HYBRID MAIZE SEED PRODUCTION UNDER DIFFERENT LEVELS OF LIME AND BORON APPLICATION

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A thesis
Submitted to the department of Agronomy,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE
IN
AGRONOMY

Semester: July-December, 2008

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This is to certify that the thesis entitled "Hybrid maize seed production under different levels of lime and boron application" submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of Master of Science in Agronomy, embodies the result of a piece of bona fide research work carried out by Shamim Ara Bagum, Registration No. 02-01510 under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENT

All praises goes to Almighty Allah for best owing mercy upon here and for imbibing confidence on her to materialize the research work.

The Author expresses her deepest sense of gratitude, sincere appreciation and immense indebtedness to her Major Professor and beloved teacher, the supervisor, Professor Dr. Md. Fazlul Karim, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207 for his continued guidance during pursuing the research work and preparation of the manuscript.

The Author respectfully expresses her indebtedness to the respected Co-supervisor, Dr. Md. Altab Hossain, CSO, Agronomy Division, BARI, Gazipur, for his ken interest, scholastic guidance, precious suggestions, encouragement, patience and constructive criticisms from the beginning to the end of the research work. The Author expresses her heartfelt indebtness to him for offering valuable suggestions for the improvement of the thesis writing and editing.

She is thankful to M. Shalim Uddin, SSO, Plant Breeding Division, BARI, Gazipur, for him thoughtful suggestion in the preparation of the research proposal and programme, continuous guidance, valued association and encouragement of studies from the beginning to the end of the research work.

The Author also humbly expresses her gratitude to the Director General, BARI for administrative support and she also thankful to the CSO, Plant Breeding Division and Project Director of "Development of Hybrid Maize Research in Bangladesh " BARI, Joyebpur , Gazipur for financial support for research.

She is also thankful to Ashratun Nessa, PSO, Seed Technology Division, BARI, Joyebpur , Gazipur; Dr. Md. Rowshin Ali CSO, RARS, BARI, Jessore; Professor Md.

Shamsul Haque, Department of BioChemistry, Sher-e-Bangla Agricultural University, Dhaka-1207; Dr. Md. Hafiz Ullah, PSO, Agricultural Research Center, BARI, Buriarhut , Rangpur; CSO, PSO, Soil Science Division; Project Director, Oilseeds Research Center; Dr. Farida Begum, PSO, Agronomy Division, BARI, Joyebpur, Gazipur for their time to time specific valuable help.

Thanks are also extended to Md. Matar Rahman, SSA, Agricultural Research Center, Buriarhut, BARI, Rangpur, for his kind assistance. She would like to thank to the staff-members in the Seed Technology Division, Soil Science Division Laboratories and Central laboratory, for their kind assistance.

With deepest emotion she would like to express her enormous appreciation and gratefulness to her beloved husband Md. Shalim Uddin for his painstaking service, continuous guidance, generous help and assistance during study period. She expresses also her cordial feelings and affectionate love to her son 'Saif Shalim' for his immense patience, untold sacrifice during inordinate absence from home.

Finally, this acknowledgement will not be complete if she do not explicit her sincere thanks to her honorable parents Md. Belayet Hossain, Late Monoara Begum, father in-law Professor Dr. Abdul Wadud, Dhaka Medical Collage Hospital, Dhaka, Dr. Abul Kashem, Ex. Director Horticulture Research Center, BARI Joyebpur, Gazipur, sisters, brother for their patience, inspiration, encouragement and endless love to complete higher study.

The Author

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ABSTRACT

Field trial on hybrid maize (cv. BARI Hybrid Maize-5) seed production was conducted in Non-Calcareous Floodplain Soils under Tista Meander Floodplain (AEZ 3) of Agricultural Research Station, BARI, Burirhat, Rangpur during *rabi* season of 2007-2008 to find out the optimum lime and boron doses for quality seed production of hybrid maize. Three levels of lime (0.0, 1.5 and 3.0 t ha^{-1}) and four levels of boron (0, 1, 2 and 3 kg ha^{-1}) were used as treatment variables. A blanket dose of $N_{120}P_{35}K_{65}S_{20}Zn_5$ kg ha^{-1} and cowdung 5.0 t ha^{-1} were used in the study. The treatments were arranged in a split plot design with 3 replications. Lime treatments were randomly arranged in main plot and boron levels in the sub plot. Different fertilizer treatments have created significant influence on growth, yield, yield contributing characters and quality of hybrid maize seed. Leaf area $plant^{-1}$, leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) of female parent of BARI hybrid maize-5 was increased sharply from 60 days after sowing (DAS) and reaching maximum at 120 DAS and then declined sharply irrespective of treatment differences.

The combined effect of boron and lime was found superior to their single application. The interaction effect between boron and lime was significant for hybrid maize seed yield. The highest yield (2809 kg) was

recorded from boron @2.12 kg ha^{-1} and lime @ 1.5 t ha^{-1} application. From regression equation, optimum and economic dose for B in respect of without liming was calculated to be 2.40 and 2.39 kg B ha^{-1}; with 1.5 t ha^{-1}liming, it was 2.13 and 2.12 kg B ha^{-1} and with 3 t ha^{-1} liming it was 2.0 and 1.99 kg B ha^{-1}along with blanket dose of $N_{120}P_{35}K_{65}S_{20}Zn_5$kg ha^{-1} plus 5.0 t cowdung ha^{-1}. The results revealed that boron @ 2.12-2.13 kg ha^{-1} and lime @ 1.5 t ha^{-1} along with a blanket dose of $N_{120}P_{35}K_{65}S_{20}Zn_5$kg ha^{-1} plus 5.0 t cowdung ha^{-1} could be optimum for maximizing the quality seed yield of hybrid maize in Rangpur region (AEZ 3).

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LIST OF ACRONYMS

%	Percentage
@	At the rate of
° C	Degree Celsius
° E	Degree East
° N	Degree North
$\mu g\ g^{-1}$	Micro gram per gram
ANOVA	analysis of variance
B	Boron
BARI	Bangladesh Agricultural Research Institute
BIL	Bangladesh Inbred Line
Ca	Calcium
CGR	Crop Growth Rate
CIMMYT	International Maize and Wheat Improvement Center
cm	Centimeter
cm^2	Centimeter square
Cu	Cupper
DAE	Day after emergence
DAE	Department of Agricultural Extension
DAS	days after sowing
DMRT	Duncan's Multiple Range Test DMRT
EC	Electric Conductivity
et al	And other
Fe	Ferrous
ft	Feet
g	Gram(s)
ha	Hector
HI	harvest index
K	Potassium
kg	Kilogram
L	leaf area
L	lime
LA)	Leaf area
LAI	Leaf Area Index
LAR	Leaf Area Ratio
LWR	Leaf Weight Ratio
m	Meter
meq	Mile equivalent
Mg	Magnesium
mm	Mile-meter
Mn	Manganese
MoA	Ministry of Agriculture
N	Nitrogen

No	Number
OM	Organic matter
P	Phosphorus
RGR	Relative growth Rate
S	Sulfur
SLA	Specific Leaf Area
SLM	Specific Leaf Mass
SLW	Specific Leaf Mass or Weight
t	Tone
TDM	total dry matter
Zn	Zink

CHAPTER 1

INTRODUCTION

Maize (*Zea mays* L.) plays a significant role in human and livestock nutrition worldwide. In Bangladesh, it is an important cereal crop ranks third and first position in terms of acreage and per hectare production respectively. It has versatile uses and can be grown almost year round .The yield potentiality of maize is higher than rice and wheat. Its grain has high nutritive value containing 66.2% starch, 11.1% protein, 7.12% oil and 1.5% minerals (Gopalan *et al.*, 1981). However, area and production of maize is increasing day by day in Bangladesh because of high demand of the fast growing poultry feed industry. Hybrid maize cultivation is also becoming popular among the farmer. Its production has increased significantly in the country.

Maize is well adapted to the climate and soils of Bangladesh. About 82% of maize is grown in *rabi* season (November to March), but maize could be grown round the year. At present maize is expanding rapidly in north, north-west, west and central part of Bangladesh (Appendix 1) because the crop grows well and the financial returns are attractive. It is the best cereal option for increasing carbohydrate production per unit land per day in a country where as the land is decreasing day by day.

Open-pollinated races of maize have been cultivated in this part of the world since long although their performance is poor compared to modern hybrids. F1 have dominated agricultural production in the developed world , whereas , open-pollinated are commonly grown in developing countries because they are viewed to be well suited to regions where traditional agricultural practices are still the rule (CIMMYT , 1984) . The superiority of maize hybrids in grain yield (Djisbar and Gardner, 1989) and open-pollinated varieties compared to inbred lines is widely recognized. However, the morphological and physiological determinants of yield among genotypes varying greatly in yield potential have not been adequately assessed. Quantitative comparisons among genotypes have generally determined ear and grain yield without considering certain vegetative and grain components that may have had a pronounced effect on the total outcome. Heterotic maize hybrids exhibit superiority in vegetative and reproductive characters and finally in yield. Yield is the result of several cumulative reactions and processes during the ontogeny of the plant. Physiologically the enhancement in yield could come either from increased capacity of the plant to produce more dry matter or from better development of grains. Of these processes, the former would be essentially dependent on the total photosynthetic potential of the plant, whereas the grain development could be dependent either on the optimum partioning of photosynthates towards the grain or their own metabolic potential to grow.

Hybrid maize cultivation has been increasing at the rate of about 20-25% per year since nineties (Appendix 2). Maize productivity in the country seems to be the highest in the Asian region with an average yield of 5.75 t ha^{-1}. In Bangladesh, higher yield up to 8-10 t ha^{-1} can be obtained using hybrid seeds, balance fertilizers and better management (Quayyum and Hoque, 1995; Iqbal, 2001). This is due to favorable agro-climatic condition during the maize growing season (October to March) and the use of hybrid seeds and also follow improve production practices by growers (Gonzalez *et al*., 2001).

Seed is one of the main limiting factors for expansion of maize area in the country. Presently, Bangladesh needs about 3000-3500 tons of hybrid maize seed per year (Appendix 3) and can meet only 10-15% of its requirement from domestic production, and the rest is imported at a huge cost of foreign currency (Uddin, *et al*., 2007). So, local production of hybrid seed should be expanded to reduce import. Bangladesh has a condition which is favorable to develop maize seed industry (Gonzalez *et al*., 2001). Private seed companies and NGOs should come forward to produce hybrid seed locally for expansion of seed industry.

The success of hybrids of maize in place of open-pollinated varieties in Bangladesh has necessitated the production of hybrid maize seed on large scale. The spectacular growth of the seed industry stands testimony to these efforts. Seed production is a specialized and essential industry today. The hybrid seed production is a specialized operation that calls for a higher level of competence to meet quality requirements when compared to commercial grain crops.

Soil acidity is a major problem in all maize-producing areas of northern region of Bangladesh. In these areas, soil pH sometimes goes down to 3-4. At this soil condition some plant nutrients become unavailable for the plant. Maize is very sensitive to the deficiency of plant nutrients. The macro and the micro nutrients deficiencies might be responsible for the lower yield of hybrid maize with pollen sterility. Boron, a micronutrient is essential for pollen viability and seed production of crops as well as flowering and fruiting. It also plays an important role in nitrogen metabolism, hormonal action and cell division. Again, boron availability in soils is very much dependent on soil reaction (pH). In light textured soils of northern region where soil pH is low (4.0-5.8), boron availability becomes restricted. Due to deficiency of boron, the reproductive process of plant is hampered. The boron status in Bangladesh soil is shown in Appendix 4.

Singh (1998) reported that application of 1.5 kg B ha^{-1} during the winter season and 2.0-2.5 kg B ha^{-1} during the *kharif* season resulted significant increase in the maize yield. Recently in northern region, severe sterility in hybrid maize has been observed. In these locations, liming is required to raise soil pH to a value where boron becomes available. Lime application increased available boron in soil (Lalljee and Facknath, 2001). Ambak *et al.*, (1991) reported that liming significantly increased dry weight of crops of all the species tested as well as dry matter of roots of maize. Soil responses to lime applications are still unknown in a major part of these areas. pH affects mineralization of organic matter and subsequent availability of major and minor nutrients.

Hybrid maize seed and their parental lines are very costly. Production of good quality seed and its cultural practices are very important in commercial cultivation of any crop. Fertilizer management practice especially micronutrient is one of the most important for successesfull crop production. Boron is an important micronutrient element essential for plant growth, yet its primary function remains unclear (Matoh, 1997). Boron deficiency is a widespread problem for field crop production where large losses of yield occur annually both quantitatively and qualitatively (Dell and Matajuruk, 1984; Hopmans and Finn, 1984; Ram *et al.*, 1989; Shorrocks, 1997.). It is well established that adequate B supply is imperative for obtaining high yields and good quality seed. The critical level of boron for maize was 0.14 (Rahman *et al.*, 2008).

Considering the above facts, the present study was undertaken with the following objectives:

i. to determine the influence of lime and boron on hybrid maize seed production and

ii. to find out the optimum and economic dose of lime and boron for hybrid maize seed production.

CHAPTER 2

REVIEW OF LITERATURE

A good number of research works have been carried out on various aspects of management practices for higher productivity of maize. Still intensive research on improving its yield and quality is in progress. Grain yield and quality of maize are complex characters and these are contributed by many morphological or physiological events. The present study is related to seed production and quality of maize as influenced by different rates of lime and boron fertilizer. The information available on this area generated from different studies has been reviewed in this chapter.

1. Soil acidity and liming

Acid soils was found throughout the world, with 41% in the Americas, 26% in Asia, 17% in Africa, 10% in Europe, and 6% in Australia and New Zealand (Von Uexkull and Mutert, 1995). In the tropics, more than 8 million hectares of acid soils are planted with maize. This crop is not acid soil-tolerant (Pandey and Gardner, 1992), but increases in demand for cereals in the developing countries have led to an increase in maize acreage on acid soils.

Acidic soils, generally have a low pH, contain toxic levels of Al and Mn, and are deficient in Ca, Mg, P, K, and Mo. These characteristics limit the fertility of acid soils and inhibit root development, leading to low water and nutrient uptake and low maize yields (Duque-Vargas *et al.*, 1994). Welcker *et al.* (2005) reported that soil acidity reduces maize (*Zea mays* L.) yields up to 70% on 8 million hectares in developing countries.

To enhance plant productivity on acid soils (pH 4.0–6.0), lime application was usually recommended but positive responses may not be immediately obtained (Warman *et al.*, 1996; Edmeades and Ridley, 2003).

In studies in north-eastern Victoria and southern NSW, with soil pH < 4.7, crop yield increased by 20– 100% after liming the soil (Cregan *et al.*, 1989; Coventry, 1992). In Western Australia, various crop responses to lime application have been reported (Dolling *et al.*, 1991), including occasional negative effects (Carr *et al.*, 1991).

In acid soils, poor plant growth may results from toxicity of Al, deficiencies of P and Ca, and reduced uptake of nutrients (Anjos and Rowell, 1987, Beckie and Ukrainetz, 1996).

Liming is an effective practice to improve crop performance on acid soils. The positive crop responses to liming were due to the amelioration of one or more of the above-mentioned factors (Aitken *et al.*, 1988).

Liming may also cause negative effects on soil properties and plant growth, and some acid soils in the tropics appeared not to respond to lime (Haynes, 1982).

In acid soils, both gypsum and lime are used in peanut (*Arachis hypogaea* L.) farming because of their ability to supply Ca in developing pods and to make available P in the soil for optimum growth of plant. (Adams and Hartzog, 1980; Adeoye and Singh, 1985).

On the other hand, the effect of liming on rice (*Oryza sativa* L.) had been quite variable, and in most cases the response had been minute or negligible (Datta, 1984).

Aluminium (Al) toxicity is a major problem for maize production on acid soils in the tropics. Exchangeable and soluble Al content are nil or negligible for soil pH greater than 5, but they increase exponentially below this pH value. The relationships between pH, exchangeable and soluble Al depend largely upon soil mineralogy, and for a given pH the amount of soluble Al may vary three times depending clay content (Sierra *et al.*, 2003).

Another constraint related to soil acidity is P deficiency. Phosphorus is relatively insoluble in acid soils and possesses a low diffusion potential that is associated with several fixation processes. In response to P stress, plants had developed mechanisms for making soil P more available; e.g., mycorrhizal symbioses and the release of exudates (Stro¨m *et al.*, 2002).

In addition, maize accumulated more P under acid soils by changes in root physiology and morphology; e.g., production of root hairs thus increased P accumulation in roots (Gaume *et al.*, 2001).

2 Effects on growth parameters

2.1 Leaf Area

Islam (2002) found that pattern of leaf area development differed with variation of genotypes as well as with that the planting time and intercropping system. Highest leaf area index (4.57) was obtained in hybrid maize.

Shivay *et al.* (1999) reported that leaf area index (LAI) of maize increased markedly with the increase of nitrogen level. The highest LAI was observed in the highest level of N and the lowest was found in plants grown without N.

Dwyer and Stewart (1986) introduced a slightly skewed bell-shaped function to describe the relationship between leaf number and the area of mature leaves where integration of individual leaf areas gave total plant leaf area.

Muchow and Carberry (1989), Keating and Wafula (1992), and Birch *et al.* (1998) have shown that this bell shaped function is superior to other equations that relate LAI to leaf number. They also showed that the parameters of this function can be related to the total number of leaves, which can be estimated from thermal time from emergence to tassel initiation, well before LAI is reached (Kiniry, 1991).

Birch *et al.* (1998), working with five cultivars, observed genetic variation in this parameter.

Montgomery (1911) found that the area of a maize leaf blade can be estimated as its length multiplied by its maximum width multiplied by 0.75.

Ross (1975) reported that the height interval with highest leaf foliage density increased from 0.5 of total canopy height at V5 to 0.8 of total canopy height at the R1 stage. That pattern was true for densely planted corn in Estonia and sparsely planted corn in Tajikistan.

2.2. Dry matter accumulation

Islam (2002) reported that dry matter production of maize increased over the growing season although planting time differentiated the pattern of biomass accumulation. Dry matter accumulation of maize increased slowly and attained plateau at around 100 days after emergence and then the pattern of curves remained similar in next of the growth period. Also showed that dry matter weight of leaf, stover and grain increased with the increase of nitrogen and phosphorus fertilizer upto certain level than decreased.

Aslam *et al.* (2000) reported that Maize showed sigmoid response curve for dry matter accumulation vs. days after planting. Crop growth rates were high from 9^{th} leaf stage to grain formation.

Saha *et al.* (2008) reported that dry matter accumulation in leaf, stem and cob was differed among the sowing period and total dry matter per plant positively correlated with crop growth duration.

Johnson and Tanner (1972) showed that hybrids, compared to inbreds, had more leaf area per plant and greater grain filling rate and duration. Even at plant population densities that equalized LAI so as to provide similar light interception, the hybrids still produced more total dry matter (TDM) and grain yield than inbred.

2.3. Growth parameter of maize

Crop growth rate of maize increased progressively with time and reached peak at 80 days after emergence (DAE) and decreased abruptly till maturity. The rapid decline in CGR of maize after 80 DAE may due to rapid cessation of leaf area and net assimilation rate (Islam, 2002).

Islam (2002) also reported that net assimilation rate (NAR) of maize increased progressively over time with the increase in LAI and reached highest at 70 DAE and thereafter decline. The decrease in NAR might be due to the increase of self-shading of maize leaves.

3. Effect of lime and boron on yield and yield attributes

3.1. Effect of lime

Akhter *et al.* (2008) reported that highest maize grain yield (9.90 t ha^{-1}) was obtained with 2.0 t lime ha^{-1}, which was significantly higher over control (L_0) but closely at par with 1.0 t lime ha^{-1} and higher 3.0 t lime ha^{-1} dose at Patgram northern part of Bangladesh. Thousand grain weight of maize were increased significantly due to lime but different lime doses produced identical results. The plant and ear height and also the cob number $plant^{-1}$ did not alter significantly due to lime even though the tallest plant ((190 cm) was obtained from 2.0 t lime ha^{-1}

where the shortest plant (182 cm) was found with control but this variation was significant. However, addition of 2.0 t lime ha^{-1} increased the grain yield by 23% while the next higher dose (3.0 t lime ha^{-1}) contributed 17% yield benefit over control. Residual lime significantly increased grain yield in Lalmonirhat, Bangladesh. The highest grain yield (8.35 t ha^{-1}) was recorded from lime treated plot. In this location, 2.0 t ha^{-1} lime was applied in the previous year and no lime was used during 2007-2008. Residual lime increased soil pH which increased the macro as well the micronutrient of the soil. Finally it increased yield of maize. The effect of lime persists up to 2 years. Residual lime contributed yield benefit over control by 33%.

Ullah *et al.*, (2007) found that the yield of hybrid maize (cv. BARI hybrid maize 5) was increased significantly due to lime and poultry manure. The highest grain yield (10.12 t/ha) was obtained from $N_{250}P_{55}K_{100}S_{40}Zn_5B_2$ along with lime (2.0 t/ha) and 6 t/ha poultry manure. Recommended dose of chemical fertilizers in presence of lime gave 98% yield advantage over control treatment.

Halder *et al.*, (2003) reported that lime significantly influenced the yield and yield attributes of hybrid maize. The yield of hybrid maize increased by 41 and 32 percent over control with the application of Dolomite and Agricultural lime respectively @ 2.0 ton ha^{-1}. The presence of magnesium as a content of Dolomite might have contribution to the higher yield of hybrid maize in the magnesium deficient soil of the experimental site.

Bodruzzaman *et al.*, (2005) conduct two long term non-replicated trials in Patgram, Lalmonirhat on maize-rice cropping pattern to know the effects of lime on soil pH and yield. There were 6 treatments 1) control 2) 250 3) 1000 4) 2000 5) 4000 and 8000 kg lime/ha. The pH was raised due to application of lime. The pH changed was higher with increasing rates of lime. However, the pH changed was not considerable due to addition 0.25ton lime ha^{-1}. The maize and rice yields in both locations were responded to liming. The yield was dramatically increased due to addition 1ton lime ha^{-1} over no-lime (control) treatment for both maize and rice. The maize yield was more or less similar in 0.25ton lime ha^{-1} and control.

3.2 Effect of Boron

Boron is an important micronutrient element essential for plant growth, yet its primary function remains unclear (Matoh, 1997).

Boric acid crosslinks two chains of pectic polysaccharide through borate-diester bonding forming a network of pectic polysaccharides in the cell walls (Loomis and Durst, 1991; Matoh, 1997).

Boron (B) deficiency is a widespread problem for field crop production where large losses of yield occur annually both quantitatively and qualitatively (Dell and Matajuruk, 1984; Hopmans and Finn, 1984; Ram et al., 1989; Shorrocks, 1997).

Although reports from agricultural practices have well established that adequate B supply is imperative for obtaining higher yields and good quality and increasing evidence suggests and metabolic function or at least beneficial effects of B in animal metabolism (Hunt, 2003).

Akhter *et al.*, (2008) reported that highest maize yield (11.43 t ha^{-1}) at Patgram was recorded from boron @ 2 kg $ha^{-1}$and lime @ 2 t ha^{-1} application followed by 3 kg B ha^{-1} and 2 t lime ha^{-1} application (10.13 t ha^{-1}). At Lalmonirhat (Bangladesh) 3.0 kg B ha^{-1} produced the highest grain yield (9.18 t ha^{-1}) with residual lime (2 t ha^{-1}). Thus, it was also reported that optimum and economic dose for B without liming was 2.56 and 2.49 kg B ha^{-1} and with liming, those were 2.88 and 2.77 kg B ha^{-1}, respectively at Lalmonirhat (Bangladesh) and 2.11 kg B ha^{-1} at Patgram respectively and optimum and economic dose for lime in respect of boron was 2.03 and 1.96 t lime ha^{-1}, respectively.

Boron played the most significant role in augmenting the yield and yield components of maize. The highest yield (10.03 t ha^{-1}) was found with 2.0 kg B ha^{-1}, which was identical with the immediate lower (1 kg B ha^{-1}) and higher (3 kg B ha^{-1}) doses. Addition of 2.0 kg B ha^{-1} increased the grain yield by 27% over control. Yield components like number of cob $plant^{-1}$, grains cob^{-1} and 1000 grain weight were influenced significantly due to the application of boron (Akhter *et al.* 2007).

Rahman *et al.* (2003) observed that the highest grain yield (7.69 t/ha) of hybrid maize was found by the application of 2.0 kg B h^{-1},which was significantly higher than that other B levels.

A wide range of B fertility levels had no effect on the vegetative growth of maize. But tassels from deficient plants had no viable pollen, whereas silks were not receptive to the pollen taken from the plants fertilized with high B (Vaughan, 1977).

