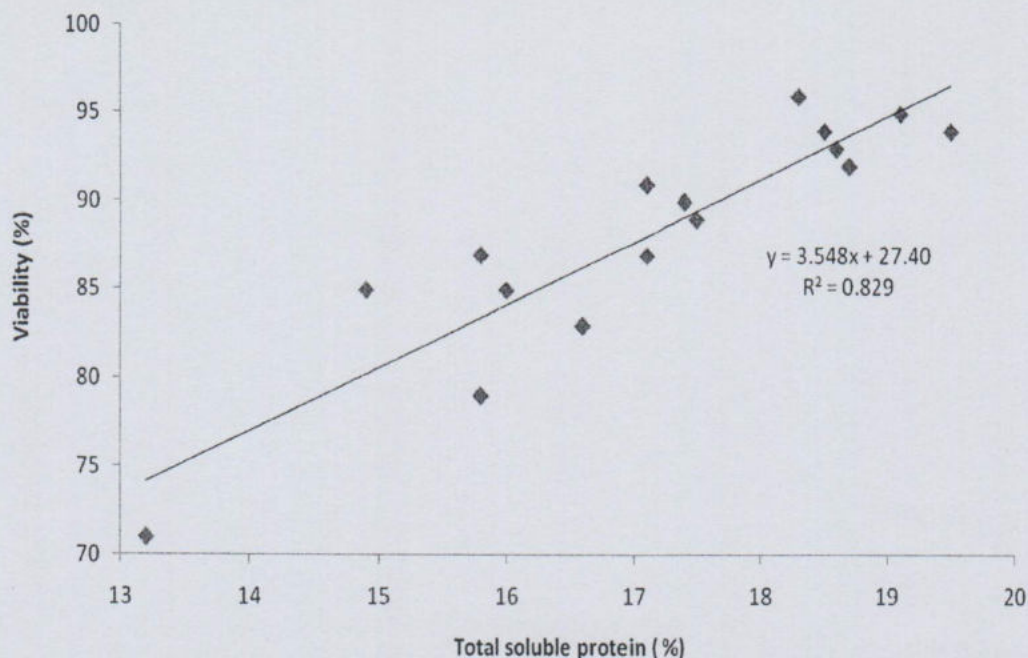


Fig.4.3.12: Relationship between total soluble protein and viability of jute seeds after 12 months of storage obtained from K and B fertilizers management

4.3.6.7: Changes in total soluble sugar

Total soluble sugar of jute seeds steadily declined with the increase of storage period irrespective of K and B application (Table 4.3.28).

Table 4.3.28: Total soluble sugar content (%) of jute seeds over storage obtained from K and B application

Trt.	1 st month	3 rd month	6 th month	9 th month	12 th month
T1	12.72 g	12.49 g	12.20 i	11.70 j	10.90 j
T2	13.09 efg	12.89 efg	12.62 fg	12.13 ghi	11.42 efg
T3	13.71 de	13.53 de	13.27 def	12.79 efgh	12.29 fg
T4	13.37 ef	13.20 ef	12.97 efg	12.50 fgh	12.06 fgh
T5	13.08 efg	12.90 efg	12.66 cd	12.17 ghi	11.39
T6	14.04 cd	13.89 cd	13.63 cd	13.15 de	12.61 ef
T7	13.96 cd	13.84 cd	13.59 cde	13.14 def	12.75 e
T8	13.79 de	13.65 de	13.38 de	12.92 ef	12.58 ef
T9	13.36 ef	13.24 ef	12.97 efg	12.49 fgh	11.90 fghi
T10	14.44 ab	14.29 bc	14.06 bc	13.59 cd	13.48 bc
T11	14.71 a	14.61 a	14.39 a	14.25 a	13.95 a
T12	13.87 cde	13.70 cde	13.43 de	13.01 defg	12.78 de
T13	13.52 def	13.37 ef	13.09 def	12.79 efgh	12.25 fg
T14	14.54 ab	14.38 abc	14.11 ab	13.82 bc	13.58 bc
T15	14.51 ab	14.37 abc	14.08 bc	13.89 bc	13.36 bcd
T16	14.44 abc	14.31 abc	14.00 bc	13.78 bcd	13.17 cd
Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level					

Decline in total soluble sugar was pronounced in control treatment (14.31%, K0B0) which might be attributed to its lower initial capital (Fig.4.3.13). The rate of decrease of soluble sugar was minimal (5.16 %) in seed produced with 60 kg K + 2 kg B ha⁻¹ after 12 months of storage. The decline on viability is associated with total soluble sugar which exhibited through positive correlation between germination percentage and total soluble sugar after 12 months of storage (Fig. 4.3.14).

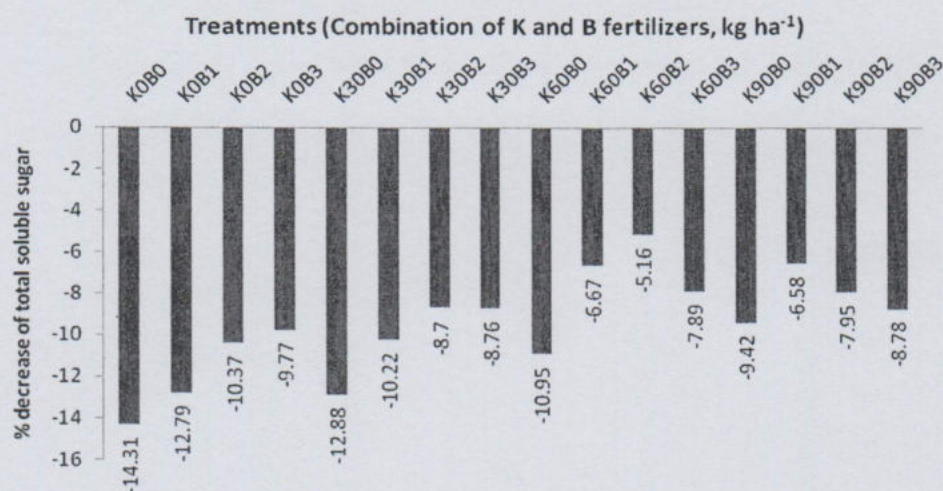


Fig.4.3.13: Decrease of total soluble sugar (%) of jute seeds after 12 months of storage obtained from combined application K and B

Another observation was that seeds harvested from this treatment maintained higher levels of soluble sugar throughout the storage period and rate of sugar degradation was minimal than that of other treatments.

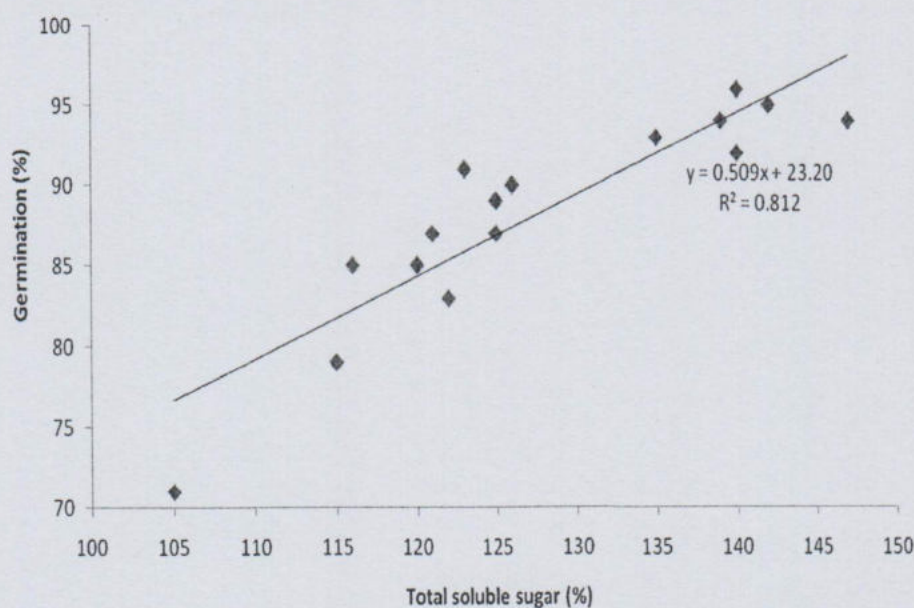


Fig.4.3.14: Relationship between total soluble sugar and germination of jute seeds after 12 months of storage obtained from K and B fertilizer management

4.3.7: Potassium and boron content, uptake and balance

4.3.7.1: Potassium content

The combined application of K and B resulted in higher K and B content (Table 4.3.29) in all parts of jute plant in seed production over single application of K or B as evidenced in this study. The content of K in leaf, seed, shoot and root of jute exhibited marked variation due to variable levels of K and B application. With increasing of K and B doses, K content more or less increased (Table 4.3.29). The content of K was 0.53- 0.68 %, 0.69- 0.85 %, 1.99% - 2.23% and 1.07% - 1.41% in root, shoot, leaves and seed. The highest content of K (2.23 % in leaves) and the lowest (0.53 % in root) was displayed with 90 kg K + 3 kg B ha⁻¹ and 0 kg K + 0 kg B ha⁻¹ fertilizer application, respectively. Linear relationship between combined application of K and B with K and B content in different parts of jute plants were observed (Fig. 4.3.15).

Table 4.3.29: Potassium and B content in different parts of jute plants as influenced by K and B fertilization in seed production.

Treat. (kg ha ⁻¹)	Root		Shoot		Leaves		Seed	
	K %	B ppm	K %	B ppm	K %	B ppm	K %	B ppm
T1 (K0B0)	0.53b	29a	0.75abcd	24c	2.03cd	29c	1.07f	17fg
T2 (K0B1)	0.56b	28a	0.7cd	29c	2.01d	34abc	1.11ef	17efg
T3 (K0B2)	0.58ab	30a	0.71bcd	32bc	1.99d	31bc	1.14def	21def
T4 (K0B3)	0.54 b	27a	0.69d	25c	2.01d	34abc	1.15cdef	16fg
T5 (K30B0)	0.58ab	29a	0.75abcd	27c	2.04cd	35abc	1.18bcdef	20efg
T6 (K30B1)	0.63ab	32a	0.74abcd	33ab	2.14abcd	31bc	1abcd.27	24efg
T7 (K30B2)	0.65ab	34a	0.77abcd	34a	2.17abc	35abc	1.29abcd	28efg
T8 (K30B3)	0.66ab	34a	0.79abcd	34ab	2.18abc	36abc	1.30abc	26cde
T9 (K60B0)	0.63ab	33a	0.82abc	32bc	2.07bcd	36abc	1.26abcde	21efg
T10 (K60B1)	0.66ab	33a	0.82abc	35a	2.13abcd	38abc	1ab.33	30bcd
T11 (K60B2)	0.66ab	32a	0.83ab	34a	2.18abc	44 a	1.37a	33ab
T12 (K60B3)	0.67ab	33a	0.85a	33ab	2.17abc	43ab	1.35a	34a
T13 (K90B0)	0.64ab	32a	0.8abcd	34bc	2.11abcd	38abc	1.29abcd	24g
T14 (K90B1)	0.67ab	34a	0.83ab	35a	2.21ab	40ab	1.34a	26efg
T15 (K90B2)	0.67ab	33a	0.85a	35a	2.22ab	46a	1.37a	31ab
T16 (K90B3)	0.68ab	35a	0.84a	36a	2.23a	42ab	1.41a	35a
Means in same column followed by same small letters did not differ significantly by DMRT at 0.05 level.								

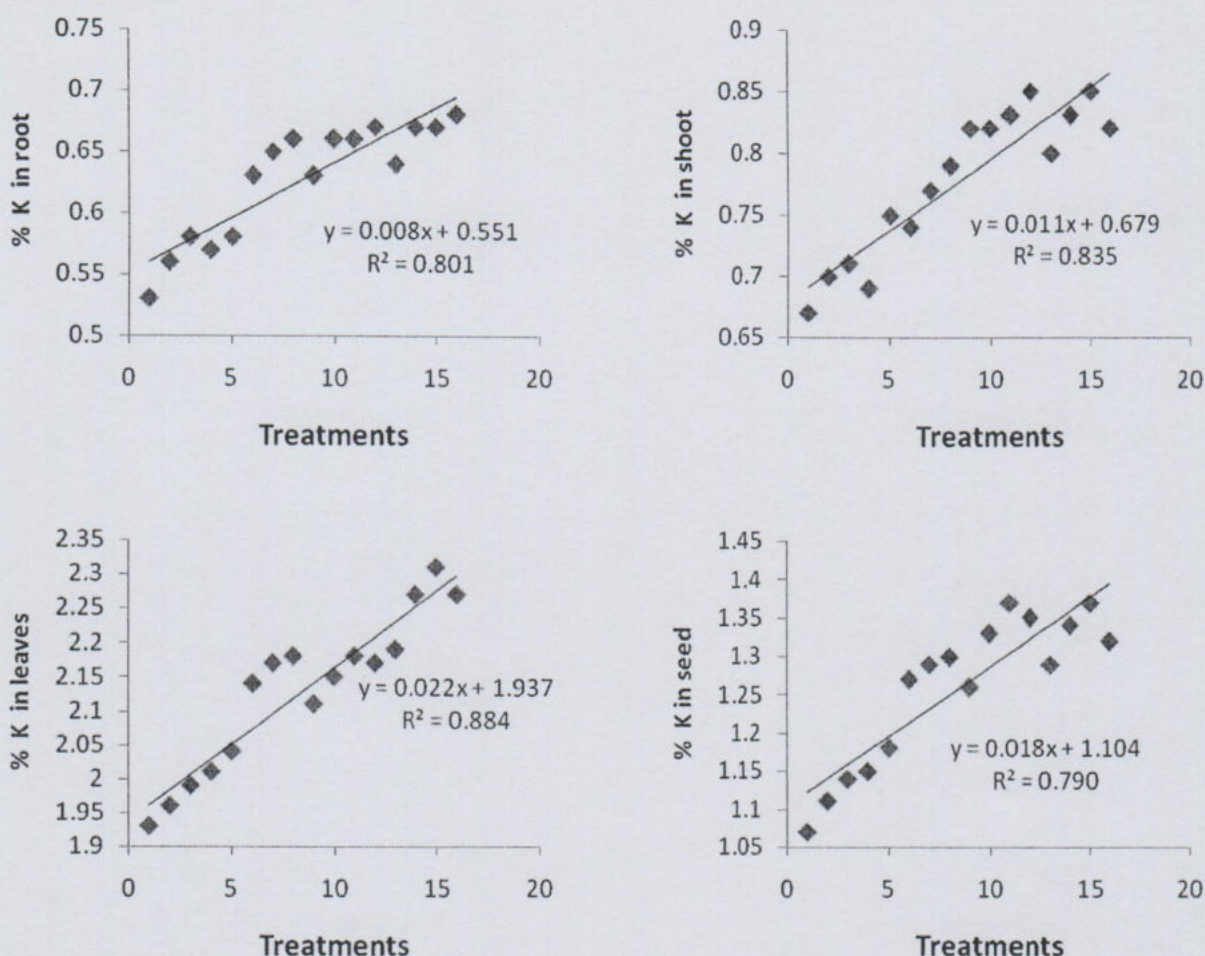


Fig.4.3.15: Relationship between combined application of K and B on K content (%) in different parts of jute plant

4.3.7.2: Boron content

In the present study, the ratio of K and B application has influenced the B content in all parts of jute plant in seed production. With increasing of K and B levels, B content more or less increased. The content of B was 27 – 35 ppm, 24-36 ppm, 29- 46 ppm and 16 – 35 ppm in root, shoot, leaves and seed respectively (Table 4.3.18). At harvest leaves displayed the highest B content (46 ppm) among the plant parts followed by root, shoot and seed. There exists a linear relationship among B content and combined application of B with rates of K application (Fig. 4.3.16). The highest (46 ppm) and lowest (16 ppm) content of B was recorded with 90 kg K + 2 kg B ha⁻¹ and 0 kg K + 3 kg B ha⁻¹ fertilizer application, in leaves and seed, respectively.

