Remediation for Rice Cultivation on Soil Affected by Coal Mining in Jaintia Hills, Meghalaya

By

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Declaration

I, Bondita Goswami, hereby declare that the subject matter of this thesis entitled 'Remediation for Rice Cultivation on Soil Affected by Coal Mining in Jaintia Hills, Meghalaya' is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other university or institute.

This is being submitted to the North-Eastern Hill University, Shillong for the award of the Degree of Doctor of Philosophy in Environmental Science.

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Preface

The work recorded in this thesis is the outcome of the study undertaken during 2004-2008 on 'Remediation for Rice Cultivation on Soil Affected by Coal Mining in Jaintia Hills, Meghalaya'. The Jaintia Hills district is situated in the eastern part of the state of Meghalaya and lies between 25°5′ N to 25°4′ N latitudes; and between 91°51′ E to 92°45′ E longitudes. It covers an area of 3819 km^2 with a total population of 2, 95,692 persons (2001 Census). The area is covered by mostly deciduous to evergreen forests and transitional tropical moist deciduous pine forests.

The thesis explains the effect of coal mining on soil quality and agricultural productivity in Jaintia Hills district of Meghalaya. A pot culture experiment was conducted on coal mine affected rice soil of Jaintia Hills with three rice varieties under different remediation options such as organic enrichment and lime treatment. Data pertaining to following aspects are included in this thesis.

(a) Variation of land utilization pattern in Jaintia Hills from 1987 to 2002

(b) Area, Production and productivity status of agricultural crops in Jaintia Hills district (1987-88 to 2001-2002)

(c) Physico-chemical analysis of soils from coal mining area

(d) Remediation of coal mine affected acidic soil by various treatments

(e) Varietal trial of rice under different remediation options.

The thesis begins with general Introduction followed by Review of Literature, Study Area, Methodology, Results and Discussion, Summary and References.

Information on land utilization and agricultural production have been analysed to know the agricultural impact of coal mining in the area. Physico-chemical analysis of soils collected from various coal mining sites of Jaintia Hills was done to know the extent of land degradation and to reveal underlying causes of such degradation. Based on the results of pot culture experiment, suitable rice variety with proper soil ameliorant has been recommended for cultivation on coal mining sites of Jaintia Hills.

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INTRODUCTION

Chapter 1

Coal is a complex mixture of compounds of carbon, hydrogen, oxygen and some free carbon (Trivedi, 2000). It is found in deep mines under the surface of earth. Coal is important because it can be used as a source of energy as such, or it can be converted into other forms of energy like coal gas and electricity. Coal is also an important source of a large number of organic compounds which are used in manufacturing dyes, drugs, explosives, synthetic fibres and synthetic detergents. Coal mining is one of the core industries that contribute to the economic development of a country.

Coal is second only to oil in meeting world's energy needs and has a critical input in the manufacture of steel. Coal continues to provide 22% of the world's energy and is used to generate about 40% of global electricity. World coal resources were estimated in 2004 at 1,000,912 tonnes of total recoverable coal (U. S. Energy Information Administration, 2004).

Coal occupies the most important place in the energy spectrum of India meeting presently about 60% of the total commercial energy consumption (Sharma, 2003a). Total coal reserves in the country up to a depth of 1200m (as on 1.1.2004) is 245.7 billion tonnes and total annual coal production (2004-05) is 382.137 million tonnes (Ministry of Mines, Govt. of India, 2006). Major coal fields in India are Raniganj, Jharia, East Bokaro and West Bokaro; Panch-Kanham (Tawa valley), Singrauli, Talchar, Chanda-Wardha and Godavari valley. The major states known for coal reserves are Bihar, Jharkhand, Orissa, West Bengal, Madhya Pradesh, Andhra Pradesh, Maharashtra, Assam and Meghalaya (Sharma, 1999).

Meghalaya, a hilly state, is one of the seven states of North Eastern Region of India. It is located between $25^{0}2'$ to $26^{0}6'$ North latitudes and $89^{0}48'$ to $92^{0}50'$ East longitude. The state is greatly blessed in respect of mineral wealth. In this context, good deposits of coal, limestone and clay are found in various parts of the state. Coal is found in all three regions of Meghalaya viz. Jaintia Hills, Khasi Hills and Garo Hills. Though the coal found in Meghalaya is of superior quality in terms of calorific value and ash content yet the drawback is in its high sulphur content. The inferred reserve of coal in the state is estimated to be about 640 million tonnes (Directorate of Economics and Statistics, 2003).

Meghalaya falls under the provisions of the sixth schedule of the Indian Constitution, and so, the land is solely owned by the people. The state and central governments have little control on the land. The prevailing land holding system allows the land owners to excavate coal without any restriction. Thus there are thousands of private coal mine owners who excavate coal for generating income for themselves. The excavation of coal by the private operators is done by a very unscientific method of mining known as 'rat-hole' method. This process of coal exploitation has severely affected the environment and ecological conditions of the area (Das Gupta *et al.*, 2002).

Although coal mining is done in all three regions of the state, Jaintia Hills contribute maximum in terms of production. From the year 1991-2002 the district alone contributed about 27,230.62 thousand tonnes which is 74.27% of the total coal production of the state (Dkhar and Rai, 2005).

Coal mining is one of the most important economic activities in Jaintia Hills District, Meghalaya. Coal mining in the area is unscientific, unsystematic and primitive in nature. Sutnga, Lakadong, Musiang-Lamare, Khliehriat, Ioksi, Ladrymbai, Rymbai, Byrwai, Chyrmang, Bapung, Jarain, Shkentalang, Lumshnong, Sakynphor etc. are the main coal mining areas of the District (Dkhar and Rai, 2005). Out of all coal mining areas Bapung is reported to have highest estimated coal reserves (34 million tonnes) (Rai, 1996).

The coal bearing areas of the district present a panorama of flat topped low hills, devoid of vegetation and plateau of rolling grasslands inter sparsed by river valleys. The main characteristics of the coal found in Jaintia Hills are its low ash content, high volatile matter, high calorific value and comparatively high sulfur content. The coal is mostly sub-bituminous in character. The physical properties of the coal of Jaintia Hills District are hard, lumpy bright and jointed except for the coal in Jarain which is both soft and hard in nature. Composition of the coal revealed by chemical analysis indicates moisture content between 0.4-9.2%, ash content between 1.3-24.7%, and sulphur content between 2.7-5.0%. The calorific value ranges from 5,694 to 8230 kilo calories/kg (Directorate of Mineral Resources, 1985).

Extraction of coal in Jaintia Hills District is carried out by primitive surface mining method commonly known as 'rat-hole' mining. In this method the land is, first cleared by cutting and removing the ground vegetation and then pit ranging from 5 to 100 m^2 is dug into the ground to reach the coal seam. Thereafter, tunnels are made into the seam sideways for extraction of coal, which is brought into the pit by using a conical basket or a wheel barrow. The coal is taken out of the pit manually and dumped on nearby un-mined area, from where it is carried to the larger dumping places near highways for its trade and transportation. Though this method may be the most economical and suitable to the local populace who own the mines, it is proving to be environmentally degrading. Deforestation, soil erosion, surface run-off, caving in of the ground and pollution of land, air and water are some of the prominent environmental problems associated with coal mining in the area (Das Gupta *et al.*, 2002; Swer and Singh, 2004a). In addition, depletion of water resources, destruction of agricultural land, adverse impact on human and disruption of socio-economic fabric in the area have also been noticed in recent past (Singh, 2005).

Mining activities directly or indirectly contribute to the environmental problem in many ways. Mining causes air pollution (Chaulya *et al.*, 2002). The main air pollutant associated with opencast coal mining has been found to be dust which is commonly referred to as suspended particulate matter (SPM). A part of SPM is Respirable Particulate Matter (RPM) whose size is less than 10 micron. Some amount of gaseous pollutants such as sulphur dioxide, nitrogen oxide and carbon dioxide are also emitted due to mining activities. Both nitrogen oxide and sulphur dioxide contribute to acid rain and carbon dioxide is the chief global warming gas (Sharma, 2003a).

A common process that is associated with coal mining is discharge of Acid Mine Drainage (AMD) (Taylor and Waters, 2003). The Acid Mine Drainage is formed when certain sulfide minerals such as pyrite and marcasite (FeS_2), present in coal mining regions are exposed to water and oxygen (De Nicola and Stapleton, 2002; Tiwary, 2001). In this oxidation reaction solid pyrite (FeS_2), oxygen (O_2)

and water (H_2O) are reactants, and sulfuric acid (H_2SO_4), solid ferric hydroxide ($Fe(OH)_3$), sulphate (SO_4^{2-}) and hydrogen ions (H^+) are products (Johnson and Bradshaw, 1978). The products together with water form a colored acidic discharge which is referred to as AMD.

Acid Mine Drainage is the greatest environmental problem of the mining sector. It is highly acidic with high concentrations of dissolved metals such as Fe, Al, Zn, Mn, Cu and Pb (DeNicola and Stapleton, 2002). This acidic water with elevated metal concentrations invariably runs off mine lands in overland flow or percolates its way through the substratum to enter streams (Dieffenbach, 1974). The AMD on contamination turns local rivers and streams acidic. The affected water bodies become unfit for consumption and disrupt the aquatic life (Swer and Singh, 2003). Aquatic organisms do not tolerate AMD physiologically (Henry *et al.*, 1999; Cole *et al.*, 2001). AMD contamination eliminates the more sensitive species from the aquatic ecosystem (Weed and Rutschky, 1971). Grey (1998) found an 87% decline in river species below a mining complex in Ireland.