Cheng and Rerkasem (1992) found that in B deficient wheat, the pollen does not accumulate starch and the nuclei, when present, are abnormal. Rerkasem *et al.* (1993) found that the fertility of both male and female plants of the wheat florets appear to be affected by boron deficiency. Subedi *et al.* (1993) found that there was a significant reduction in percent wheat sterility with the application of boron.

Bodruzzaman *et al.* (2003) reported that the wheat yield benefits due to application of 2 kg B ha^{-1} from borax and boric acid and 3 kg B ha^{-1} also from borax and boric acid were a 19%, 20%, 28% and 23 % increase in yield over control, respectively.

Jahiruddin *et al.* (1992) reported that the use of boron caused a higher formation of grains resulting in higher grain yield of wheat compared to that obtained from Cu, Mo or control treatment.

Jahiruddin *et al.* (1995) also reported that B had a marked influence on grain set and yield of wheat in another experiment.

Bodruzzaman *et al.* (2003) stated that boron had tremendous effect on wheat grain yield in boron deficient soils.

There was no significant influence of boron on wheat sterility in 1994-95 in Bangladesh but humidity, light, temperature and rainfall during the important critical growth stages had adverse effect (Sifuzzaman, 1995).

The process of reproductive development begins with flower initiation, followed by flower formation, which includes development of floral parts, and is completed with fertilization. It has often been observed that reproductive growth, especially flowering, fruit and seed set and seed yield, is more sensitive than vegetative growth to B deficiency (Dear and Lipsett, 1987; Noppakoonwong *et al.*, 1997; Woodbridge *et al.*, 1971).

The effect of boron on the development of pollen grain has been reported for many species, including wheat (Li *et al.*, 1978; Rerkasem and Jamjod, 1989) maize (Agarwala *et al.*, 1981) and rice (Garg *et al.*, 1979).

3.4. Harvest index

Donald (1962) first defined harvest index as the economic (grain) yield of a wheat crop expressed as a decimal fraction of *total* biological yield, but he clearly meant *total aboveground* dry matter production (Donald & Hamblin, 1976).

Harvest index, i.e., grain as the proportion of above ground DM, is a useful parameter to predict grain yield (Kiniry *et al.*, 1992).

However, harvest indices in tropically adapted genotypes of maize (0.3-0.4) are lower than that in temperate genotypes (0.5-0.55) (Aluko and Fischer 1987;

Karanja,1993). The rate of increase in harvest index as grain is filled has received less attention than terminal harvest index.

Linear increase in harvest index has been used in models of maize (Muchow *et al.,* 1990a), *sorghum* (Hammer and Muchow, 1991) and sunflower (Chapman *et al.*, 1993), but for satisfactory use needs to be stable or predictable. It was stable in maize and grain sorghum grown in limited range of environment (Muchow 1990a, 1990b), but varied in sunflowers, especially when temperature was low (Bange, 1995).

The crop sample for harvest index determination should be cut at maturity by hand at ground level, dried to constant weight, threshed, and the resulting grain weighed (Donald & Hamblin, 1976; Innes, *et al.*, 1981).

Maize is probably unique among major world crops in that the harvest index of many commercial varieties was already quite high in the first decades of this century. Thus the open pollinated types used in the USA up to the 1925 had values of around 0.45 (Russell, 1991; 1993).

Harvest index of maize may be more variable in North America (Jain, *et al.*, 1976; Mostert & Marais, 1982; Hammes *et al.*, 1986).

4. Starch, protein and oil content in maize

Belitz and Grosch (1985) reported that maize contained 62.6% starch. Starch content of the maize varieties ranged from 45.53% to 58.49% (Ashrafi, 2006).

Isalm, and Kaul, (1986) reported that Boranli, Mohar, Shuvra and Khoibhutta contained 73.28%, 71.10%, 73.99% and 70.61% carbohydrate respectively. Martin *et al.* (1976) stated that the corn kernel contained 72.10% carbohydrate. They considered starch, sugars, pentose, crude fiber, and ash together in Carbohydrate.

Gujral, *et al.* (2001) reported that dry maize contained 1.78% total nitrogen and 11.1% protein. Bresani *et al.* (1953), Saldana and Brown (1984) reported that yellow maize contained 8.4% protein.

Shahjahan (2002) in his work reported that Bornali, Mohor, BARI Bhutta-5, BARI Bhutta-6, Khoi Bhutta and Pacific-11 contained 10.26%, 11.17%, 8.25%, 10.77%, 10.87% and 9.76% protein respectively. Isam and Kaul (1986) stated that corn (Shuvra) contained 6.88% protein. American Association of Cereal

Gopalan *et al.* (1981) reported that dry maize contained 3.6% fat. Ashrafi (2006) reported that maize kernel contained 3.3% oil. Bonnett (1954) reported that maize kernel contained 2.3% oil. Bornali, Mohor, Shuvra and khoibhuta contained 4.50% 4.39% and 4.53% oil respectively as evaluated by Mowlah *et al.* (1998).

Iken *et al.* (2002) recorded 4.4%, 4.6% and 4.7% fat for white dent maize, improved yellow dent and local floury respectively.

Shahjahan (2002) assessed Bornali, Mohor, BARI Maize-5, BARI Maize-6, Khoibhutta and Pacific-II that contained 3.13%, 3.17%, 3.25% 3.21%, 22.77% and 2.82% fat respectively.

5. Economics of hybrid maize seed production

Uddin *et al.* (2007) reported that the estimated variable cost and fixed cost of maize hybrid seed production ha^{-1} were Tk. 83749.0 and Tk. 10387.0 which are 88.97% and 11.03%, respectively out of the total cost of production i.e., Tk. 94136. The observations indicated that about 64.11 % of variable costs are due to human labour and material inputs. The total value of the gross produce involving processed hybrid seed, rejected seed, male line seed and fodder is estimated as Tk. 204900.0. The benefit cost ratio worked out is 1.91 with the net income of Tk. 85764.0 per ha for maize hybrid seed production. However, this benefit cost ratio can be expected only under normal favorable conditions, with the availability of all facilities and inputs to carry out seed production.

Haque *et al.* (2008) found that the cost of production of hybrid maize seed under NGO (BRAC) was found higher than public agency (BADC) and private company (LAL TEER). The yield was found highest in NGO (3780 kg/ha) compared to public agency (BADC) (2352 kg ha^{-1}) and private company (LAL TEER) (3198 kg ha^{-1}). Gross return of hybrid maize seed under public agency was found the highest than private company and NGO. Gross return, net return and benefit cost ratio were found the highest in public agency compared to private company and NGO. Net return of hybrid maize seed cultivation was 50 percent higher than hybrid maize non-seed cultivation. More emphasis should be given by the Research Institute (BARI) to develop improved variety of hybrid maize inbreed seeds/lines and supply those seeds to the contract growers through Government Organization (BADC), other Non-Government Organization and private seed companies at reasonable price. Technical and financial support should be provided to the contract growers through Government and Non Government Organization for producing good quality hybrid maize seed.

CHAPTER 3

MATERIALS AND METHODS

3.1 Experimental site and duration

The experiment was conducted at the Agricultural Research Station, Burirhat, Rangpur during rabi season of 2007-2008. The station was located 12 kilometer north from Rangpur town by the side of Rangpur –Gangachara road. Geographical location of this station was 25°33́N latitude and 87°1́E longitude.

3.2 Climate and Soil

The experimental site is situated in the subtropical zone. It was about 32.2 m above the sea level. Average annual rainfall is about 2169 mm. The monthly maximum air temperature was 31°C and the minimum 15° C during the cropping period. The soil of the experimental field belongs to Calcareous Grey Floodplain soil under Agro Ecological Zone -3. Descriptions of some chemical properties of experimental soil was collected from a depth of 0-20 cm prior to application of fertilizer are presented in Appendix-5. The soil was highly acidic (pH 4.8) having low organic matter content. The total N content was very low. Exchangeable Mg, K and available P and S contents were low. Fe content is just at per with critical level. Boron content was also low.

Meteorological data during the crop growing period are shown in Appendix-6.

3.3 Isolation

The seed production plot was temporally or spatially isolated to avoid contamination during the flowering stage by wind-borne pollen from neighboring fields. About 500 m distance isolation was maintained and two border rows were sown around the field to enhance isolation.

3.4 Plant materials used

Parental lines of BARI Hybrid maize -5, viz. BARI Introduced Line-20 (BIL-20) and BIL-22 as a female and male line, respectively were used in this study. The materials were collected from Plant Breeding Division, BARI, Gazipur.

3.5 Treatments:

There were 12 treatment combinations comprising 4 levels of B (0, 1, 2 and 3 kg ha^{-1}) and 3 levels of lime (0, 1.5 and 3 t ha^{-1}).

3.6 Experimental design

The experiment was carried out in split plot design with three replications. The main plot treatment was lime and subplot treatment was boron levels. The unit plot size was 4.5 m × 5m.

3.7 Land preparation

The experimental plots were prepared by ploughing, harrowing and laddering to bring the desirable tilth.

3.8 Fertilizer application

Recommended dose of $N_{120}P_{35}K_{65}S_{20}Zn_5$ kg ha^{-1} and cowdung 5 t ha^{-1} was used in the form of Urea, TSP, MoP, Gypsum and Zinc oxide respectively. All P, K, S, Zn, B and cowdung and 1/3rd N were applied at the time of final land preparation. The remaining 2/3rd N were applied in two equal installments at 40 and 80 days after sowing (DAS). Lime (Dolomite) was applied one month before final land preparation as per of treatment variables. Boric acid (17%, Boron) was applied during final land preparation following treatment variables.

Symbol of treatment	Added lime (t ha^{-1})	Added boron (kg ha^{-1})
L_0B_0	0.0	0.0
L_0B_1	0.0	1.0
L_0B_2	0.0	2.0
L_0B_3	0.0	3.0
L_1B_0	1.5	0.0
L_1B_1	1.5	1.0
L_1B_2	1.5	2.0
L_1B_3	1.5	3.0
L_2B_0	3.0	0.0
L_2B_1	3.0	1.0
L_2B_2	3.0	2.0
L_2B_3	3.0	3.0

3.9 Seed treatment

To protect seedlings diseases seeds were treated with Vitavex 200WP, @ 2.5 g kg^{-1} seed before sowing from protection of fungal and bacterial infections from seed and soil.

3.10 Seeds sowing

Seeds were sown with a spacing of row to row 75 cm and seed to seed 20 cm @ 21 kg seeds ha^{-1} (14 kg BIL 20 and 7 kg BIL 22). Sowing was done in space isolation maintaining a ratio of four female rows alternate with two male rows (4: 2). Male parents were sown in two different dates for synchronization of flowering. One row male line was sown three day after female line sown and another male row was sown six day after female line sowing. Two seed were sown per hill at a depth of 3-5 cm. The seeds were covered with soil for uniform germination. The date of sowing of 4 rows female was 15 November 2007. First male row was sown three days after female row sowing (18 November 2007) and second row male parent was sown six days after female parent sowing (21 November 2007).

3.11 Drive away birds

Drive birds away for 10-12 days after sowing to protect the crop from bird damage.

3.12 Thinning

Thinning was done to maintain the desired number of plant population (66,666 plants ha^{-1}.) maintaining plant to plant distances as 20 cm within two weeks of emergence.

3.13 Weed control

One weeding was done at the 4-5 leaf stage of seedling growth.

3.14 Irrigation

The plot was irrigated four times during the growing period of the crop; first irrigation was given at 3 to 5 leaf stage. The second irrigation after 8-10 leaf stage, the third irrigation during tassel emergence stage and the fourth irrigation was given at grain filling stage. Excess water was drained out from the field.

3.15 Earthing up

Earthing up was done in between the two lines, making a 15-20 cm ridge and furrow at 8-10 leaf stage.

3.16 Insect control

Cutworms were observed at the 2-4 leaf stage. This insect cuts the stem of young seedlings from the base at night and hides under the soil surface at day time. This insect was controlled by spraying Dursban 20EC (5 ml in 1 liter water) in a 15-20 cm radius of the plant base.

3.17. Disease control

Leaf blight (*Helminthosporium maydis*) was observed in the experimental field during tassel initiating stage. This disease was controlled by spraying Tilth 25 EC (Triazoe group) 0.1%.

3.18 Detasseling

Detasseling was done from the female parents before the tassels shed pollen or silks emerge on the ear shoots of the female parents.

3.19 Roguing

Roguing was done during at post emergence, vegetative development, flowering, post flowering and pre-harvest stage.

3.20 Harvesting

Harvesting was done when plants show distinct signs of drying, the husk cover is completely dry and the grains are fully matures. Grain maturity was identified from the milk line of kernels or the formation of a black layer at the junction of grain and placenta. The crop was harvested on 28 May 2008. The harvested crop of each plot was bundled separately, tagged and taken to the threshing floor and threshed and the grain cleaned properly. Grains were thoroughly dried in the sun for 5-6 days. The grain of each plot was then weighed individually.

3.21 Nutrient analysis of soil samples

Soil pH was measured by a combined glass calomel electrode (Jakson, 1958). Organic carbon determination was done by wet oxidation method (Walkley and Black). Total N was determined by modified Kjeldahl method. Ca and Mg were determined by KCL extractable method. K, Cu, Fe, Mn and Zn were determined by $NaHCO_3$ extraction followed by AAS reading. Boron was determined by $CaCl_2$ extraction method. Phosphorus was determined by Bray and Kurtz method. S was determined by turbidity method with $BaCl_2$ (Appendix-6)

3.22 Plant Growth analysis

3.22.1 Dry matter accumulation

Three plants were sampled in each plot at 30 days interval from 30 DAE to 160 DAE. At each sampling plants were cut at the ground level, separated into leaf, stover, and reproductive parts. The segmented plant parts were oven dried at $70^{\circ}C$ for constant weight.

3.22.2 Crop Growth Rate (CGR)

Crop growth rate of a unit area of a canopy cover, at any instant in time (t) is defined as 'the increase of plant material per unit of time' (Radford, 1967).

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \cdot \frac{1}{GA} \quad g\,m^{-2}day^{-1}$$

Where, W_1 = Dry weight at time T_1, W_2 = Dry weight at time T_2, T_2-T_1 = Time interval between the second and first measurements and GA = Ground area of sample.

3.22.3. Relative growth Rate (RGR)

The increase of plant material per unit of material present per unit of time (Radford, 1967).

$$RGR = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1} \text{ g g}^{-1}\text{day}^{-1}$$

Where, W_1 = Dry weight at time T_1, W_2 = Dry weight at time T_2 and T_2-T_1 = Time interval between the second and first measurements.

3.22.4. Net Assimilation Rate (NAR)

The increase of plant material per unit of assimilatory material per unit of time (Radford, 1967).

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} X \frac{\text{Log}_e L_{A2} - \text{Log}_e L_{A1}}{L_{A2} - L_{A1}} \text{ g m}^{-2} \text{ day}^{-1}$$

Where, W_1 = Dry weight at time T_1, W_2 = Dry weight at time T_2 and T_2-T_1 = Time interval between the second and first measurements.

3.22.5 Leaf area (LA)

Leaf area was measured as per formula (Montgomery, 1911) given below.

LA = L x W x F

Where, L= Length

W = Maximum width and

F = Factor

F for: Maize = 0.75 (Montgomery, 1911)

3.22.6 Leaf Area Index (LAI)

It is the ratio of the leaf area to the area of ground covered

$$LAI = \frac{\text{Total green leaf area } (m^{-2})}{\text{Ground area covered by the plant } (m^{-2})}$$

3.23 Yield and yield components

From each plot the central two undisturbed lines were harvested for grain yield. The yield was expressed in ton ha^{-1} at 12% moisture content. Ten plants were selected randomly for data on number of leaves $plant^{-1}$, plant height and cobs $plant^{-1}$. At harvest plants were cut at the base and the following data were recorded.

3.23.1 Plant height (cm)

Height of plant was measured with meter scale from the ground level to the top of the main shoot and the average was determined.

3.23.2 Leaves $plant^{-1}$

Number of leaves from ten plants was recorded and the mean value $plant^{-1}$ was calculated.

3.23.3 Mature cobs $plant^{-1}$

The number of mature cobs of each plant from ten plants was recorded and the mean was expressed $plant^{-1}$ basis.

3.23.4 Length of cob (cm)

Ten randomly selected cobs were taken from the cobs harvested for determining grain yield, and length of the cob was measured from the bottom to the top of the cob by a measuring tape.

3.23.5 Girth of the Cob (cm)

Measurement on the girth of ten cobs at the base, middle and top were taken by a measuring tape and the mean value was recorded.

3.23.6 Number of seeds cob^{-1}

Ten randomly selected cobs were taken from the samples harvested for grain yield and the number of seeds in three to four rows was counted and the mean value was multiplied by number of rows present in each cob. The mean value of ten cobs was recorded.

3.23.7 100 grain weight (g)

For each individual treatments, samples of well dried 100 seeds were counted in automatic seed counter and weighed by a sensitive digital balance and mean weight was expressed in gram. .

3.23.8 Grain yield (t ha^{-1})

The cobs harvested from each plot were separated from plants, cleaned, dried and weighed separately. Grain yield of each plot was recorded and adjusted at 12% moisture content.

3.23.9 Harvest index

The harvest index (HI) was computed as the ratio of economic yield (grain) to the total biological yield (the total above ground dry matter including the grain) expressed as:

$$HI(\%)=\frac{\text{Grain yield}}{\text{Total biological yield}}\times 100$$

3.24 Seed quality characters

Observation on germination percentage, seedling length and seedling dry weights were recorded from a random seed sample of each treatment. Measurement of seedling length was taken on 8^{th} day and root-shoot growth ratio was calculated. Seedling dry weight of 10 normal seedlings was recorded after drying in an oven at $70^{O}C$. Vigor index analysis was also carried by the formula,

$$\text{Vigor indexes} = \text{Germination \%} \times \text{seedling dry weight (mg)}.$$

3.25 Statistical analysis

Data on plant characters, yield and yield components of maize were analyses statistically using the analysis of variance (ANOVA) and mean difference among the treatments were compared by LSD at 5% level of significance.

3.26 Response curve

From the response function equation the value of an added nutrient that maximizes yield was estimated as follows:

$Y = a + bX + cX^2$, Where Y is the maximum crop growth of yield, a, b, and c are co-efficient and X is added nutrient

From the equation, an optimum lime and boron rate has been computed following the procedure as outlined in Gomez and Gomez (1984).

The optimum nutrient rate (Ny) for maximizes yield: $Ny = \frac{-b}{2c}$

The nutrient rate for maximize profit (Np): $Np = \frac{1}{2c}(\frac{Pf}{Py} - b)$

Where, Pf = Price of nutrient and Py = Price of crop product

3.27 Economics

Cost benefit analysis were done according to prevailing local market price. Benefit cost ratio of different treatment was computed as follows:

$$BCR = \frac{\text{Gross return}}{\text{Cost of production}}$$

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Leaf development and crop growth

4.1.1 Leaf area (LA)

Leas area is made up of the total lamina area of emerged leaves. Dry matter production of crop plant depends almost wholly on the amount of intercepted photoactive radiation (PhAR) by the crop and the conversion efficiency of absorbed radiation. However, greater leaf area development is assumed to absorb more light and consequently greater photosynthesis as long as the lower leaves are not shaded (Gardner *et al.*, 1985). The conspicuous effects of lime on leaf area development of female parent of BARI hybrid maize 5 were presented in Fig. 1. Leaf area as influenced by lime treatments and increased over time. The leaf area increased sharply and reaching peak at 120 DAS and then decreased irrespective of lime treatment. Leaf area decreased after 120 DAS reflecting the loss of some older leaves through senescence. Among the lime treatment L_1 (1.5 t ha^{-1}) showed the highest leaf area than that of other lime treatments. Similar trend also found in boron treatment (Fig. 2).

The leaf area $plant^{-1}$ of female parent of BARI hybrid maize-5 responded to applied lime and boron fertilizer greatly over the growth period (Fig.3). Regardless of treatment variation leaf area was maximum at 120 DAS and ranged between

3747.50 and 5266.13 cm^2 and then decreased up to harvest due to senescence of other leaves. It is evident from Fig. 1, that despite the magnitude of differences in leaf area due to treatment differences, the general trend of leaf area development over the growing season remained identical for female parent of hybrid maize-5. However, maximum leaf area $plant^{-1}$ was obtained from 1.5 t lime ha^{-1} with 2.0 kg B ha^{-1} (T_7) throughout the growing period. Female parent of BARI hybrid maize-5 grown without lime and boron (L_0B_0) gave the lowest leaf area $plant^{-1}$ at all the growth stages.

4.1.2. Leaf Area Index

Leaf area index (LAI) expresses the ratio of leaf surface area to the ground area. Leaf area is made up of the total green lamina of emerged leaves (Kerting and Carberry, 1993). LAI influenced by different treatments of lime is presented in Fig 4. LAI increased sharply from 60 DAS and reached maximum at 120 DAS, thereafter declined sharply irrespective of lime treatment. The decrease in LAI at later period may be attributed to senescence of leaves. Difference in LAI was quite apparent across the treatment in different growth stages.

Among the lime treatment L_1 (1.5 t $limeha^{-1}$) showed higher LAI at later growth period. However, the trend of LAI did not differ remarkably among the treatments. Among the boron treatment, B_2 (2 kg boron ha^{-1}) showed higher LAI and B_0 (0 kg boron ha^{-1}) gave the lowest LAI in almost all the growing periods(Fig. 5).

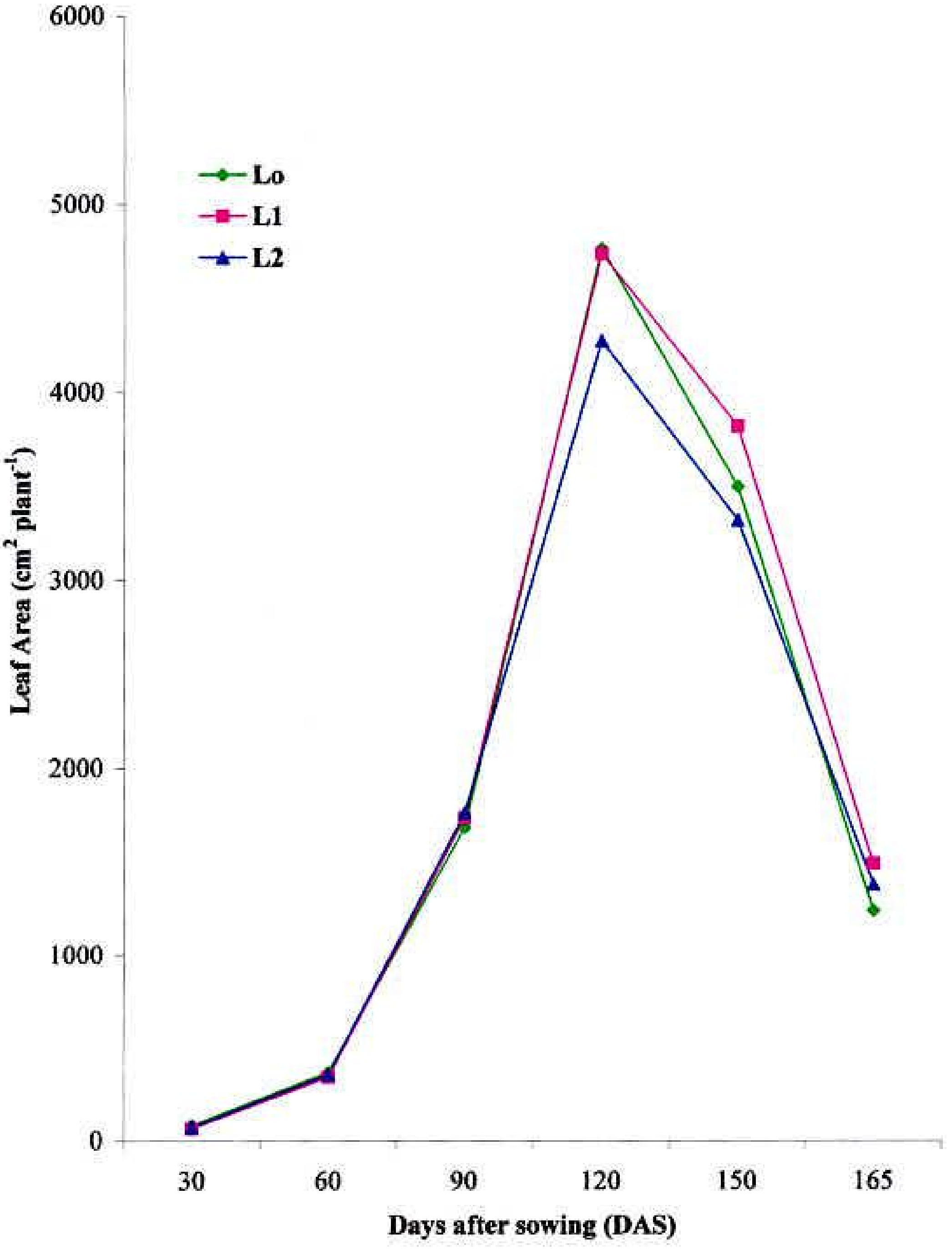

Fig. 1. Leaf area of female parent of BARI hybrid maize-5 (BIL-20) as influenced by liming at different day. (LSD $_{(0.05)}$ =ns, ns, ns, 0.076, 0.112, 0.121 for 30, 60, 90, 120, 150 and 165 DAS, respectively).