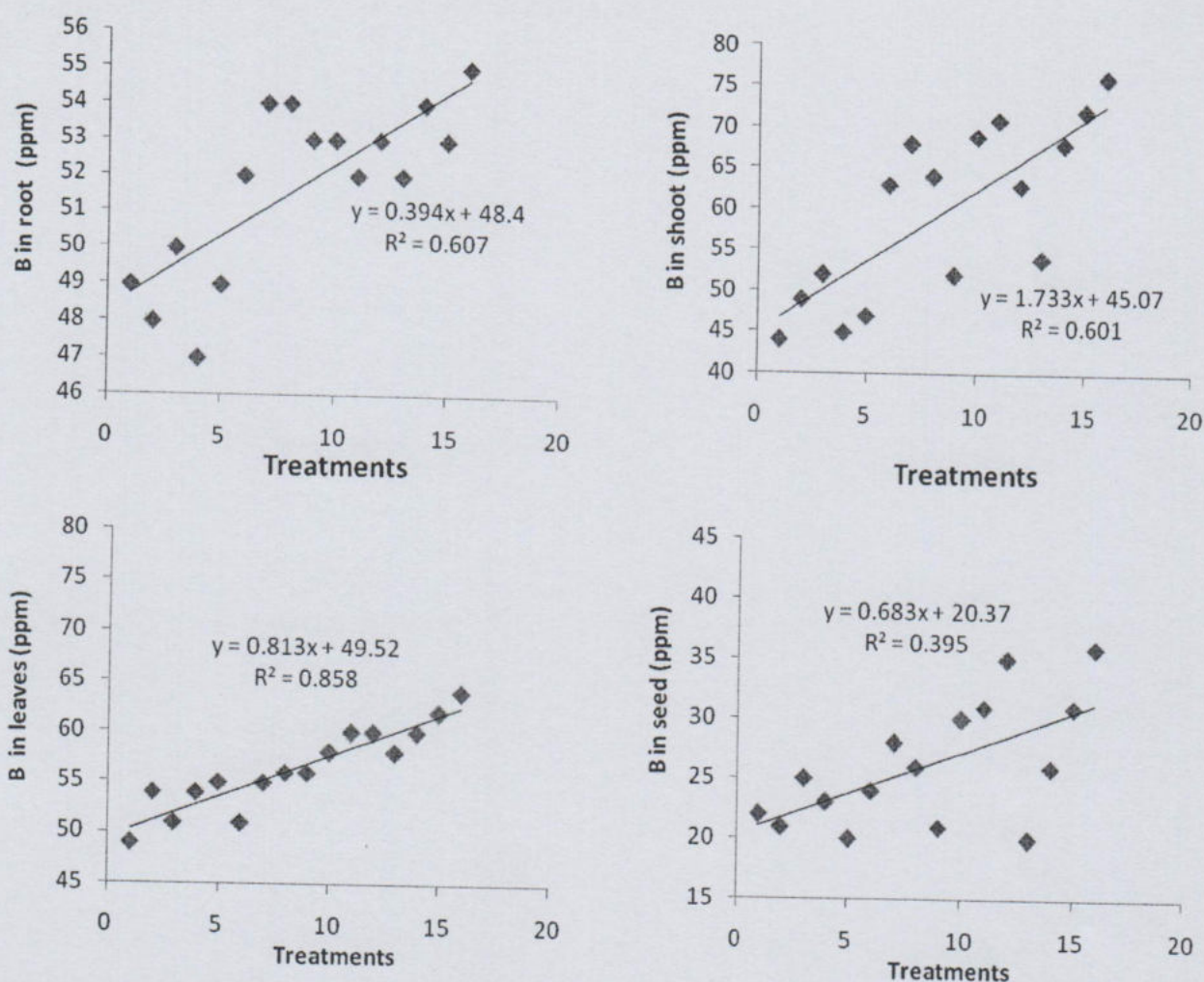


Fig.4.3.16: Relationship between combined application of K and B on B content (ppm) in different parts of jute plant

Correlation among K and B contents in different parts of jute plant and seed yield:

The yield of jute seed was highly and positively correlated with K and B content in root and leaf. The B content in root and leaf was highly correlated with K content in root and leaf (Table 4.3.30). This result shows that jute seed yield was paralleled with the changes of the applied B and K. The K content also showed significant correlation with B (0.920**). Highly and significant positive correlations were found between root K and total K and B content of jute plant in seed production. Shorrocks (1990) reported that effects of B and membrane permeability could lead to association between B and K. The stimulation of K accumulation by the ATP-ase proton pumps which may account for positive correlations between K and B.

4.3.7.3: Potassium uptake

There was significant variation in K uptake with K and B application (Table 4.3.31). The uptake of K by different plant parts of jute ranged from 3.80 kg to 9.11 kg ha⁻¹ in root, 25.16 kg to 49.89 kg ha⁻¹ in shoot, 7.47 to 21.81 kg ha⁻¹ in leaf and 7.36 kg to 15.61 kg ha⁻¹ in seed. The highest total K uptake (93.43 kg ha⁻¹) was recorded in treatment (T₁₁) where 60 kg K + 2 kg B ha⁻¹ were applied, which was 114.78 % higher compared to control i.e. 0 kg K + 0 kg B ha⁻¹.

Table 4.3.30: Bivariate correlation between root, leaf, yield and nutrient content influenced by K and B fertilization in jute seed production

Parameters	Root Yield	Leaf Yield	Seed Yield	Root K	Root B	Shoot K	Shoot B	Leaf K	Leaf B	Seed K
Leaf Yield	0.930(**)									
Seed Yield	0.886(**)	0.821(**)								
Root K	0.870(**)	0.895(**)	0.763(**)							
Root B	0.686(**)	0.705(**)	0.550(*)	0.908(**)						
Shoot K	0.656(**)	0.747(**)	0.465	0.841(**)	0.813(**)					
Shoot B	0.810(**)	0.837(**)	0.719(**)	0.903(**)	0.846(**)	0.733(**)				
Leaf K	0.719(**)	0.805(**)	0.631(**)	0.916(**)	0.874(**)	0.819(**)	0.925(**)			
Leaf B	0.819(**)	0.874(**)	0.728(**)	0.834(**)	0.662(**)	0.861(**)	0.816(**)	0.775(**)		
Seed K	0.855(**)	0.910(**)	0.544(*)	0.982(**)	0.866(**)	0.869(**)	0.912(**)	0.927(**)	0.882(**)	
Seed B	0.572(*)	0.628(**)	0.678(**)	0.703(**)	0.613(*)	0.650(**)	0.816(**)	0.724(**)	0.766(**)	0.743(**)

**** Correlation is significant at the 0.01 level (2-tailed); Correlation is significant at the 0.05 level (2-tailed).**

4.3.7.4: Boron uptake

In jute seed production, the B uptake depended on B application and seed yield (Table 4.3.32). Significant variation in uptake of B with combined application of K and B fertilizers was observed. The uptake of B by different plant parts of jute for seed production ranged from 30.17 to 63.87g ha⁻¹ in root, 141.73 to 373.09 g ha⁻¹ in shoot, 16.83 to 54.53 g ha⁻¹ in leaf and 13.02 to 33.26 g ha⁻¹ in seed. The highest total B uptake (519.29 g ha⁻¹) was recorded by the application of 60 kg K + 1 kg B ha⁻¹ (T₁₀), which was 157.39 % higher compared to uptake of 201.75 g ha⁻¹ in control treatment i.e. 0 kg K + 0 kg B ha⁻¹.

Boron uptake was increased with increasing rates of fertilizers and in plant parts the shoot removed the highest amount of B than that of roots, leaves and seeds.

Table 4.3.31: Interaction effect of K and B application on K uptake (kg ha^{-1}) of jute plants in seed production

Treatments	K uptake (kg ha^{-1}) by different parts of jute plants				
	Root	Shoot	Leaves	Seed	Total
T1 (K0B0)	3.80 i	25.16 f	7.47 f	7.36 f	43.50 g
T2 (K0B1)	4.68 h	26.36 ef	9.16 f	7.43 f	47.63 g
T3 (K0B2)	5.93 f	30.53 def	11.08 def	10.06 cdef	57.60 defg
T4 (K0B3)	5.35 g	29.08 def	10.36 ef	9.54 def	55.33 efg
T5 (K30B0)	4.65 h	29.29 def	11.26 def	8.65 ef	53.85 fg
T6 (K30B1)	6.84 cde	39.76 abc	18.96 ab	12.79 abcd	78.35 bc
T7 (K30B2)	6.58 e	33.88 cdef	15.05 bcd	12.06 abcde	67.57 cdef
T8 (K30B3)	6.64 e	36.19 cd	14.09 cde	11.57 bcde	68.49 cde
T9 (K60B0)	5.89 f	37.31 bcd	13.78 cde	10.73 cdef	69.71 cde
T10 (K60B1)	8.88 a	47.08 ab	21.77 a	14.44 ab	92.17 ab
T11 (K60B2)	9.11 a	46.90 ab	21.81 a	15.61 a	93.43 a
T12 (K60B3)	7.22 bcd	40.29 abc	17.73 bc	13.33 abc	78.57 bc
T13 (K90B0)	7.16 bcd	35.30 cde	17.61 bc	11.53 bcde	70.60 cd
T14 (K90B1)	7.32 bc	49.89 a	18.84 ab	12.63 abcd	88.68 ab
T15 (K90B2)	7.42 b	41.13 abc	18.52 ab	12.68 abcd	79.75 abc
T16 (K90B3)	6.73 de	40.55 abc	17.74 bc	12.30 abcd	77.32 c

Means in a column followed by same small letter did not differ significantly by DMRT at 0.05 levels.

4.3.7.5: Potassium Balance

The combined application of K and B have led to increase the K uptake by the jute plant tremendously and exerted remarkable impact on K balance on the soil (Fig.4.3.17). The negative balance was observed in lower amount of K application and with increasing the K doses the negative status was reduced gradually. The highest negative balance ($-57.60 \text{ kg ha}^{-1}$) was recorded with $0 \text{ kg K} + 2 \text{ kg B ha}^{-1}$ application (T₃) and highest positive balance (12.68 kg ha^{-1}) was observed $90 \text{ kg K} + 3 \text{ kg B ha}^{-1}$ (T₁₆). The minimum negative balance (-9.71 kg ha^{-1}) of K was observed where $60 \text{ kg K} + 0 \text{ kg B ha}^{-1}$ was applied. The minimum positive balance of K (1.32 kg ha^{-1}) was recorded with application of $90 \text{ kg K} + 1 \text{ kg B ha}^{-1}$.

Table 4.3.32: Interaction effect of K and B application on B uptake (g ha^{-1}) of jute plants in seed production

Treatments	B uptake (g ha^{-1})				
	Root	Shoot	Leaves	Seed	Total
T1 (K0B0)	30.17 c	141.73 d	16.83 h	13.02 g	201.75 e
T2 (K0B1)	35.13 c	184.99 cd	23.61 gh	13.49 g	257.22 de
T3 (K0B2)	42.51 bc	208.92 cd	25.82 g	19.87 efg	297.12 d
T4 (K0B3)	40.89 c	190.11 cd	30.15 fg	21.09 defg	282.24 d
T5 (K30B0)	39.25 c	183.55 cd	30.35 fg	14.67 fg	267.82 de
T6 (K30B1)	56.44 a	304.46 bc	40.41 de	22.29 cdef	423.60 bc
T7 (K30B2)	54.63 ab	299.16 bc	38.15 e	26.18 abcde	418.12 bc
T8 (K30B3)	54.31 ab	293.22 bc	36.21 ef	23.14 bcde	406.88 c
T9 (K60B0)	59.56 a	246.23 bcd	41.88 cde	21.22 defg	368.89 c
T10 (K60B1)	63.26 a	373.09 a	53.08 ab	29.86 abc	519.29 a
T11 (K60B2)	63.87 a	366.20 ab	54.53 a	33.06 a	517.66 a
T12 (K60B3)	53.14 ab	268.95 bcd	46.24 bcd	33.26 a	401.59 c
T13 (K90B0)	60.02 a	251.28 bcd	52.90 ab	23.33 bcde	387.53 c
T14 (K90B1)	58.96 a	351.36 b	51.14 ab	24.48 bcde	485.94 ab
T15 (K90B2)	58.72 a	348.37 b	51.71 ab	28.69 abcd	487.49 ab
T16 (K90B3)	54.47 ab	348.74 b	48.48 abc	31.39 ab	483.08 ab

Means in a column followed by same small letter did not differ significantly by DMRT at 0.05 levels.