Acid Mine Drainage has marked impacts on soil environment, too (Das Gupta *et al.*, 2002; Long peng *et al.*, 2004). Soil is a basic natural resource that should not only be preserved but where ever possible also improved (Pascual *et al.*, 2000). Acid Mine Drainage deteriorates soil's physico-chemical properties and thereby adversely affects crop growth and yield (Foy *et al.*, 1979; Bonta *et al.*, 1992; Smeth and De-Smeth, 1992). Major impacts of Acid Mine Drainage on soil include soil acidity (Visser *et al.*, 1979; Chandra and Kehri, 1994; Das Gupta *et al.*, 2002) and soil contamination with heavy metals (Filipek and Pawlowski, 1990; Long peng *et al.*, 2004). Irrigation of agricultural fields with AMD contaminated water also causes various problems, which altogether decrease agricultural productivity (Moran *et al.*, 1989; Tiwary and Dhar, 1994; Swer and Singh, 2004b).

Soil acidity has negative impact on fertility, biological activity and plant productivity. The direct effect of acidity on plants is the high concentrations of hydrogen ions, which inactivate most enzyme systems, restrict respiration, and root uptake of salts and water (Tan, 1980). Soil pH influences nutrient availability. Aluminium toxicity is the most important associated problem of acidic soils, when pH drops below 5.0. The aluminium sensitive crops may get damaged when aluminium saturation of Cation Exchange Capacity exceeds 10%. Aluminium toxicity usually damages the root system first. Aluminium affected roots tend to be shortened and swollen, having a stubby appearance (Patiram *et al.*, 1991). In addition to aluminium toxicity to plants growing on acidic soils, there may be deficiency of nitrogen, phosphorous, calcium, magnesium, molybdenum and boron and toxicity of iron and manganese, which overall imbalance the nutrient status in the soil and plant (Panda, 1987). Phosphorus deficiency takes place in acidic soil due to leaching and lack of binding power of the soil (Das Gupta *et al.*, 2002). Phosphorus can also react strongly with Iron and Aluminium components of acidic soils thereby becoming unavailable for plant uptake (Prasad and Biswas, 1998). Rice and wheat are highly responsive to nitrogen (Biswas and Mukherjee, 1999). Solubilization and transport of phosphorus to the water environment from soil and manure caused by Acid Mine Drainage is a critical environmental issue associated with agricultural productivity (Adler and Sibrell, 2003).

The uptake of nutrients by plants is strongly dependent upon soil microorganisms. Certain bacteria which live in root nodules of leguminous plants help plants in obtaining Nitrogen by converting atmospheric Nitrogen into a form of N that plants can use (Venkataraman, 1988). The effectiveness of these bacteria which enter legume roots and fix nitrogen (nodulation) is highest at pH 6.5 to 7.0 and declines rapidly when pH levels falls under 6.0 (Biswas and Mukharjee, 1999). Decomposition of organic matter also contributes to aggregation (clumping) of soil particles which provide good soil tilth, aeration and drainage (Bhardwaj, 1998). Although these organisms function best at soil pH levels of 8.0, their effectiveness drop rapidly when pH level drops below 6.0 (Biswas and Mukharjee, 1999). Strongly acidic soils ($pH<3.5$) also favour the development of plant pathogenic fungi i.e. *Pythium* spp. which commonly cause damping-off of seedlings and necrosis of feeder roots of established plants (Stovold, 1974).

AMD also affects crop productivity by deteriorating the quality of irrigation water. Low pH, high conductivity, high concentration of sulphates, iron and toxic metals, low Dissolved Oxygen (DO) and high Biochemical Oxygen Demand (BOD) are some of the features of AMD contaminated surface water that indicate extensive degradation of water quality (Swer and Singh, 2003). Under such circumstances, the yield of crops is very poor.

Coal mining activities significantly contribute to heavy metal pollution of the soil and metal accumulation especially with Co, Cu, Zn, Ni, and Pb (Long Peng *et al.*, 2004). Movement of heavy metals down the profile is more near AMD discharge site, leading to higher pollution problem than at the points of increasing distances (Campos *et al.*, 2003).

Another reason that mine spoils are generally nutritionally and microbiologically poor is that mining activity results in the loss of topsoil, which is an integral exchange and storage site for nutrients (Visser *et al.*, 1979). Besides, mining is one of the major contributors of soil erosion due to loosening of soil and increasing vulnerability of loosened soil to water and wind erosion (Wiles, 1987).

Mining operation undoubtedly has brought wealth and employment opportunities in Jaintia Hills District (JHD), Meghalaya but simultaneously has led to extensive environmental degradation. Large-scale denudation of forest cover, scarcity of water, pollution of air, water and soil and degradation of agricultural land are some of the conspicuous environmental implications of coal mining in the area. Entire road sides in and around mining areas are used for piling of coal which is a major source of air, water and soil pollution. Off road movement of trucks and other vehicles in the area causes further damage to the ecology of the area. Hence, a large area of land is spoiled and denuded of vegetal cover not only by mining but also by dumping and storage of coal and associated vehicular movement. Further, entire coal mining area of the Jaintia Hills District has become full of mine pits and caves. These open, unfilled pits are the places where surface water percolates and disappears. As a result smaller streams and rivers of the area, which served as life lines of the people, are either completely disappearing from the face of the earth or becoming seasonal. Consequently, the area is facing acute shortage of clean drinking and irrigation water. Besides, a vast area has become physically disfigured due to haphazard dumping of overburden and mined coal, and caving in of the ground and subsidence of land (Swer and Singh, 2003). The water bodies of the area are the greatest victims of coal mining. The water bodies are badly affected by contamination of Acid Mine Drainage originating from mines and spoils, leaching of heavy metals, organic enrichment and silting by coal and sand particles. The polluted water has contaminated the agricultural fields and reduced the agricultural productivity drastically (Swer and Singh, 2004b).

Various heavy metals such as Se, Pb, Fe, Ni, Mn, Co and Zn have been detected in mine water of coal-bearing strata of Jarain coal field of JHD (Nath, 2004).

Agriculture is an age-old practice in Jaintia Hills. Majority of the population has to depend on agriculture as the source of livelihood. There is a wide range of farming systems in Jaintia Hills of Meghalaya, of which rice based farming system is dominant. A variety of crops including rice is grown in the area. Though rice is a staple food of the district, yet its production is not sufficient to meet the requirement in the region (Directorate of Economics and Statistics, Meghalaya, 2003). Unfortunately, during recent years the area is experiencing overall decline in agricultural productivity due to multiple environmental problems caused by coal mining including remarkable qualitative and quantitative reduction of agricultural fields.

Coal mining has severely affected the physico-chemical and biological properties of soil of the district, thus making it less suitable for growth and development of plants. Lower soil moisture content, overwhelming percentage of sand, inadequate nitrogen, phosphorous and potassium make the soil less suitable for growth and development of crops (Das Gupta *et al.*, 2002; Swer and Singh, 2003). As a result farmers are forced to abandon the agricultural activity and to engage in some other professions. However, in the absence of comprehensive data on the extent and severity of impact of coal mining on land degradation and agricultural productivity, it is obviously not possible to estimate the actual loss in terms of productivity and economic costs. However, a variety of indications is available that suggest the adverse impact of coal mining on agriculture in the area. Das Gupta *et al.,* (2002) reported that the low moisture content (6%) of coal mine spoil of Bapung area of Janitia Hills District, Meghalaya has been considered an important factor limiting the plant growth. Jaintia Hills District of Meghalaya has the largest proportion of wasteland (30.72%) of the total geographical area of the state due to extensive 'rat-hole' mining of coal (Sharma, 2003b). The results of impact assessment of coal mining on land use/land cover using IRS-1A satellite data for Jaintia Hills District, Meghalaya showed that during the last 12 years (1983-95) coal mining area has increased by 1.2% and agricultural land has decreased by 1.5%. Deposition of coal particles, soil erosion and water-logging through seepage water are major causes of agricultural land degradation in the coal mining area (Semwal *et al.*, 2004).

As mining operations alter ecosystem structure and function, there is an urgent need for ecorestoration of mine affected area. Use of Acid mine drainage ameliorant, conservation of topsoil, revegetation of mine spoils, channeling of acidic seepage for checking Acid Mine drainage contamination of water bodies and agriculture fields coupled with scientific management of mining operation are some of the measures which can be helpful in ameliorating the problems of coal mining (Swer and Singh, 2003). Use of alkaline material such as lime in scientific manner may reduce the acidity of water and save agricultural field and water bodies of neighbouring areas to some extent. Lime treated Acid Mine Drainage can also be used for irrigation of agricultural crops (Javanovic *et al.*, 1998).

Caruccio (1968) found while evaluating the factors affecting AMD that soil cover plays an important role in preventing AMD. Study revealed that soil cover is extremely important in developing alkalinity as high carbon-di-oxide levels found in soil air contribute towards increasing neutralization capacity. Thus, conservation of topsoil is very important in the process of ecorestoration and to sustain agricultural productivity in mine affected soil. Removal of topsoil prior to mining and its replacement as the final cover following coal mining is a beneficial method for assuring quick establishment of vegetation and ecorestoration (Dancer, 1982). Establishing vegetation on coal mined land is another important step in overall reclamation process. Vegetation aids in stabilizing the soil surface from erosion and controlling siltation of water bodies. Growth characteristics of some plants help to bind the soil particles thus making the loose mine spoil more stable and less prone to soil erosion (Lyngdoh *et al.*, 1992). On disturbed mine land with exposed acidic spoil/overburden, the plant species which volunteer and become established are species which are capable of surviving under acidic conditions. Bermuda grass (*Cynadon dactylon*) has been recommended as a suitable species for acid mine rehabilitation (Taylor *et al.*, 1989).

Although, technologies have been developed for rehabilitation of mine spoil by developing silvi-pastural system (Sharma *et al.,* 1997), very few studies have been done for restoration of agricultural land severely affected by AMD. In a study, superior strains of *Eragrostis* spp. were selected for adaptation in acid mine soils (Foy *et al.*, 1979). Utilization of lime treated AMD for irrigation of agricultural crops have also been tried and yielded some promising results (Du Plessis, 1983). It has been indicated that level of existing deterioration of soil decides the lime requirement for AMD treatment. However, no study has been done in local conditions of Jaintia Hills considering the prevailing environmental conditions, extent of soil degradation and crop varieties grown in the area.