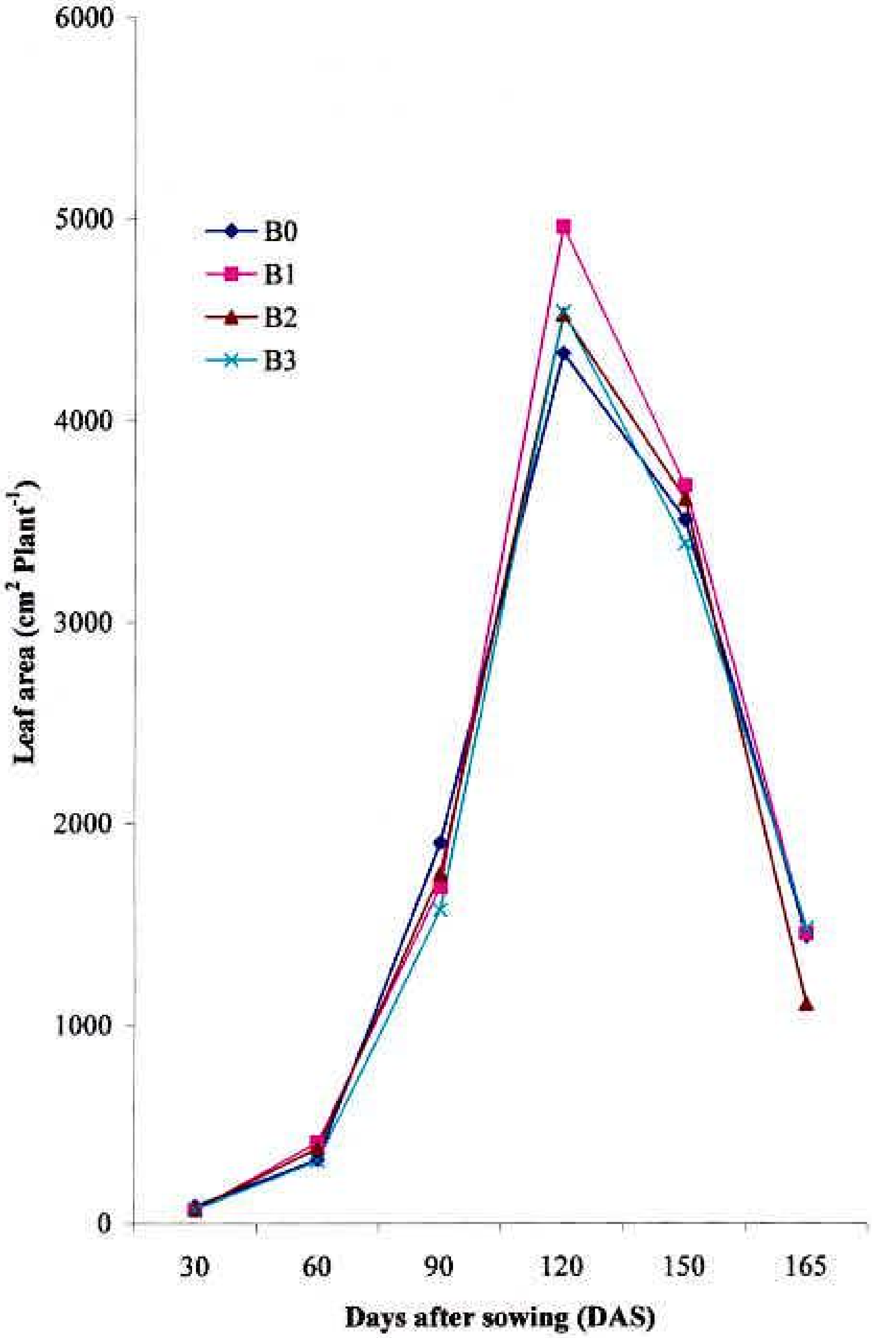

Fig. 2. Leaf area of female parent of BARI hybrid maize-5 (BIL-20) as influenced by application of boron fertilizer at different day. (LSD $_{(0.05)}$=ns, 0.021, 0.091, 0.235, 0.102, 0.110 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

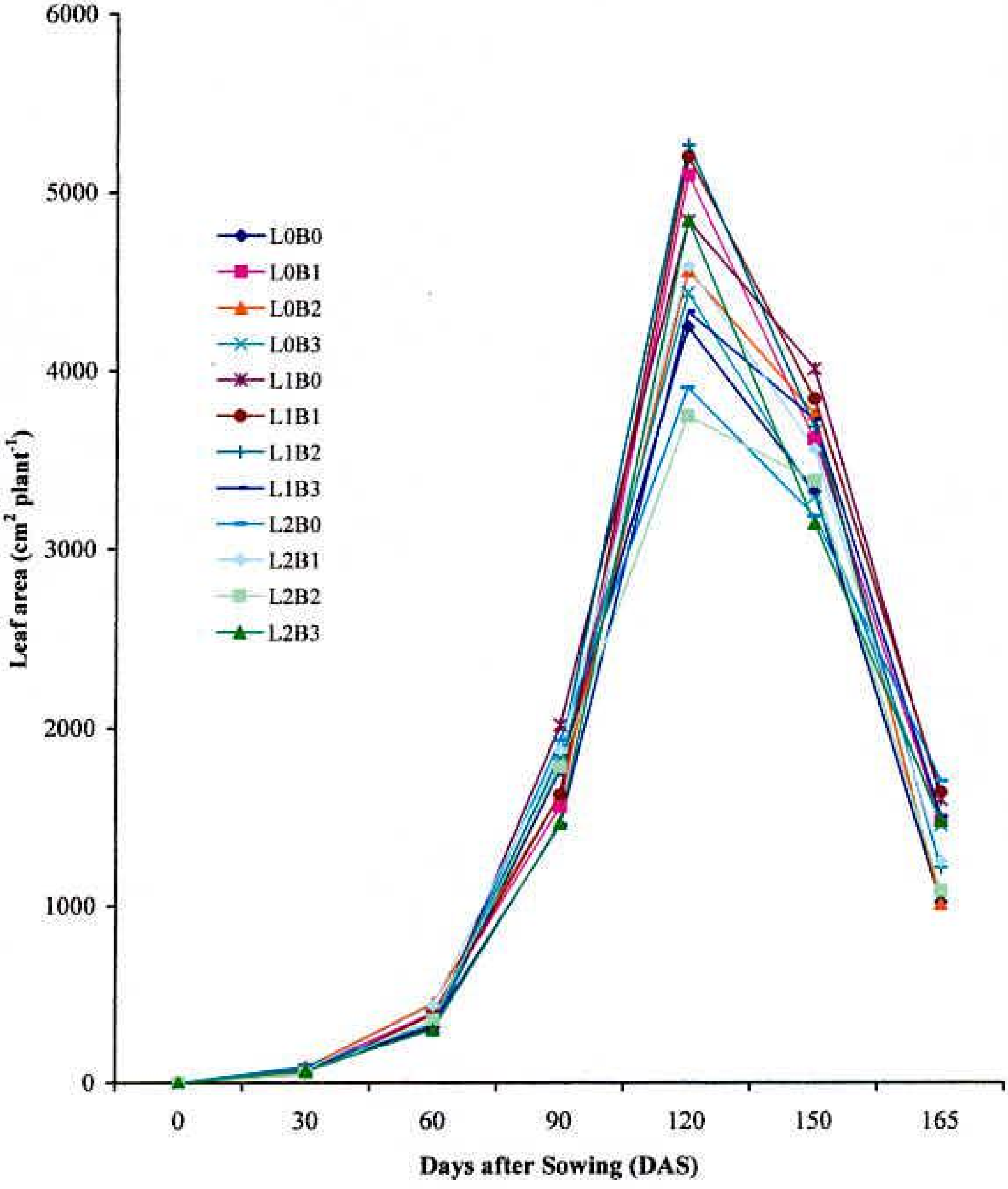

Fig. 3. Leaf area of female parent of BARI hybrid maize-5 (BIL-20) as affected by liming and application of boron fertilizer at different day. ($LSD_{(0.05)}$=0.008, 0.037, 0.101, 0.355, 0.136, 0.135 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

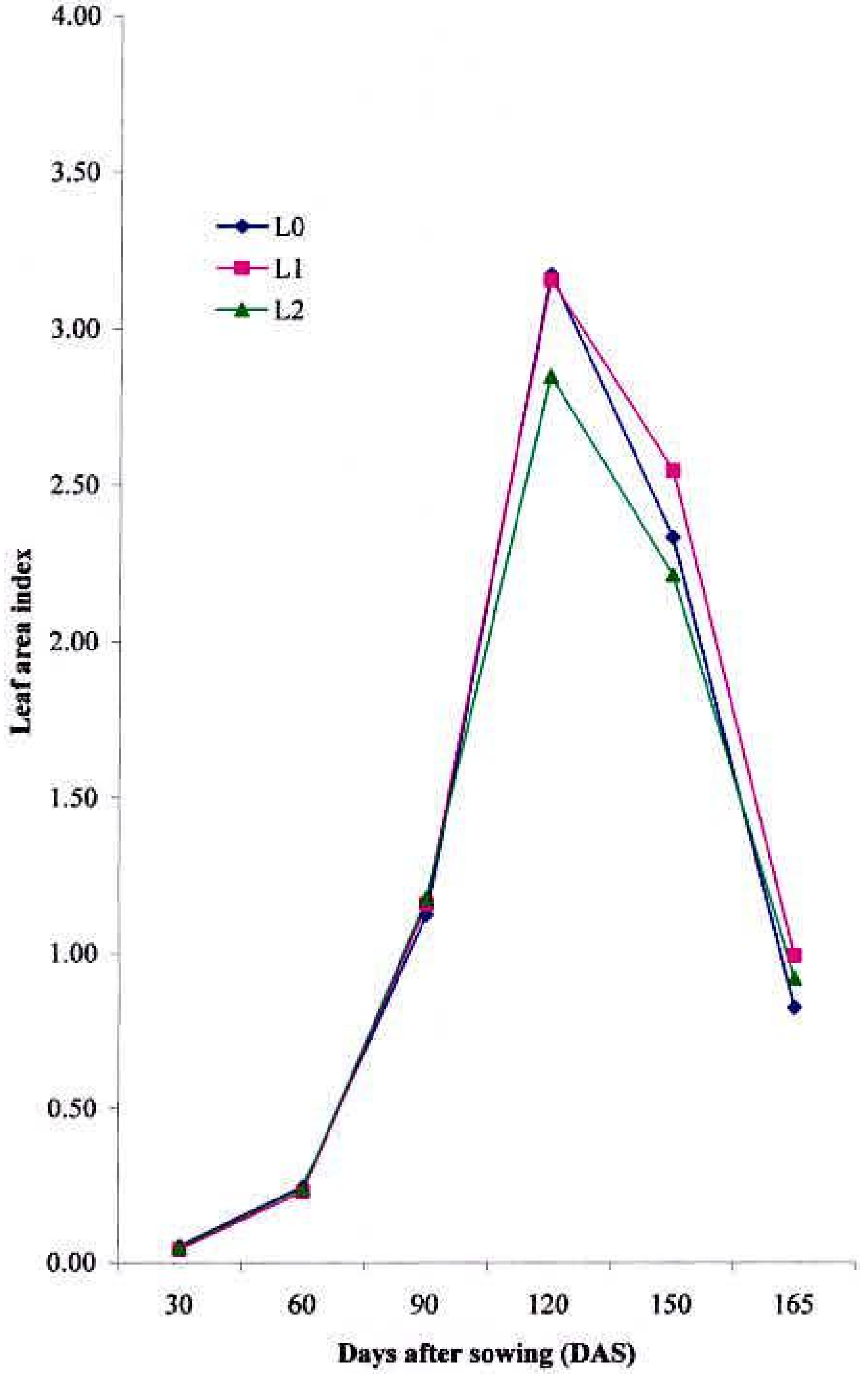

Fig.4. Leaf area index (LAI) of female parent of BARI hybrid maize-5 (BIL-20) as affected by liming at different day. ($LSD_{(0.05)}$=ns, ns, ns, 0.215, 0.165, 0.114 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

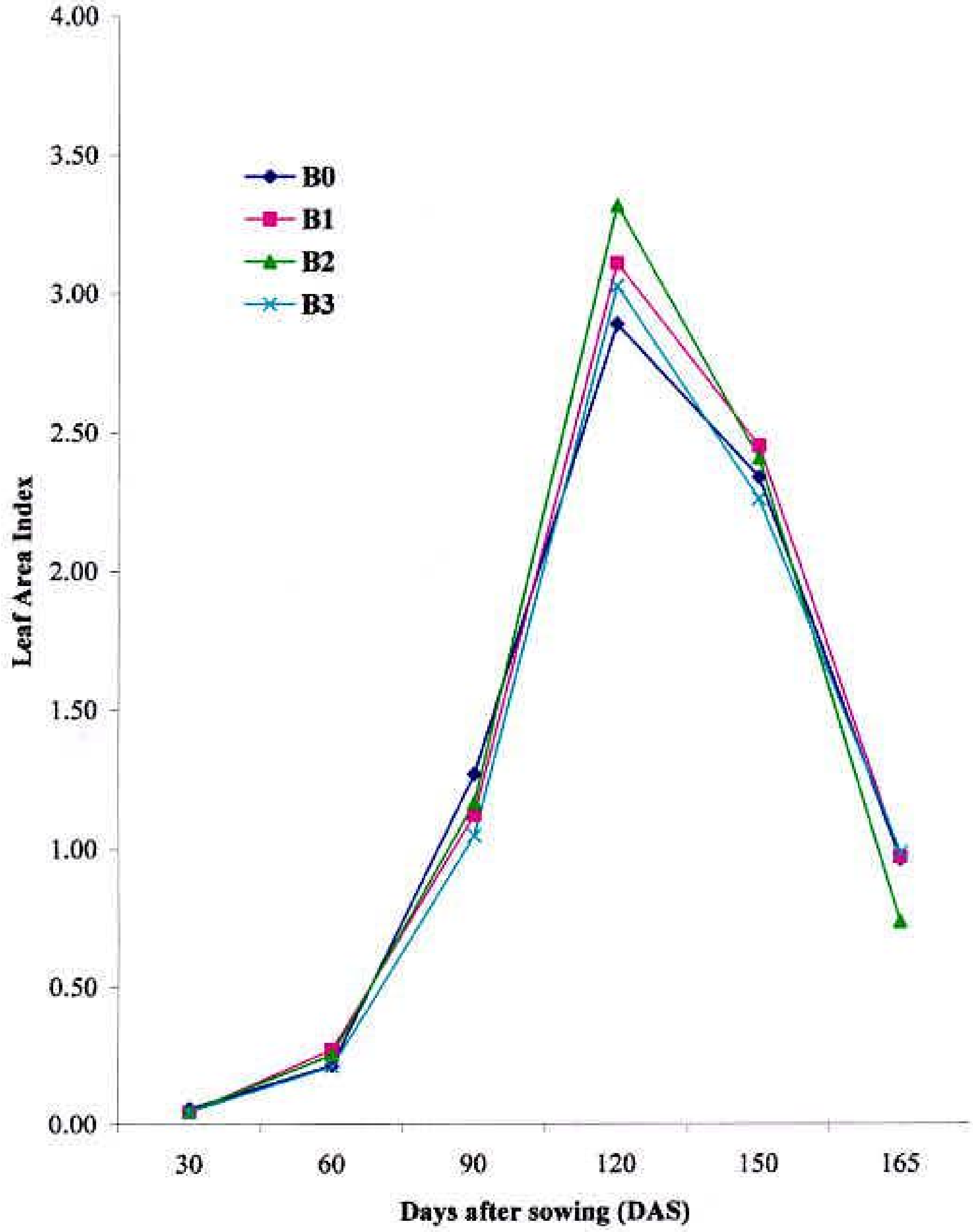

Fig.5. Leaf area index (LAI) of female parent of BARI hybrid maize-5 (BIL-20) as affected by liming and application of boron fertilizer at different day. ($LSD_{(0.05)}$=ns, 0.034, 0.099, 0.320, 0.135, 0.132 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

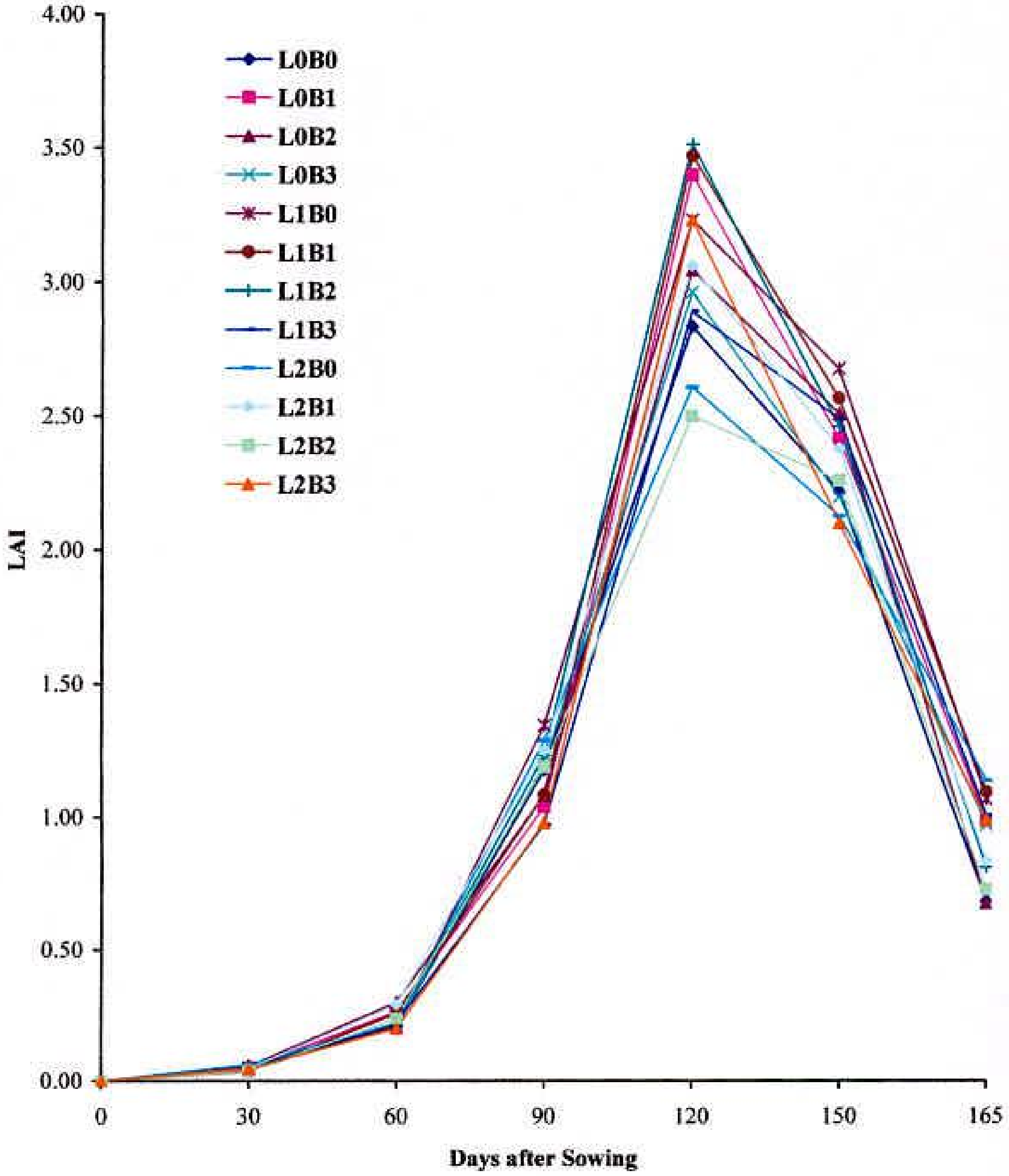

Fig. 6. Leaf area index (LAI) of female parent of BARI hybrid maize-5 (BIL-20) as affected by liming and application of boron fertilizer at different day. ($LSD_{(0.05)}$=ns, 0.034, 0.099, 0.320, 0.135, 0.132 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

LAI of maize with different levels of lime and boron showed remarkable variation over the growth stages (Fig. 6). LAI increased sharply from 60 DAS and reaching maximum at 120 DAS and then declined sharply irrespective of treatment differences. The reduction of LAI in the later part of the growth i.e., after 120 DAS, the female parent of BARI hybrid-5 was associated with senescence of older leaves. Application of 1.5 t Lime ha^{-1} had higher LAI with 2.0 kg B ha^{-1} (T_7) at all growth stages while the lowest LAI was recorded in L_0B_0 (T_1). A similar result of applied nitrogen to maize was reported by Shivay *et al.*, (1999).

4.1.3 Total dry matter (TDM) production

The yield of a crop is determined by the accumulation of total dry matter and it's partitioning into the economic part. Dry matter production over time is useful in explaining the growth characteristics of maize. A high TDM production is the prerequisite for high yield. Accumulation of TDM increased progressively over time attaining the highest at maturity stage irrespective of treatment differences (Fig. 7). The highest TDM was observed in L_1 (1.5 t lime ha^{-1}) application and lowest in L_0 (without lime) application at all the growth period.

Application of boron fertilizer caused marked variation in total dry matter accumulation (Fig. 8). TDM increased progressively with increasing B fertilizer up to 2 kg ha^{-1} at the all growth period. The highest TDM was found in plant treated with 2 kg ha^{-1} B and lowest in plant treated without boron.

However, the pattern of biomass accumulation was different due to different levels of lime and born fertilizer. All the treatment combinations seem to have a lag phase in early growth stage (30-60 DAS) followed by a linear phase after 60 DAS that continued till 165 DAS. Highest rate of TDM production was observed from 90 to 120 DAS. Dry matter accumulation of maize was in agreement with the result of Aslam *et al.* (2000) and Isalm (2002). Increase of TDM production of this growth phase might be due to increased photosynthetic rate with higher leaf area. Consistently higher TDM was observed in plant treated with 1.5 t lime and 3 kg boron ha^{-1} followed by 1.5 t lime with 2.0 kg boron ha^{-1} (T_7). Further increase in lime (3.0 t lime ha^{-1}) trended to depress TDM accumulation might be due to toxic effect of lime. On the contrary, plants grown without lime and boron fertilizer produced the lowest dry matter. This might be due to plants suffered from nutrient stress during the generative phase when nutrient demand of the crop was high.