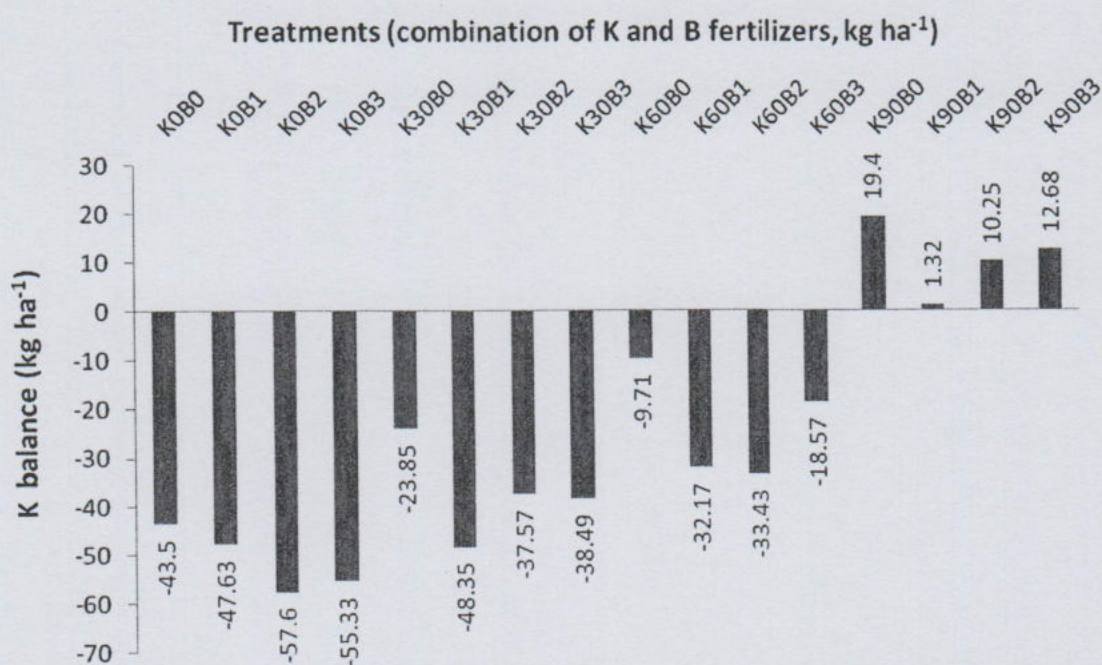


Fig.4.3.17: K balance in jute seed production with combined application of K and B

A difference between the calculated and the measured final amounts of K indicated unaccounted gain of the nutrient. In lower application this unaccounted K gain was higher and the higher K application, it was lower.

4.3.7.6: Boron Balance

In jute seed production, K and B application have resulted in negative balance of B in the control treatment and with increasing B doses the negative status was reduced gradually (Fig.4.3.18). The maximum negative balance of B ($-0.388 \text{ kg ha}^{-1}$) was recorded with 90 kg K + 0 kg B ha^{-1} while highest positive balance (2.598 kg ha^{-1}) was observed with 60 kg K + 3 kg B ha^{-1} application. The minimum negative balance ($-0.202 \text{ kg ha}^{-1}$) of B in 0 kg K + 0 kg B ha^{-1} treatment may be due to lower dry matter and seed production. The minimum positive balance (0.481 kg ha^{-1}) of B was recorded with the application of 60 kg K + 1 kg B ha^{-1} . An unaccounted gain of B was observed in calculated and measured final amounts.

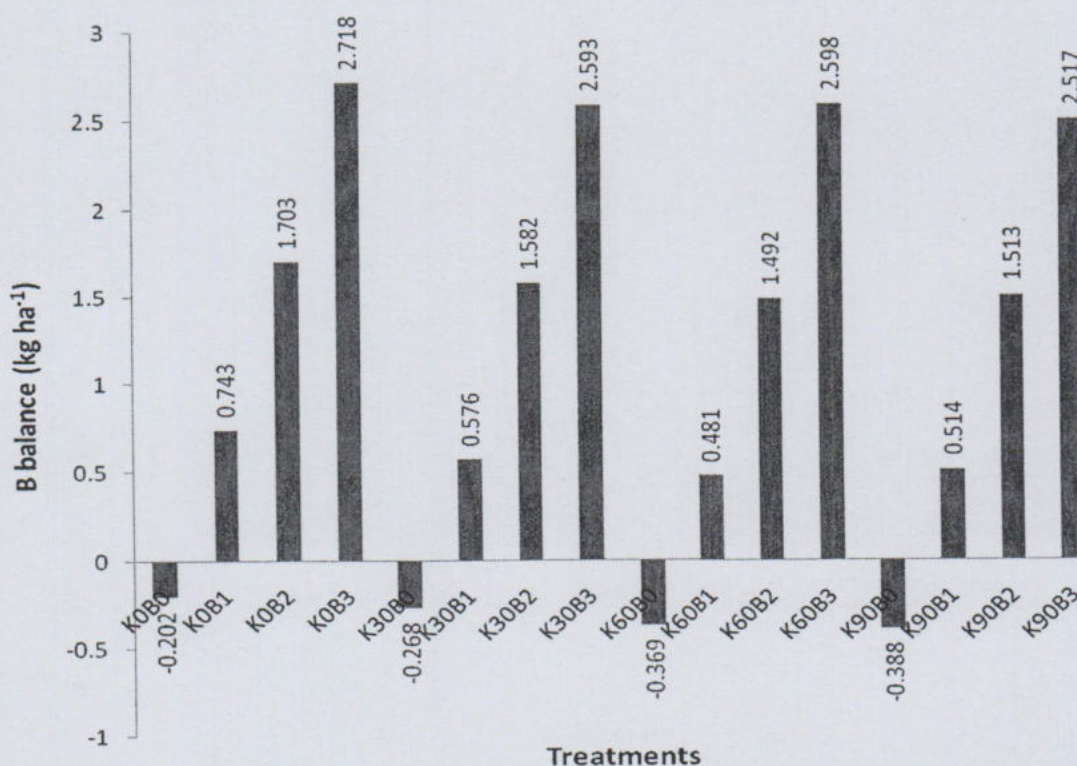


Fig.4.3.18: Balance of B in jute seed production with combined application of K and B

4.3.8: Potassium and boron use efficiency (KUE and BUE)

In combined application of K and B significant difference in KUE and BUE among treatments were observed (Table 4.3.33). Potassium use efficiency was found to increase with increasing B fertilizers in jute seed production but boron use efficiency was found to reduce with increasing K and B rates of application. The highest KUE (14.84 kg dry jute seed / kg K uptake) was achieved with 30 kg K ha⁻¹ + 1 kg B ha⁻¹ application.

Boron use efficiency decreased with increase in B uptake through increased B application. The highest BUE (2924.41 kg ha⁻¹/ kg B uptake) was found with 0 kg K + 0 B ha⁻¹ applications. At the higher level of B (2 kg ha⁻¹) with 60 kg K ha⁻¹, BUE was found to be the lowest (1885.85 kg seed/kg B uptake).

Table 4.3.33: Interaction effect of K and B application on their use efficiency in in tossa jute seed production

Treatment (K and B kg ha ⁻¹)	Potassium use efficiency (kg dry jute seed / kg K uptake)	Boron use efficiency (kg dry jute seed / kg B uptake)
K0B0	13.56ab	2924.41a
K0B1	13.98ab	2774.04b
K0B2	13.44ab	2673.53b
K0B3	13.71ab	2635.62bc
K30B0	13.85bc	2383.05de
K30B1	14.84a	2190.22f
K30B2	13.85ab	2239.78ef
K30B3	13.67ab	2302.47ef
K60B0	13.19ab	2494.12cd
K60B1	10.67c	1925.2g
K60B2	10.59c	1885.85g
K60B3	11.72bc	2294.62ef
K90B0	13.12ab	2390.37de
K90B1	11.83bc	1989.5g
K90B2	12.00bc	1964.14g
K90B3	11.78bc	1886.29g

Means in a column followed by same small letter did not differ significantly by DMRT at 0.05 levels.

4.3.9: Benefit cost ratio (BCR)

Application of K and B combinedly varied the BCR among different doses. With increasing K and B levels increased BCR was recorded up to a certain level and then it decreased (Fig.4.3.19). The highest BCR (1.36) was achieved with the application of 60 kg K + 2 kg B ha^{-1} and this was statistically identical to the application of 60 kg K + 1 kg B ha^{-1} (BCR, 1.33) and 90 kg K + 1 kg B ha^{-1} (BCR, 1.31). The lowest BCR (0.46) was recorded with control i.e. 0 kg K + 0 kg B ha^{-1} .

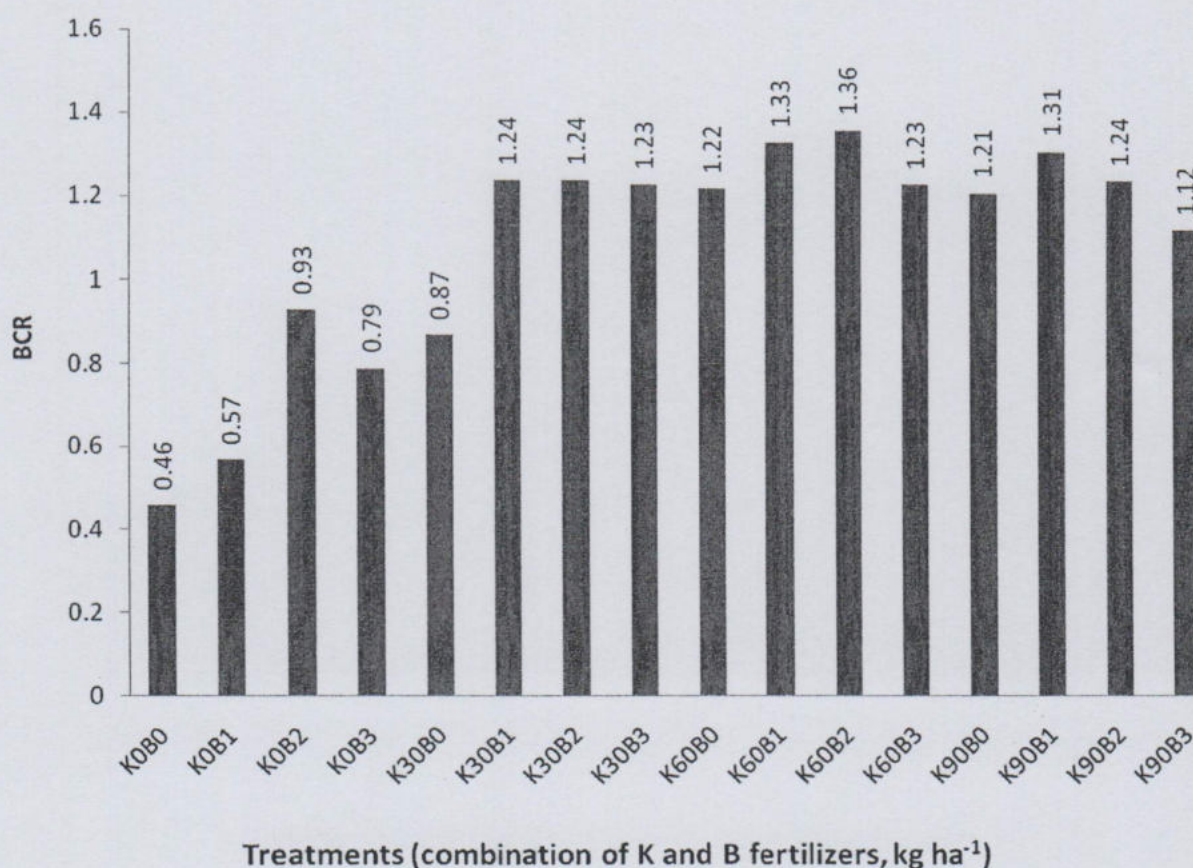
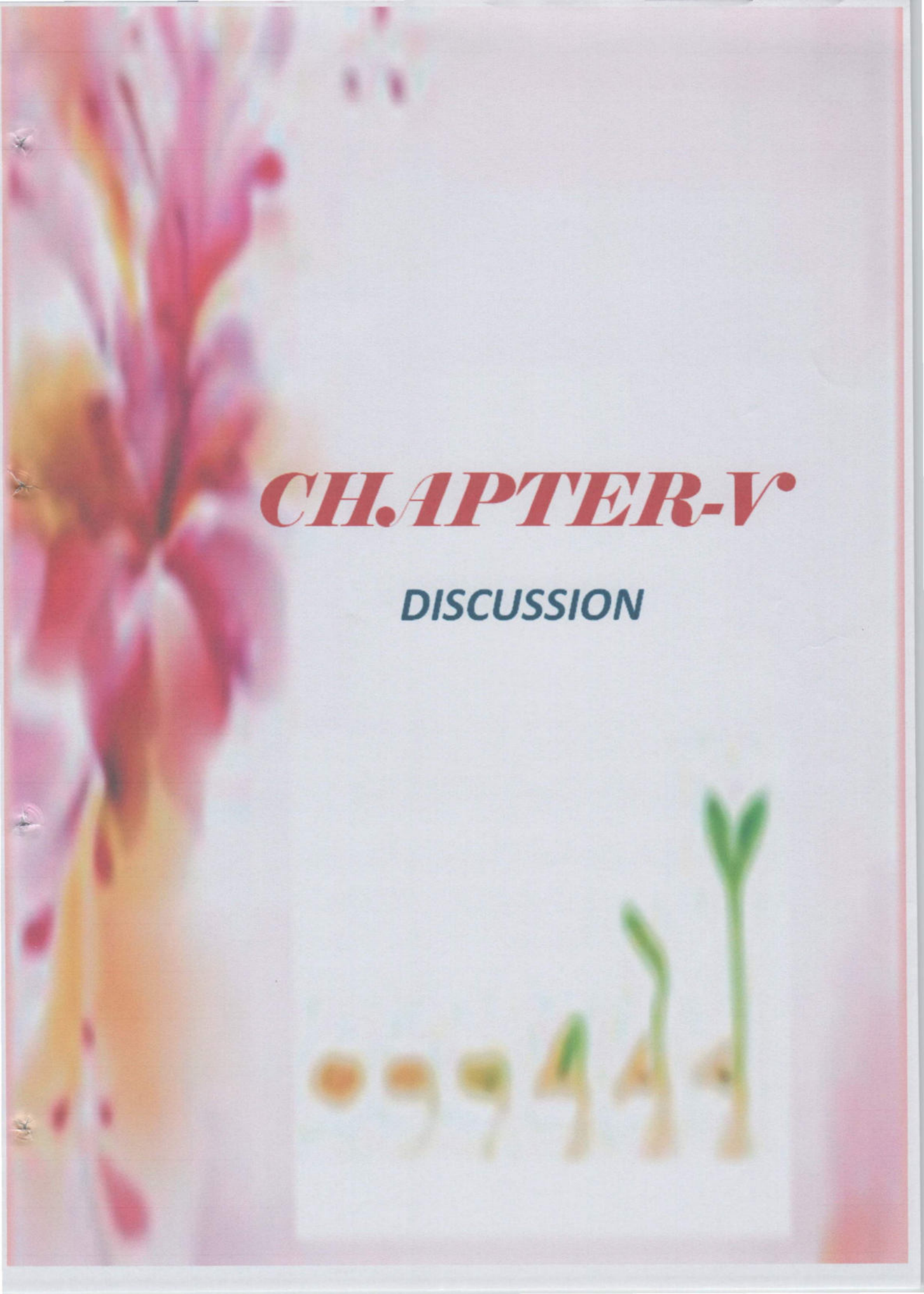


Fig.4.3.19: BCR in jute seed production with combined application of K and B



CHAPTER-V

DISCUSSION

DISCUSSION

5.1 Plant population

Nutrients and its interactive effect play an important role for crop production especially for seed production. The increase in plant population due to K application up to 60 kg ha⁻¹ was noticed in this study. It may be attributed to increased nutrient availability through increased soil pH by replacing H⁺ and Al³⁺ from the exchange sites of the soil colloids (Krishna Kumari *et al.*, 1984) and increasing crop resistance to diseases caused by bacteria and fungi (Perrenoud, 1990). Alam *et al.* (2009b) reported the highest plant population in jute seed production with cutting and seedling transplanting method by the application of 60 kg K ha⁻¹.