As basic socio-economy of the area is highly dependent on agriculture, it is extremely important to find out proper management practices to minimize the risk of such environmental damages on agriculture. This requires soil profile modifications and planting suitable crop varieties, as we know that there is wide variation in inherent acid tolerance of various crop species and their varieties. The inter-varietal differences can be exploited for selection of crop variety under a given root zone acidity. Therefore, study of physico-chemical properties of mine affected soils and its detailed monitoring under various remediation options are essential for improving soil quality and restoration of agriculture. In order to restore the agriculture, a proper choice of crop varieties is therefore very important considering the soil conditions. The choice of tolerant varieties is essential for better production and economic returns from acid mine degraded soils of this region.

Thus, considering the seriousness of the problem, present study has been done to assess the effects of coal mining on soil quality and its impact on agriculture in Jaintia Hills district of Meghalaya. We have also evaluated various rice varieties for growing in AMD contaminated soils under different remediation options such as organic enrichment and lime treatment. Based on the study suitable rice varieties have been recommended for cultivation in AMD affected soil of Jaintia Hills district. The results include information on the impact of coal mining on quality of soil and agricultural productivity in Jaintia Hills; underlying causes of land degradation in the area; tolerant rice varieties for cultivation on degraded soils under different remediation options. Measures for restoration of cultivation of rice in soil degraded by coal mining have also been suggested.

Pollution of air, water and soil, deforestation and degradation of agricultural land are some of the environmental implications of coal mining which has been well illustrated by Dhar (1994). Bell and Kar (1993) reported that the major pollutants associated with coal mining were suspended solids, dissolved salts (especially chloride), acidity and iron compounds. Based on a study done on air pollution problem from various opencast coal mining operations in Dhanbad, Chaulya *et al.* (2002) developed a user friendly software called 'EmissCalc' to calculate emission rate of dust as well as gaseous pollutants (sulphur dioxide and nitrogen oxide) from various opencast coal mining activities. Sharma (2003a) reported that the main air pollutant associated with opencast coal mining was dust. Dust, SO_2 and NO_X were found in the range of 287.1-1911.0 $\mu g/m^3$, 64.4-129.6 $\mu g/m^3$ and 75.0-89.0 $\mu g/m^3$ in coal mining areas of Damodar river basin, India (Tiwary and Dhar, 1994).

Many Studies have been done on effect of Acid Mine Drainage (AMD) on water quality and aquatic life (Weed and Rutschky, 1971; Rosemond *et al.*, 1992; Pentreath, 1994; Henry *et al.*, 1999; Cole *et al.*, 2001). The study on the effect of different levels of AMD contamination on aquatic species revealed that moderate AMD contamination eliminated the more sensitive species whereas severely contaminated conditions were characterized by dominance of certain taxonomic representatives of pollution tolerant organism, such as aquatic worms, midge larvae, caddis fly larvae and non-benthic insects like predaceous diving beetles and waterboatman etc. The study done by Dieffenbach (1974) indicated that the acidic water with elevated metal concentrations invariably runs off mine lands in overland flow or percolates its way through the substratum to enter streams and degrade aquatic ecosystem. Pentreath (1994) reported that Acid Mine Drainage made water highly acidic and rich in heavy metal concentration which was responsible for degradation of water quality and the declining trend of biodiversity in the water bodies of the coal mining area. Henry *et al.* (1999) and Cole *et al.* (2001) reported that aquatic organisms do not tolerate AMD physiologically. Studies done by Tiwary (2001) on water quality status of coal mining regions of Dhanbad revealed that AMD degraded surrounding water resources by lowering the pH and increasing the level of Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and some heavy metals. Study on water quality status of coal mining areas of Jaintia Hills District, Meghalaya revealed that Acid Mine Drainage adversely affected water quality by decreasing pH (between 3-4), increasing conductivity (2.7 mMHOS), increasing concentration of sulphates (76-168 mg/L) and decreasing Dissolved Oxygen (4.2 mg/L) (Swer and Singh, 2004a). The study done by Swer and Singh (2004b) also revealed that low pH, low Dissolved Oxygen, higher sulphate content and turbidity in water of coal mining areas of Jaintia Hills district lowered abundance and species diversity of macroinvertebrates.

Effect of Acid Mine Drainage on soil physico-chemical properties and thereby on agricultural productivity has been reported by many workers (Darmody *et al.*, 1989; Haigh, 1992; Bai *et al.*, 1998; Tedesco *et al.*, 1999; Das Gupta *et al.*, 2002; Adler and Sibrell, 2003). Study on probable impact on land due to open-cast coal mining in Dhanbad, Bihar done by Ghose and Kundu (1999) revealed that field capacity, wilting coefficient, bulk density, moisture coefficient, moisture retention capacity, pH and fertility status of the area were modified by mining activities. Darmody *et al.* (1989) reported that the weighted average yield reduction (affected area multiplied by the associated yield reduction) of maize was 4.7% for Long wall (LW) and 1.8% for High Extraction Retreat (HER) mining due to coalmine subsidence at Illinois, USA. Kundu and Ghose (1994) reported that field capacity of danga land (cultivable wasteland where there is little or no cultivation) ranged from 12.86 to 14.65% compared with 17.94 to 21.05% for agricultural land and Wilting coefficient on agricultural land ranged from 5.31 to 6.75 compared with 4.70 to 5.25% for danga land at an underground coal-mining site at Raniganj coalfield in eastern India. Das Gupta *et al.* (2002) reported that the low moisture content

(6%) of coal mine spoil of Bapung area of Janitia Hills District, Meghalaya has been considered an important factor limiting the plant growth.

Rao (1989) reported that the region of Cherrapunji in the state of Meghalaya, the world's wettest place shows sign of desertification now days due to extensive coal mining activities. Sarma (2005) reported that due to extensive coal mining, large areas of Jaintia Hills district of Meghalaya has been turned into degraded land, creating unfavourable condition for plant growth. The results of impact assessment of coal mining on land use/land cover using IRS-1A satellite data for Jaintia Hills District, Meghalaya showed that during the last 12 years (1983-95) coal mining area has increased by 1.2% and agricultural land has decreased by 1.5% due to the deposition of coal particles, soil erosion and water-logging through seepage water (Semwal *et al.*, 2004).

Gruszcznski *et al.* (1998) reported that land degradation in Szczyglowicze coal mined area, Poland was the result of post mining subsidence and flooding. Ghose and Kundu (1998) reported that underground coal mining activities in South Bihar caused land subsidence resulting in accumulation of sand and increase of bulk density of soil of nearby area. Prakash and Gupta (1998) studied the impact of coal mining on the land use changes in the Jharia coalfield (JCF) by using temporal remote sensing data. The study revealed that extensive mining, establishment of communication networks, expansion of settlements, decrease in the vegetation cover etc. have remodeled the face of JCF.

According to Haigh (1992) degradation of reclaimed lands previously disturbed by coal mining in Wales was due to gulling, soil erosion, soil compaction, accelerated run-off and poor vegetation cover. Problem of soil erosion in an abandoned coalmine in Cospuden, Germany was studied by Zartle *et al.* (1998). Bai *et al.* (1998) reported that open cast coal mining at Antaibao Coal Mine, Pingshuo city, China destroyed original vegetation of the mining site resulting in a soil erosion index greater than 1500 t/km^2 per year.

The contents of heavy metals Zn, Cu, Mn and Fe were determined in opencast coal mine spoil of Kolubara coal mining basin by atomic absorption spectrometry. Zinc availability was low, but those of the other trace elements high (Durdevic *et al.*, 1988). Increasing concentration of total and extractable heavy metals (Ni, Pb, Cu, Zn, Mn) were found in some soils of the Lublin coal mining region (Filipek and Pawlowski, 1990). According to Sakel *et al.* (1996) movement of heavy metals down the profile is more near AMD discharge site, leading to higher pollution problem than at the points of increasing distances. Zhulidov *et al.* (1997) reported that various heavy metals namely Cd, Pb, Zn and Cu were found in the ranges of 10-32; 57-78; 315-480; 87-350 mg/kg, dry weight, respectively, in hydric soils of coal waste contaminated wetlands of the Russian

Arctic. The study conducted by Kuczynska and Zarudzki (1998) showed that the heavy metal contents of wheat grown near the coal mining site at Belchatow, Poland were more than the crop grown in unmined soil due to soil contamination with various heavy metals such as Cu, Mn, Zn, Pb, Ni and Cd. Field experiment conducted by Tedesco *et al.* (1999) revealed that plant species grown in a coal waste dumping area located on the Butia County Recreio mine, in Rio Grande do Sul state, Brazil were contaminated with four different types of heavy metals namely Cr, Cd, Ni and Pb. Bian *et al.* (1999) reported that the heavy metal content of the mine soils at Fan coal mine, China did not exceed the standard limit, but it was higher in surface soils than at 30 cm depth.

Nath (2004) reported the presence of as many as six heavy metals viz. Cobalt (0.1-0.2 ppm), Zinc (1.3-3.4 ppm), Manganese (0.2-3.8 ppm), Iron (1.6-2.7 ppm), Lead (0.1-0.4ppm) and Copper (0.2-0.4 ppm) in mine water of Jarain coal field, JHD, Meghalaya. Long Peng *et al.* (2004) reported that coal mining activities significantly contributed to heavy metal pollution (Cu, Ni, Pb, Zn, Sn, Cr, Co) and metal accumulation in the soil of Huainan, East China which had a 100-year coal mining history and the concentration of heavy metals decreased with the history of mining. Lin *et al.* (2005) reported that the pH of agricultural soils irrigated with acidic mine water from the Guangdong Dabaoshan Mine, China, could be as low as 3.9 and the crops grown in these soils were highly contaminated by heavy metals, particularly Cd.