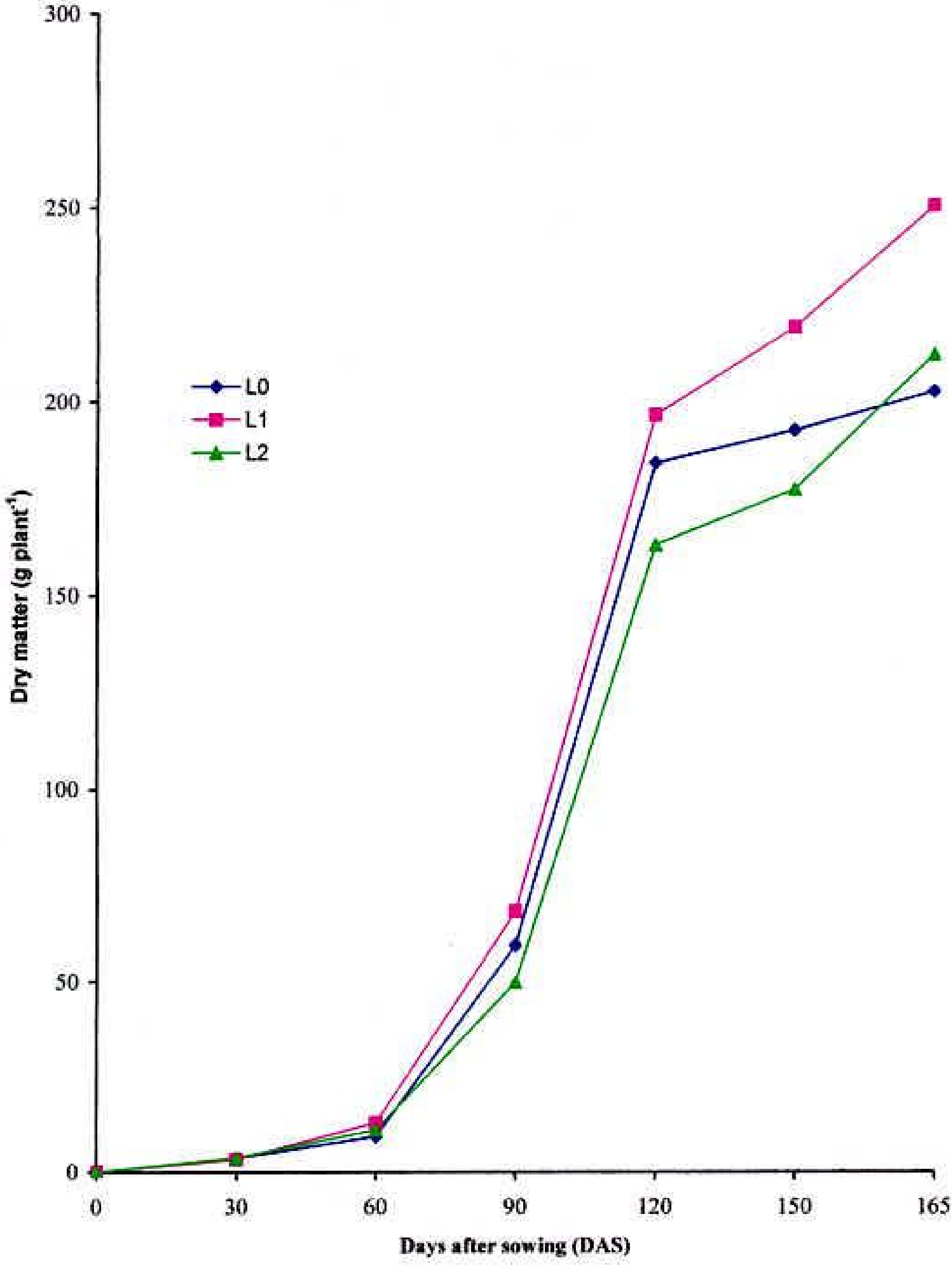

Fig.7. Total dry matter production at different growth stages of female parent of BARI hybrid maize-5 as influenced by liming. ($LSD_{(0.05)}$= ns, 0.032, 0.110, 0.245, 0.192, 0.131 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

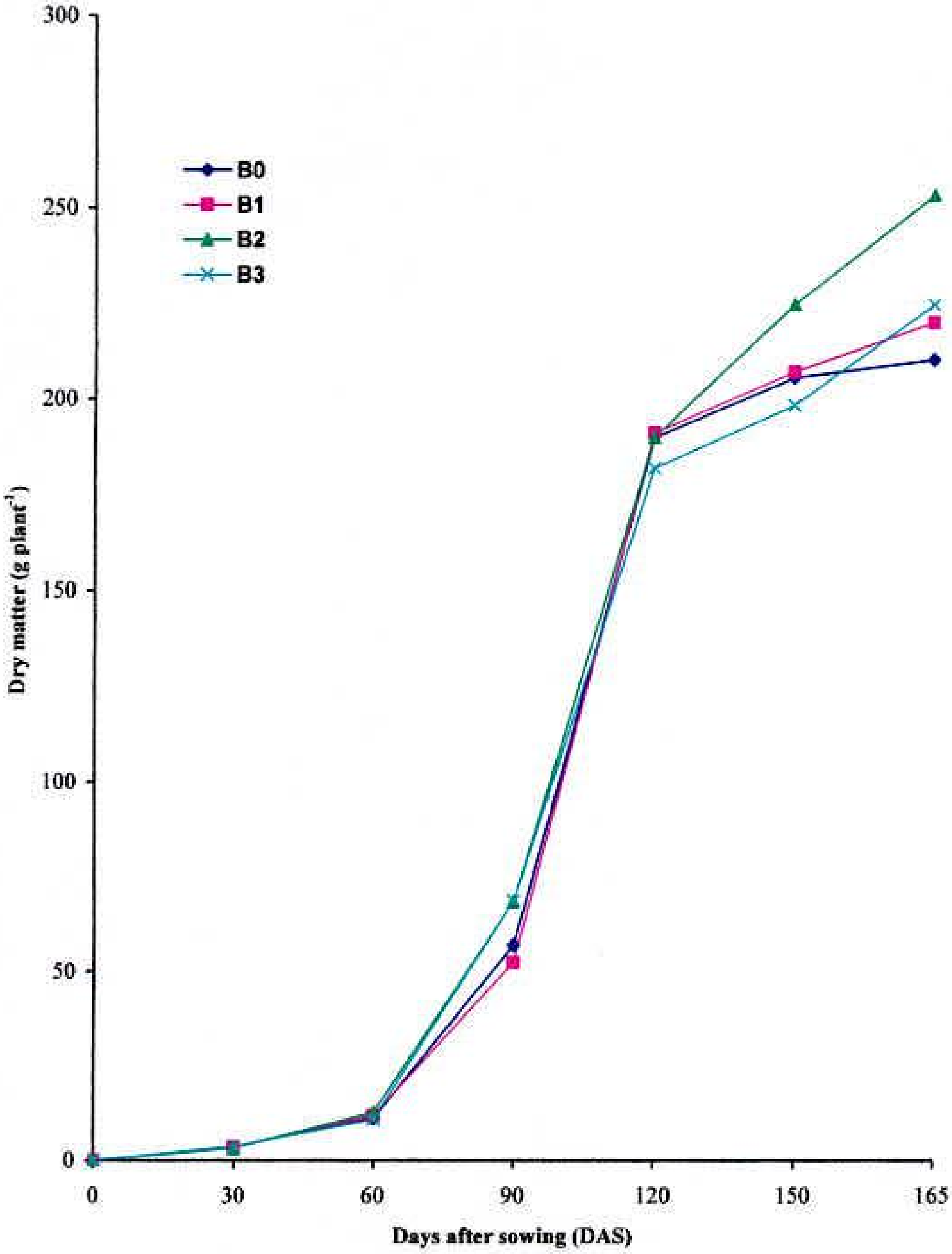

Fig.8. Total dry matter production at different growth stages of female parent of BARI hybrid maize-5 as influenced by application of boron fertilizer. ($LSD_{(0.05)}$= ns, ns, 0.113, 0.265, 0.324, 0.316 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

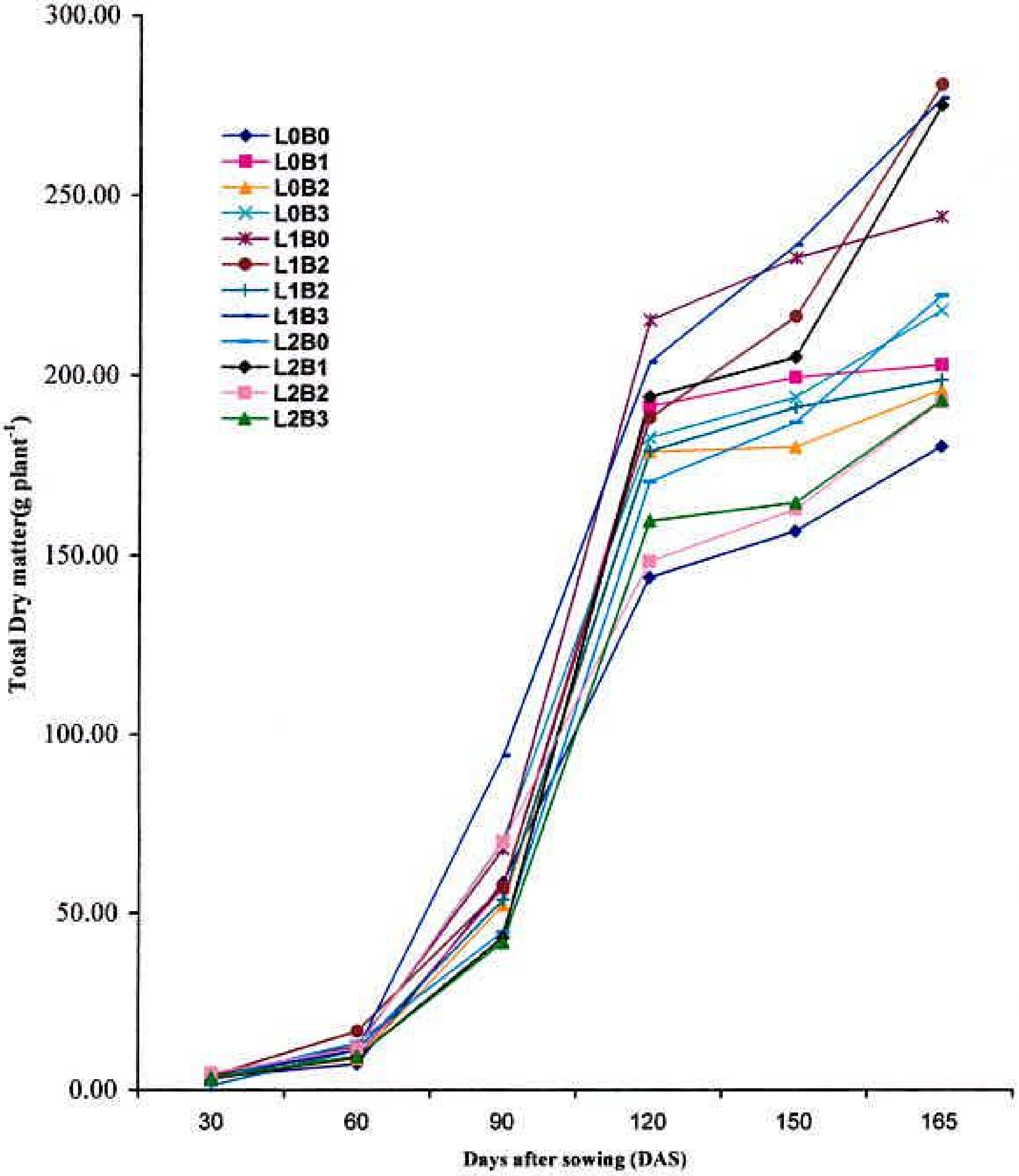

Fig.9. Total dry matter production at different growth stages of female parent of BARI hybrid maize-5 as influenced by liming and application of boron fertilizer. ($LSD_{(0.05)}$= 0.005, 0.051, 0.124, 0.324, 0.214, 0.142 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

4.1.4 Dry matter partitioning

Apart from high dry matter production, favourable partitioning and dry matter translocation into cob is critical for higher yield. Lime and Boron fertilizer markedly influenced the dry matter production and partitioning of female parent of BARI hybrid maize-5. The pattern of dry matter distribution into different parts of maize in response to lime and boron fertilizer is shown on Figs. 10a, 10b, 10c. Application of lime and boron had significantly positive influence in partitioning of DM into different components of maize. Irrespective of treatments, the difference in dry weight of leaf, stover, husk, rachis and grain was smaller at early stages and widened with the advancement of plant age. Pattern of DM partitioning of female parent in to leaves and stover was similar and increased to a plateau and then decreased with concomitant increase in allocation to reproductive organ i.e. husk, rachis and grain. Dry matter partitioning into leaf and stover of maize inbred line peaked at 120 DAS and thereafter declined irrespective of lime and boron application. The dry matter accumulation into these two organs increased with the increasing B levels and continued up to 2.0 kg ha^{-1}. Further increase in B levels failed to increase leaf and stover dry matter weight in both the cases. Similar findings are also reported by Islam (2002) from composite maize in case of N application. However, dry matter in leaves and stover declined after attainment of peak in all the treatments. This might be due to translocation of assimilate to reproductive organs and leaf withering began due to senescence.

In the reproductive stage, husk and rachis development starts earlier than grain development. Assimilate accumulation starts in these two organs at 90 DAS and initially accumulation rate is negligible and attains the peak at 120 DAS, thereafter declined resulting the remobilization of dry matter to grains. Boron fertilization influenced the distribution of DM to husk and rachis but not very sharply, and DM increased with the increasing boron levels. Highest DM accumulation was accounted for 2.0 kg Boron ha^{-1} with 1.5 ton ha^{-1} lime (T_7) (Fig.11). The lowest dry matter was accumulated in the plant receiving control treatment.

4.1.5 Growth analysis

Growth analysis technique has made substantial contributions to the current concepts of physiological basis of yield variation in crops. It is also done for the purpose of quantifying pattern of dry matter production (Hedge, 1988).

4.1.6 Crop growth rate

The crop growth rate of maize differed remarkably due to different levels of lime and boron fertilizer application (Fig.12). Regardless of treatments, crop growth rate (CGR) values increased progressively with time reaching peak at 120 DAS and thereafter declined sharply till maturity (165 DAS). Reduction in growth rate with plant age was probably due to cessation of vegetative growth, loss of leaves and senescence. Such information in maize was also reported by Adelana and Milbonrn (1972). The higher CGR at 120 DAS was accomplished with its higher dry matter and LAI. Islam (2002) also found higher CGR owing to higher LAI and higher interception of light in maize. Among the treatments, application of 1.5 t lime with 2 kg B ha^{-1} registered a maximum CGR values during the whole growth period while plants treated with L_0B_0 produced the lowest CGR irrespective of growth stages.

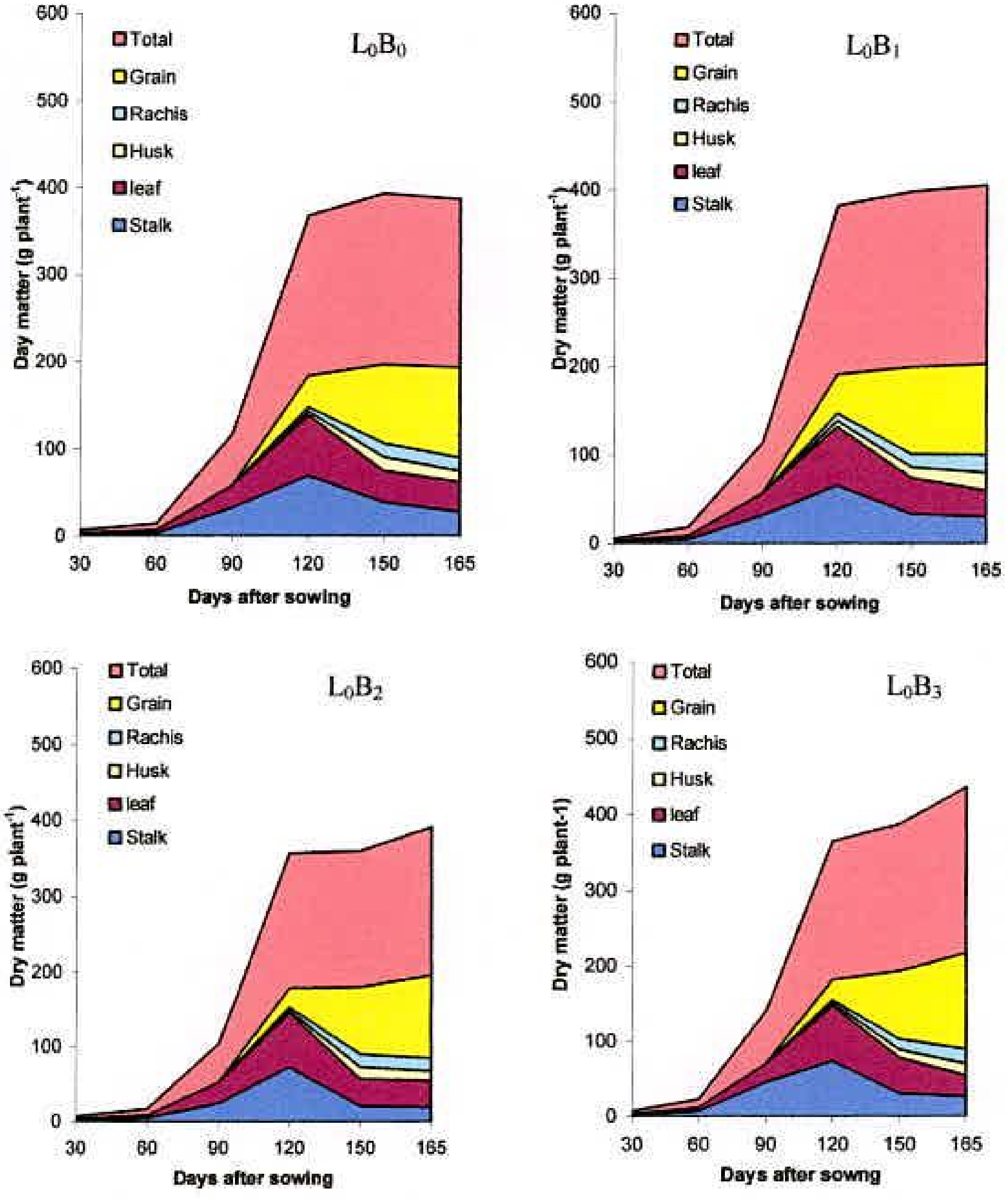

Fig.10a. Dry matter accumulation in different component of female parent of BABI hybrid maize-5 (BIL 20) as influenced by lime and boron fertilizer of different growth stages

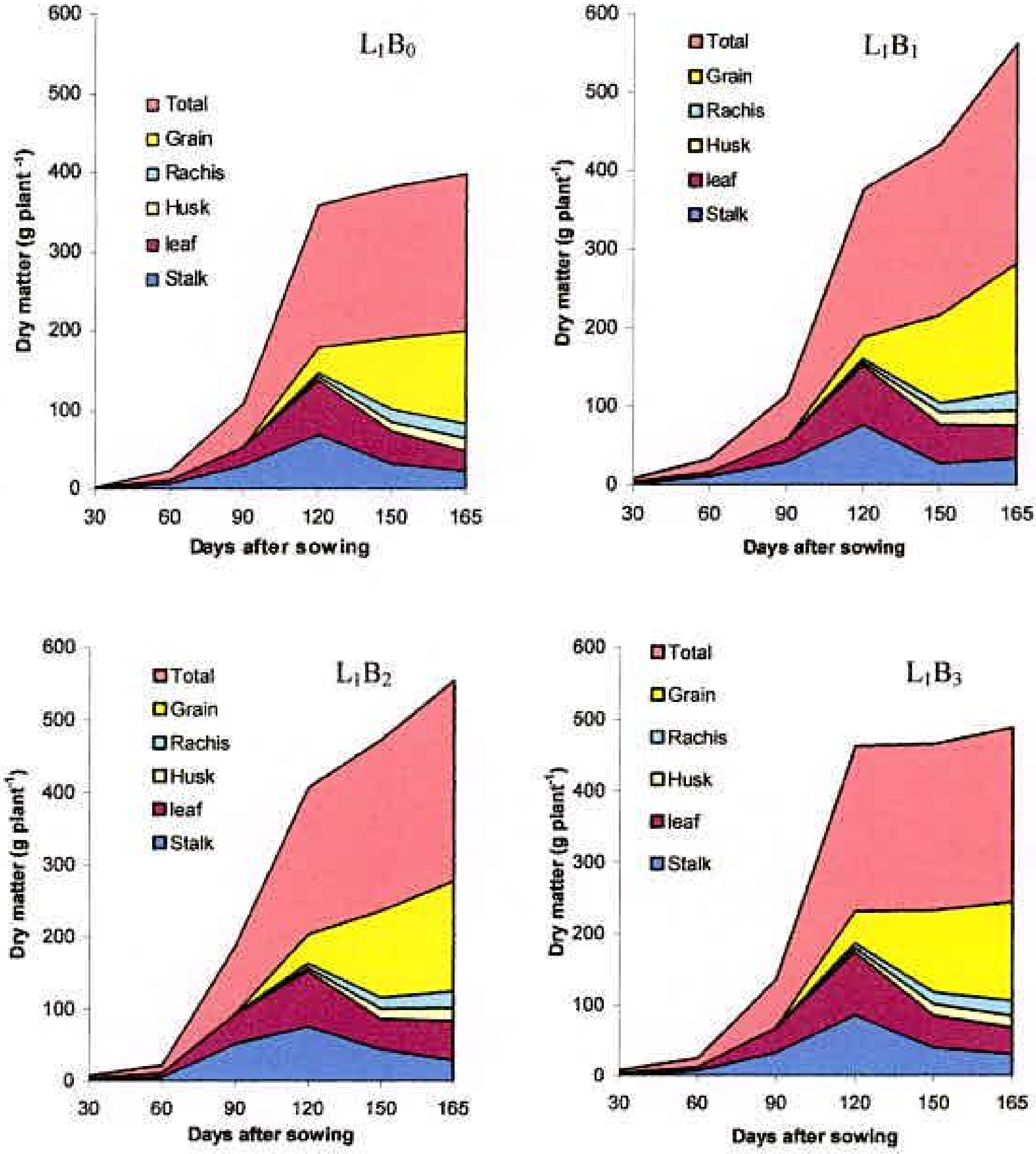

Fig.10b. Dry matter accumulation in different component of female parent of BABI hybrid maize-5 (BIL 20)as influenced by different lime and boron fertilizer as different growth stages

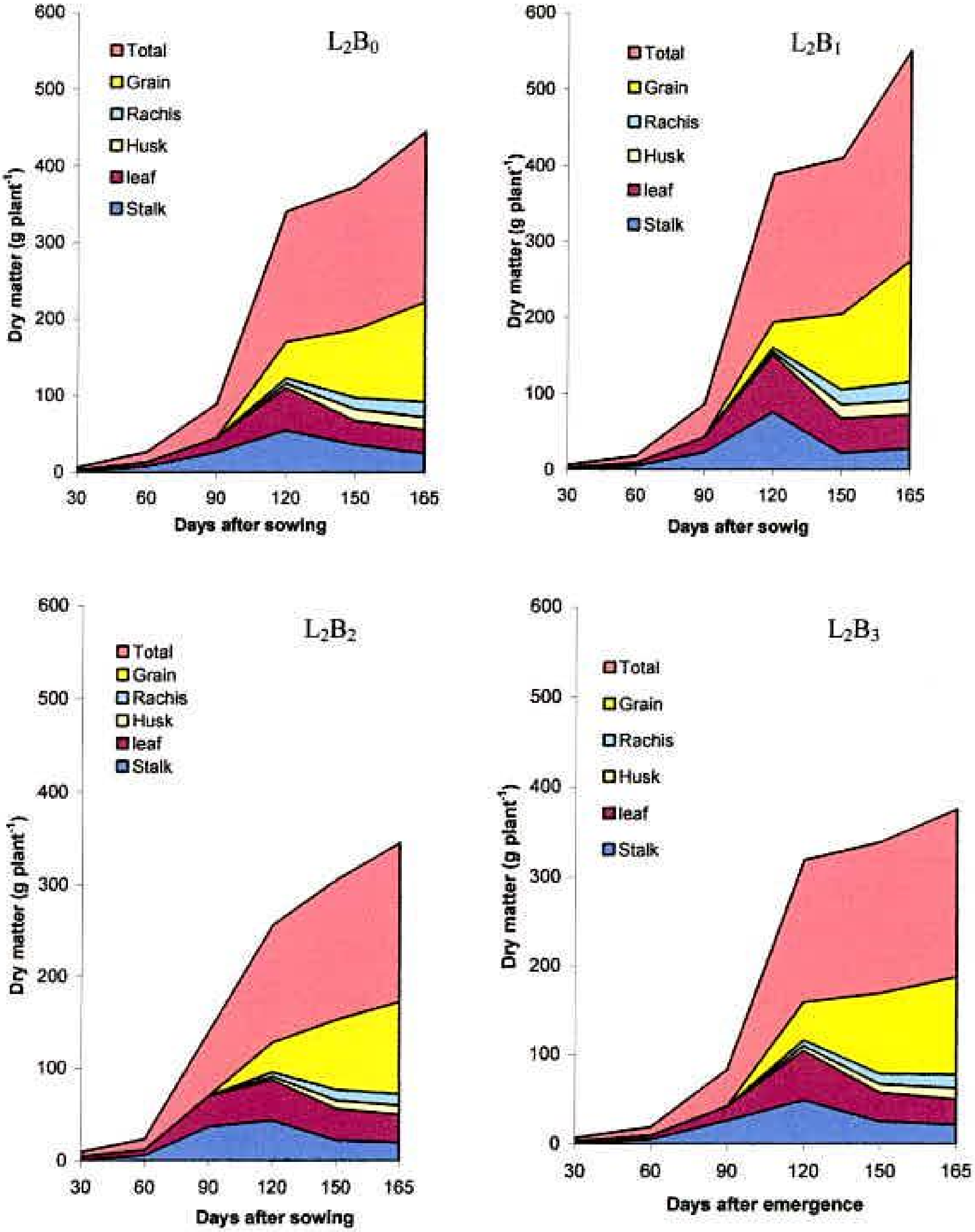

Fig. 10c. Dry matter accumulation in different component of female parent of BARI hybrid maize-5 (BIL 20) as influenced by different lime and boron fertilizer of different growth stages