Findings from recent studies show that boron (B) deficient soil is not ideal for jute culture especially for seed production. Boron is the most important nutrient for seed yield. Insignificant increase of plant population was recorded with B fertilization up to 2 kg ha⁻¹ then decreased which may be for toxic effect of B more than 2kg ha⁻¹. Khandaker *et al.* (2002) reported highest plant population in jute with 2 kg B ha⁻¹ application. The interactive effect of K and B was more pronounced than individual effect. The highest plant population was registered with 60 kg K + 1kg B ha⁻¹. Alam *et al.* (2009d) reported positive effect of combined application of K and B fertilizers in jute seed production.

5.2 Plant height

Plant height is an important morphological character that acts as a potent indicator of availability of growth sources in its vicinity. The height of a plant depends on nutrient availability in the soil. With increasing level of K fertilizer increased the plant height. It might be attributed due to the effect of K on increasing use efficiency of N fertilizer which might have increased the plant height through enhanced cell division. Gani *et al.* (2008) confirmed the effect of K on plant height of jute. Application of B also influenced plant height significantly. It may be attributed due to balanced adsorption of nutrients, increased rate of photosynthesis and stimulation of root system. Khandaker *et al.* (2002) reported the highest plant height with application of 2 kg B ha⁻¹. Alam *et al.* (2009 c) reported highest plant height of jute plant with 90 kg K and 1 kg B ha⁻¹ at Manikganj.

Sarkar *et al.* (2000) and Gani *et al.* (2008) also confirmed the positive effect of combined application of K and B on plant height of jute than individual application.

5.3 Branch per plant

The increasing rate of K up to 60 kg ha⁻¹ recorded increased branch plant⁻¹. But the lowest number of branch plant⁻¹ (3.95) was noticed with T₁₆ treatment having the maximum rate (150 kg) of K application indicating that over dose of K application creates detrimental effects on jute plant. It reveals from the findings that excess B application above 2.0 kg ha⁻¹ might have created toxic effect on jute plants and reduced the number of branches plant⁻¹. Khandker *et al.* (2001) reported significant increase of the number of branch per plant with B fertilizer management in jute seed production. Paul (2005) reported significant increase of the number of branch per plant with K and B fertilizer management along with other nutrients in jute seed production. Increase of number of branches increases the more fruits/ plant as well as seed yield. The association of number of branches with treatment combination was positive and B was more responsive than K but found non significant.

5.4 Dry matter production

Application of K @ 90 kg ha⁻¹, B @ 2 kg ha⁻¹ as basal and combined application of K and B @ 60kg K + 2 kg B ha⁻¹ recorded the highest total dry matter (TDM) in present study. There also have been reports on the increase of TDM due to increasing K application (Gani *et al.*, 2001). It might be due to increased growth owing to higher K level resulted in adequate supply of photosynthates for the formation of higher TDM (Alim, 2003). Since B was hypothesized to work on the level of plasma membranes in the root system, its deficiency caused a dramatic decrease in all nutrient contents in the plant tissues (Zude *et al.*, 1997) which resultant effect was decreased TDM in plants in control treatment of B. The increased dry weight with combined application of K and B might be due to increased growth owing to higher K and B level resulted in adequate supply of photosynthates for the formation of higher TDM. Paul (2005) reported significant increase of dry weight of jute plant by increasing K application in combination with B.

5.5 Pods plant⁻¹

Increased K fertilization (90 kg K ha⁻¹) increased seeds per pod. Alam *et al.*, (2009a) reported increased pods per plant by applying increased K fertilizer in jute. It was also revealed from the study that single application of 1 kg B ha⁻¹ and two split of 2 kg B ha⁻¹ increase the number of pods per plant without significant difference. It might be due to better pollen germination and development of pollen tubes resulting in increased fruit set due to increased B application. But application of B @ 3kg ha⁻¹ decreased the seeds per pod. Decrease of pod number might be attributed to injurious effect of higher concentrations of B in pods (Kumar *et al.*, 1996). This result is in agreement with findings of Paul (2005) and Khandker *et al.* (2001). Number of pods plant⁻¹ and seed weight were positively correlated ($r = 0.813$, Table 4.3.10) as results showed in present studies. So, more pods were designated as, or seed yield.

5.6 Pod length

The results showed the significant effect of K and B on pod length of jute. The significant responses of K in increasing the pod length might be due to increased rate of photosynthesis resulting adequate supply of photosynthates in the pod. The positive responses of boron in increasing the pod length might be due to balanced adsorption of nutrients, increased rate of photosynthates resulting adequate supply of photosynthetic in the pod. But individual and combined application of B with K was more pronouncing in enhancing pod length indicating that the B is essential for flowering and fruit setting of tossa jute seed crop. Paul (2005) and Ali (2011) reported increased pod length in jute seed production with fertilizer management.

5.7 Seeds per pod

The results revealed that split application increase seeds per pod than basal application especially in case of higher doses. Numbers of seeds per pod and seed weight were positively correlated. Alam *et al.*, (2009a) reported similar trend of results in jute seed production through plant cutting method through K fertilizer management.

The positive responses of potassium and boron in increasing the number of seeds per pod were probably due to enhanced pollination, fertilization and transport of carbohydrate to the seeds as influenced by the application of the elements (Chen *et al.*, 1998). Similar results were reported by Alam *et al.* (2009d) and Paul (2005) in jute seeds production with the variety BJRI tossa 4 (O-72).

5.8 1000 seed weight

The results showed that with increasing level of K up to 90 kg ha⁻¹ increased the 1000 seed weight (seed size) through basal application. But in split application higher doses of K fertilizer produced comparatively the higher size of jute seed indicating the quality improvement of the seed. This was at par with the findings of He-Ping *et al.* (2002) in wheat. With increasing B level up to 2 kg ha⁻¹ increased the seed size through basal application. But in split application of higher doses of B fertilizer produced comparatively the higher size of jute seed than its basal application indicating the quality improvement of the seed through split application of B fertilizers at higher doses. But combined application of K and B level up to 60 kg K + 2 kg B ha⁻¹, respectively increased the seed size indicating the quality improvement of the seed. The increased seed size may be linked with adequate supply of photosynthates for the accumulation of metabolites with direct impact on seed. This result was at par with the findings of Alam *et al.* (2009a). Similar trends of results were also reported by Paul (2005) and Khandker *et al.* (2001) in jute seed production with jute variety O-72 and O-9897, respectively.

5.9 Seed yield

Nutrients have great importance on jute seeds production. Yield is the resultant effect of plant height, number of branches, number of pod plant⁻¹, and seeds per pod which is profoundly influenced by nutrients. Increased K application increased yield and seed quality as it increased leaf K content as evidenced in Table 4.1.6, as leaf K content improves photosynthesis rate, water use efficiency and stomatal conductance of plants and led to increased yield and improved seed quality. The basal application of K was found better than that of split application in seed yield. But the split application of K was desirable to produce higher yield as the experimental soil was sandy loam. Though the soil was

sandy loam but it may be the presence of 2:1 type clay minerals (as K fixation and release is related to the composition of K-bearing minerals in soil (Uddin *et al.*, 2011)) which holds more K that contributes K to plants in growing periods and may encourage basal application as remunerative to plants. It needs further investigation. Alam *et al.* (2009a) opined that jute seed yield primarily depends on number of pod bearing branches per plant and other yield contributing characters of the crop. Siddaramppa *et al.* (1993) reported that pod, seed and oil yields were highest with potassium sulphate and the higher rate of K application.

The range of seed production with boron application was 849 (T₁₉) kg to 985 kg ha⁻¹ (T₁₁). Increasing seed yield through increased B fertilization may be attributed due to adequate supply of photosynthates for the accumulation of metabolites with direct impact on pod and seed weight and consequently on seed yield of jute. Increased B application increased yield and seed quality as it increased leaf B content as evidenced in Table 4.2.6 as leaf B content improves photosynthesis rate, transport of carbohydrate to the seeds and led to increase yield and improves seed quality (Petracek and Sams, 1987).

The application of K and B combinedly influenced the jute seed yield. At higher doses of K and B, yield might be decreased due to detrimental effect of the elements. Increasing seed yield through increased K and B fertilization up to certain doses may be attributed due to adequate supply of photosynthetic for the accumulation of metabolites with direct impact on pod and seed weight and consequently on seed yield of jute. These results were in conformity with the findings of Alam *et al.* (2009d), who reported synergistic effects of K and B on jute seed production. Similar trends of results were also observed by Bhattacharjee *et al.* (2000) on jute seed yield and Ahmed *et al.* (2004) reported synergistic effect of K and B on rice.

5.10 Correlation growth and yield parameters

Correlation among jute seed yield and plant population, plant height, branch number, pods per plant and seeds per pod (Table 4.1.5, 4.2.3 and 4.3.10). Similar observations were also made by Alim *et al.* (2002), Paul (2005) and Ali (2011).

5.11 Germination

Germination is the emergence and development from the seed embryo of those essential structures, which indicate the ability to develop into a normal plant under favorable conditions in soil (ISTA, 1976). Sangakkara *et al.* (1996), who reported that seed quality, determined by germination before and after controlled deterioration, was highest when K was applied in split dressings. Bhattacharjee *et al.* (2000) observed maximum seed germination at fresh jute seeds with NPK fertilization. Shrestha (2002) stated that seeds harvested from earlier B applied treatments had higher germination; vigor and produced strong seedlings as compared to without B. Lima *et al.* (2003) reported that seed quality determined by germination percentage, was increased by the combined application of K and B. Ahmed *et al.* (2004) reported that abnormal seedlings and dead seeds were very poor in combined application of K and B in rice.

5.12 Seed leachate conductivity

Seed leachate conductivity test has been used by many researchers to indicate seed vigour (Normash and Chin, 1991). Higher electrical conductivity of the produced seeds from the control treatment (0 kg K ha^{-1}) might be associated with its smaller sized seed production having under developed seeds with weak membrane structure which facilitated leachate leakage. The electrical conductivity test is acknowledged as one of the best tests for the evaluation of the loss of cell membrane integrity by the concentration of electrolytes released by seeds during imbibitions; cell membrane integrity is considered one of the primary physiological events of seed deterioration process (Delouche, 1976); consequently, lower vigor seed lots exhibit higher intensity of cellular constituent losses, such as inorganic ions. Application of K or B singly or in combinedly resulted lowers EC over control treatment. Muhammad *et al.* (2004), who reported that electrical conductivity of seed leachates were affected significantly being minimum at the dose of 100 kg K ha^{-1} . Hamsaveni *et al.* (2003) observed the least EC of 0.98 dS m^{-1} in tomato with B application and Lima *et al.* (2003) reported that electrical conductivity of seed leachates were affected by combine application of K and B.

5.13 Seed vigour

Seed vigor is the sum total of genetic properties, which determine the potential for rapid, uniform emergence and development of normal seedling under a wide range of field conditions (McDonald, 1999). Seed vigor is basically the potential for growth and the

ability to sustain life. High vigor seed lots have significantly higher emergence than low vigor seed lots (Steiner, 1990). The advantage to be gained from planting high vigor seed is improved stands and not, necessarily, increased yields (TeKrony and Egli, 1991). The increased vigour with increasing K or B or K and B combinedly up to certain level may be ascribed with improvement in seed chemical composition and involvement of increasing photosynthesis resulting translocation of assimilates from leaf to seed. Bhattacharjee *et al.* (2000) reported increased growth, seed yield and its vigour with gradual increasing in the level of NPK in jute. Similar observations were also made by Hamsaveni *et al.* (2003) in tomato and Rathinavel *et al.* (1999) in cotton.

5.14 Seedling dry weight (SDM)

Increase in seedling dry weight at higher levels of K or B or combined fertilization of K and B was associated with increase in seed size (Table 4.1.3, 4.2.4 and 4.3.17) as large seeds produced more seedling dry matter due to its large initial capital in seed reserve (Shrestha, 2002). Conversely, the seed produced from lower level of nutrition (K or B or its combined application) showed lower seedling dry matter. Lower seedling dry weight may be for smaller size of seeds and lower amount of food reserves.

5.15 Total soluble protein

Increase of total soluble protein is observed in single application of K or B or its combined application and it is in agreement with the findings of Gadgil *et al.* (1989) who found 16-20% protein in jute seeds. The increase of protein may be happened because of increased K rates increased transport of amino acids to the sites of protein synthesis, enzyme activation, balancing of electrical charges which are required for every major steps of protein synthesis and the "reading" of the genetic code in plant cells to produce the proteins and enzymes that are regulated by potassium (Pedroso *et al.*, 2002). Significant increase of protein by B application might be linked with the mobilization of proteins stored in leaves and stems and also promoted the translocation of amino acids towards the seeds (Motamed, 2006). Ali (2011) reported strong positive correlation between seed protein content and seed viability and seedling vigour of jute seed. He also reported 19.63 % to 22.49% total soluble protein in tossa jute seed with N and P fertilizer

management. Li-BaoZhen *et al.* (2005) stated considerable increase of protein content in rapeseed with combine application of K and B, and to get a protein content higher than 45%, he suggested the fertilizer application rate for K and B should be 103.2-126.8, and 8.9-10.3 kg per hm², respectively.

5.16 Total soluble sugar

Total soluble sugar of tossa jute seed was profoundly influenced by the application of K or B or its combined application (Table 4.1.4, 4.2.4 and 4.3.16). Better seed quality, especially higher sugar content, can be explained by the role of K and B that plays in carbohydrate synthesis, breakdown and translocation and synthesis of protein and neutralization of physiologically important organic acids (Tisdale and Nelson, 1966). Potassium is responsible for energy production in the form of ATP and NADPH in chloroplasts by maintaining balanced electric charges. Besides, K is involved in phloem loading and unloading of sucrose and amino acids and storage in the form of starch in developing fruits by activating enzyme starch synthase (Mengel and Kirkby, 1987) and B plays in the transport of carbohydrates and translocation of sugar is thought to be enhanced by the formation of borate-sugar complexes (Marcus-Wyner and Rains, 1982; Katyal and Randhawa, 1983). The promotive effect of B may be interpreted in terms of manufacturing more carbohydrates and proteins (Verma, 1983) along with its role in enhancing their translocation from site of synthesis to the storage organs (Sharma, 2002). Begum (1977) reported 12-13% soluble sugar in tossa jute seed and Ali (2011) reported increase of total soluble sugar content of jute seed after fertilization by N and P.