Studies were made on the condition of plantations on leveled spoil banks of open-cast brown coal (lignite) working in the Moscow region. The substrate was highly acidic, with high sulfide and low nutrient content. It was pointless to plant trees on substrates with pH less than 2.8 and with exchange acidity greater than 5mg.eq./100g (Vasil, 1991). Results of analysis of soil collected from coal mine spoils of Galicia, Spain indicated acidic pH range (2.4) associated with low available phosphorous concentration (1 mg/Kg) (Monterroso *et al.*, 1996). The results of soil analysis of a coal mining site in Taiwan indicated that the soils were extremely acidic (pH 3.2) associated with nutrient deficiency due to contamination with large amount of coal debris (Lin, 1999). Tedesco (1999) reported that low soil pH due to the oxidation of sulphur compounds was the most limiting factor for plant growth on the Butia County Recreio mine, in Rio Grande do Sul state, Brazil. Nath and Ahmed (2005) reported that agricultural activity has been on the decline in Bapung coal mining area of Jaintia Hills district, Meghalaya due to degradation of paddy fields. The land has become infertile (due to acidic nature) forcing farmers to give up cultivation of crops.

Concentration of soluble aluminum that could be toxic to plants were found in mine spoils that had a pH of 5.5 or below (Berg *et al.*, 1973). Foy *et al.* (1978)

reported that aluminum inhibits root growth and interferes with the uptake of phosphorus, an essential plant nutrient.

The results of the analysis of a series of coal mine spoils (5, 10, 12, 16 and 20 years old) in a dry tropical environment of Madhya Pradesh, India indicated that total soil N, NaHCO3-extractable P and exchangeable K were lower in mine spoils than native forest soil even after 20 years of succession (Jha and Singh, 1991). The nutrient status of N, P and K in plants grown on a recently reclaimed loose soils (4-20 years after recultivation) situated in a brown coal mining district in Germany was below the critical limit of 30, 3 and 35 g/kg, respectively (Springob and Lebert, 1995). Adler and Sibrell (2003) reported that solubilization and transport of phosphorous to the water environment from soil and manure caused by AMD is a critical environmental issue associated with agricultural productivity in coal mining areas.

Moran *et al.* (1989) reported that agricultural capability of surface coal-mined land in east-central Alberta was decreased due to degradation of chemical quality of ground water that provided the majority of agricultural water supplies. Studies done by Tiwary and Dhar (1994) revealed that Total Dissolved Solids (200-860 mg/L), Sulphates (14-401.2 mg/L), Hardness (68-711.4 mg/L) and Iron (0.28-4.2 mg/L) content of all major coal fields of Damodar river Basin were high enough to affect the chemical quality of both groundwater and surface water into which mine waters are pumped in. Study done by Nath (2004) revealed that the seepage water from various coal mines of Jarain area, Jaintia Hills district, Meghalaya were quite acidic (pH < 6) and the corresponding conductivity varied from 305 to 950 μs/cm and TDS varied from 150 to 490 mg/L which rendered the water unsuitable and unsafe for drinking and other domestic uses.

Studies have indicated that certain types of alkaline amendments can successfully control AMD from pyritic spoil and refuse (Rich and Hutchinson, 1990; Brady *et al.*, 1994; Rose *et al.*, 1995). Smith and Dodge (1995) reported that the mine water discharge from a surface coal mine in Pennsylvania improved from an acidity of 120 mg/L as CaCO3 to 19 mg/L net alkalinity and Fe was significantly reduced by adding 1350 Mg/ha (600 tons/ac) limestone. Caruccio and Geidel (1996) reported that limestone or lime routinely added to the soil as a surface amendment has improved ground water quality of coal mining area and enhanced vegetation growth. Javanovic *et al.* (1998) reported that the use of lime-treated acid mine drainage for irrigation of agricultural crops at Landau Kromdraai opencast section (near Witbank, Mpumalanga Province, South Africa) considerably increased soil pH as well as yields of irrigated crops compared with rainfed cropping.

Some studies indicated that phosphate rock could be used as an amendment to control AMD due to its reaction with Fe released during pyrite oxidation to form insoluble coatings (Ghazi, 1985; Ziemkiewicz and Meek, 1994). Ghazi (1985) reported that rock phosphate applied alone at the rate of 0, 10, 20 or 40 g/kg soil in extremely acid mine spoils from Valley Point, Westover and Lenox alone increased maize yields more than treatment of rock phosphate and fly ash in combination in greenhouse trials. Sodium carbonate ($NaCO_3$) and Calcium hydroxide [$Ca(OH)_2$] were also found to reduce the acidity of AMD (Caruccio *et al.*, 1984; Nawrot *et al.*, 1994).

Study done by Bruns and Jochimsen (1989) in Germany reported that application of fertilizer significantly controlled soil erosion of coal mine spoils through the improvement of root growth of most of tree species grown on the spoils. The results of the study on effects of various reclamation methods such as lime, ground rock phosphate, manures, a mixture of coal with urea, ammonium phosphate and potassium chloride and various NPK fertilizers on the biological activity of coal mine spoil heaps in Moscow done by Lukina *et al.* (1990) indicated that the greatest increase in the bacterial population was caused by the application of manure with 300, 600, 600 kg N, P, K per ha, respectively. Kulhavy and Grunda (1991) found significant improvements to soil properties in coal- mining region of Czechoslovakia by liming, application of nitrogenous fertilizers and planting with suitable plant species *Alnus glutinosa*, *A. incana*, *Lotus corniculatus* and *Lupinus*. Jha (1992) reported that both NPK medium and forest soil had beneficial effects on growth and development of leguminous plants grown on coal mine spoil of Singrauli, Madhya Pradesh, India.

Lundgren (1971) reported that readily decomposable organic matter reduces formation of AMD in coal mining areas by reducing the activity of *Thiobacillus* bacteria, which catalyzes iron oxidation. There is evidence from laboratory studies that the oxidation of pyrite can be inhibited by organic waste materials such as manures and sewage sludge (Backes *et al.*, 1987). Study on use of organic waste to affect nitrogen fertility at a surface coal mine site of Kentucky, USA revealed that gross N mineralization and nitrification rates were 4.5 times greater in waste amended soil than unamended soil (Coyne *et al.*, 1998).

Results of the study on effect of different combinations of overburden samples and compost on the distribution of nutrients in different plant parts and the biomass production of *Albizia procera* on coal mine overburden samples from Talcher, Orissa indicated that nutrient accumulation was highest in the 1:2 mixture followed by 1:1 and 1:0.5 mixtures (Singh *et al.,* 1994).

Results of the pot experiment conducted using various combinations of coal mine spoil, fly ash and compost showed the maximum height, collar diameter, number of leaves, leaf area, nodule weight and biomass of *Albizia procera* grown in 1:1:1 (coal mine spoil : fly ash : compost) combination followed by 1:0.5 (coal mine spoil : fly ash) (Singh *et al.*, 1997).

Treatment of an open cast coal mining spoil of Hungary with sewage sludge (2.4% N, 1.3% P and 0.5% Ca) at 40-240 t DM/ha improved the soil moisture holding capacity, reduced soil bulk density and increased wheat grain yields to 5.7-6.7 t/ha compared with 1.0 t/ha on untreated spoil (Kreisztian *et al.*, 1988). Result of a study done by Hangyel and Krisztian (1995) in Hungary showed that application of sewage sludge at the rate of 160 kg/ha in split dose increased the yield of wheat grown in coal mine spoil. Addition of alkaline sludges or flocs, generated from the neutralization of AMD, was reported to provide several benefits when used on the surface of backfills or to acid producing materials during mining and backfilling (Coleman *et al.*, 1997).

Many studies have suggested remediation of coal mining site with vegetation (Spirik, 1988; Spotts *et al.*, 1997). Struthers and Vimmerstedt (1965) concluded that revegetation of mine spoil was generally more successful in the spring months as plant establishment and growth are improved by precipitation infiltrating the mine spoil and leaching the salts from the surface layer. Study on reclamation of soils devastated by coal mining in Czechoslovakia found that forestry practice and important tree and shrub species not only had an economic importance, but also were important for the regeneration of landscape and environment (Spirik, 1988). Hawkins (1995) reported that many Pennsylvania remining operations showed reduced pollution loading rates due to two factors- the regrading of abandoned mine lands and improved vegetation. Spotts *et al.* (1997) reported that runoff water from the vegetated area of a barren coal mine tailings in Montana had a higher pH (6.2), and metal loadings of As, Cu, and Zn were also more than four orders of magnitude lower than the unvegetated area.

Results of the trial conducted in coal mine overburdens at Talcher, Orissa to investigate the suitability of different species for afforestation indicated that Pithecellobium dulce was the most promising species in terms of survival and growth (Gupta *et al.*, 1994). Results of the study done by Sonkar *et al.* (1998) on relative suitability of different nitrogen fixing and non-nitrogen fixing tree species on coal mine overburdens of Singrauli, Madhya Pradesh, India showed that *Eucalyptus tereticornis* among non-nitrogen fixing tree species and *Albizia procera* among N-fixing species were considered to be most promising for reclaiming mine spoil.