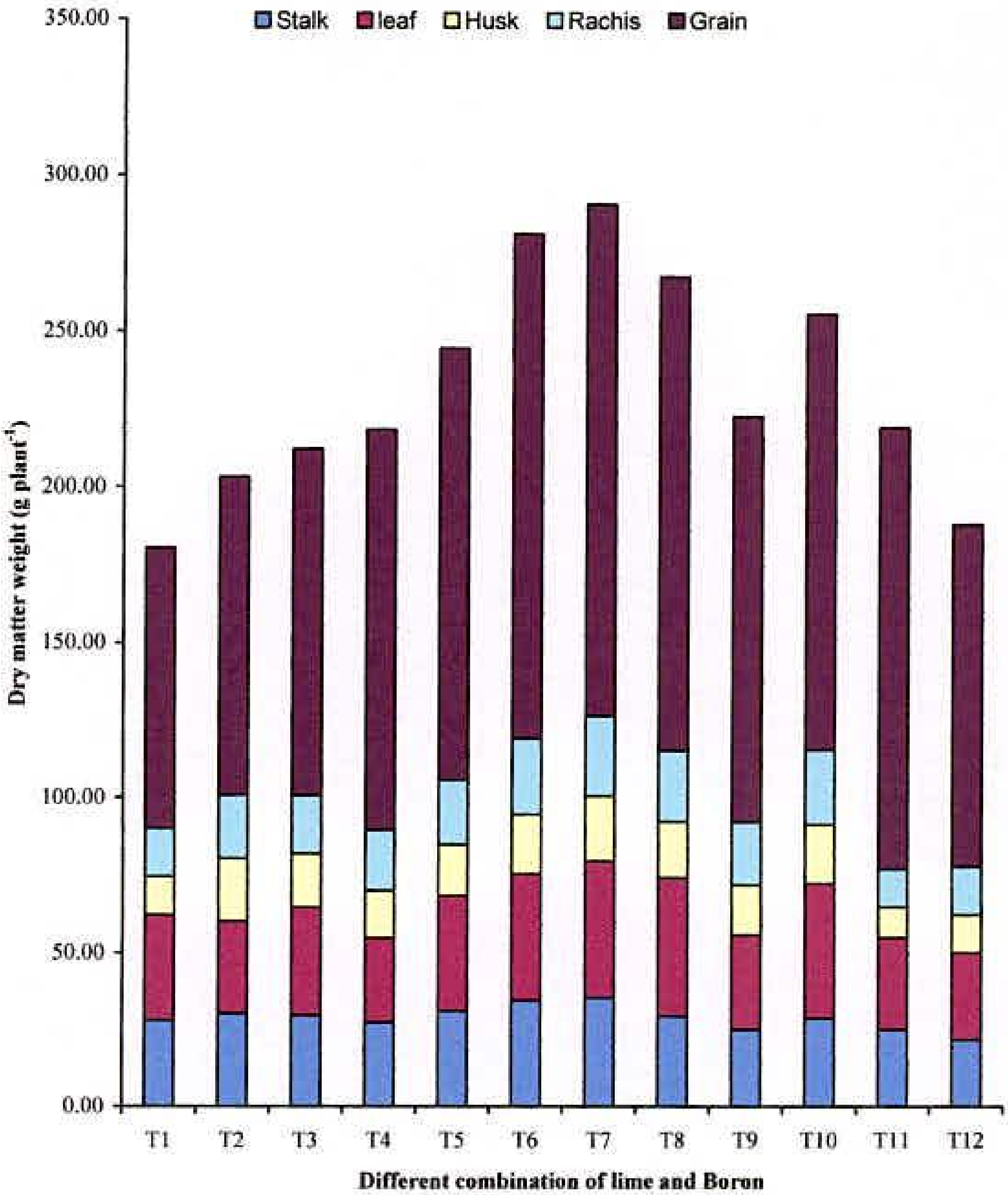

Fig.11. Dry matter distribution in different component of female parent of BARI hybrid maize-5 (BIL 20) as influenced by different lime and boron fertilizer of different growth stages

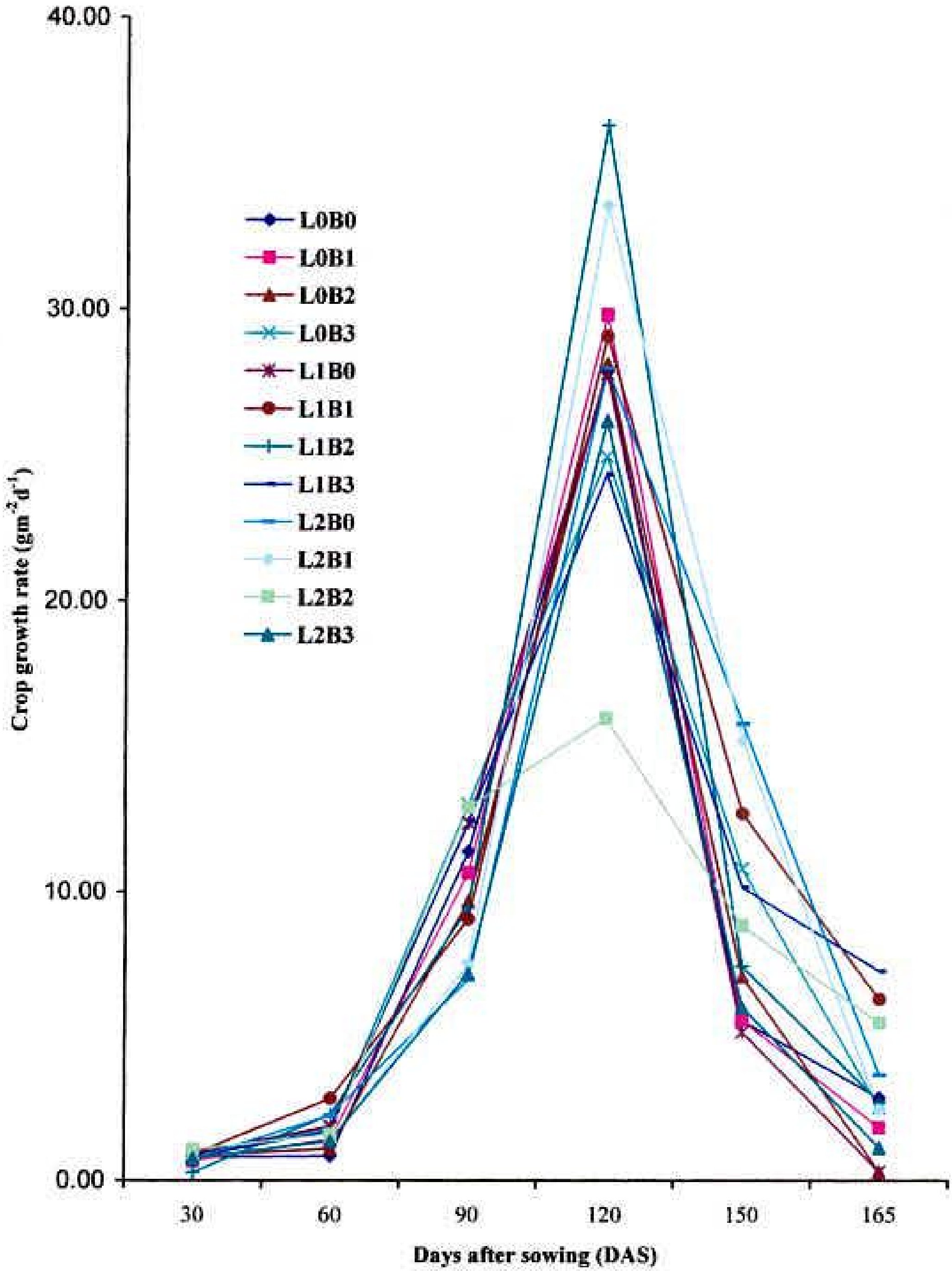

Fig.12. Crop growth rate (CGR) of female parent of BARI hybrid maize-5 (BIL 20) as affected by liming and application of boron at different day. ($LSD_{(0.05)}$= ns, 0.042, 0.123, 0.241, 0.341, 0.256 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

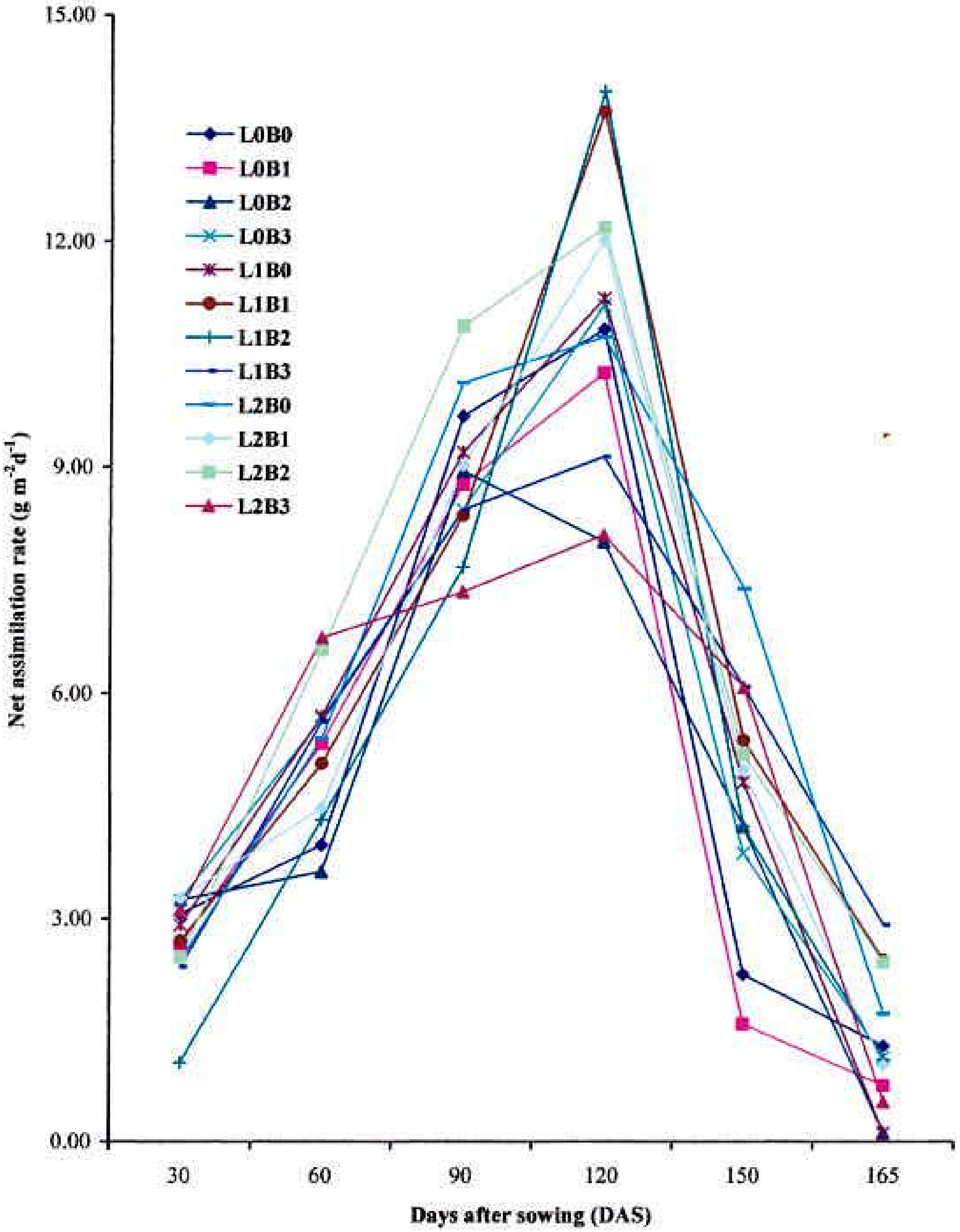

Fig.13. Net assimilation rate (NAR) of female parent of BARI hybrid maize-5 (BIL-20) as affected by liming and application of boron fertilizer as different day. ($LSD_{(0.05)}$= 0.142, 0.257, 0.224, 0.467, 0.328, 0.319 for 30, 60, 90, 120, 150 and 165 DAS, respectively)

4.1.7 Relative growth rate

Relative growth rate (RGR) of female parent of BARI hybrid maize-5 as influenced by lime and boron fertilizer is shown in Fig.12. Irrespective of treatments, RGR was more at early stage (30 DAS) and showed a decreasing trend with the advancement of plant age. The decrease in RGR was probably due to the increase of metabolically active tissue and as such contributed less to the plant growth. Variations in RGR across the treatment were not apparent in the later growth stage but the difference was observed in the early growth period. However, application of 1.5 t lime ha^{-1} with 2.0 kg B ha^{-1} gave the highest RGR value while the lowest in L_0B_0 treatment, irrespective of growth stages.

4.1.8 Net assimilation rate

The assimilation rate of maize differed significantly due to different levels of lime and boron fertilizer (Fig. 13). Regardless of treatments, net assimilation rate (NAR) of female parent of BARI hybrid maize-5 increased progressively into 120 DAS and thereafter declined sharply. The increase in NAR upto 120 DAS was probably due to the increase in leaf area. On the contrary, the decrease of NAR with the advancement of time was due to mutual shading of leaves and resulting in lower photosynthetic efficiency. Similar result was also reported by Islam (2002) and Hedge and Sardinivas (1989). However application of 1.5 t lime ha^{-1} with 2 kg B ha^{-1} gave the highest NAR while the lowest in L_0B_0 treatment.

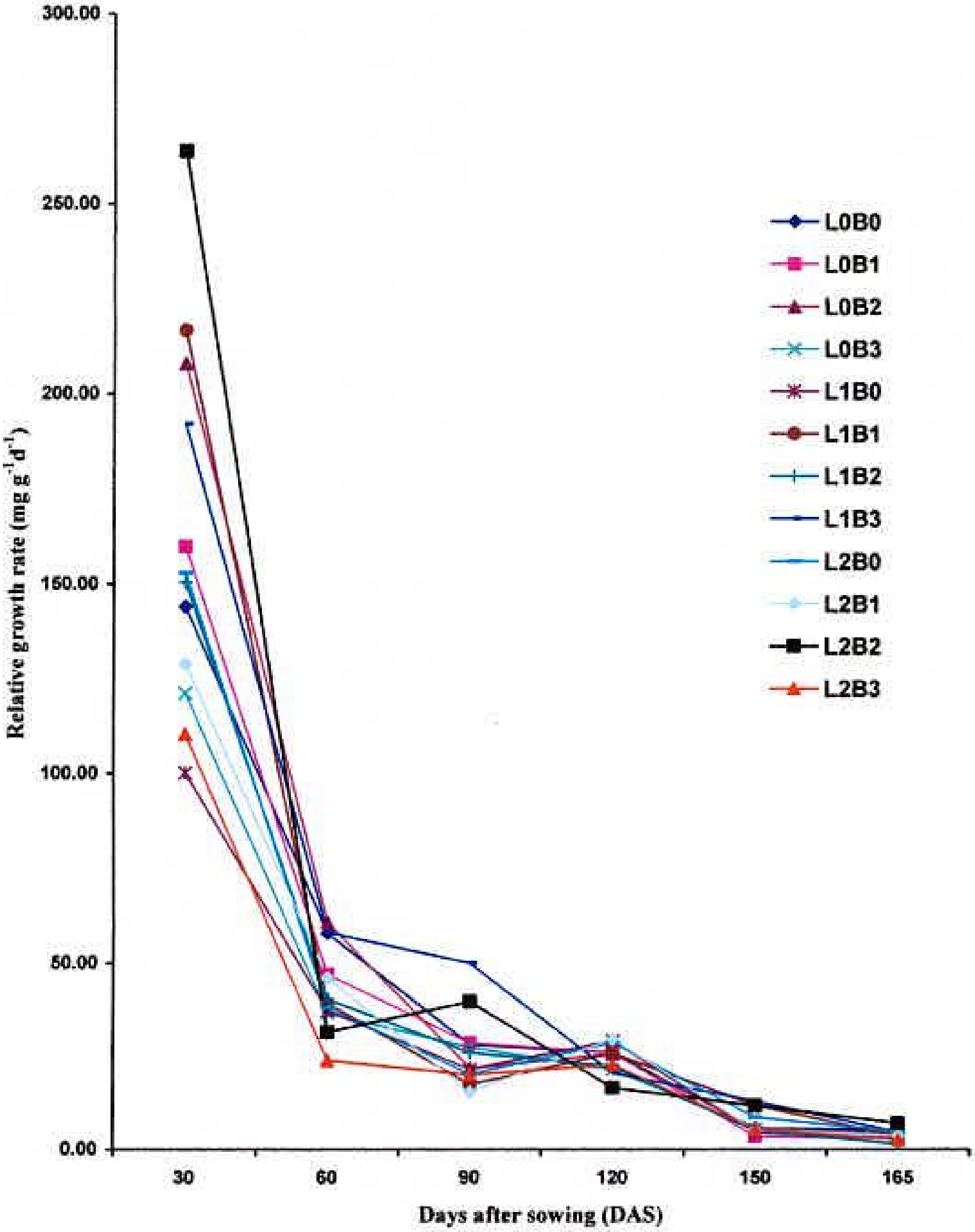

Fig.14. Relative growth rate of maize inbred line (BIL. 20) as influenced by liming and application of boron fertilizer of different day. (LSD(0.05)= 0.356, 0.241, 0.257, 0.189, 0.176, ns for 30, 60, 90, 120, 150 and 165 DAS, respectively)

4.2 Yield and yield components of maize

4.2.1 Effect of lime

Application of lime fertilizer had significant influence on plant height, number of rows cob^{-1}, seeds row^{-1}, cob length, 100 seed weight and seed yield. Lime fertilizer did not show any significant variation in respect of 50% teasseling and days to 50% silking (Table 1). Plant height at maturity varied from 121.40 to 125.90 cm across the lime fertilization. The maximum height of plant was recorded for plants treated with 1.5 t lime ha^{-1} while plants grown without added lime fertilizer displayed shorter plants. However, the differences in plant height due to 0 and 3.0 t lime ha^{-1} application were not statistically significant. The highest number of rows cob^{-1} (12.52) was obtained from 3.0 t lime ha^{-1} and it was significantly different from 0.0 t and 1.5 t lime ha^{-1}. Application of 0.0 t lime ha^{-1}, however, gave the lowest. The highest number of seed row^{-1} (26.26) was found in 1.5 t lime ha^{-1} and the lowest in control. Longest cob (16.21 cm) was obtained from 1.5 t lime ha^{-1}, which was significantly different from that of the plants treated with 0 and 3.0 ton lime ha^{-1}. The untreated control plants (without lime) produced the smallest cob. Hundred seed weight was increased with the increased levels of lime fertilizer. The highest seed weight was found in the plants treated with 3.0 t lime ha^{-1}. This shows the beneficial effect of lime fertilizer in development of seeds. However, the response of 1.5 and 3.0 ton lime ha^{-1} was not statistically significant. Seed yield of maize also varied significantly due to lime fertilizer application

(Table 1). Seed yield differed from 1889 to 260 kg ha^{-1} with treatments variation. The highest hybrid seed yield (2604 kg ha^{-1}) was obtained from 1.5 t lime ha^{-1}, which was significantly higher over the control (L_0) and 3.0 t lime ha^{-1}. The yield advantage of lime fertilizer application at 1.5 t ha^{-1} was 38% higher over the control (without lime). The yield advantage of lime application upto 1.5 t ha^{-1} was mainly due to cob length and number of seeds cob^{-1}. Further increase in lime (1.5 t ha^{-1}) tended to depress seed yield.

4.2.2 Effect of Boron

Boron application exerted significant influence on cob length, number of rows cob^{-1}, no. of seed row^{-1}, 100 seed weight and seed yield of maize. Days to 50% silking and plant height remained unaffected due to boron fertilizer application (Table 1). Similar results reported by Akter *et al.* (2007) and Vaughan (1977). Cob length of female parent of BARI hybrid maize-5 ranged from 10.18 to 15.61 cm due to boron levels. Longest cob was observed in the plants grown with 2.0 kg boron ha^{-1} and thereafter it reduced. The untreated control (without B) or lower levels of boron (1.0 t ha^{-1}) plants produced the smallest cob. The highest (12.44) number of rows cob^{-1} was obtained from 2.0 kg boron ha^{-1} and it was statistically different from the other treatments. The response of 1.0 and 3.0 kg boron ha^{-1} was satistically identical. Plants grown without added boron fertilizer gave the lowest number of rows cob^{-1}. Number of seed row^{-1} increased with increasing boron fertilizer reaching maximum at 3.0 kg ha^{-1} although response of 2.0 and 3.0 kg B ha^{-1} was statistically identical. The untreated control plants (without B) produced the lower number of seeds row^{-1}. Hundred seed weight varied significantly among the boron levels and it ranged between 31.06 and 37.63 g. However, seed size increased linearly with increasing levels of boron fertilizer upto 2.0 kg ha^{-1} and thereafter decreased. Further addition of boron (beyond 2 kg ha^{-1}) tended to reduce 100 seed weight possibly due to toxic effect of boron on plant. This might have reduced the seed weight. Plants grown without boron fertilizer gave the lowest 100 seed weight.

Table 1. Effect of lime and boron on plant characters, yield component and yield of hybrid maize seed

Treatments	Days to 50% tasseling	Days to 50% silking	Plant height (cm)	Cob length (cm)	No. of rows per cob	No. of seed per row^{-1}	100 seed weight (g)	Yield (kg ha^{-1})
Lime (t ha^{-1})								
L_0 =0	96	99	121.41	10.72	8.27	15.75	30.25	1889
L_1=1.5	97	99	125.90	16.21	10.63	26.26	35.67	2604
L_2=3.0	96	99	121.40	14.70	12.52	24.87	36.18	2447
LSD (0.05)	NS	NS	1.30	0.56	1.12	0.96	0.77	15.75
CV (%)	7.5	10.2	8.9	5.4	3.2	5.6	2.4	6.4
Boron (kg ha^{-1})								
B_0=0	98	99	122.58	10.18	8.58	11.03	31.06	1507
B_1=1	96	99	123.17	12.72	10.44	20.31	34.48	2475
B_2=2	96	99	123.17	15.61	12.44	25.98	37.63	2641
B3=3	96	99	122.70	14.66	10.42	26.18	34.29	2564
LSD (0.05)	NS	NS	NS	0.65	1.04	1.10	0.89	18.18
CV (%)	9.7	8.6	7.4	4.6	4.7	5.1	3.8	5.8

NS=Not significant

The seed yield of BARI hybrid maize-5 also responded significantly to boron fertilizer application. The mean seed yield varied from 1507 to 2641 kg. The seed yield of BARI hybrid maize-5 increased progressively with added boron fertilizer upto 2.0 kg ha^{-1} and thereafter a sharp reduction in yield with 3.0 kg boron ha^{-1} was noticed. The yield advantage with boron fertilizer at 2.0 kg ha^{-1} was 75% higher over the control (without B). The higher hybrid maize seed yield with application of boron might be due to increased cob length, number of seed cob^{-1} and 100 seed weight. Plants grown without boron had the lowest hybrid maize seed yield. It was observed that application of boron increased fertile pollen of maize plant (Plate. 7).

4.2.3 Interaction effect of lime and boron

Interaction effect of boron and lime fertilizer on plant height, rows cob^{-1}, seeds row^{-1}, cob length, 100-seed weight, seed yield and harvest index (HI) were significant (Table-2a b). Days to 50% tasseling and 50% silking remained unaltered due to lime and boron fertilizer application (Table-2a).