5.17 Correlation among seed quality attributes

The result revealed that higher the seed size higher the viability, seedling dry weight and seedling vigour which indicated that the seed size is related to seed metabolism and seedling growth rate (Krieg and Carrol, 1978). As larger seeds contain higher amount of reserve and metabolize those reserve towards the germinating seedling which consequently enhanced seed and seedling vigour (Raveendranath and Singh, 1991). The negative relationship (Table 4.1.5) between leachate conductivity (EC) with viability percent ($r = -0.943$), Seedling dry weight ($r = -0.940$), seed vigour ($r = -0.813$) and seed

size ($r = -0.908$) indicated that more leachates were escaped from poor quality seeds obtained from lower levels of K or B nutrition and lowered the viability of seed vigour. Similar results were also observed by Krishnasamy and Seshu (1990) in rice and Ali (2001) in jute seeds.

5.18 Changes in seed moisture

At the time of storing, initial moisture content varied from 8.86 to 8.94% in different treatments. Seed moisture content influences its viability profoundly. Such differences in seed moisture content might be due to differences in seed oil content (Ali, 2011) and intake of water in to the cell (Wallace, 1961) as seeds harvested from low nutrition contained lower proportion of oil content than those of higher nutrition of K or B or its combined application. Briggs (1943) in his early work reported that boron deficient (*N. aquaticum* L.) plants showed decreased moisture percentage, less succulence, less metabolic activity and a lower growth rate, in comparison to boron-sufficient plants. This was confirmed many years later by Sharma and Ramchandra (1990) who also reported that boron deficient plants had low water potential, stomatal pore opening and transpiration. It also may be due to the contribution of B in cell wall stability (Allen and Pilbeam, 2007) which hinders moisture absorbance from the adjacent space.

5.19 Changes in seed germination

High viability (germination) is the most important physiological seed quality required for long term storage (Holmes and Buszewicz, 1958). Seed deterioration during storage is a complex physiological and biochemical process leading to loss of germination ability. Fresh jute seeds maintaining 95-99 % germination was stored for the study. At the end of 12 months storage only some seeds produced by certain amount and a particular method of the nutrients application showed better performance of jute seeds stored for longer period indicating that that applied nutrition has significant influence in maintaining germination capacity of jute seed under storage environment (Fig. 4.1.8, 4.2.10 and 4.3.6). These results agree with the findings of Ali (2011) in jute seeds and Freitas *et al.* (2006) in cotton seeds. Panayotov (2005) stated that special B @ 1.5% application improved the

storability of pepper and maintained higher values of seed germination in comparison to the control after 55 months of storage period.

The seeds which hold initially high moisture decreased its germinability highly. It might be as the resultant effect of higher seed moisture along with higher storage temperature enhanced respiration rate and consequently loosed the viability as well as germination capacity of stored seeds (Barton, 1985). The results indicated that applied nutrients might have positive impact on seed moisture relationship (Ali, 2011) and cell wall development (Sutcliffe and Baker, 1981) which determined the variability in germination of jute seeds stored for longer period.

5.20 Changes in seedling dry weight

In different treatments of the applied nutrients of K or B or its combined application, seedling dry weight decreased over the storage period differently and gradually (Fig.4.1.10, Fig. 4.2.13 and Fig.4.3.9). However, decrease of seedling dry weight was more profound in control treatment which confirms that applied nutrients maintained better seedling dry weight even after 12 months of storage. Similar observations were made by Ali (2011) who reported similarly in jute seed production with N and P fertilizer management.

5.21 Changes in seed vigour

Decrease in vigour indices varied on the levels of applied K or B or its combined application. Applied nutrients contributed to a great extent to maintain better vigour of jute seed after 12 months of storage (Fig.4.1.12, Fig. 4.2.17 and Fig. 4.3.8). This was happened because of production of bolder seeds by higher levels of applied nutrients. Bolder seeds contain larger initial reserve and metabolize these reserves towards the germinability of seedling and enhanced the seed vigour (Krieg and Carrol. 1978; Raveendranath and Singh, 1991).

5.22 Changes in seed leachate conductivity

The leaching of solutes from the imbibed seed increased with the increase of storage period as it is exhibited by the increase of electrical conductivity of seed electrolytes (Fig.4.1.14, Fig. 4.2.19 and Fig. 4.3. 11). This is an indication of seed deterioration with

passing of storage time. This might be ascribed due to production of smaller seed under lower level of applied nutrient. This confirms with the existence of negative relationship between seed size and electrical conductivity ($r = -0.908$, Table 4.1.5), which indicated that smaller the seed size higher is the electrical conductivity. Pattern of leachate conductivity differed widely over the applied B and the storage period. In higher doses of B results lower leachate conductivity which might be due to induce of cell wall synthesis (Sutcliffe and Baker, 1981) and maintaining membrane integrity (Parr and Louhgman, 1983). Combined application of K and B also resulted lower electric conductivity which might be for larger sized seed production with the applied nutrients, resulting lower surface area and induced lower rate of leakage out of cell wall and also of development of cell wall stability (Allen and Pilbeam, 2007), which resultant effect was reduced electrical conductivity of the seeds. These results corresponded well to findings of Ali (2011), who reported that jute seeds harvested from lower levels of applied nutrients showed higher levels of electrical conductivity and explained that the jute seed deterioration is accompanied with leakage of electrolytes, increase in electrical conductivity and decrease of germination over storage period.

5.23 Changes in total soluble protein

In all the experiments with increasing of storage period the total soluble protein of the produced seeds decreased whatever might be the fertilizer or its dose or its method of application. The declining rate in total soluble protein with progressive storage period can be attributed to variations in the rate of declining of soluble protein and association with the increasing activity of proteinases and degradation of protein (Kalpana and Madhava Rao, 1997). They also mentioned that the activities of malate dehydrogenase, catalase and peroxydase play an important role in protein degradation and seed longevity (Kalpana and Madhava Rao, 1994). Pukacka and Ratajczak (2007) reported that soluble protein degradation can result from reactive oxygen species (ROS) action, which can diminish enzyme activities and the content of late embryogenesis abundant (LEA) – like proteins or small heat shock proteins (SHSP) that play an important role in maintaining long storage life of dry seeds (Wolkers *et al.*, 2001). The decline in viability

(germination %) is associated with total soluble protein which exhibited through positive correlation between seed germination and total soluble protein of jute seeds obtained from different doses of K and its split application (Fig.4.1.18). Another observation was that seeds harvested from higher levels of fertilizers like K (90 kg ha^{-1}) or 2 kg B ha^{-1} or combined application of $60 \text{ kg K} + 2 \text{ kg B}$ per hectare maintained higher levels of soluble protein throughout the storage period and rate of protein degradation was minimal than that of other treatments. It was possible because seed harvested from higher levels of K or B or its combined application contained higher amount of soluble protein and maintained it throughout the storage period.

5.24 Changes in total soluble sugar

Total soluble sugar generally decline with the increase of seed ageing (Petruzelli and Taranto, 1989) irrespective of fertilization, as a result of availability of limited respiratory substrates (Edge and Burris, 1970). In case of single application of K or B or its combined application in certain doses resulted some delay in decreasing total soluble sugar and recorded higher germination even after 12 months storage which indicated that higher the amount of soluble sugar higher is the germination percentage?

The reason of depletion of disaccharides may diminish the protective effects of sugars on structural integrity of membranes (Crowe *et al.*, 1984) which may limit the ability of seeds to maintain the verified state. This might be due to the presence of reducing sugars, may lead to deterioration of protein components through Amadori and Maillard reactions. These are non – enzymatic carbonyl amine reactions that take place preferentially in dry systems (Feeny and Whitaker, 1982) and contribute to seed deterioration (Wettlaufer and Leopold, 1991). Similar relationship was also reported by Ali (2011) in jute seeds and Cieslak *et al.* (2010) in many cases of cereal seeds. Seeds produced from fertilization with K and or B maintained the viability throughout the storage period, it was possible because seed harvested from higher levels of K and B, recorded higher amount of soluble sugar and maintained it throughout the storage period.

5.25 Potassium (K) content

It is noted that K is not structural constituent of any plant body and is highly mobile in nature. Potassium thus participates in physiological and biochemical processes within plant and finally stored in leaves. In general, higher levels of K application increased leaf K content. Jute plants continue to absorb K even when available K exceeds plant needs. This unique property of K uptake of plant called "luxury consumption" (Havlin *et al.*, 1999) was observed in which the jute plants continued to absorb K in excess of needs for dry matter production so that large amounts of K were accumulated without any increase in crop yield. The reasons for this high uptake are not clear but it should be remembered that K fulfills many physiological and biochemical functions, which are not necessarily directed towards dry matter yield production. This may be attributed to best amendment of K and B feeding which might have led to the improvement of the physiological performance of the plants (Hellal *et al.*, 2009). The higher level of K in leaves may be ascribing as of the function of K as it is highly mobile in nature and participates in physiological and biochemical processes within plant body and finally stored in leaves. Paul (2005) stated that combined application of K and B fertilizers influenced the content, uptake and nutrient use efficiency in jute seed production.

5.26 Potassium (K) uptake

Potassium uptake was increased with increasing rates of K fertilizers in single or in combination with B. But no definitive trend was observed in case of split application of K. Of the plant parts the shoot removed the highest amount of K than that of roots, leaves and seed. Paul (2005) reported 43.89 to 92.33 kg uptake of K ha⁻¹ in jute seed production with combined application of NPK. Sarkar *et al.* (2000) observed increasing K uptake with increasing K rate with B application. Similar trend of results were also reported by Maitra *et al.* (1999).

5.27 Potassium (K) balance

For jute seed production the uptake of K was quite high as compared to the original soil K status. The difference between the calculated and the measured final amounts of K indicated unaccounted gain. In lower application this unaccounted K gain was higher

and in higher K application it was lower. It may be for releasing higher K from its native pool where receiving lower K application to maintain a nutritional equilibrium in soil. The defoliated jute leaves and left over root of jute crop also contributed to build up of nutritional positive balance. From that addition in soil, measured final amount was higher than the calculated final amount. It may be concluded from the balance sheet that jute crop uptake higher amount of K compared to applied amount and ultimately large amount of K was removed from the soil leading the soil into negative balance. Similar trend of results were also observed by Paul (2005) in jute seed production.

5.28 K use efficiency

At lower level of K, KUE was found higher compared to higher levels of K application (Table 4.1.8). KUE decreased with increase in K uptake through increased K application. However the reduction of KUE with increased K uptake through increased added K indicated that yield of jute seed did not increase proportionately with the increase in K uptake. With the increase of K rates, the imbalance of N and P against K may restrict agronomic use efficiency of K at the higher doses of application (Chatterjee *et al.*, 2007). The result is in agreement with the findings of Paul (2005) who reported highest K use efficiency in olitorius jute seed with lower level of K application. In combined application of K and B significant difference in KUE among the treatments (Table 4.3.22). Potassium use efficiency was found to increase with increasing B fertilizers in jute seed production but boron use efficiency was found to reduce with increasing K and B rates of application.

5.29 Boron content

Since B was hypothesized to work on the level of plasma membrane in the root system, its deficiency caused a dramatic decrease in all nutrient contents of the plant tissues (Zude *et al.*, 1997). Paul (2005) stated similar observations in the production of jute seeds. Chatterjee *et al.* (2005) stated that concentration of B increased in leaves and seeds with an increase in B supply. But present study shows that boron application without K addition has led to decrease the B contents in different parts of jute plant. It might be due to the detrimental effect of B at higher doses without K application. Silva *et al.* (2008)

observed in cotton that positive yield responses to B were associated with K applications. Hill *et al.* (1975) reported that peanuts showed a significant increase of B by K interaction. The results showed that B fertilization was necessary to prevent yield reduction where high K fertilization was used.

5.30 Boron uptake

Increasing rate of B fertilization in single or in combination with K increased the B uptake and reported 0.28 to 0.62 kg B ha⁻¹ uptake in off season jute seed production (Paul, 2005). Singh *et al.* (2006) observed that total uptake of B increased with the increment of B supply and stated that total B uptake at 0 and 2.0 kg B ha⁻¹ was 98.58 and 198.72 g ha⁻¹, respectively in soybean. Reddy *et al.* (2002) reported that boron is important not only in increasing the yield but also to increasing the nutrient uptake. Significantly increase uptake of B was also reported by Islam *et al.* (1997) in rice production.

5.31 Boron balance

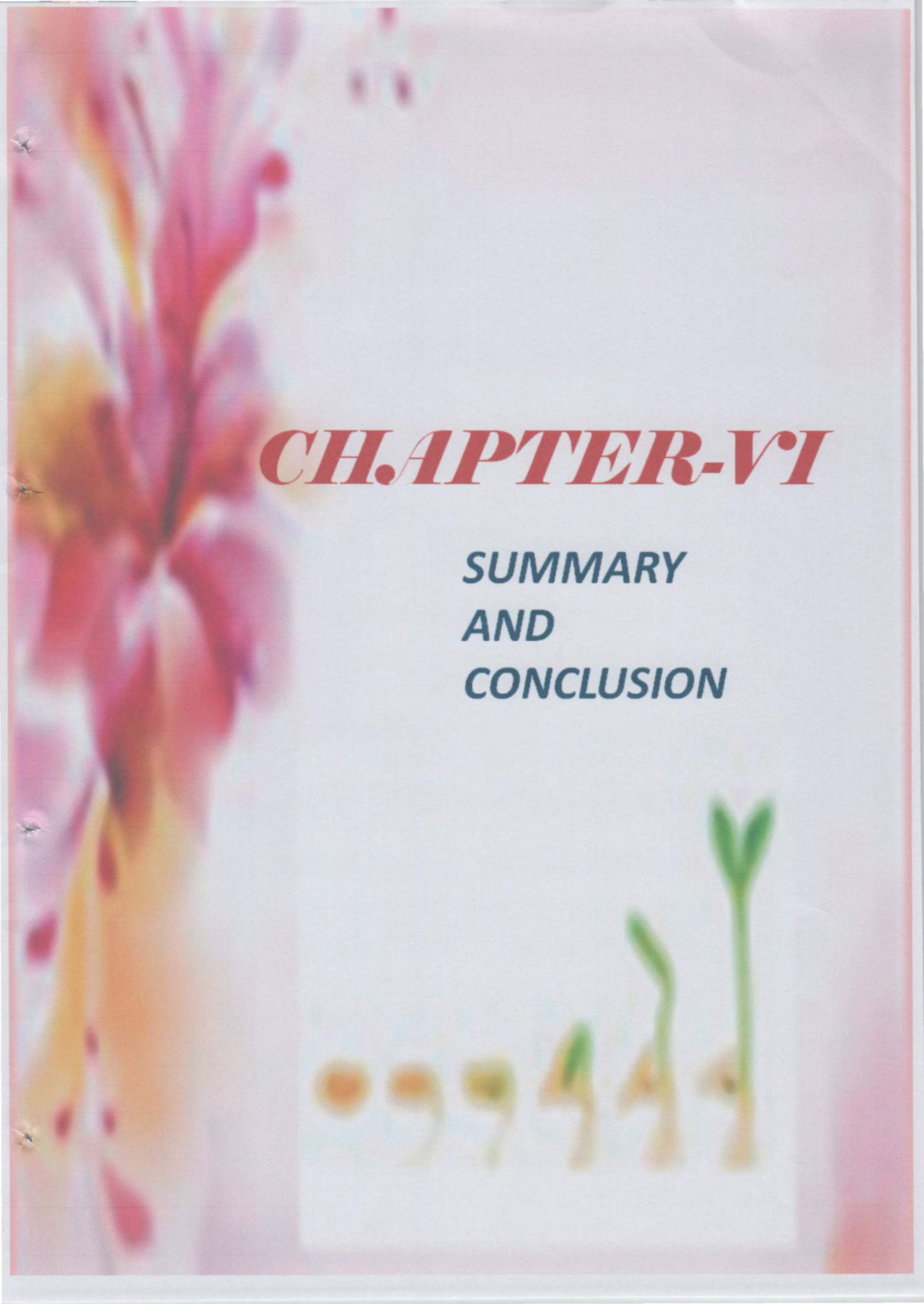
The application of B reduced the negative balance gradually. It may be for releasing higher B from its native pool where receiving lower B application to maintain a nutritional equilibrium in soil. The defoliated jute leaves and left over root of jute crop also contribute to build up of nutritional positive balance. From that addition in soil, measured final amount of B was higher than the calculated final amount. Reddy *et al.* (2002) in sunflower and Singh *et al.* (2006) in soyabean observed the same phenomenon.