Phytoremediation of coal mine spoil with legumes had been studied by many researchers (Jha and Singh, 1993; Lyngdoh, 1995; Maiti, 1997). Study done to compare the performance of two crops (*Cajanus cajan* and *Phaseolus mungo*) grown on fertilized farm plots and coal mine spoil in Singrauli, Madhya Pradesh indicated that *Cajanus cajan* performed better on the mine spoil than on the farm plots (Jha and Singh, 1993). Lyngdoh (1995) reported that a leguminous plant *Erisaema chinese* could grow frequently in the coal mine area of Jarain in the Jaintia Hills district and according to the study, this plant by virtue of nodulating profusely and by showing its ability to grow on the soils collected from the mine spoils, was likely to play a significant role in nitrogen economy of the soil. A field study conducted on the use of the legume *Stylosanthes humilis* and the grass *Pennisetum pedicellatum* in a ratio of 1:2 to provide vegetation cover and promote soil formation on coal spoil heaps at the Jharia coal fields, India resulted in increase of organic carbon by 140 and 79% at the end of second and third years respectively and increase of N accumulation rate to 715 kg/ha after three years (Maiti, 1997).

Phytoremediation of coal mine spoil with grass species has been reported by many workers (Lyngdoh *et al.*, 1992; Rensburg *et al.*, 1998). Lyngdoh *et al.* (1992) reported that the *Rhizomatous* and *Soloniferous* grass species such as *Axonopus compressus*, *Crysopogon gryllus* and *Arundinella nepalensis* could grow successfully on coal mine spoils of Jaintia Hills district, because the growth characteristics of these plants helped to bind the soil particles thus making the loose mine spoil more stable and less prone to soil erosion. Based on a study done in Queensland, Australia Truong and Hengchaovanich (1997) reported that vetiver grass was very much effective in land stabilization and erosion control of coal mining site. Rensburg *et al.* (1998) reported that perennials Bermuda grass (*Cynodon dactylon*), weeping love grass (*Eragrostis curvula*) and the annual teff (*Eragrostis tef*) occurred with highest frequency on a coal fine ash disposal site in Sasolburg, South Africa.

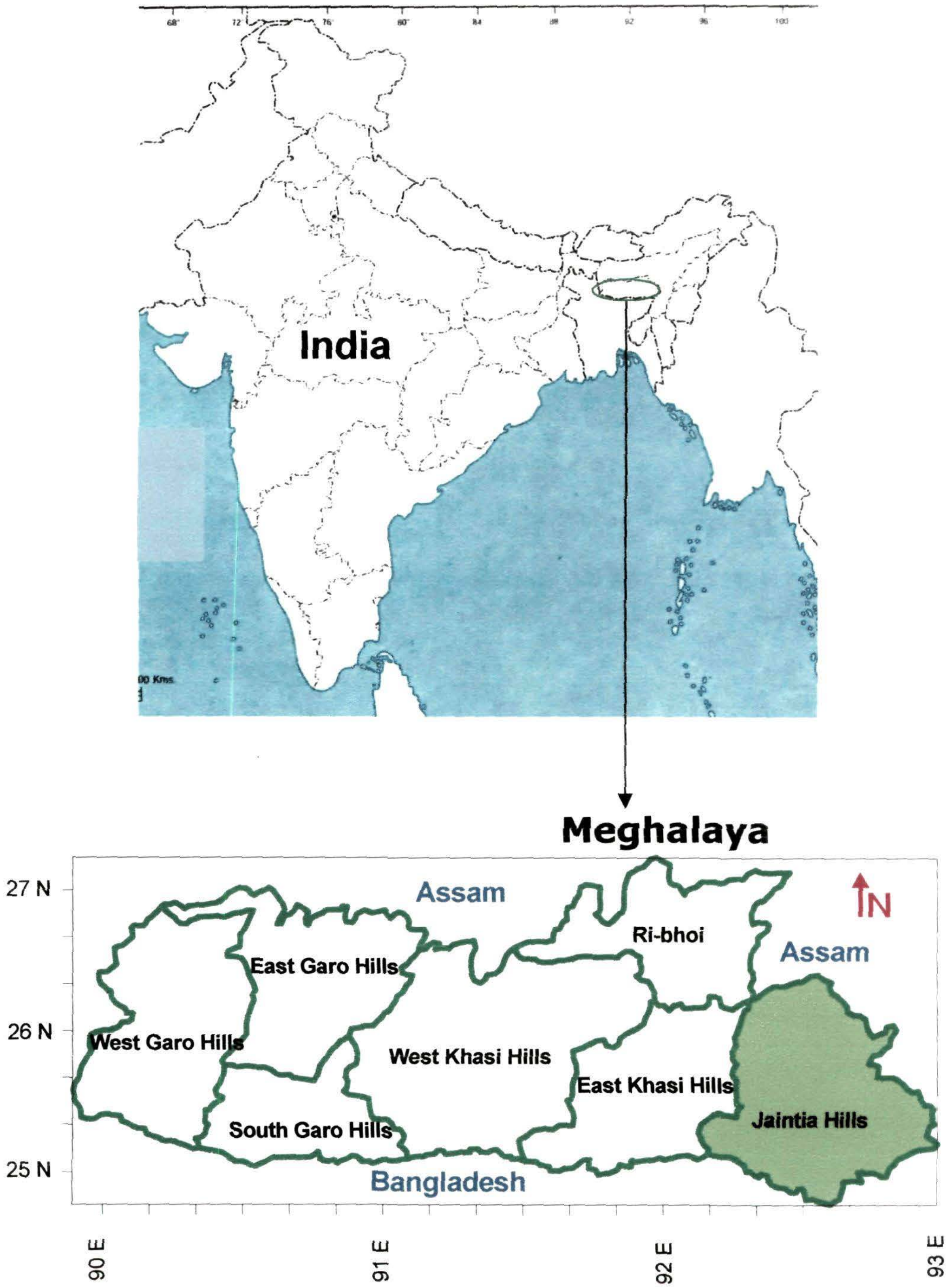
Caruccio (1968) found in his work in evaluation of factors affecting Acid Mine Drainage that a soil cover played an important role in preventing AMD due to development of alkalinity as high carbon dioxide levels found in soil air contribute towards increasing neutralization capacity. Ciolkosz *et al.* (1979) reported that the effects of topsoil on oxygen concentrations within underlying mine spoil becomes more significant considering that mine spoil is typically comprised of coarse rock fragments resulting in substantial pore or void space which provides pathways for oxygen transport. The effect of straw, bark and newsprint mulches, lime and fertilizer applications on the establishment and growth of vegetation was determined on two surfaces mine sites in Western Pennsylvania, USA. Generally the response of vegetation to all treatments was better on the site with topsoil replacement than it was on the older site (Brenner, 1990). Bian *et al.* (1999) reported that appropriate pattern of covering soil, e.g. overall-covering and strip-covering effectively controlled acidic pollution of mine soil at Fan coal mine, China.

Results of a series of drainage trials set up to investigate various aspects of drainage design on opencast coal mining land of Hungary showed that secondary drainage was an essential type of field drainage reducing surface wetness and run-off from coal mined areas (Scullion and Mahammed, 1986). Shankar *et al.* (1993) suggested that the seepage water from the coal mined areas should be properly channelised to stop deterioration of soil quality in agricultural fields and low lying marginal land.

Although, studies have been done on environmental problems of coal mining of North East India in terms of water (Swer and Singh, 2003; Nath, 2004; Swer and Singh, 2004a, Swer and Singh, 2004b, Swer and Singh, 2004c, Swer and Singh, 2004d) and soil condition (Das Gupta *et al.*, 2002; Sharma, 2003b; Semwal *et al.*, 2004), no direct study has been done on agricultural impact of coal mining and its remediation in this region.

Jaintia Hills is one of the eight districts of Meghalaya. It is situated in the eastern part of the state. It lies between 25°5′ N to 25°4″ N latitudes; and between 91°51′E to 92°45″E longitudes. The district is surrounded by the state of Assam on the north and east, the East Khasi Hills district of Meghalaya on the west and Bangladesh in the south (Fig. 3.1). The district covers an area of 3,819 km^2 constituting 17.03% of the total area of the state (Directorate of Economics and Statistics, 2003). Jaintia Hills has its district headquarter at Jowai. It has five community development blocks namely Thadlaskein, Amlarem, Laskein, Khliehriat and Saipung. As per 2001 census total population of the district was recorded 2,95,692 persons. Out of total population 91.54% is rural and 8.46% is urban. Density of population in the district was recorded to be 77 persons per km^2. There are 55,100 cultivators and 15,100 agricultural labourers in the district.

Figure 3.1: Location Map of Jaintia Hills District, Meghalaya



3.1 Geology: Jaintia Hills constitutes of rock formations ranging from Pre-Cambrian to Recent age. The pre-Cambrian formation is traversed by swarms of dykes and stills of both acidic and basic nature. The major part is covered by the Gneissic complex of Pre-Cambrian. The Shillong Group of rock is marked by the presence of still and dykes. The Tertiary groups of rocks are represented by the Shella formation comprising alterations of sandstone and limestone. These also include formation of Kopili, Barail, Surma and Dupitila. The quaternary deposits older alluvium and recent alluvium is found in the river valleys and consists of fine silty and light to dark grey clay with pockets and layers of coarse sand and pebbles.

3.2 Climate: Jaintia Hills experiences a tropical monsoon climate. On the basis of weather conditions, the district as a whole has four distinct seasons namely summer (March-May), Monsoon (June to September), post monsoon (October to November) and winter (December to February). The district receives maximum rainfall during the months of June to September (Table 3.1). The district has moderately warm summer and severe winter. Maximum temperature goes up to 26.8°C during summer season and minimum temperature goes down to 10.7°C during winter season (Table 3.1). Mean temperature ranges between 15°C to 24°C throughout the year.