Lime and boron fertilizer deficient plants (L_0B_0) were found to be significantly shortest than the plants grown with added lime and boron fertilizer. Lime and boron in combination upto L_1B_1 (T_6) produced the tallest plants followed by T_7 and T_5 treatments,and further addition of fertilizer decreased plant height. The highest rows cob^{-1} was found in combination of L_1B_2 followed by L_1B_2, L_1B_2,

L_2Bo, L_2B_1 and L_2B_2 treatments; these were significantly higher than the others. Minimum rows cob^{-1} was noted with L_0B_0. The interaction between lime and boron fertilizer level on seeds row^{-1}, cob length, 100-seed weight, and seed yield followed the same trend as observed in the case of number of rows cob^{-1}. Lime and boron levels interacted significantly hybrid maize seed yield (Table 2b). The yield of maize varied from 1469 to 2809 kg ha^{-1} due to lime and boron levels. There was almost a linear increase in seed yield with the increase of boron fertilizer upto 2.0 kg ha^{-1} and further increase in boron decreased the seed yield irrespective of lime levels. Decrease in yield at higher dose of boron in the experiment might be due to the imbalance and toxic effect caused by increasing level of boron. Significantly the highest hybrid seed yield (2809 kg ha^{-1}) was obtained from 1.5 t lime with 2.0 kg boron ha^{-1} fertilizer. The higher hybrid seed yield with application of 1.5 t lime plus 2.0 kg B ha^{-1} might be due to increased formation of reproduction structure for sink strength and increased production of assimilate to fill the economically important sink resulting increased cob length, seeds cob^{-1} and larger seed size. Moreover, boron deficient in soil that might have contributed to higher yield response to added boron fertilizers. Plants grown without lime and boron produced the lowest seed yield (1869 kg ha^{-1}). It is also evident from Table 2b that combined application of both lime and boron contributed to higher maize yield than their sole application where lime was less than boron.

Lime and boron in combination upto L_2B_2 (T_7) produced the highest harvest index followed by T_6, T_{11} and T_8 treatments and further addition of fertilizer decreased harvest index.

Increase of yield over control by different treatments were compared (Table 2b), the combined application of both boron and lime contributed 18-50 % higher yield over control while sole application contributed 18-20 %, which signifies their requirement for optimizing the seed yield of hybrid maize.

Table 2a. Interaction effect of lime and boron fertilizer on days to 50% tasseling, days to 50% silking, plant height, rows cob^{-1} seed row^{-1} of hybrid maize.

Treatment	Days to 50% tasseling	Days to 50% silking	Plant height(cm)	rows cob^{-1}	No. seed row^{-1}
L_0B_0	97	99	120.33	6.40	15.44
L_0B_1	96	98	122.28	8.13	20.06
L_0B_2	97	98	121.39	8.40	24.22
L_0B_3	96	99	121.65	9.13	23.27
L_1B_0	99	100	125.40	10.07	22.42
L_1B_1	96	98	126.37	11.67	27.13
L_1B_2	96	101	126.11	12.40	28.88
L_1B_3	97	99	125.73	12.40	26.62
L_2B_0	97	99	120.86	12.27	21.24
L_2B_1	96	99	122.00	12.53	26.75
L_2B_2	96	99	122.00	11.53	25.08
L_2B_3	96	99	120.73	10.73	25.40
LSD (5%)	NS	NS	1.07	1.03	1.91
CV (%)	8.0	7.5	9.4	4.9	4.6

NS = Not significant

Table 2.b. Interaction effect of lime and boron fertilizer on cob length, 100 seed weight, yield, harvest index and yield increase over control of hybrid maize

Treatment	Cob length (cm)	100 seed weight (g)	Yield (kg ha^{-1})	Harvest Index	Yield increase over control (%)
L_0B_0	10.28	34.13	1869	0.42	-
L_0B_1	13.07	34.53	2248	0.47	20.30
L_0B_2	13.60	34.23	2565	0.52	37.26
L_0B_3	13.93	34.10	2473	0.55	32.33
L_1B_0	15.46	35.00	2200	0.57	17.73
L_1B_1	15.84	35.63	2674	0.59	43.11
L_1B_2	17.83	36.73	2809	0.60	50.26
L_1B_3	15.70	34.50	2734	0.58	46.32
L_2B_0	13.79	33.03	2251	0.57	20.45
L_2B_1	15.92	36.63	2602	0.57	33.91
L_2B_2	14.73	36.57	2651	0.59	36.41
L_2B_3	14.37	34.27	2584	0.57	32.92
LSD (5%)	1.55	1.12	31.50	0.028	-
CV (%)	5.1	3.1	5.7	3.0	-

4.2.4 Response Function

A positive quadratic relationship was observed between hybrid maize seed yield and added limes (Fig.15). Similar result was also recorded by Akter *et al.* (2007) and Ullah *et al.* (2006) in maize. The R^2 value of 1.00 indicated that 100% of the total valuation in seed yield could be explained by the estimated. From regression equation optimum and economic dose of lime was calculated to be 1.75 and 1.70 t lime ha^{-1} respectively. Using optimum dose of lime along with boron and blanket dose of other fertilizers, the maximum seed yield (2610 kg ha^{-1}) of hybrid maize could be expected.

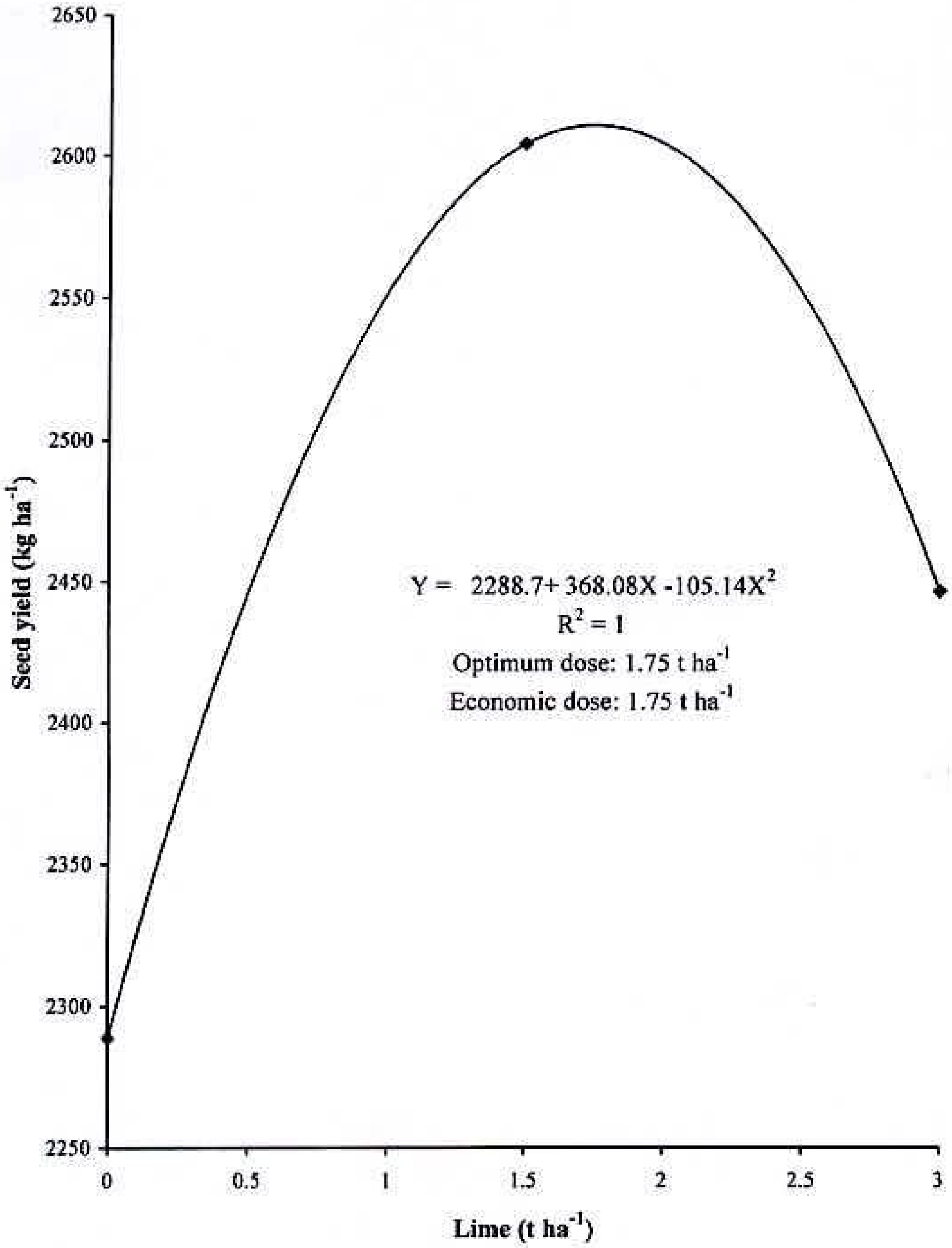

Fig.15. Relationship between seed yield and lime of hybrid maize

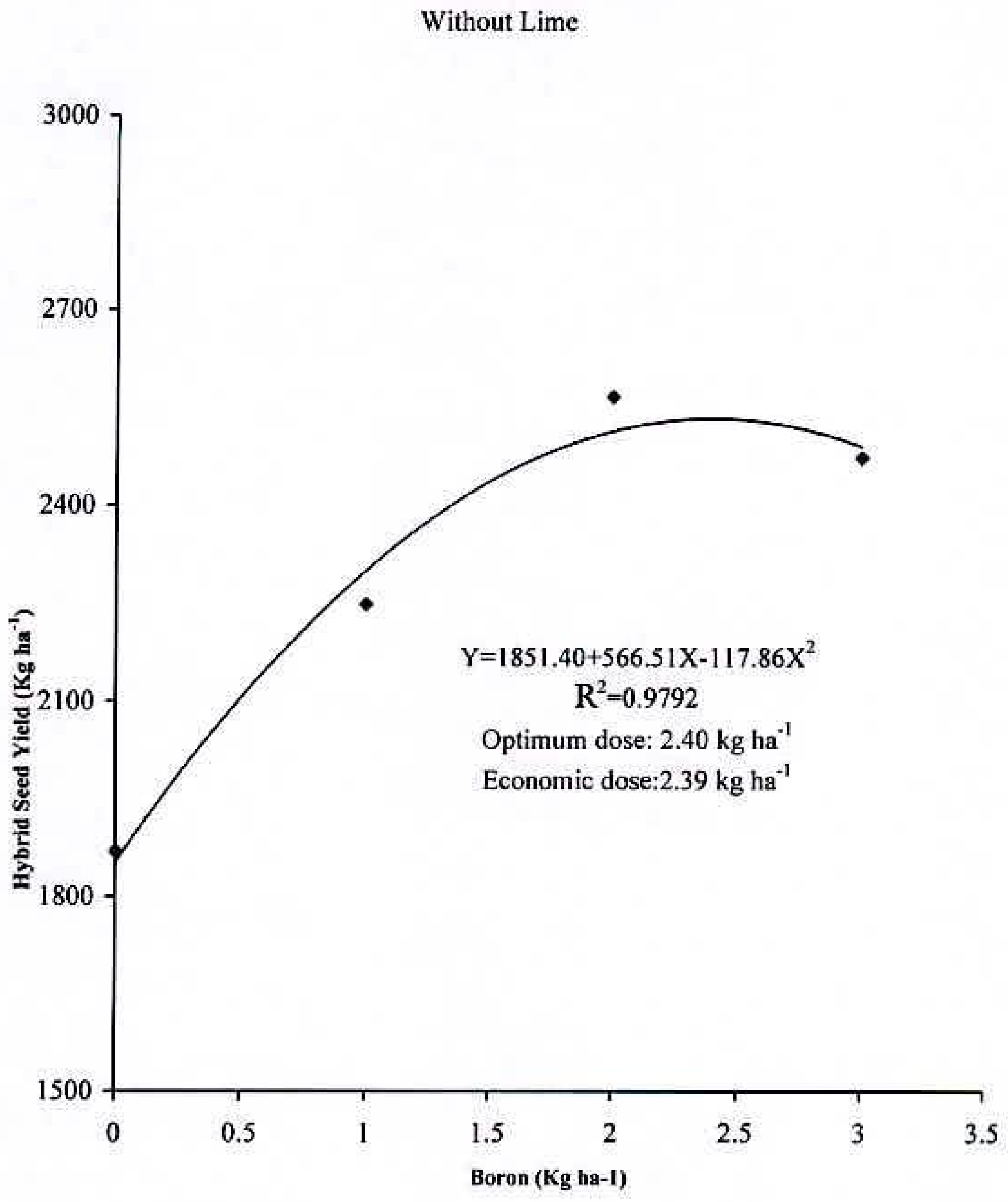

Fig.16. Response of hybrid maize seed to boron fertilization without lime

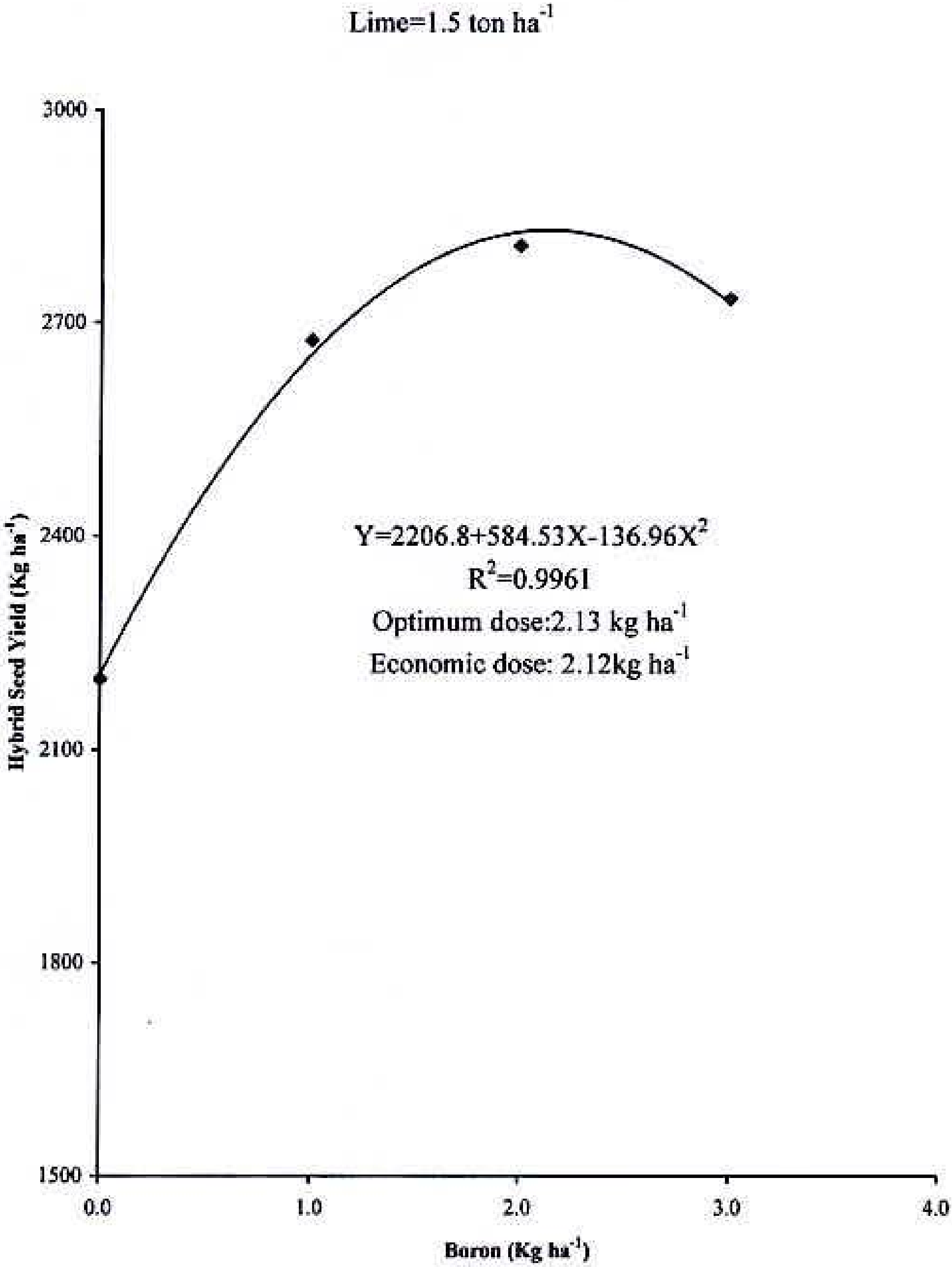

Fig.17. Response of hybrid maize seed to boron fertilization with 1.5 t ha^{-1} lime.

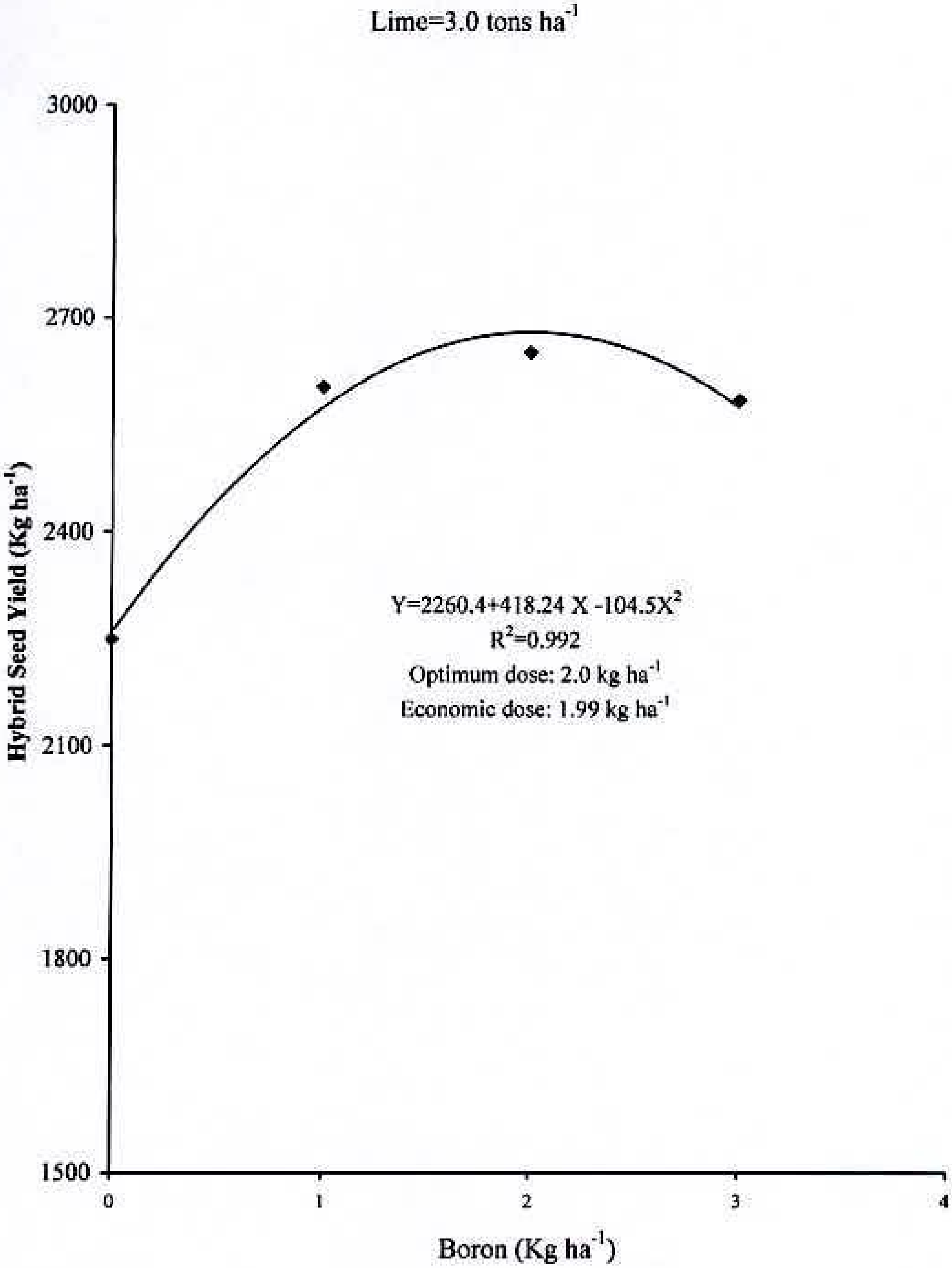

Fig.18. Response of hybrid maize seed production to B fertilization with 3.0 tons lime

Table 3. Response function of hybrid maize seed production to lime and boron

Sl. No.	Regression equation	Coefficient of determination (R^2)	Optimum dose	Economic dose	Maximum yield (kg) from optimum dose	Production of hybrid maize seed for 1 ton lime or 1 kg Boron
For lime (ton ha^{-1})						
1.	$Y = 2288.7 + 368.08X - 105.14X^2$	1.00	1.75	1.75	2610	262
For boron (kg ha^{-1}) (without lime)						
2.	$Y = 1851.40 + 566.51X - 117.86X^2$	0.97	2.40	2.39	2532	448
For boron (kg ha^{-1}) and lime (1.5 ton ha^{-1})						
3.	$Y = 2206.8 + 584.53X - 136.96X^2$	0.99	2.13	2.12	2829	447
For boron (kg ha^{-1}) and lime (3.0 ton ha^{-1})						
4.	$Y = 2260.4 + 418.24X - 104.5X^2$	0.99	2.0	1.99	2678	313

A quadratic relationship was observed between hybrid maize seed yield and added boron without lime (Fig.16). The value of R^2 indicates that 0.97 or 0.99% of total variation in seed yield could be accounted for the quadratic function of boron levels. The optimum dose of boron (2.40 kg ha^{-1}) was calculated from the quadratic equation without lime (Table 3). Using the said optimum dose, the maximum hybrid seed yield (2532.15 kg ha^{-1}) of hybrid maize could be expected at ARS, Burirhut, Rangpur. The economic dose (2.39 kg ha^{-1}) of boron was worked out from the regression equation. The use efficiency showed that 1.0 kg boron could produce 448.65 kg hybrid maize seed ha^{-1} up to optimum level. Beyond the optimum dose, if 1.0 kg ha^{-1} excess boron is applied, then there is a risk of reducing 117.86 kg ha^{-1} of hybrid seed yield.

Positive quadratic relationship was also observed between hybrid maize seed yield and added boron with 1.5 ton lime ha^{-1} (Fig.17). The optimum dose of boron (2.13 kg ha^{-1}) was calculated from the quadratic equation with 1.5 ton ha^{-1} lime (Table 3). Using 2.13 kg boron ha^{-1}, the maximum hybrid maize seed yield (2829.67 kg ha^{-1}) could be expected. The economic dose (2.12 kg ha^{-1}) of boron was worked out from the regression equation. The use efficiency showed that each 1.0 kg boron could produce 447.57 kg hybrid maize seed ha^{-1} up to optimum level. Beyond the dose, if 1.0 kg ha^{-1} excess boron is applied, then there is a risk of reducing 136.96 kg ha^{-1} of hybrid seed yield.

A positive quadratic relationship was also observed between hybrid maize seed yield and added boron with 3.0 ton ha^{-1} lime (Fig.18). The value R^2 indicates that 99% of the total variation in seed yield of hybrid maize could be explained by the variation in boron fertilizer. Similar result also recorded by Akter *et al.* (2007) in maize production. The optimum dose of boron (2.00 kg ha^{-1}) was calculated from the quadratic equation with 1.5 ton ha^{-1} lime (Table3). Using optimum dose, the maximum hybrid seed yield (2678.88 kg ha^{-1}) could be expected for hybrid maize seed production at Rangpur. The economic dose (1.99 kg ha^{-1}) of boron was worked out from the regression equation. The use efficiency showed that 1kg boron could produce 313.74 kg hybrid maize seed ha^{-1} up to optimum level. Beyond the said optimum dose, if 1 kg ha^{-1} excess boron is applied, then there is a risk of loosening 104.50 kg ha^{-1} of hybrid seed yield.

4.3 Effect of lime and boron on seed quality parameters

4.3.1 Effect of lime on seed quality parameters

Variation in lime fertilizer rates did not show any significant effect on germination percentage, root and shoot length, root-shoot ratio, dry weight of seedlings and vigour index (Table 4).

4.3.2 Effect of Boron on seed quality parameters

Levels of boron fertilizer significantly improved seed germination, root and shoot length, root-shoot ratio, seedling dry weight and vigour index (Table4). Plants grown with 2 kg B ha^{-1} showed the highest germination (99%) which was at par with, other treatments except control (without B). Bagum *et al.*, (2007) also reported germination percentage varies from 90 to 99 in maize due to boron fertilization. Root and shoot length were significantly higher in seedling obtained from 2 kg B ha^{-1} as compared to control (without B). Similar trend was found in case of seedling weight. Maximum root shoot ratio (1.37) was registered by plants grown without B and it was identical with 1kg B ha^{-1} and the lowest (1.13) in 2 kg B ha^{-1} root-shoot ratio is an indication for good seed health. Vigour index depends on percent germination and seedlings dry weight express in milligram and it differed from 14957 the 21757 Maximum vigour index (21757) was obverted when the plants grown with 2kg B ha^{-1} and it was statistically identical with 3kg ha^{-1} and lowest from control(14957). Bagum *et al.* (2007) also reported similar result in maize.