5.32 Boron use efficiency

Boron use efficiency expressed as the ratio of dry jute seed yield to total B uptake was found significant. Boron use efficiency was found higher at lower doses whether it was applied in single or in combination with K. The reduction of BUE with increased B uptake through increased added B indicated that yield of jute seed did not increase proportionately with the increase in B uptake. The result is in agreement with the findings of Paul (2005) who reported highest B use efficiency in olitorius jute seed with 0 kg B ha⁻¹ application.

5.33 Benefit cost ratio (BCR)

Cost effectiveness of any crop determines its cultivation and higher the BCR lower the risk of cultivation of the crops. Individual and or combined application of K and B increased BCR in jute seed production. In case of single application of K the highest BCR (1.31) was recorded with 60 kg K ha⁻¹ as basal application where as it (BCR) was 1.34 by application of 2 kg B ha⁻¹ as basal at Dinajpur condition and in combined application the highest BCR (1.36) was achieved with 60 kg K + 2 kg B ha⁻¹ which was statistically identical with 60 kg K + 1 kg B ha⁻¹ (BCR= 1.33) and 90 kg K + 1 kg B ha⁻¹ (BCR=1.31) indicating that any of these treatment package may be recommended if soil fertility is ensured. Borhan *et al.* (2009) reported increased BCR (2.16) in jute cultivation with the application of 90 kg K ha⁻¹. Increased BCR with increased B fertilization was also reported by Abid *et al.* (2007) in cotton cultivation. It reveals from the study that jute seeds can be produced economically by application of K at 60kg ha⁻¹ at basal, but led to K mining at the rate of 17.51 kg ha⁻¹ and 2 kg B ha⁻¹ builds B reservation largely which may cause injurious effect to jute seed production. Hence, for sustainable soil productivity and considering profitability application of 90 kg K ha⁻¹ + 1kg B ha⁻¹ may be recommended for jute seed production.

The background of the page features a soft-focus image of a pink flower on the left and a white rectangular area on the right containing a diagram of a seedling's growth. The diagram shows a series of six stages of a plant growing from a seed. The first stage is a small brown seed. The second and third stages show the seedling with two small green leaves. The fourth stage shows the seedling with two larger green leaves. The fifth stage shows the seedling with two even larger green leaves. The sixth stage shows the seedling with two very large green leaves. The text 'CHAPTER-VI' is written in a large, bold, red, serif font across the middle of the page.

CHAPTER-VI

**SUMMARY
AND
CONCLUSION**

SUMMARY AND CONCLUSION

6.1 Summary

Three experiments were conducted in late sown condition at the Jute Seed Production and Research Centre, Nashipur, Dinajpur during 2007 and 2008 to determine the effective dose, time and methods for K and B application in order to increase (i) yield and quality of jute seeds, (ii) assess the changes in chemical composition of jute seeds as influenced by K and B, (iii) find out the effects of the nutrients on storability of the produced seeds, and (iv) prepare a balance sheet to ascertain the status of K and B after each crop harvest. For these purposes, *Corchorus olitorius* (Tossa) jute was used as test crop. First experiment had the target for selecting appropriate dose and methods for K application from amongst six levels of K (0, 30, 60, 90, 120 & 150 kg ha⁻¹) applied in three ways – (i) all K as basal at final land preparation, (ii) half as basal and rest half as top dressing at 35 days after sowing (DAS), and (iii) one third as basal one third at 25 DAS and the rest one third at 45 DAS as top dressing. The second experiment was also conducted parallel to first experiment to select the appropriate dose and methods of B application with four levels of B (0, 1, 2, & 3 kg ha⁻¹) applied as – (i) all B as basal (ii) half as basal and half as top dressing at 35 DAS, (iii) half as basal and half at 35 DAS as foliar spray, (iv) one third as basal, one third at 25 DAS and one third at 45 DAS as top dressing, and (v) one third as basal, one third at 25 DAS and one third at 45 DAS as foliar spray. The third experiment was carried out in the second year to find out the interaction effects of K and B with 16 treatment-combinations of K (four levels - 0, 30, 60 and 90 kg ha⁻¹) and B (four levels - 0, 1, 2 and 3 kg ha⁻¹), applying as basal modulated from the findings of earlier two experiments.

Results revealed that plant population, plant height, number of branch per plant, pod per plant, pod length, seed per pod, seed size and jute seed yield were significantly influenced by applied K and B fertilizers and their interaction effects. In case of K fertilization alone, at harvest the tallest plant (1.39 m), longest pod (6.29 cm), highest number of seeds per pod (173.50), maximum dry matter (6.77 t ha⁻¹) and the biggest seed size (2.149 mg) was recorded at the nutrient level 90 kg K ha⁻¹ as basal application. The highest plant population (4.24 lacs ha⁻¹), highest number of branches plant⁻¹ (4.44), highest number of pods plant⁻¹ (16.79) and highest seed yield (914 kg ha⁻¹, 19.24% higher compared to control) were recorded with 60 kg

K ha⁻¹ as basal application. In case of B fertilization alone, all the yield and yield attributing characters like highest plant population (4.35 lacs ha⁻¹), tallest plant height (1.28m), highest number of branch plant⁻¹ (4.47), highest TDM (6.59 t ha⁻¹), highest number of pods per plant (21.77), the biggest seed size (2.327 mg) and highest seed yield (985 kg ha⁻¹, 34.93% higher compared to that of control) were recorded with 2 kg B ha⁻¹ as basal application except maximum pod length (6.60 cm) and highest number of seeds per pod (184.75) which were recorded with 1 kg B ha⁻¹ as basal application. In case of interaction effect of K and B, all the growth parameters recorded highest with 60 kg K + 2 kg B ha⁻¹ as basal application resulting highest seed yield 997.66 kg ha⁻¹ (69.03% higher compared to that of control).

Qualitative attributes like germination, seed vigour, seedling dry weight, seed leachate conductivity, total soluble protein and total soluble sugar of freshly harvested seeds were significantly effected by K or B alone or their interaction effects. The highest germination 99.00%, 99.00 % and 99.00 % were recorded with the basal application of 90 kg K, 2 kg B and 60 kg K + 2 kg B per hectare, respectively which however, did not differ, statistically from the other treatments. The maximum seed leachate conductivity (455 μ S cm⁻¹) was recorded with no application of K and B and the lowest leachate reading (317 μ S cm⁻¹) was marked with the combined application of 60 kg K + 2 kg B ha⁻¹, which remained statistically at par with that of 60 kg K + 1 kg B ha⁻¹ (349 μ S cm⁻¹), 90 kg K + 1 kg B ha⁻¹ (342 μ S cm⁻¹) indicating increased of seed quality through combined application of K and B. The highest seedling dry weight (1.023 mg plant⁻¹) was recorded with 60 kg K + 1 kg B ha⁻¹, applied as basal followed by 0.97 mg and 0.984 mg plant⁻¹ recorded for basal application of 90 kg K ha⁻¹ or 2 kg B ha⁻¹ with the corresponding seed vigour 98.50, 97.83 and 98.33, respectively. The total soluble protein and sugar increased due to K and B fertilization and their interaction effects. The highest total soluble protein of 21.05 % was estimated from the seeds obtained by the application of 60 kg K + 1 kg B ha⁻¹ as basal whereas it was 20.45% with K @ 90 kg ha⁻¹ as basal and 21.0% for basal application of 2 kg B ha⁻¹. The total soluble sugar increased from 12.80 to 14.50% in case of K, 13.10 to 14.70 % in case of B and 12.72 to 14.71 % for combined application of K and B. The highest value of total soluble sugar were estimated from the seeds of the treatments with 90 kg K ha⁻¹, 2 kg B ha⁻¹ and 60 kg K + 2 kg B ha⁻¹, respectively. Lower values of the germination, seedling dry weight, total soluble protein and total soluble sugar were obtained

under control treatments i.e. K0, B0 and K0B0, respectively. Presence of soluble sugar in seed has great implication on seed quality as shows by a positive correlation between the total soluble sugar content and germination percentage of jute seeds.

In jute seed production, the K and B content, uptake and their balance was significantly influenced by K and B fertilization in single or in combined application. At harvest among the plant parts the K content were 0.53- 0.68 %, 0.69-0.85 %, 1.99% - 2.23% and 1.07% - 1.41% in root, shoot, leaves and seed. The content of B were 27 – 35ppm, 24-36 ppm, 29-46 ppm and 16-35 ppm in root, shoot, leaves and seeds, respectively. The highest B concentration (46ppm) was recorded in leaves and the lowest (16 ppm) in seeds with 90 kg K + 2 kg B ha⁻¹ and 0 kg K + 3 kg B ha⁻¹ fertilizer application, respectively indicating that increased application of B without K decreased the B contents in different parts of jute plants. The uptake of K by different plant parts of jute ranged from 3.80 kg to 9.11 kg ha⁻¹, 25.16 kg to 47.08 kg ha⁻¹, 7.47 to 21.81 kg ha⁻¹ and 7.36 kg to 15.61 kg ha⁻¹ in roots, shoots, leaves and seeds, respectively leading the total highest uptake of K (93.43 kg ha⁻¹, 114.78 % higher compared to that of control) with the application of 60 kg K + 2 kg B ha⁻¹. As a result the soil was a depleted state of -32.62 kg K ha⁻¹ while it was a positive balance of 1.32 kg K ha⁻¹ with the application of 90 kg K + 1 kg B ha⁻¹. The uptake of B by different plant parts of jute ranged from 30.17 to 63.87g ha⁻¹ in roots, 141.73 to 373.09 g ha⁻¹ in shoots, 16.83 to 54.53 g ha⁻¹ in leaves and 13.02 to 33.26 g ha⁻¹ in seeds. The highest total B uptake (519.29 g ha⁻¹, 157.39 % higher compared to control) was recorded for the application of 60 kg K + 1 kg B ha⁻¹. The maximum negative balance of B (-0.321 kg ha⁻¹) was recorded for the application of 90 kg K + 0 kg B ha⁻¹ while it was a positive balance of 0.514 kg B ha⁻¹ with the application of 90 kg K + 1 kg B ha⁻¹. The application of 1 or 2 kg B ha⁻¹, either alone or in combination with K, resulted in a positive balance of B in soils.

For shelf life study, seeds harvested from the three experiments were stored in air tight plastic pot and the corks were covered with wax. Seed qualities like germination, seedling dry weight, seed vigour, seed leachate conductivity (EC), total soluble protein and total soluble sugar were evaluated in 3 months interval up to one year. Irrespective of fertilization, all the seed qualities except EC, declined gradually during the storage period

and jute seeds maintained over 90% germination up to 6 months in storage. Application of 90 kg K ha⁻¹ as basal recorded the maximum germination 89% after 12 months storage which was 91% with 2 kg B ha⁻¹ as basal. Interaction effect of K and B, maintained a higher viability during the storage period and the maximum germination (92 %, after 12 months storage) was observed with the seeds obtained by the application of 90 kg K + 1 kg B ha⁻¹, which remained statistically at par with that of 60 kg K + 1 kg B ha⁻¹, 60 kg K + 2 kg B ha⁻¹, 60 kg K + 3 kg B ha⁻¹, 90 kg K + 2 kg B ha⁻¹, 90 kg K + 3 kg B ha⁻¹. The results indicated that the application of K and B combinedly had positive influence in maintaining the higher viability during the storage period. The minimal seedling dry weight reduction 7.08 %, 5.35 % and 5.18 %, were observed with 90 kg K, 2 kg B and 60 kg K + 2 kg B ha⁻¹ fertilization, respectively. Like seedling dry weight, applied nutrients contributed to a great extent in maintaining better seed vigour of jute seeds at storage. The electrical conductivity of seed leachate increased with the increase in storage period irrespective of fertilization. The minimal increase of electrical conductivity (17.03%) was observed for the seeds obtained with the combined application of 60 kg K ha⁻¹ + 2 kg B ha⁻¹ which remained statistically identical with that of 60 kg K + 1 kg B ha⁻¹, 90 kg K + 1 kg B ha⁻¹ and 90 kg K + 2 kg B ha⁻¹ treatments. Declining rate of total soluble protein and total soluble sugar contents in the seeds of control plots were faster where neither K nor B individually or combinedly were applied. The application of 90 K, 2 kg B and 60 kg K + 2 kg B per hectare recorded the minimal decline of total soluble protein contents of 9.17%, 6.67% and 4.41% whereas it was 9.21%, 7.14% and 5.16% in case of total soluble sugar , respectively. Jute seeds produced by higher levels of K or B fertilization or combined application of K and B could maintain higher levels of soluble protein and sugar contents throughout the storage period. This could happen due to slower rate of degradation of protein and sugar regulated by the higher levels of K and B in seeds.