Table 3.1: Mean data of climatic parameters for different seasons of Jaintia Hills district, Meghalaya (1984-2005) (India Meteorological Department, Pune, India, 2006)

Season	Seasonal Max. Temp. (^{0}C)	Seasonal Min. Temp. (^{0}C)	Seasonal mean Temp. (^{0}C)	Rainfall (mm)
Summer	26.8	20.5	23.6	213.2
Monsoon	25.5	17.5	21.5	267.2
Post monsoon	24.1	13.4	20.6	101.6
Winter	20.1	10.7	15.7	12.8

3.3 Soil: Thin surface layer on earth comprising of mineral particles formed by the disintegration of the rocks, decayed organic material, living organisms and moisture is known as soil. The soil in Jaintia Hills is red and loamy. It is derived from the weathering of rocks such as granite, gneisses, diorites etc., which are relatively richer in clay forming minerals but poor in silica contents. The soils are thin, immature, light in color, less clayey and less fertile. The exposed red and loamy soils are rich in organic matter and nitrogen due to humus contents from the litters of tree leaves, grasses etc. These are usually acidic and suitable for the cultivation of potato, fruits, rice in hill slopes and terraces. Various soil attributes of Jaintia Hills are given in Table 3.2.

Table 3.2: Soil attributes of Jaintia Hills District of Meghalaya (Singh *et al.*, 1999)

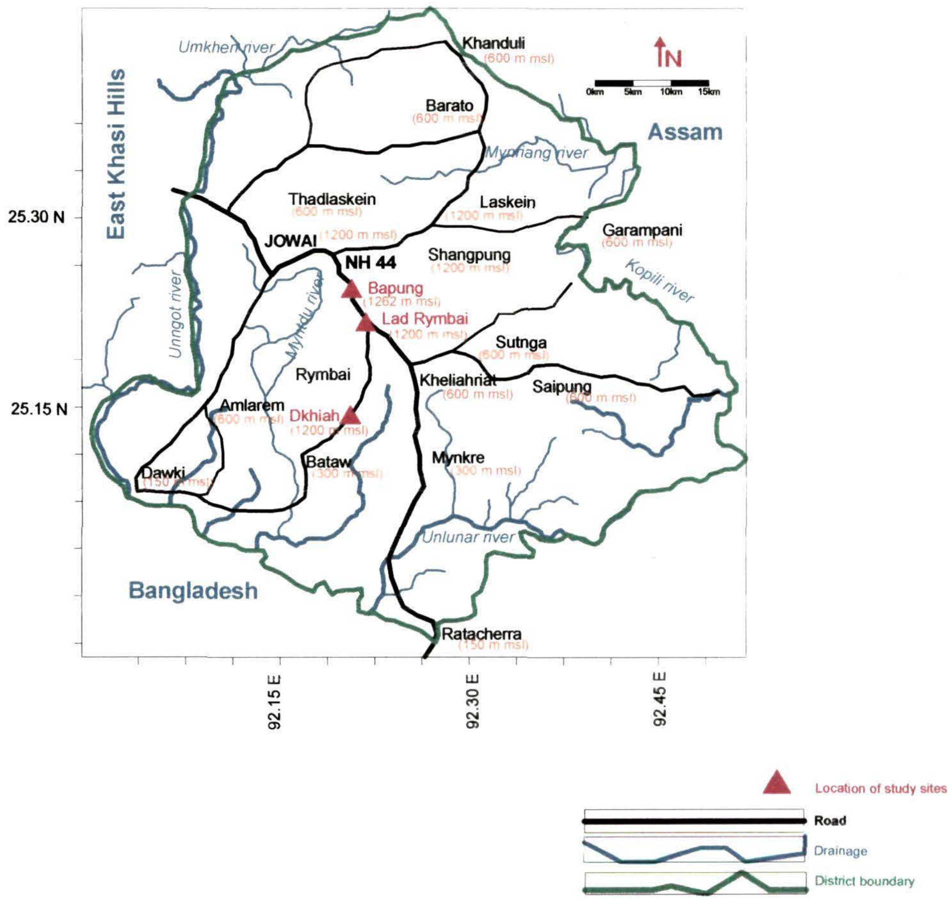
Surface form	Soil depth	Soil texture	Soil drainage	Soil Erosion	Surface Stoniness	Available water Capacity	Soil reaction (pH)	Organic Carbon (Surface)
Rolling to steeply sloppy	Deep to moderately deep	Loamy	Excessive	Severe to very severe	Slight to strong	Very low to medium	Moderately acidic	Low to very high

3.4 Physical features: Jaintia Hills forms a contiguous part of the Meghalaya Plateau and it has been divided into three physiographic divisions: (i) The Northern Hills, (ii) The Central Plateau or the Central Jowai upland (iii) The Southern Escarpment. The northern hills take the form of tumbled ranges and have height of 2,000-3,000 feet. The Central Plateau covers the central part of the district. The area is characterized by rolling mounds and hummocks of gentle height and shows flat topography. The highest elevation is observed in the southeastern parts of the district at Maryngksih (1,627m) and Lum-Bah-Bo-Bah-Kong (1,592m). The central plateau covers the central part of the district. The area is characterized by rolling mounds and hummocks of gentle height and shows flat topography. The three sampling sites (Bapung, Lad-Rymbai and Dkhiah) selected for the purpose of study are located in this particular physiographic division.

3.5 Drainage Pattern: Jaintia Hills District is drained in the north by the Umkhen River, in the northeast by Kopili River and in the southern part by Myntdu River and Lukha River. In the west the Umngot river is separating East Khasi Hills and Jaintia Hills. Myntriang and Waikhyrwi are the tributaries of kopili, Umsynlieh is the tributary of Myntdu, whereas Shasem and Weilong are tributaries of Lubha river (Fig. 3.2).

3.6 Slope: The north and eastern parts of Jaintia Hills are of moderate slope (5-10°) area. The central highland zone of Jaintia Hills District though fall under high altitude zone shows moderate slope (5-10°) due to prolonged erosional activities over the area. A long strip of moderately steep slope (10-15° and 15-20°) is seen in Jaintia Hills through the places like Thadlaskein, Bapung, Khlieriat, Mynkre and it ends at Ratachera near Bangladesh Border. A small patch of steep slope (above 20°) is found near Katdum of Jaintia Hills District where relief rainfall occurs frequently.

Figure 3.2: Sites of Study in Jaintia Hills District with Elevation from Mean Sea Level



3.7 Natural vegetation: The Jaintia Hills District is covered by mostly deciduous to evergreen forests and transitional tropical moist deciduous pine forest. The upper part of the southern slope of Jaintia Hills is devoid of tall trees. A few shrubs like *Lantana*, *Eupatorium*, *Odoratum* and a few species of *Pandanus* make its main vegetation. Besides, tall grasses, bamboo, calamus etc. are also found in this region. Tropical evergreen forests are found in the area where rainfall is high. These forests are composed of large number of species of which prominent ones are cham, gamari, paroli, sonaru, karoi, kumbhi, bonsum, sam, amari, simul etc.

3.8 Forest cover: The total land under forest in Jaintia Hills is 1,53,916 ha i.e. 42.34% of the total geographical area. Out of this 31,145 ha is owned and managed by state government as reserved forest (Directorate of Economics and Statistics, Govt. of Meghalaya, 2003). As per records available, the Saipung reserve forest is the first reserved forest established in Jaintia Hills. There are at present three reserved forests in Jaintia Hills District namely Saipung, Narpuh (Block I) and Narpuh (Block II) with area coverage of 15,035, 6,241 and 9,867 ha, respectively (Sharma, 2003b). The forests of Jaintia Hills are under extreme human pressure. The principal causes of uncontrolled deforestation in the area are fuelwood gathering and encroachment of coal mining to the forest cover area (Dkhar and Rai, 2005).

3.9 Land utilization: Land utilization statistics provide detailed information of the land use in the district. Major land use classification of Jaintia Hills is given in Table 3.3.

Table 3.3: Land Utilization in Jaintia Hills District (2002-2003)

Types of land utilization	Area (ha)
Reporting area	3,81,100
Forest	1,53,916
Not available for cultivation	30,314
Other uncultivated land excluding fallow land	1,36,980
Fallow land	26,763
Net area sown	33,127

3.10 Agriculture: Majority of population of Jaintia Hills depends on agriculture as the source of livelihood. Both settled and jhum cultivation are practiced in the district. Agriculture in the district is mainly rainfed in nature. Farmers have to depend on monsoon for the supply of water to paddy fields and other wet cultivation. The principal crops that are grown in the district are rice, maize and other cereals. Oilseed crops like sesamum, rapeseed and mustard, soybean are also cultivated though the production is not much. Other important crops include pineapple, papaya, citrus, potato, sweet potato, tapioca, chillies, turmeric, ginger, arecanut, tobacco and vegetables.

Among all the agricultural crops grown in the region rice constitutes the principal crop. Land utilization statistics show that rice occupies highest area under cultivation among all agricultural crops grown in the district (Table 3.4). Though rice is a staple food of JHD, however the district contributes only 16% of total rice area of the state (Directorate of Economics and Statistics, Govt. of Meghalaya, 2003). During recent years rice cultivation has been affected to some extent by coal and limestone mining in the district. Hence, rice production requires top priority attention, so as to come closer to self sufficiency in the near future and to catch up with the rice requirements of growing population.

3.11 Mineral Resources in Jaintia Hills: Jaintia Hills is rich in various mineral resources. In this context, good deposits of coal, limestone and kaolin are found in the district (Table 3.5). Jaintia Hills is the major producer of coal in the state. It is observed that from the year 1991-2002 the district alone contributed about 27,230.62 thousand tonnes of coal which is 74.27% of the total production of the state (Table 3.6).