4.3.3 Interaction effect of lime and boron on seed quality parameter

The interaction effects of lime and boron showed significant variation on germination percentage, root and shoot length, root-shoot ratio, dry weight or seedling and vigour index, of maize (Table 5). The germination percentage varied from 95.3 to 99.4%. The highest germination was observed from the treatment combination of L_1 B_2 and L_1, B_3, which was statistically identical with L_0 B_2, L_3 B_2 and L_3 B_3. The lowest germination percentage of seed (95.9) was found from L_1 B_0 combination followed by L_0 B_0 and L_3 B_0. The highest root length (25.83 cm) was recorded in L_2B_3 treatment, which was identical with L_0B_2, L_0B_3, L_1B_2, L_1B_3 and L_2B_2 treatments and the lowest (22.31 cm) in L_0B_0 treatment. The highest shoot length (22.04 cm) was found in L_2B_2 and it was statistically similar with L_0B_2, L_0B_3, L_1B_2, L_1B_3 and L_2B_{21} treatment. The lowest shoot length (16.92) was recorded in L_2B_1treatment. Maximum root-shoot ratio (1.40) was found in L_2B_1 which was identical with all treatments except L_1B_2 (1.10) treatment. The highest seedling dry weight (220.89 mg) was recorded in L_1B_2 treatment and it was statistically identical with L_0B_2, L_0B_3, L_1B_1, L_1B_3, L_2B_1 and L_2B_2 treatment. The lowest seedlings dry weight (155.0 mg) was obtained from L_2B_0 treatment.

Vigour index also differed significantly among the boron treatments (Table 5). Maximum vigour index (21949) was obtained in L_1B_2treatment, which was identical with L_0B_2, L_0B_3, L_1B_2, L_2B_2 and L_2B_3 treatment and the lowest (14724) in L_2B_0 treatment.

Table: 4. Effect of lime and boron on seed quality parameter

Treatment	Germination (G)%	Root length (cm)	short length (cm)	Root-short ratio	Seedling Dry Weight (mg)	Vigour index (VI)
Lime(ton ha^{-1})						
L_0 =0	97.5	23.9	19.4	1.24	196.83	19224
L_1=1.5	97.8	23.7	19.7	1.22	198.17	19422
L_2=3.0	97.5	24.0	19.7	1.23	197.64	19312
LSD (0.05)	NS	NS	NS	NS	NS	NS
Boron (kg ha^{-1})						
B_0=0	95.0	22.43	17.94	1.37	157.30	14957
B_1=1	97.3	23.10	17.23	1.25	201.11	19449
B_2=2	99.6	24.44	21.75	1.13	219.19	21757
B3=3	99.5	25.56	21.63	1.17	212.59	21115
LSD(0.05)	1.12	2.08	1.33	0.17	12.79	1221

NS = Not significant

Table: 5. Interaction effect of lime and boron on seed quality parameter

Treatment	Germination (G)%	Root length (cm)	short length (cm)	Root-short ratio	Seedling Dry wt. (mg)	Vigour index
L_0B_0	95.3	22.31	17.67	1.26	159.56	15153
L_0B_1	97.4	23.17	17.47	1.35	198.89	19207
L_0B_2	99.2	25.12	21.33	1.21	216.67	21460
L_0B_3	99.1	25.31	21.31	1.14	212.22	21078
L_1B_0	95.2	22.48	17.92	1.25	157.33	14994
L_1B_1	97.2	23.06	17.31	1.35	202.22	19666
L_1B_2	99.4	25.07	21.87	1.10	220.89	21949
L_1B_3	99.4	24.39	21.88	1.14	212.22	21078
L_2B_0	95.4	22.51	18.23	1.24	155.00	14724
L_2B_1	96.2	23.08	16.92	1.40	202.22	19473
L_2B_2	99.1	25.61	22.04	1.17	220.00	21862
L_2B_3	99.0	25.83	21.71	1.14	213.33	21189
LSD (0.05)	1.95	2.60	2.31	0.26	25.73	2450

4.4 Cost and Return Analysis of Hybrid maize seed production

The highest gross return was obtained at $L_{1.5}B_2$ (Tk 293895 ha^{-1}) followed by $L_{1.5}B_3$ treatment (Tk. 286543 ha^{-1}) due to the higher productivity. The gross expenditure was the highest in T_{12} and the lowest in T_1 due to variation of fertilizers cost. The cost of production for per kilogram hybrid maize seed varies from Tk 65.52 to Tk 77.11 depending on the treatments. The highest hybrid maize seed cost (Tk 77.11 Kg^{-1}) was obtained in T_{12} due to highest amount of lime and boron cost. The highest gross margin also was recurred with T_7 treatment (Tk.186398 ha^{-1}) followed by treatment T_8 (Tk.178000 ha^{-1}). The highest benefit cost ratio was recorded from T_7 treatment followed by T_8 due to high productivity. The treatment T_7 is more profitable than the others.

Table 6: Cost and return of hybrid maize seed production

Treatment	Gross return (Tk ha^{-1})	Gross expenditure (Tk ha^{-1})	Cost / kg seed (Tk ha^{-1}	Gross margin (Tk ha^{-1})	BCR
L_0B_0	199976	98385	65.52	101591	2.04
L_0B_1	237908	99331	66.22	138577	2.40
L_0B_2	269600	100378	66.92	169222	2.69
L_0B_3	260300	101424	67.62	158876	2.57
L_1B_0	233100	105404	70.27	127696	2.21
L_1B_1	280544	106450	70.97	174094	2.64
L_1B_2	293895	107497	71.66	186398	2.73
L_1B_3	286543	108543	72.36	178000	2.64
L_2B_0	238191	112523	75.02	125668	2.12
L_2B_1	273341	113569	75.71	159772	2.41
L_2B_2	278150	114616	76.41	163534	2.43
L_2B_3	271500	115662	77.11	155838	2.35

4.5 Effect of lime and boron on Oil (%), Protein (%) and Starch (%) content of hybrid maize seeds

Lime and boron fertilizer exerted significant influence on oil, protein and starch content of BARI hybrid maize 5 (Table 7). The highest oil content (5.83%) percent of oil content was found from T_7 which was statistically higher than the rest of the treatments. The Lowest oil content (4.90%) was obtained from treatmentT_1 and it was statistically identical with T_2 and T_{12}. Islam (2009) reported that BARI hybrid maize 5 content 5.8% oil.

Protein ranks the second position among the major nutrient components of maize kernel. Maximum protein content (10.97%) of was observed in T_7 which was significantly higher than that of the other treatments. Minimum protein content (8.87%) was found in T_1. Khatun *et al.* (2005) reported that BARI hybrid maize-5 11.0% protein. Protein content is genetically controlled. It is also influenced by nitrogen fertilizer and agronomic practices. Starch content of maize ranged from 68.57% to 71.43% (Table 10). The highest amount of starch (71.43%) was found in $T_{7,}$ which was significantly higher than that of other treatments and the lowest (68.57%) in T_1 treatment. The present values were found higher than the values (62.6%, 66.2%) reported by Yau, (1985).

Table 7. Effect of lime and boron on oil, protein and starch content of BARI hybrid maize 5 seeds

Treatment	Oil (%)	Protein (%)	Starch (%)
L_0B_0	4.90	8.87	68.57
L_0B_1	4.97	9.67	70.37
L_0B_2	5.20	9.53	70.53
L_0B_3	5.40	9.57	70.67
L_1B_0	5.37	10.20	70.67
L_1B_1	5.33	10.50	71.03
L_1B_2	5.83	10.97	71.43
L_1B_3	5.30	10.47	70.67
L_2B_0	5.20	10.53	70.37
L_2B_1	5.20	9.50	70.17
L_2B_2	5.10	9.73	70.07
L_2B_3	4.97	9.47	69.13
LSD (0.05)	0.11	0.19	0.33

4.6 Changes in soil properties

The fertility status of initial and post harvest soil are shown in Table 8. The soil was highly acidic (pH-4.5) and thus initial fertility was low having only 1.2% organic matter. However, the fertility statuses of lime treated plots were improved slightly. But boron treated plots without lime were more or less same as before. In lime treated plots, soil pH increased upto 6.15. Similar results were reported by Akter and Mahmud, (2009) in hybrid maize and Noor and Ullah (2009) in onion seed production in acidic soil.

A little change was observed in case of organic matter, Ca, Mg, K, P, S, Zn and B in respect of lime application (Table 8). However, integrated use of lime and boron along with recommended fertilizer showed better results in respect of yield sustainability and improvement of soil fertility in the study area.

Table.8. Changes in soil properties during the crop season

Soil Status	pH	OM	Total N	Ca	Mg	K	P	S	B	Zn	Cu	Fe	Mn
		(%)		(meq 100 g soil^{-1})			(μg g^{-1})						
Initial	4.5	1.20	0.05	0.87	0.30	0.10	12	11	0.11	1.01	3.5	145	1.1
Post harvest													
L_0B_0	4.45	1.20	0.07	1.4	0.52	0.11	14.0	19.0	0.17	1.62	2.78	153	5.18
L_0B_1	4.50	0.87	0.05	1.5	0.54	0.10	15.0	20.0	0.12	1.54	2.92	159	7.10
L_0B_2	4.50	0.90	0.05	1.3	0.50	0.11	17.0	16.0	0.10	1.82	2.11	151	3.20
L_0B_3	4.50	0.98	0.05	1.4	0.50	0.15	16.0	17.0	0.18	1.37	2.80	161	5.40
L_1B_0	5.80	0.84	0.04	1.1	0.60	0.12	43.0	18.0	0.17	1.21	2.08	148	2.00
L_1B_1	5.80	0.95	0.05	1.3	0.67	0.13	42.0	17.0	0.30	1.00	1.95	155	2.50
L_1B_2	5.75	0.90	0.05	1.2	0.68	0.13	47.0	24.0	0.30	0.58	3.71	153	2.85
L_1B_3	5.85	0.87	0.05	1.3	0.60	0.12	53.0	19.0	0.29	1.01	2.30	160	2.40
L_2B_0	6.00	1.11	0.06	1.6	0.78	0.16	51.0	19.0	0.20	1.04	1.95	150	2.26
L_2B_1	6.10	1.00	0.05	1.5	0.78	0.16	49.0	19.0	0.23	1.00	2.07	140	2.26
L_2B_2	6.15	1.08	0.06	1.7	0.70	0.14	50.0	21.0	0.24	1.89	2.14	148	2.36
L_2B_3	6.15	1.04	0.06	1.8	0.73	0.16	48.0	18.0	0.22	1.79	2.19	137	2.08

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the research field of Agricultural Research Station, Burrirhat, Rangpur during the October 2007 to May 2008 to find out the optimum requirement of lime and boron for hybrid maize seed production. The soil of the experimental field belongs to Calcareous Grey Floodplain soil under Agro Ecological Zone-3. The experiment was carried out in split plot design with three replications. The main plot treatment was lime and subplot treatment was boron level. There were 12 treatment combinations comprising 4 levels of B (0, 1, 2 and 3 kg ha^{-1}) and 3 levels of lime (0, 1.5 and 3 t ha^{-1}). A blanket dose of $N_{120}P_{35}K_{65}S_{20}Zn_5$ kg ha^{-1} and cowdung 5.0 t ha^{-1} was used in the form of Urea, TSP, MoP, Gypsum, Zinc oxide and Boric acid, respectively. All P, K, S, Zn, B and cowdung and $1/3^{rd}$ N were applied at the time of final land preparation. The remaining $2/3^{rd}$ N were applied in two equal installments at 40 and 80 days after sowing (DAS).

The leaf area $plant^{-1}$ of female parent of BARI hybrid maize-5 responded to applied lime and boron fertilizer greatly over the growth period. Regardless of treatment variations leaf area was maximum at 120 DAS and ranged between 3747.50 and 5266.13 cm^2. Maximum leaf area $plant^{-1}$ was obtained from the lime 1.5 t lime ha^{-1} and 2.0 kg B ha^{-1} combination irrespective of growth stages. Female parent of BARI hybrid maize-5 grown without L and B (L_0B_0) gave the lowest leaf area plant^{-1} at all the growth stages.

LAI of female parent of BARI hybrid maize-5 was increased sharply from 60 DAS and reaching maximum at 120 DAS and then declined sharply irrespective of treatment differences. The rate of decrease in LAI of after attaining peak was more rapid. Application of 1.5 t lime ha^{-1} produced higher LAI with 2.0 kg B ha^{-1} at all growth stages while the lowest LAI was recorded in L_0B_0.

Highest rate of TDM production was observed from 90 to 120 DAS irrespective of lime and boron levels. Consistently higher TDM was observed in plant treated with 1.5 t lime and 3 kg boron ha^{-1} followed by 1.5 t lime with 2.0 kg boron ha^{-1} Further increase in lime and boron rate (3.0 t limes with 2.0 kg boron ha^{-1} and 3.0 t lime with 3.0 kg boron ha^{-1}) trended to depress TDM accumulation might be due to toxic effect of boron.

Pattern of DM partitioning of female parent was similar to leaves and stover increased to a plateau and then decreased with concomitant increase in allocation to reproductive organ i.e. husk, rachis and grain. Dry matter partitioning into leaf and stover of maize inbred line peaked at 120 DAS and thereafter declined irrespective of lime and boron application. The dry matter accumulation into these two organs increased with the increasing B levels and continued up to 2.0 kg ha^{-1}. Further increase in B levels failed to increase leaf and stover dry matter weight in both the cases.

Among the treatments, application of 1.5 t lime with 2 kg B ha^{-1} registered a maximum CGR values during the whole growth period while plants treated with L_0B_0 produced lowest CGR irrigative of growth stages. RGR was more at early stage (30 DAS) and showed a decreasing trend with the advancement of plant age. Application of 1.5 t lime with 2.0 kg B ha^{-1} gave the highest RGR while the lowest in L_0B_0 treatment at all the growth stages. On the contrary, net assimilation rate (NAR) of female parent of BARI hybrid maize-5 increased progressively upto 120 DAS and thereafter declined sharply. Application of 1.5 t lime with 2 kg B ha^{-1} gave the highest NAR while the lowest in L_0B_0 treatment.

Application of lime fertilizer had significant influence plant height, number of rows cob^{-1}, seeds row^{-1}, cob length, 100 seed weight and yield. The tallest plant was receded for plants treated with 1.5 t lime ha^{-1} while plants grown without added lime fertilizer displayed shorter plants. The highest number of row cob^{-1} (12.52) was obtained from 3.0 t lime ha^{-1} and it was significantly different from 0.0 t and 1.5 t lime ha^{-1}. The highest number of seed row^{-1} (26.26) was found in 1.5 t lime ha^{-1} and the lowest in control. The height length of cob (16.21 cm) was obtained from 1.5 t lime ha^{-1}which was significantly different from the plants treated with 0.0 and 3.0 to lime ha^{-1}. . The highest seed weight was found from the plants treated with 3.0 t lime ha^{-1}. The highest hybrid seed yield (2604 kg ha^{-1}) was obtained from 1.5 t lime ha^{-1}, which was significantly higher over the control (L_0) and 3.0 t lime ha^{-1}. The yield advantage of lime application 1.5 t ha^{-1} was 38% higher over the control (without lime).

Boron application exerted significant influence number of rows cob^{-1}, cob length, seeds row^{-1} and 1000 seed weight. Days to 50% silking and plant height remained unaffected due to boron fertilizer application. The highest number of rows per cob (12.44) was obtained from 2.0 kg boron ha^{-1} and it was statistically different from the other treatments. Number of seeds row^{-1} increased with increasing boron fertilizer, reaching maximum at 3.0 kg ha^{-1} although response of 2.0 and 3.0 kg B ha^{-1} was statistically identical. The longest cob observed in the plants grown with 2.0 kg boron $ha^{-1}$and thereafter it reduced. Seed size increased linearly with increasing levels of boron fertilizer upto 2.0 kg ha^{-1} and thereafter decreased. Further addition of boron (beyond 2 kg ha^{-1}) tended to reduce 100 seed weight possibly due to toxic effect on the plant. The seed yield of BARI hybrid maize-5 increased progressively with added boron fertilizer upto 2.0 kg ha^{-1} and therefore decreased

Boron and lime fertilizer interaction effect on plant height, cob length, number of rows cob^{-1}, seeds row^{-1} and 100-seed weight significant. Lime and boron combination upto L_1B_1 produced the taller plant followed by L_1B_0 and L_1B_2 treatments and further addition of fertilizer deceased plant height. The highest number of rows cob^{-1} was found in L_1B_2 combination followed by L_1B_2, L_1B_2, L_2Bo, L_2B_1 and L_2B_2 were was significantly higher than the others. Significantly the highest hybrid seed yield was obtained from 1.5 t lime with

2.0 kg boron fertilizer. The combined application of both B and lime contributed 17.73-50.26 % increased yield over control while sole application contributed 17.73-20.30 %, which signifies their requirement for optimizing the seed yield of hybrid maize seed.

A positive quadratic relationship was observed between hybrid maize seed yield and added limes. From regression equation optimum and economic dose for B in respect of without liming was calculated to be 1.75 & 1.70 ton lime ha^{-1}, respectively. Using optimum lime dose along with boron and a blanket dose of other fertilizers, the maximum seed yield (2610.84 kg ha^{-1}) could be expected for hybrid maize seed production.

A quadratic relationship was observed between hybrid maize seed yield and added boron without lime. The value of R^2 indicates that 0.97 or 0.99% of total variation in seed yield could be accounted for the quadratic function of boron levels. The optimum dose of boron (2.40 kg ha^{-1}) was calculated from the quadratic equation without lime. Using the said optimum dose, the maximum hybrid seed yield (2532.15 kg ha^{-1}) could be expected for hybrid maize seed production. The economic dose (2.39 kg ha^{-1}) of boron was worked out from the regression equation. The use efficiency showed that 1kg boron could produce 448.65 kg hybrid maize seed ha^{-1} up to optimum level. Beyond the optimum dose, if 1 kg ha^{-1} excess boron is applied, then there is a risk of decreasing 117.86 kg ha^{-1} of hybrid seed yield.

Positive and quadratic relationship was also observed between hybrid maize seed yield and added boron with 1.5 ton lime ha^{-1}. The optimum dose of boron (2.13 kg ha^{-1}) was calculated from the quadratic equation with 1.5 ton ha^{-1} lime. Using 2.13kg Bha^{-1}(optimum dose), the maximum hybrid seed yield (2829.67 kg ha^{-1}) could be expected. The economic dose (2.12 kg ha^{-1}) of boron was worked out from the regression equation. The use efficiency showed that each 1.0 kg boron could produce 447.57 kg hybrid maize seed ha^{-1} up to optimum level. Beyond the dose, if 1 kg ha^{-1} excess boron is applied, then there is a risk of reducing 136.96 kg ha^{-1} of hybrid seed yield.

A positive quadratic relationship was observed between hybrid maize seed yield and added boron with 3.0 ton ha^{-1} lime. The optimum dose of boron (2.00 kg ha^{-1}) was calculated from the quadratic equation with 1.5 ton ha^{-1} lime. Using the same optimum dose, the maximum hybrid seed yield (2678.88 kg ha^{-1}) could be expected for hybrid maize seed production at Rangpur. The economic dose (1.99 kg ha^{-1}) of boron was worked out from the regression equation. The use efficiency showed that 1.0kg boron could produce 313.74 kg hybrid maize seed ha^{-1} up to optimum level. Beyond the optimum dose, if 1.0 kg ha^{-1} excess boron is applied, then there is a risk of loosing 104.50 kg ha^{-1} of hybrid seed yield.

Levels of boron fertilizer significantly improved seed germination, root and shoot length, root-shoot ratio, seedling dry weight and vigor index. Plants grown with 2.0 kg Bha-1 showed the highest germination (99%), which was at par with other treatments except control (without B). Maximum root shoot-ratio (1.37) was registered by plants grown without B and it was identical with 1.0 kg B $ha^{-1}$and the lowest (1.13) in 2.0 kg B ha^{-1}. Maximum vigour index (21757) was recorded when the plants grown with 2kg B ha^{-1} and the lowest from control (without B).

The interaction effects of lime and boron showed significant variation on germination percentage, root and shoot length, root-shoot ratio, dry weight of seedling and vigour index of maize seed production. The lowest shoot length (16.92) was recorded in L_2B_1 treatment. Maximum root shoot ratio (1.40) was found in L_2B_1, which was identical with the rest of treatments except L_1B_2 (1.10) treatment. Maximum vigour index (21948.9) was obtained in L_1B_2 treatment and it was identical with L_0B_2, L_0B_3, L_1B_3, L_2B_2 and L_2B_3 treatments and the lowest (14723.9) in L_2B_0 treatment.

The gross return was higher (Tk. 293895 ha^{-1}) in L_1B_2, followed by the treatment (Tk. 286543 ha^{-1}) due to the higher productivity. The cost of production for per kilogram hybrid maize seed varies from Tk 65.52 to Tk. 77.11 depending on the treatments. The highest hybrid maize seed cost (Tk 77.11 Kg^{-1}) was obtained in L_2B_3 due the higher investment of lime and boron. The gross margin was the highest (Tk.186398 ha^{-1}) in L_1B_2 treatment followed by treatment L_1B_3 (Tk.178000 ha^{-1}). The highest benefit cost ratio (2.73) was also recorded from the same treatment due to high productivity.

CONCLUSIONS

Lime and Boron played a significant role in increasing the yield of hybrid maize seed as well as qualities of seed in the study areas. Boron @ 2.12-2.13 kg ha^{-1} and lime @ 1.5 t ha^{-1} along with a blanket dose of $N_{120}P_{35}K_{65}S_{20}Zn_5$ kg ha^{-1} and cowdung 5.0 t ha^{-1} appeared to be the best-suited dose for maximizing the yield of hybrid maize seed production in the study area. However, this experiment could be done further under different agro ecological zones.

RECOMMENDATIONS

Boron @ 2.12-2.13 kg ha^{-1} and lime @ 1.5 t ha^{-1} along with a blanket dose of $N_{120}P_{35}K_{65}S_{20}Zn_5$ kg ha^{-1} and cowdung 5.0 t ha^{-1} may be recommended for profitable hybrid maize seed production where the farmers are facing the problems of hybrid maize seed.