Combined application of 60 kg K + 2 kg B per hectare recorded the highest BCR (1.36) which did not differ significantly from the BCR (1.33 and 1.31) recorded for the corresponding application of 60 kg K + 1 kg B and 90 kg K + 1 kg per hectare, respectively indicating that from these treatment packages recommendation may be made for increased amount of jute seed production after consideration of seed quality and soil fertility.

6.2 Conclusion

The application of K and B significantly increased both seed yield and seed quality of jute (*Corchorus olitorius*). Their basal application was found better than split application as top dressing or foliar sprays.

Potassium and boron uptake increased with their increased application and produced higher soluble protein and soluble sugar contents in seeds.

Seeds obtained from the application of K and B retained excellent germinability up to 9 months in storage compared to 6 months for no application of K and B.

Decline in total soluble protein and total soluble sugar in storage was much slower in seeds produced with K and B.

Application of 3 kg B ha⁻¹ caused some toxic effects on jute growth and seed production.

The treatment 60 kg K + 2 kg B per hectare produced more seeds and higher BCR compared to 90 kg K ha⁻¹ + 1 kg B ha⁻¹ but this difference was not statistically significant.

Positive K balance (1.32 kg ha⁻¹) in post harvest soil was found for the application of 90 kg K + 1 kg B per hectare whereas a negative balance of K (- 32.62 kg ha⁻¹) was recorded for the application of 60 kg K + 2 kg B per hectare.

7. RECOMMENDATION

Application of 90 kg K + 1 kg B ha⁻¹ as basal may be recommended for achieving consistent higher yields of good quality seeds of Tossa Jute (*Corchorus olitorius*).

Jute seeds may be stored in air tight plastic pots for one year without significant deterioration of seed qualities.

8. FUTURE STUDY

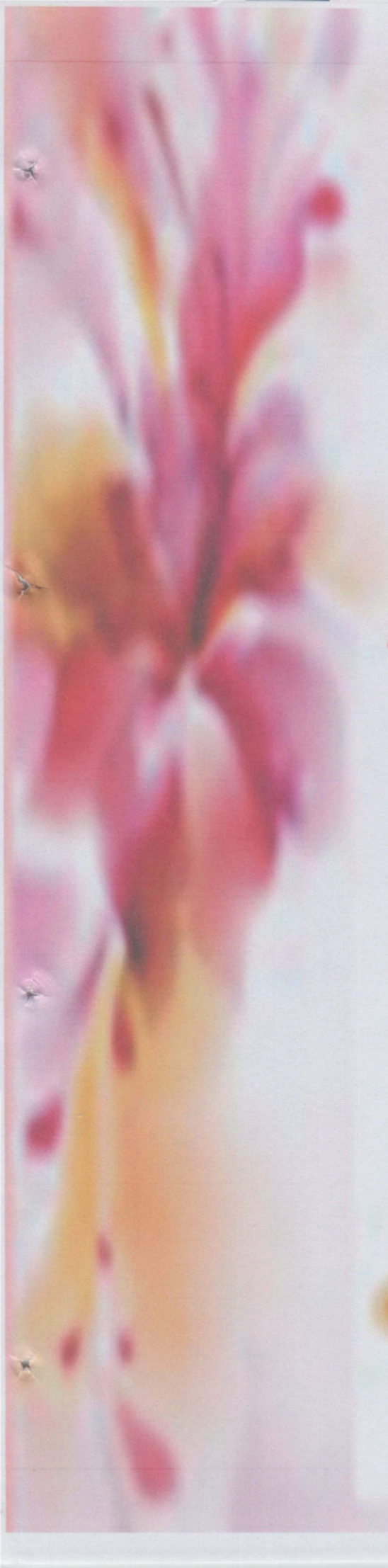
Similar trials may be carried out in other jute growing areas for arriving at a national recommendation.

Investigations on balanced fertilization and integrated nutrient management may also be done to determine its optimal dose for higher yield and quality seed production.

More studies should be done on tracing the causes for deterioration of seed qualities in storage.

Biochemical studies should be conducted to find out the correlation or regression between changes in enzymatic activities and seed quality deterioration.

Studies should be done to find out the role of selected nutrients on jute seed cell wall development and durability in storage.



CHAPTER-VII

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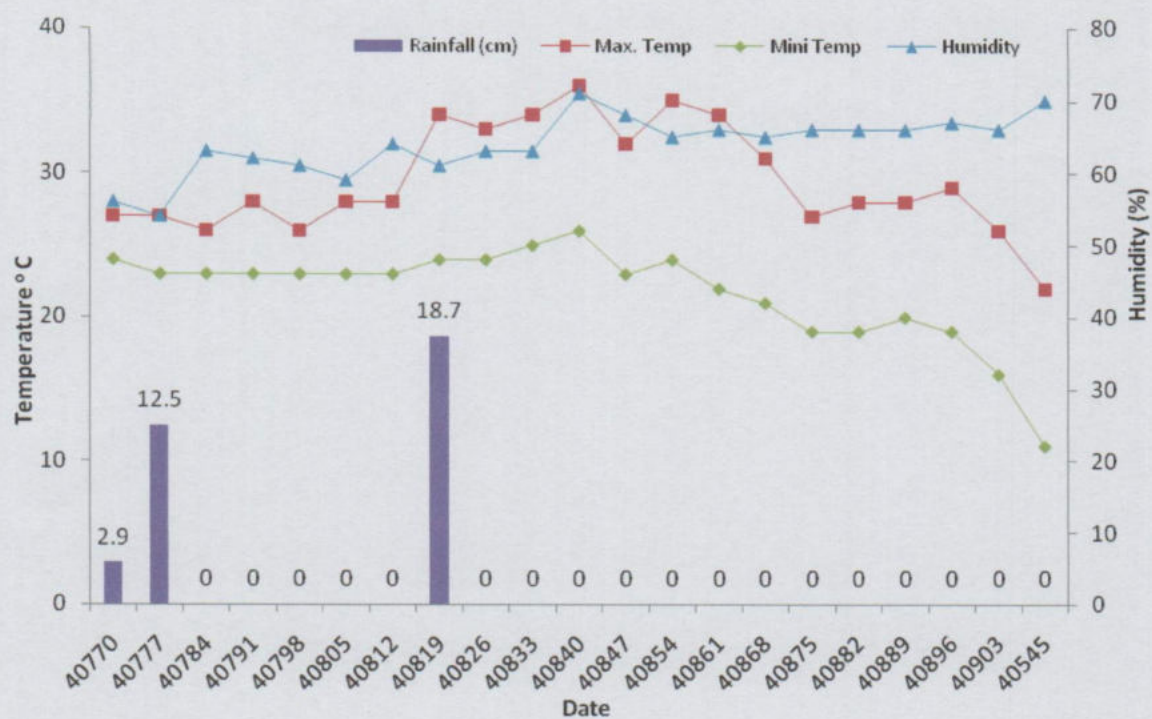
CHAPTER-VIII

APPENDICES

APPENDICES

Appendix Table 1: Weekly mean maximum-minimum temperature (°C), relative humidity (%) and rainfall during crop growing period in 2007-08

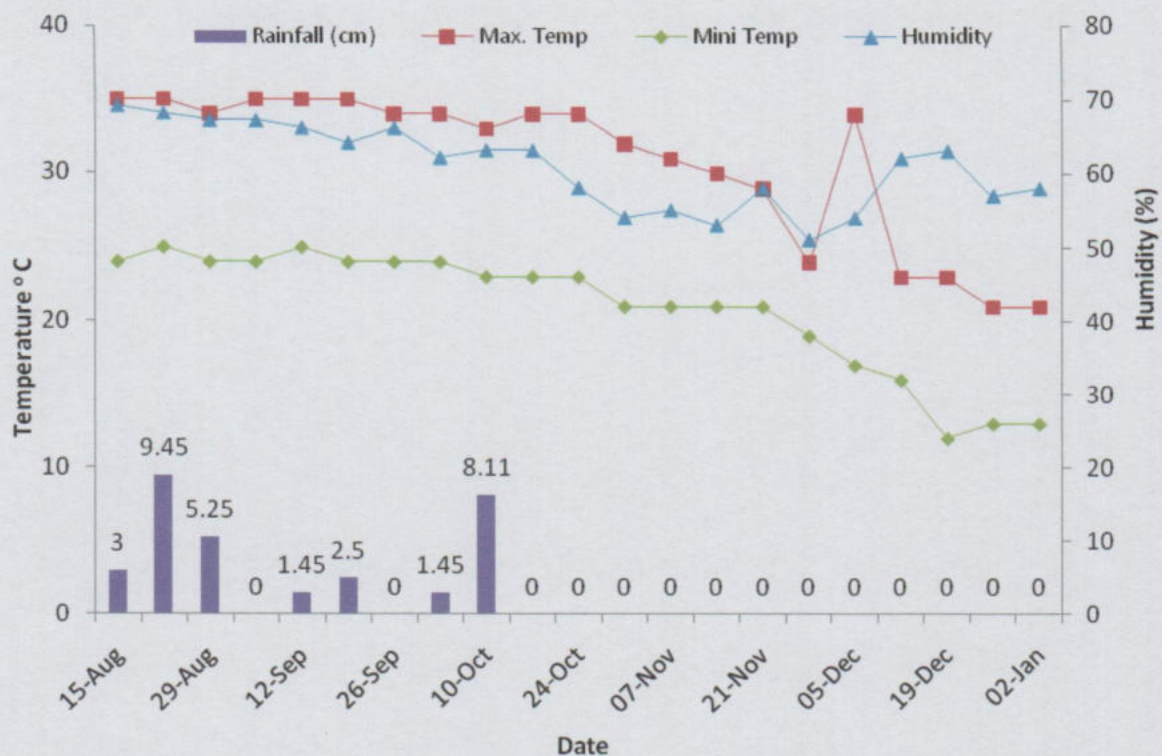
Time	Rainfall (cm)	Humidity (%)	Max. Temp (°C)	Mini Temp (°C)
15-Aug	2.9	56	27	24
22-Aug	12.5	54	27	23
29-Aug	0	63	26	23
05-Sep	0	62	28	23
12-Sep	0	61	26	23
19-Sep	0	59	28	23
26-Sep	0	64	28	23
03-Oct	18.7	61	34	24
10-Oct	0	63	33	24
17-Oct	0	63	34	25
24-Oct	0	71	36	26
31-Oct	0	68	32	23
07-Nov	0	65	35	24
14-Nov	0	66	34	22
21-Nov	0	65	31	21
28-Nov	0	66	27	19
05-Dec	0	66	28	19
12-Dec	0	66	28	20
19-Dec	0	67	29	19
26-Dec	0	66	26	16
02-Jan	0	70	22	11



Appendix Fig.1: Weekly mean maximum minimum temperature (°C), relative humidity (%) and rainfall during crop growing period in 2007-08.

Appendix Table 2: Weekly mean maximum-minimum temperature (°C), relative humidity (%) and rainfall during crop growing period in 2008-09

Time	Humidity (%)	Max. Temp (°C)	Mini Temp (°C)	Rainfall (cm)
15-Aug	56	27	24	2.9
22-Aug	54	27	23	12.5
29-Aug	63	26	23	0
05-Sep	62	28	23	0
12-Sep	61	26	23	0
19-Sep	59	28	23	0
26-Sep	64	28	23	0
03-Oct	61	34	24	18.7
10-Oct	63	33	24	0
17-Oct	63	34	25	0
24-Oct	71	36	26	0
31-Oct	68	32	23	0
07-Nov	65	35	24	0
14-Nov	66	34	22	0
21-Nov	65	31	21	0
28-Nov	66	27	19	0
05-Dec	66	28	19	0
12-Dec	66	28	20	0
19-Dec	67	29	19	0
26-Dec	66	26	16	0
02-Jan	70	22	11	0



Appendix Fig.2: Weekly mean maximum minimum temperature ($^{\circ}\text{C}$), relative humidity (%) and rainfall during crop growing period in 2008-09.

[Source: Weather yeard, Nashipur sub-station, BJRI]

Appendix Table- 3: Balance sheet of K as affected by K dose and split application in jute seed production

Treat 1	Initial soil status or balance (kg ha ⁻¹) 2	Added nutrients or Inputs (kg ha ⁻¹) 3	Uptake of nutrients or Output (kg ha ⁻¹) 4	Nutrients balance (Apparent) (kg ha ⁻¹) 5= (3-4)	Post harvest status or balance at harvest (kg ha ⁻¹) 6
T1	122.60	0	59.47	-59.47	113.84
T2	122.60	0	59.51	-59.51	113.84
T3	122.60	0	59.51	-59.51	105.09
T4	122.60	30	70.94	-40.94	122.60
T5	122.60	30	69.21	-39.21	131.36
T6	122.60	30	66.43	-36.43	131.36
T7	122.60	60	91.95	-31.95	148.87
T8	122.60	60	78.23	-18.23	131.36
T9	122.60	60	77.15	-17.15	148.87
T10	122.60	90	96.72	-6.72	175.15
T11	122.60	90	79.22	10.78	157.63
T12	122.60	90	77.05	12.95	148.87
T13	122.60	120	85.56	34.44	192.66
T14	122.60	120	77.29	42.71	183.90
T15	122.60	120	77.29	42.71	192.66
T16	122.60	150	80.98	69.02	201.42
T17	122.60	150	78.01	71.99	183.90
T18	122.60	150	79.87	70.13	192.66

Appen. Table 5: BCR in seed production with different doses and split application of K

Treatments	GB (Tk ha ⁻¹)	Cost (Tk ha ⁻¹)	NR (Tk ha ⁻¹)	BCR
T1 (0 kg K ha ⁻¹ : all as basal at final land preparation)	76650/-	39210/-	37440/-	0.95fg
T2 (0 kg K ha ⁻¹ : half as basal and rest half at 30- 35 DAS as top dressing)	77400/-	39210/-	38190/-	0.97f
T3 (0 kg K ha ⁻¹ : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	76950/-	39210/-	37740/-	0.96fg
T4 (30 kg K ha ⁻¹ : all as basal at final land preparation)	77650/-	39690/-	37960/-	0.96fg
T5 (30 kg K ha ⁻¹ : half as basal and rest half at 30- 35 DAS as top dressing)	74600/-	39690/-	34910/-	0.88g
T6 (30 kg K ha ⁻¹ : One- third as basal, one- third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	77200/-	39690/-	37510/-	0.95fg
T7 (60 kg K ha ⁻¹ : all as basal at final land preparation)	92790/-	40170/-	52620/-	1.31a
T8 (60 kg K ha ⁻¹ : half as basal and rest half at 30- 35 DAS as top dressing)	89170/-	40170/-	49000/-	1.22bc
T9 (60 kg K ha ⁻¹ : One- third as basal, one- third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	81550/-	40570/-	40980/-	1.01ef
T10 (90 kg K ha ⁻¹ : all as basal at final land preparation)	92650/-	40650/-	52000/-	1.28ab
T11 (90 kg K ha ⁻¹ : half as basal and rest half at 30- 35 DAS as top dressing)	87550/-	39250/-	48300/-	1.23cd
T12 (90 kg K ha ⁻¹ : One- third as basal, one-third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	88500/-	40050/-	48450/-	1.21bc
T13 (120 kg K ha ⁻¹ : all as basal at final land preparation)	85350/-	40530/-	44820/-	1.11cd
T14 (120 kg K ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	84600/-	41930/-	42670/-	1.02ef
T15 (120 kg K ha ⁻¹ : One- third as basal, one- third at 20- 25 DAS and rest one-third at 40-45 DAS as top dressing)	81950/-	41930/-	40020/-	0.95fg
T16 (150 kg K ha ⁻¹ : all as basal at final land preparation)	80450/-	39810/-	40640/-	1.02ef
T17 (150 kg K ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	89000/-	40610/-	48390/-	1.19abc
T18 (150 kg K ha ⁻¹ : One- third as basal, one- third at 20- 25 DAS and rest one-third at 40- 45 DAS as top dressing)	84100/-	40610/-	43490/-	1.07de