Table 3.4: Annual average (1987-2002) of Area, Production and Yield of different agricultural crops grown in Jaintia Hills District, Meghalaya

Crops	Area (ha)	Production (tonnes)	Yield (kg/ha)
Rice	16,538	20,192	1,231
Maize	3,373	3,722	1,097
Other cereals and small millets	370	420	1,131
Rabi and other pulses	48	38	803
Sesamum	31	15	497
Rapeseed and mustard	17	10	611
Soya bean	384	388	1,010
Banana	310	1,552	4,918
Papaya	93	367	3,902
Pine apple	281	2,189	7,770
Citrus fruit	963	5,651	5,872
Potato	404	2,476	6,189
Sweet potato	1,824	5,377	2,962
Tapioca	42	226	14,078
Chilies	114	80	697
Turmeric	815	2,073	2,538
Ginger	93	367	3,905
Areca nut	1,327	1,741	1,257
Tobacco	9	30	332
Vegetables	313	2,949	9,395

Table 3.5: Mineral reserves of Jaintia Hills, Meghalaya (Sharma, 2003b)

Mineral	Area (km^2)	Estimated Reserve (Million tonnes)
Coal	23.86	39.60
Limestone	82.96	1,149.85
Kaolin	8.10	1.94

Table 3.6: Production of coal (Thousands tonnes) in Jaintia Hills District and Meghalaya (Dkhar and Rai, 2005)

Year	Coal production (thousand tonnes)	
	Jaintia Hills	Meghalaya
1992-1993	3,040.80	3,487.70
1993-1994	2,062.20	2,585.50
1994-1995	2,389.70	3,266.20
1995-1996	2,159.50	3,247.50
1996-1997	2,273.60	3,240.90
1997-1998	2,414.60	3,233.50
1998-1999	3,246.10	4,237.80
1999-2000	2,935.00	4,657.00
2000-2001	2,839.80	4,160.80
2001-2002	3,869.32	5,149.32
Total	27,230.50	36,565.70

3.12 Coal mining in Jaintia Hills

Coal mining is one of the most important economic activities in Jaintia Hills. Coalfields of Jaintia Hills are small and spread out in different patches, namely, Bapung, Lakadong, Lumshnong, Malwar-Musiang Lamare, Mutang, Sutnga, Jarain-Tkentalang and Ioksi (Fig. 3.3). Coal reserves in Jaintia coal fields are given in Table 3.7. Various coal fields are described below:

Bapung: It is situated between 25°5′ N to 25°4″ N latitudes; and between 92°18′ to 92°28′ E longitudes. There is no major river within the coalfield, but a few streams namely, Umshawai, Ummawaksieh etc. with a southerly flow, drain the area. The streams on the eastern side of NH-44 fall in the catchment area of Kapli river and those on the western side, directly flow in to the Bangladesh Plain. There are three coal seams in the Bapung coal field covering an area of 12 Km^2. All the coal seams in the Bapung area are less than a metre in thickness. The seams are impressments, characterized by pinching and swelling and often the coal seams degrade to carbonaceous shale.

Lakadong: It is situated between 25°11′47″ to 25°17′ N latitudes; and between 92°11′40″ to 92°20′ E longitudes. The Lakadong plateau covers a considerable area in the Jaintia Hills district between the Hari and Prang rivers. The Umlatdoh village is situated on Hill top at an altitude of 762 m. The area is dissected by several seasonal as well as perennial streams. Thick vegetation is found in the valley. The coal seams in Umlatdoh Plateau occur in the Lakadong sandstone of Ecocene age. The main coal seam of the area varies in thickness from 0.31 to 0.91 m spread over as of 1.05 km^2.

Lumshnong: It is situated between 25°13′ to 25°14′ N latitudes; and between 92°25′ E longitudes. Several isolated exposures of coal have been recorded to the west and south west of Lumshnong over an area of 0.6 km^2. The seam varies in thickness from 0.3 m to 0.6 m. The seam has an E-W trend and dips towards south at 4° to 6°.

Malwar-Musiang Lamare: It is situated between 25°13′ to 25°14′ N latitudes; and between 92°21′ to 92°24′ E longitudes. Munsiang Lamare coal field occurs near Lumshnong. It covers an area of 2.31 km^2 with a coal seam of variable thickness from 0.15 to 0.65 m.

Mutang: It is situated in 25°12′ N latitudes; and 92°24′ E longitudes. Mutang is located about 1.6 km south west of Malwar. A coal seam varying in the thickness from 0.25 to 1.80 m is noted in a water course half a km. to the northwest of Mutang village. The seam shows conspicuous pinching and swelling. To the south of the village, an outrop of 0.35 m thick coal is also seen and this also exhibits pinching and swelling.

Sutnga coal fields: It is situated between 25°20′ to 25°22′ N latitudes; and between 92°26′30″ to 92°26′32″ E longitudes. There are two coal seams covering an area of 0.16 km^2. The coal field is the eastern extensions of Bapung coal field. The top seam is very thin of 0.10 to 0.20 m and the bottom seam is of 0.30 to 0.60 m thickness.

Jarain Tkentalang area: It is situated between 25°19′19″ N; and between 92°0′8″ E longitudes. In Jarain, there is only one coal seam with a variable thickness of 0.3 to 1.10 m covering an area of 2.8 km^2. In an area around

Tkentalang, about 3 km north of Jarain, there are two coal seams, the top seam being very thin of 10 to 15 cm while the bottom seam is 0.30 to 1.00 m thick.

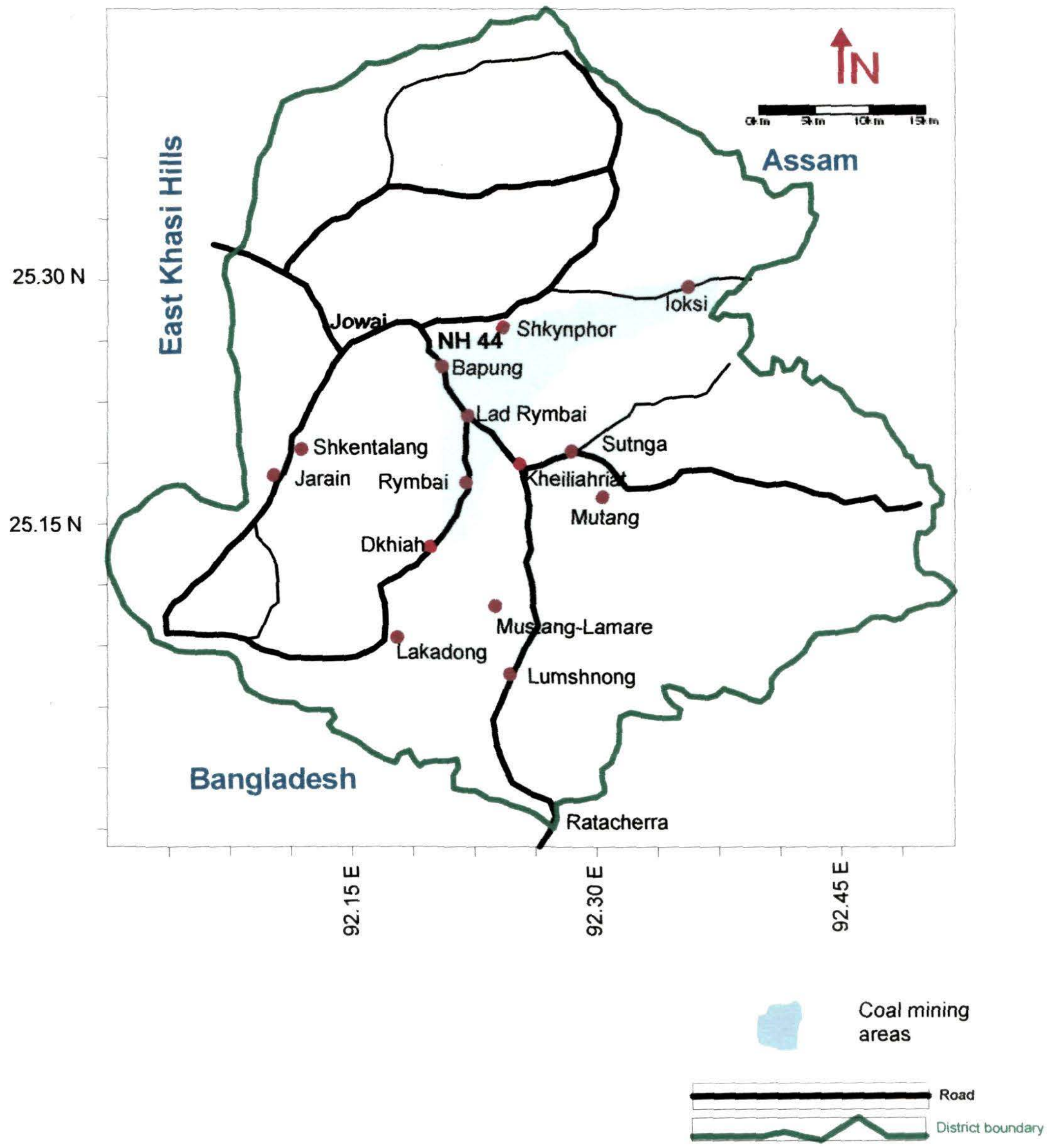
Ioksi coalfield: It is situated in 25°28′ N latitudes; and in 92°33′33″ E longitudes. It covers an area of 3.6 Km^2 with an average seam thickness of 0.80 m.

In addition to these coalfields, there are a few other coal deposits, which have been either small or still remain unexplored all over the district.

Table 3.7: Coal Reserves in different Coal fields of Jaintia Hills District (Million tonnes) (Rai, 1996)

Coal Fields	Coal Reserves (Million tonnes)
Bapung	33.66
Lakadong	0.53
Lumshnong	0.20
Malwar Musiang Lamare	1.00
Sutnga	0.68
Jarain-Tkentalang	1.00
Ioksi	1.24

Figure 3.3: Coal Mining areas of Jaintia Hills District, Meghalaya



3.13 Environmental degradation associated with coal mining in Jaintia Hills District

Coal mining has become one of the most important economic activities in Jaintia Hills District, Meghalaya. It is becoming the most profitable business in the area. But, there are various environmental problems associated with coal mining in the area. The burning problems in Jaintia Hills District due to coal mining are acute scarcity of potable water, deforestation, water pollution, land subsidence, air pollution and encroachment of forest and agricultural land (Das Gupta *et al.*, 2002; Swer and Singh, 2004a; Nath and Ahmed, 2005). These problems have cropped up due to indiscriminate and unscientific mining activities. The unscientific mining has caused environmental degradation beyond one's imagination.