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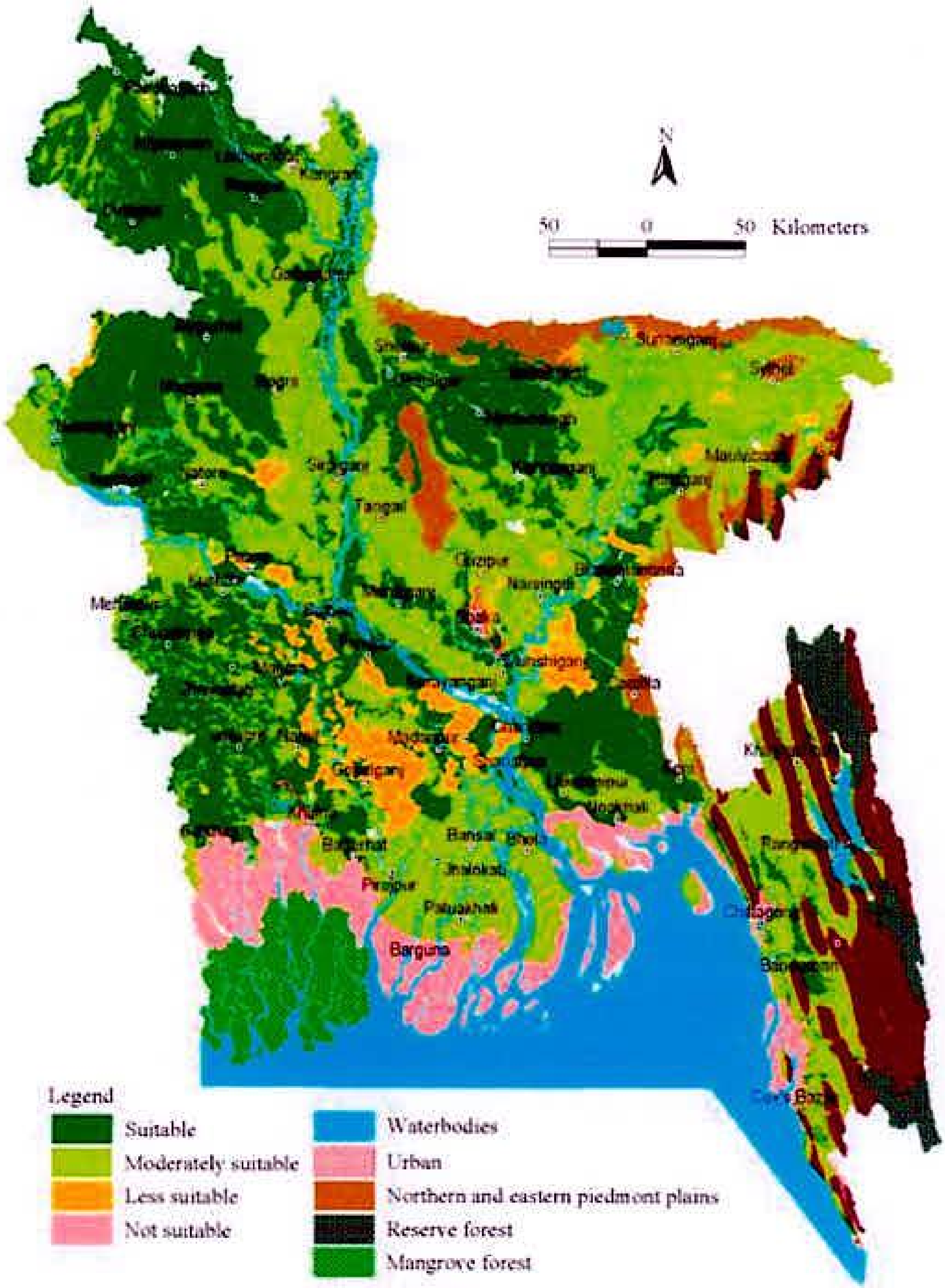
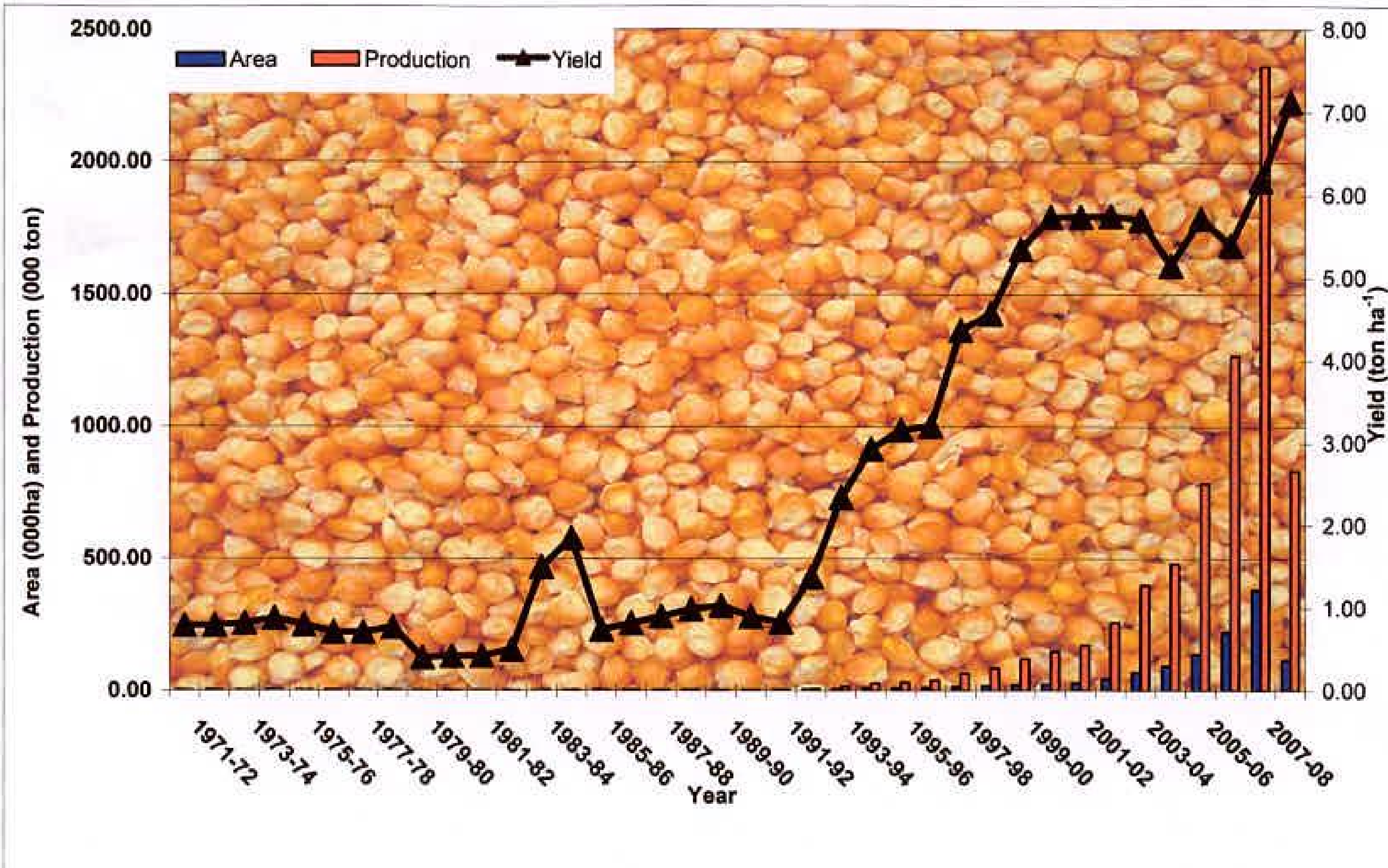
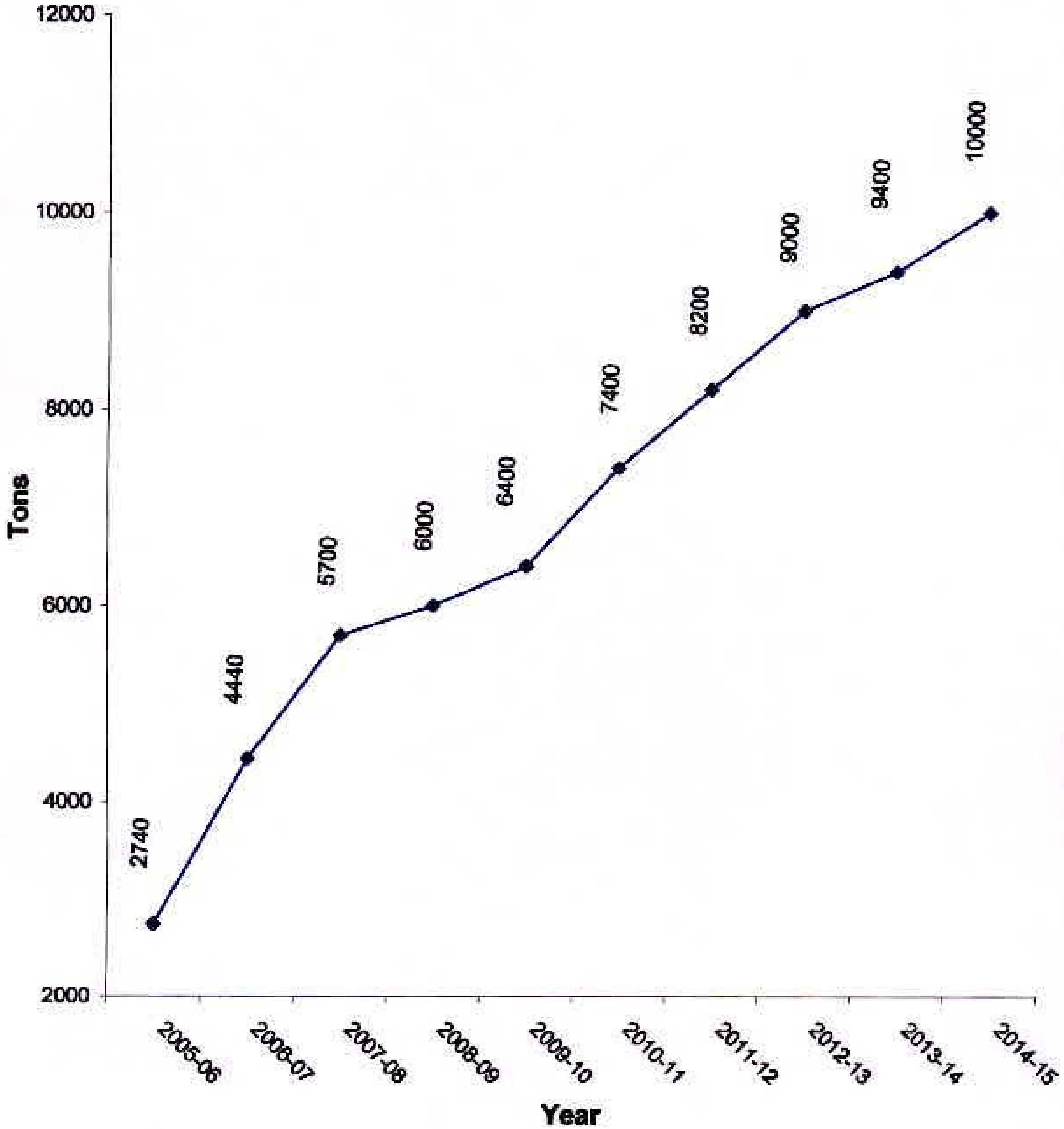


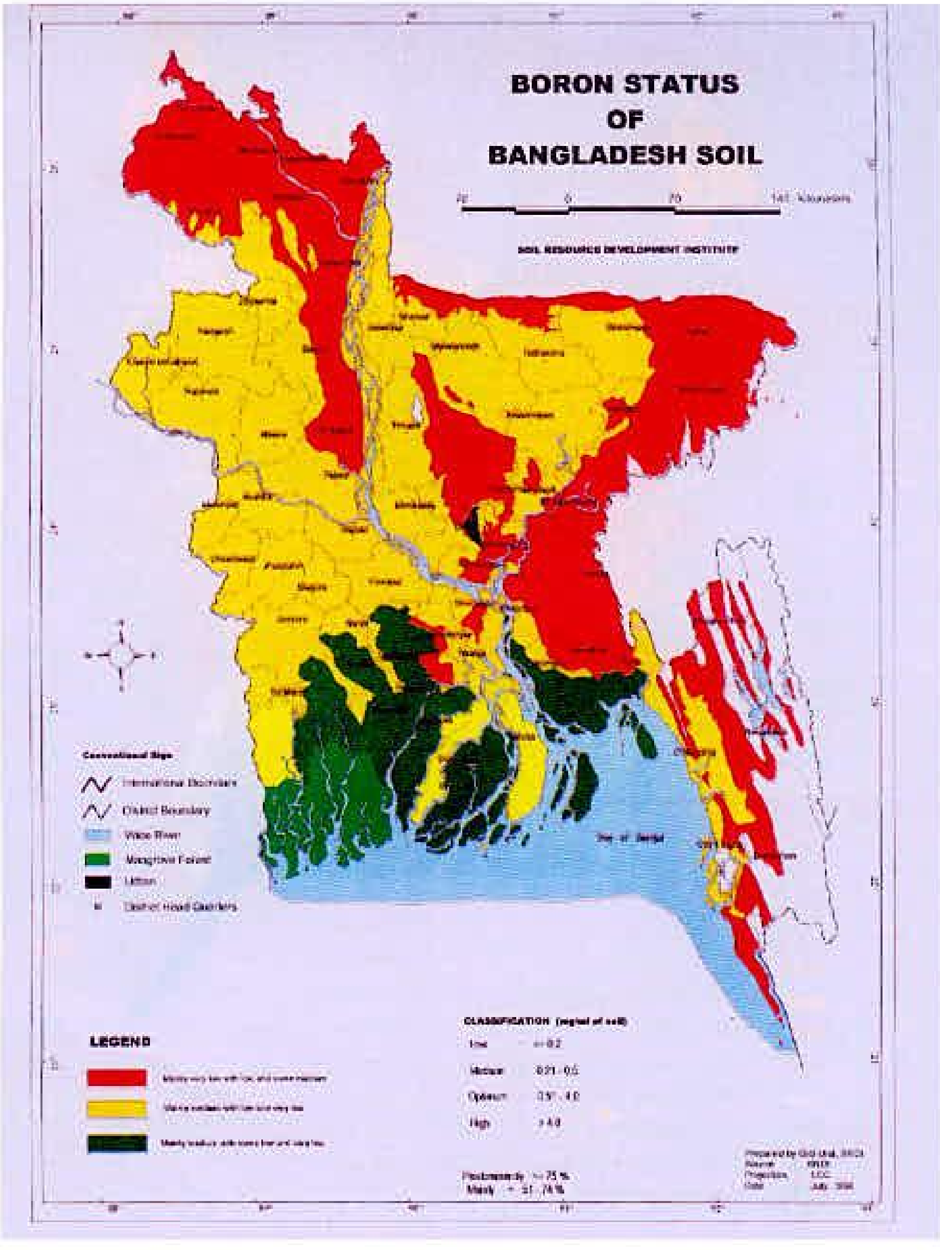
Appendix.1. Maize growing area of Bangladesh, (Source: CIMMYT, Bangladesh)



Appendix-2. Maize area, production, and yield in Bangladesh (Source: DAE, 2008)



Appendix 3. Hybrid maize seed requiement in Bangladesh (Source: MoA, 2008)



Appendix: 4 Boron Status of Bangladesh Soil

Appendix-5 Analytical data of the experimental soil

Item	pH	OM (%)	Total N (%)	Ca	Mg	K	P	S	B	Zn	Cu	Fe	Mn
				(meq 100 g soil^{-1})					(μg g^{-1})				
Result	4.5	1.20	0.05	0.87	0.30	0.10	12	11	0.11	1.01	3.5	145	1.1
Critical level	-	-	0.12	2.0	0.80	0.20	14	14	0.20	2.00	1.0	10	2.0
Interpretation	Acidic	Low	Low	Low	Low	Low	Low	Low	Low	Low	Optimum	At par	low

Appandix-6 Methods used for soil analysis

Soil properties	**Methods**
Soil texture	Hydrometer method (Black, 1965). The textural class was determined using Marshall's Triangular Coordinates of USDA system.
pH	Glass-electrode pH meter with I: 2.5 soil-water ratio (Jackson, 1973).
Organic carbon	Wet digestion method (Nelson and Sommers, 1982): The organic matter was oxidized by I N potassium dichromate and the amount *of* organic carbon in the aliquot was determined by titration against 0.5 N ferrous sulphate heptahydrate solution in presence *of* 0.025M 0-phenanthroline ferrous complex.
Total N	MicroKjeldahl method (Bremner and Mulvaney, 1982). Soil sample was digested with conc. H2SO4 in presence *of* K2SO4 catalyst mixture (K2SO4 : CUS04 : Se = 10: 1: 0.1). Nitrogen in the digest was estimated by distillation with IO N NaOH followed by titration *of* the distillate trapped in H3B03 indicator solution with 0.01 H2SO4.
CEC	Sodium acetate saturation method (Rhoades, 1982). The soil was shaken with an excess *of* 1 M sodium acetate solution to remove the exchangeable cations and saturate the exchange material with sodium. The replaced sodium was determined by flame photometer.
Available P	Extracted by O.5M NaHCO3 (pH 8.5) and determined colorimetrically using molybdate blue ascorbic acid method (Olsen and Sommers, 1982).
Exchangeable K,Ca& Mg	Extracted by repeated shaking and centrifugation *of* the soil with neutral 1M NH4OAc followed by decantation. The K, Ca & Mg concentrations in the extract were determined by flame photometer as outlined by Knudsen *et al.* (1982).
Available S	Extracted by *500* ppm P solution from Ca(H2PO4h.H20 and estimated by turbidity method using BaCh (Fox *et al.*, 1964)
Available In, Cu, Mn and Fe	Extracted by 0.005 M DTPA solution and directly measured by AAS (Lindsay and Norvell, 1978).
Available B	The available B was determined by mono-calcium bi-phosphate extraction method. The extractable B was determined by spectrophotometer following azomethine-H method (Page *et al.*,1982).

Appendix-7Weather data for the growing season of maize, 2007-08

Month		Sun-shine (hr)	Humidity (%)	Temperature		Evapor ation (mm)	Wind-run 2 mt-ht (km/hr)	Total rainfall (mm)
				Mini. (°C)	Max. (°C)			
November	I-I5	8.7	93.6	18.9	31	3.0	18.7	3
	16-30	8.5	90.7	15.2	29.2	3.1	25.4	-
December	1 -15	6.4	92.3	12.5	26.5	2.0	16.9	-
	16-31	4.4	91.6	10.1	24.6	1.5	13.2	-
January	1-15	5.6	89.0	10.4	25.6	1.4	15.4	-
	16-31	2.3	89.3	11.7	22.1	1.9	40.7	41
February	1-15	5.6	89.9	10.0	22.9	2.0	19.9	1
	16-29	7.0	89.1	12.2	27.7	2.4	23.1	4
March	I-IS	3.3	88	16.7	29.5	2.7	31.8	24.5
	16-31	2.9	88.3	12.3	31.4	4.6	40.9	0.5
April	1-15	7.4	90.1	11.2	32.4	4.7	42.8	19
	16-31	7.5	88.0	20.9	34.8	4.9	43.7	-
May	1-15	7.7	91.2	21.5	35.1	4.5	45.2	17.5
	16-31	7.5	92.4	22.4	34.9	4.4	44.7	145.94

Appendix-8

Plate: 1 Mixing lime with ploughing

Plate:2 After detassling the experimental plot

Plate:3 Ears are harvesting


Plate :4 L=0 ton ha^{-1} B=0 kg ha^{-1}

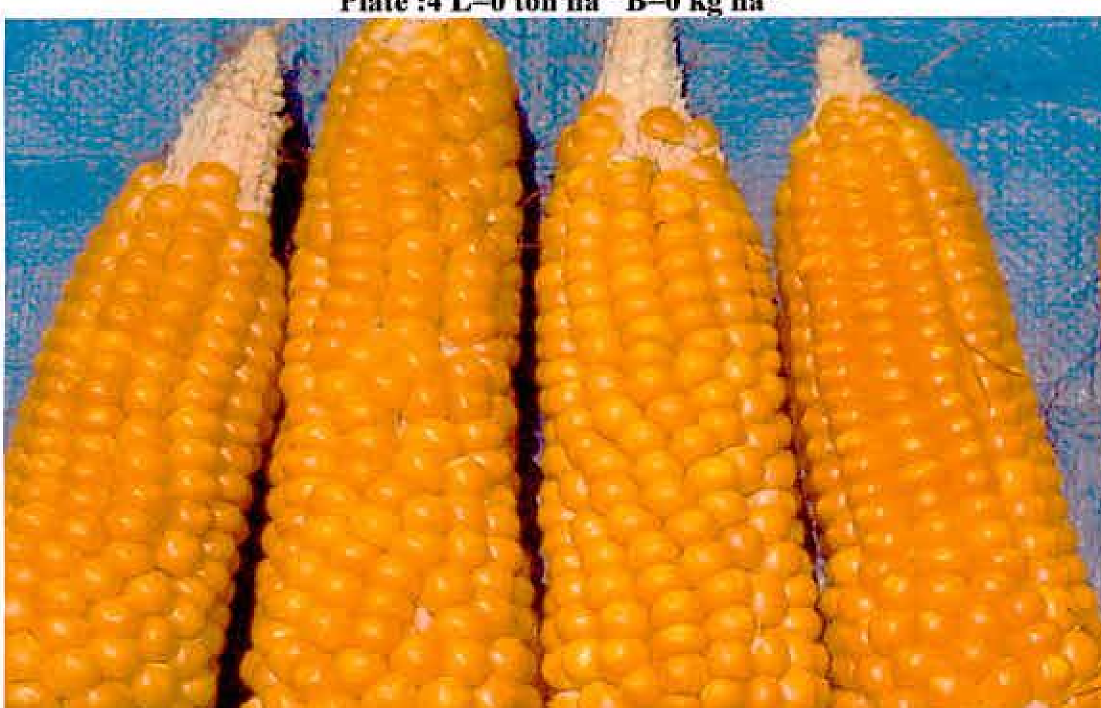


Plate :5 L=0 ton ha^{-1} B=1 kg ha^{-1}

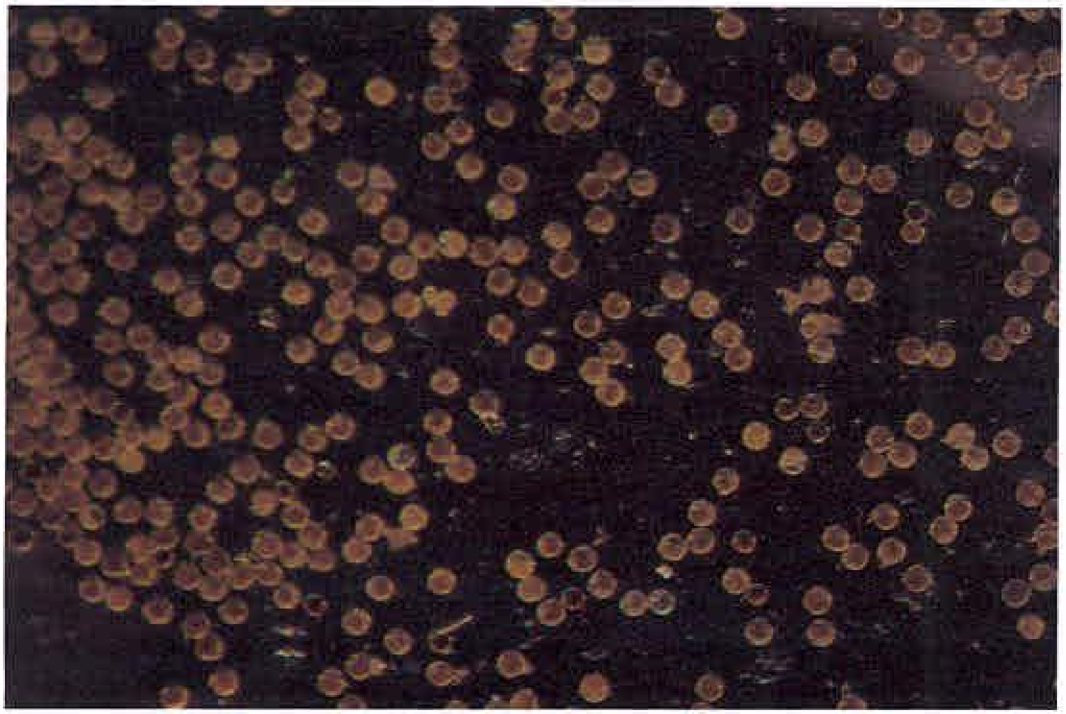


Plate :6 Non fertile Pollen form control plot

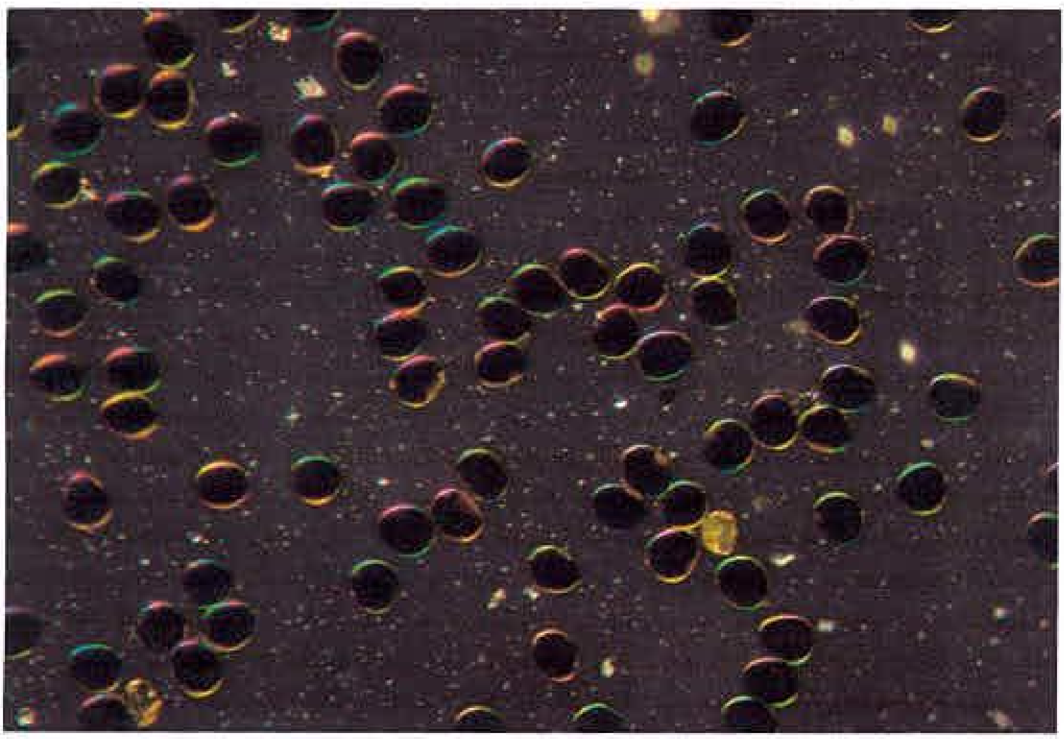


Plate :7 Fertile pollen from boron applied plot