Means within column followed by common letters are not significantly different at 5% level of DMRT

Appendix Table 6: Balance sheet of B as affected by B dose and methods of application in jute seed production

Treatments 1	Initial soil status or balance (kg ha ⁻¹) 2	Added nutrient or Inputs (kg ha ⁻¹) 3	Uptake of nutrients or Output (kg ha ⁻¹) 4	Nutrients balance (Apparent) (kg ha ⁻¹) 5= (3-4)	Soil balance at harvest (kg ha ⁻¹) 6
T1 (0 kg B ha ⁻¹ : all as basal at final land preparation)	0.359	0	0.275	-0.275	0.314
T2 (0 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	0.359	0	0.286	-0.286	0.269
T3 (0 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	0.359	0	0.287	-0.287	0.292
T4 (0 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	0.359	0	0.281	-0.281	0.314
T5 (0 kg B ha ⁻¹ : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	0.359	0	0.285	-0.285	0.314
T6 (1 kg B ha ⁻¹ : all as basal at final land preparation)	0.359	1	0.463	0.537	0.314
T7 (1 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	0.359	1	0.425	0.575	0.292
T8 (1 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	0.359	1	0.412	0.588	0.314
T9 (1 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	0.359	1	0.419	0.581	0.337
T10 (1 kg B ha ⁻¹ : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	0.359	1	0.400	0.599	0.337
T11 (2 kg B ha ⁻¹ : all as basal at final land preparation)	0.359	2	0.498	1.502	0.337
T12 (2 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	0.359	2	0.488	1.512	0.314
T13 (2 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	0.359	2	0.448	1.551	0.314
T14 (2 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	0.359	2	0.416	1.583	0.337
T15 (2 kg B ha ⁻¹ : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	0.359	2	0.454	1.545	0.337
T16 (3 kg B ha ⁻¹ : all as basal at final land preparation)	0.359	3	0.417	2.583	0.359
T17 (3 kg B ha ⁻¹ : half as basal and rest half at 30-35 DAS as top dressing)	0.359	3	0.400	2.600	0.337
T18 (3 kg B ha ⁻¹ : Half as basal and half at 30-35 DAS as foliar spray)	0.359	3	0.402	2.598	0.359
T19 (3 kg B ha ⁻¹ : One third as basal, One-third at 20-25 DAS and rest one-third at 40-45 DAS as top dressing)	0.359	3	0.415	2.585	0.359
T20 (3 kg B ha ⁻¹ : One- third as basal, one-third at 20-25 DAS and rest one-third at 40-45 DAS as foliar spray)	0.359	3	0.426	2.574	0.337

Appendix Table 7: Cost of jute seed production per hectare of land by B application

Treat.	Fuel required for ploughing (Power tiller) and laddering ¹	Labour ² No.	Seed ³ (kg ha ⁻¹)	Fertilizer ⁴ (kg ha ⁻¹)	Total cost (TK)
T1	51.5 litre diesel	141	4	U=200,T=100,MP=30 G=100 , Z= 4, B= 0	40402/-
T2	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 0	40402/-
T3	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 0	40402/-
T4	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 0	40402/-
T5	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 0	40402/-
T6	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 1	40767/-
T7	51.5 litre diesel	145	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 1	41567/-
T8	51.5 litre diesel	145	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 1	41567/-
T9	51.5 litre diesel	149	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 1	42367/-
T10	51.5 litre diesel	149	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 1	42367/-
T11	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 2	41132/-
T12	51.5 litre diesel	145	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 2	41932/-
T13	51.5 litre diesel	145	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 2	41932/-
T14	51.5 litre diesel	149	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 2	42732/-
T15	51.5 litre diesel	149	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 2	42732/-
T16	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 3	41497/-
T17	51.5 litre diesel	145	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 3	42297/-
T18	51.5 litre diesel	145	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 3	42297/-
T19	51.5 litre diesel	149	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 3	43097/-
T20	51.5 litre diesel	149	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 3	43097/-

1= No. of operation 4 and 11 Litre Diesel oil is required for one operation and 2.5 litre for 1 laddering and 3 laddering is required and oil cost TK. 68/Litre

2=Labour = (ploughing +Laddering) + (Grass cleaning + Leveling) + Sowing+ 1st weeding + 2nd weeding + fertilizer application+ Harvesting and carrying+ Drying, threshing and cleaning = 12+12+6+25+20+5+33+28=141 and labour cost TK. 200/-/day

3= Seed, 4 kg and seed cost TK. 200/kg

4=Fertilizer: U= Urea, 20.00 Tk / kg, , T=TSP, 22.00Tk /kg, 35 tk/kg, M= MP, 16.00Tk/kg, G=Gypsum, 7 Tk/kg, Z=Zinc sulphate, 130/-Tk/kg and B=Solubor boron, 365.00Tk/kg.

Appendix Table 8: BCR in seed production with different doses and methods of B application

Sl. No.	GB (Tk ha ⁻¹)	Cost (Tk ha ⁻¹)	NR (Tk ha ⁻¹)	BCR
T1	75400	40402	34998	0.87hi
T2	76400	40402	35998	0.89ghi
T3	75500	40402	35098	0.87hi
T4	76700	40402	36298	0.90ghi
T5	73000	40402	32598	0.81i
T6	94171	40767	53404	1.31ab
T7	93000	41567	51433	1.24cd
T8	86100	41567	44533	1.07ef
T9	90100	42367	47733	1.13de
T10	84500	42367	42133	0.99fg
T11	24796	41132	55115	1.34a
T12	95800	41932	53868	1.28bc
T13	87300	41932	45368	1.08ef
T14	91000	42732	48268	1.13de
T15	91200	42732	48468	1.13de
T16	91600	41497	50103	1.21cd
T17	94900	42297	52603	1.24cd
T18	85700	42297	43403	1.03ef
T19	84900	43097	41803	0.97fgh
T20	86900	43097	43803	1.02ef

**Appendix Table 9: Balance sheet of K and B as affected by interaction effect of K and B
in jute seed production**

Treatment (K and B kg ha ⁻¹) 1	Initial soil status or balance (kg ha ⁻¹) 2		Added nutrients or Inputs (kg ha ⁻¹) 3		Uptake of nutrients Or outputs (kg ha ⁻¹) 4		Nutrients balance (Apparent) (kg ha ⁻¹) 6 = (3-4)		Post harvest Soil balance/status (kg ha ⁻¹) 7	
	K	B	K	B	K	B	K	B	K	B
T1 (K0B0)	122.60	0.359	0	0	43.50	0.202	-43.50	-0.202	113.84	0.404
T2 (K0B1)	122.60	0.359	0	1	47.63	0.257	-47.63	0.743	113.84	0.404
T3 (K0B2)	122.60	0.359	0	2	57.60	0.297	-57.60	1.703	105.09	0.382
T4 (K0B3)	122.60	0.359	0	3	55.33	0.282	-55.33	2.718	113.84	0.404
T5 (K30B0)	122.60	0.359	30	0	53.85	0.268	-23.85	-0.268	140.12	0.404
T6 (K30B1)	122.60	0.359	30	1	78.35	0.424	-48.35	0.576	140.12	0.449
T7 (K30B2)	122.60	0.359	30	2	67.57	0.418	-37.57	1.582	140.12	0.472
T8 (K30B3)	122.60	0.359	30	3	68.49	0.407	-38.49	2.593	131.36	0.472
T9 (K60B0)	122.60	0.359	60	0	69.71	0.369	-09.71	-0.369	148.88	0.404
T10 (K60B1)	122.60	0.359	60	1	92.17	0.519	-32.17	0.481	157.63	0.494
T11 (K60B2)	122.60	0.359	60	2	93.43	0.518	-33.43	1.492	157.63	0.494
T12 (K60B3)	122.60	0.359	60	3	78.57	0.402	-18.57	2.598	166.39	0.494
T13 (K90B0)	122.60	0.359	90	0	70.60	0.388	19.40	-0.388	166.39	0.404
T14 (K90B1)	122.60	0.359	90	1	88.68	0.486	1.32	0.514	175.15	0.539
T15 (K90B2)	122.60	0.359	90	2	79.75	0.487	10.25	1.513	183.90	0.561
T16 (K90B3)	122.60	0.359	90	3	77.32	0.483	12.68	2.517	183.90	0.539

Appendix Table 10: Cost of jute seed production per hectare of land by combined application of K and B

Trt.	Fuel required for ploughing (Power tiller) and laddering ¹	Labour ² No.	Seed ³ Kg ha ⁻¹	Fertilizer ⁴ Kg ha ⁻¹	Total cost (TK)
T1	51.5 litre diesel	141	4	U=200,T=100,MP=0, G=100 , Z= 4, B= 0 200X20+ 100X22+ 0X16+ 100X 7+4X130+0X365=	40522
T2	51.5 litre diesel	141	4	U=200,T=100,MP=0, G=100 , Z= 4, B= 1 200X20+ 100X22+ 0X16+ 100X 7+4X130+1X365=	40887
T3	51.5 litre diesel	141	4	U=200,T=100,MP=0, G=100 , Z= 4, B= 2 200X20+ 100X22+ 0X16+ 100X 7+4X130+2X365=	41252
T4	51.5 litre diesel	141	4	U=200,T=100,MP=0, G=100 , Z= 4, B= 3 200X20+ 100X22+ 0X16+ 100X 7+4X130+3X365=	41617
T5	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 0 200X20+ 100X22+ 30X16+ 100X 7+4X130+0X365=	41002
T6	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 1 200X20+ 100X22+ 30X16+ 100X 7+4X130+1X365=	41367
T7	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 2 200X20+ 100X22+ 30X16+ 100X 7+4X130+2X365=	41732
T8	51.5 litre diesel	141	4	U=200,T=100,MP=30, G=100 , Z= 4, B= 3 200X20+ 100X22+ 30X16+ 100X 7+4X130+3X365=	42097
T9	51.5 litre diesel	141	4	U=200,T=100,MP=60, G=100 , Z= 4, B= 0 200X20+ 100X22+ 60X16+ 100X 7+4X130+0X365=	41482
T10	51.5 litre diesel	141	4	U=200,T=100,MP=60, G=100 , Z= 4, B= 1 200X20+ 100X22+ 60X16+ 100X 7+4X130+0X365=	41847
T11	51.5 litre diesel	141	4	U=200,T=100,MP=60, G=100 , Z= 4, B= 2 200X20+ 100X22+ 0X16+ 100X 7+4X130+0X365=	42212
T12	51.5 litre diesel	141	4	U=200,T=100,MP=60, G=100 , Z= 4, B= 3 200X20+ 100X22+ 60X16+ 100X 7+4X130+0X365=	42577
T13	51.5 litre diesel	141	4	U=200,T=100,MP=90, G=100 , Z= 4, B= 0 200X20+ 100X22+ 90X16+ 100X 7+4X130+0X365=	41962
T14	51.5 litre diesel	141	4	U=200,T=100,MP=90, G=100 , Z= 4, B= 1 200X20+ 100X22+ 90X16+ 100X 7+4X130+0X365=	42327
T15	51.5 litre diesel	141	4	U=200,T=100,MP=90, G=100 , Z= 4, B= 2 200X20+ 100X22+ 90X16+ 100X 7+4X130+0X365=	42692
T16	51.5 litre diesel	141	4	U=200,T=100,MP=90, G=100 , Z= 4, B= 3 200X20+ 100X22+ 90X16+ 100X 7+4X130+0X365=	43057

1= No. of operation 4 and 11 Litre Diesel oil is required for one operation and 2.5 litre for 1 laddering and 3 laddering is required and oil cost TK. 68/Litre

2=Labour = (ploughing +Laddering) + (Grass cleaning + Leveling) + Sowing+ 1st weeding + 2nd weeding + fertilizer application+ Harvesting and carrying+ Drying, threshing and cleaning and storing = 12+12+6+25+20+5+33+33=146 and labour cost TK. 200/-/day

3= Seed, 4 kg and seed cost TK. 200 kg⁻¹

4=Fertilizer: U= Urea, 20.00 Tk kg⁻¹, T=TSP, 22.00Tk kg⁻¹, 35 Tk kg⁻¹, M= MP, 16.00Tk kg⁻¹, G=Gypsum, 7 Tk kg⁻¹, Z=Zinc sulphate, 130/-Tk kg⁻¹ and B=Solubor boron, 365.00Tk kg⁻¹.

Appendix Table 11: BCR in seed production with interaction effect of K and B

Sl. No.	GB (Tk ha ⁻¹)	Cost (Tk ha ⁻¹)	NR (Tk ha ⁻¹)	BCR
T1 (K0B0)	59024	40522	18502	0.46e
T2 (K0B1)	64354	40887	23467	0.57e
T3 (K0B2)	79436	41252	38184	0.93cd
T4 (K0B3)	74388	41617	32771	0.79d
T5 (K30B0)	76823	41002	35821	0.87d
T6 (K30B1)	92778	41367	51411	1.24ab
T7 (K30B2)	93650	41732	51918	1.24ab
T8 (K30B3)	93683	42097	51586	1.23ab
T9 (K60B0)	91956	41482	50474	1.22ab
T10 (K60B1)	97666	41847	55819	1.33ab
T11 (K60B2)	99723	42212	57511	1.36a
T12 (K60B3)	95150	42577	52573	1.23ab
T13 (K90B0)	92634	41962	50672	1.21ab
T14 (K90B1)	97727	42327	55400	1.31ab
T15 (K90B2)	95750	42692	53058	1.24ab
T16 (K90B3)	91123	43057	48066	1.12bc