The coal mining in Jaintia Hills District is being taken up in different scattered pockets. The mining in general is carried out by digging pits ranging from 5-100 m^2 either from the surface of the coal bearing location or rat-holes from the sides of a hill to reach the coal seams. The whole area seems to be littered with small rat holes resulting huge, ugly and disfigurement of the land. At places, even existing paddy fields are being destroyed. Due to coal mining, soil has become acidic and unfit for agricultural activity. Large-scale mining has caused serious disturbance to the traditional land use pattern of the area. At many places, large-scale deforestation has taken place, which ultimately is causing severe soil erosion. Although no precise estimate of the amount of agricultural land lost due to mining is available for the area as such. The abandoned mining areas are left unguarded and in nowhere, back filling, land reclamation etc. are practiced thereby causing serious soil erosion. Acid Mine Drainage is the greatest environmental problem of the mining sector. Effect of Acid Mine drainage on water quality and aquatic life of the area has been studied in detail (Swer and Singh, 2004; Nath, 2004). On contamination with nearby agricultural field, the Acid Mine Drainage deteriorates soil's physico-chemical properties and thereby adversely affects crop growth and yield. Although studies have been done on effect of coal mining activities on soil's physico-chemical properties of the region (Das Gupta *et al.*, 2002), but no remediation measures has been undertaken for restoration of agriculture on these mine affected soils.

3.14 Sampling locations: Although there is large-scale exploitation of coal in Jaintia Hills district but for the purpose of study three representative coal mining sites namely Lad Rymbai, Bapung and Dkhiah have been selected (Fig. 3.2). The schematic representation of sampling sites have been presented in Figures 3.4 (a)-Fig. 3.4(c). The details of study sites are explained below:

Lad Rymbai: Lad Rymbai is a coal mining area of Jaintia Hills situated in 25°22'14" N latitudes; and in 92°19'4"E longitudes. The area is at an altitude of 1200m above mean sea level. It is about 93 km from Shillong, the capital of Meghalaya and is situated on Jowai-Silchar road. It is under Khliehriat Community Development block. It falls in in Umsynlieh river basin which is the tributary of Myntdu river. The village is around 27 Km. from Saipung and 23 km. from Narpuh reserve forest. The village covers approximately 10-12 km^2 area. There are about 250-300 households in the village. Agriculture is the primary occupation of the villagers. Rice is the main crop covering about 75% of total area sown in the village. Except rice other crops which are mainly vegetables are grown as homsted farming. Coal mining is done only 2-3 km. away from the sampling site. Coal dumps are scatteredly distributed in and around habitants and crop fields of the area (Fig. 3.5). Although main occupation of the villagers is agriculture, but during off season of cultivation the workforce is diverted to coal mine activities as daily wage labours. Expansion of land under mining and encroachment of agricultural land are taking place at a fast pace in this area.

Figure 3.4 (a): Schematic sampling locations at Lad Rymbai

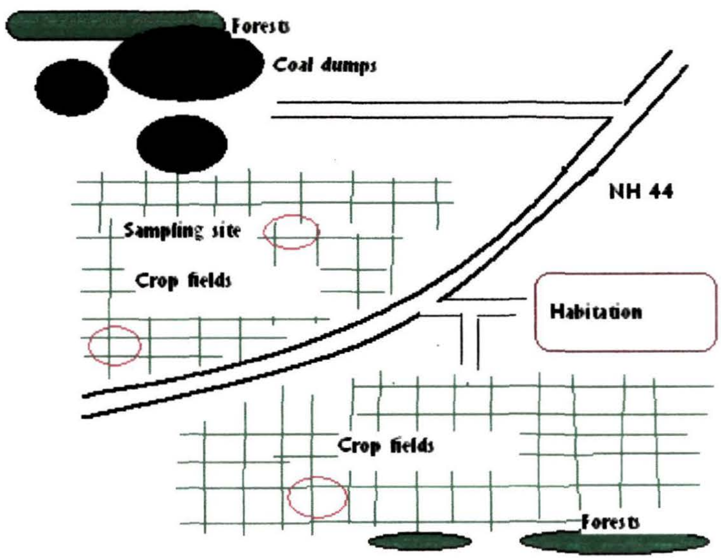


Figure 3.4 (b): Schematic sampling locations at Dkhiah

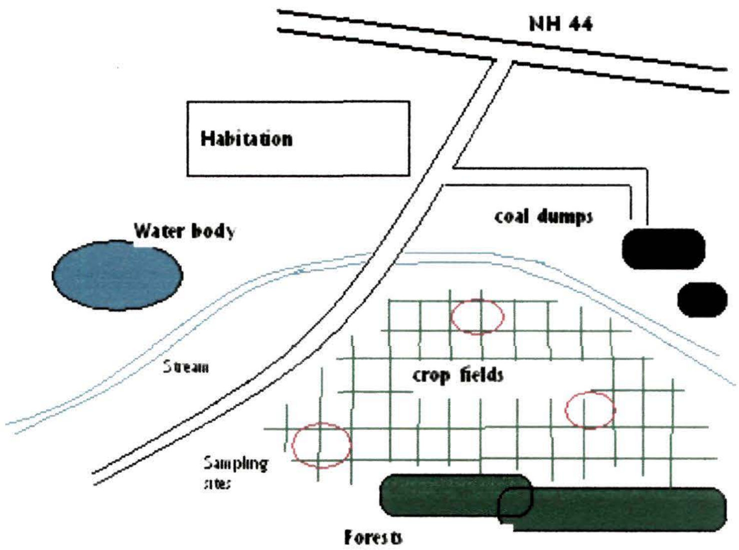
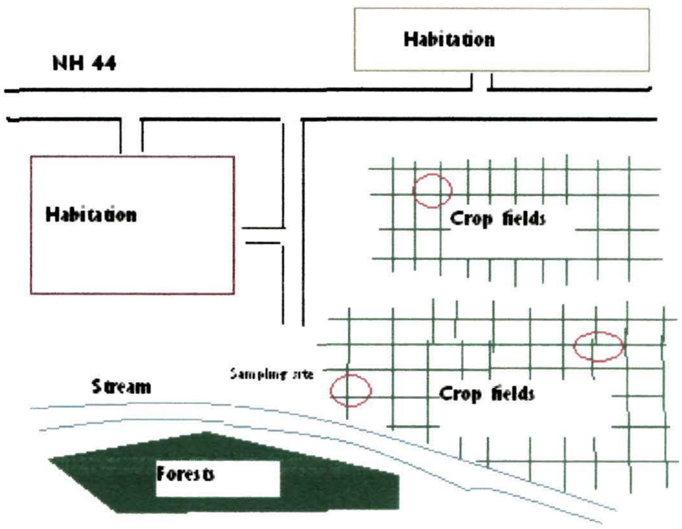


Figure 3.4 (c): Schematic sampling locations at Bapung



Dkhiah: Dkhiah is a mining area situated in 25°22′18″ N latitudes; and in 92°21′32″E longitudes. The area is at an altitude of 1200m above mean sea level. It is about 110 km from Shillong, the capital of Meghalaya and is situated on Jowai-Silchar road. It is under Khliehriat Community Development block. It falls in Umsynlieh river basin which is the tributary of Myntdu river. The village is around 25 Km. away from Saipung and 20 Km. from Narpuh reserve forest. The village covers approximately 5 km^2 area. There are about 70-80 households in the village. Although main occupation of the villagers is agriculture, but many of them work in coal mines as daily wage laborers. Rice is the main crop of the area occupying about 80% of total cropped area. Except rice other crops are mainly fruits and vegetables grown as homsted farming. Coal mining is done only 2-3 km. away from the sampling site. Large numbers of agricultural fields are left barren by the farmers due to degradation of soil through contamination of coal waste (Fig. 3.6).

Bapung: Bapung is situated in 25°23'45"N latitudes and in 92°18'24"E longitudes. The area is at an altitude of 1262m above mean sea level. It is about 87 km from Shillong. It is under Khliehriat Community Development block. It falls in Myntriang river basin which is the tributary of Kharkar river. The village is around 29 km. from Saipung and 32 km. from Narpuh reserve forest. The village covers approximately 12-14 km^2 area. There are about 400-500 households in the village. Main occupation of the villagers is agriculture. Rice is the main crop of the area occupying about 80% of total cropped area. Except rice, other crops are mainly fruits and vegetables grown as homsted farming. Coal mining is done only 0.5 km. away from the sampling site. Although main occupation of the villagers is agriculture, but during off season of cultivation the workforce is diverted to coal mine activities as daily wage labours. The entire area is very much under environmental concern due to large scale coal mining in the area. Degradation of agricultural land is one of the major problems of this area. The drainage of water from various coal mines has made the agricultural fields of the area highly unproductive (Fig. 3.7).

Figure 3.5: Coal dumps around habitation and rice fields at Lad Rymbai

Figure 3.6: Crop fields abandoned due to deposition of coal particles which are no fit for cultivation at Dkhiah

Figure 3.7: Coal particles carried by rain water and deposited on rice fields at Bapung

4.1 Collection of secondary data

Data on area, production and yield of major agricultural crops grown in Jaintia Hills District have been collected from Directorate of Economics and Statistics, Govt. of Meghalaya. Land use statistics of Jaintia Hills District were also collected for the same period. Data was analyzed to determine the extent of land degradation and impact of land used for various activities on agriculture of the region.

4.2 Analysis of secondary data on land use

Land Use statistics of Jaintia Hills District, Meghalaya were collected since 1987-88 till 2001-02. Contribution of each category of land use to the total geographical area of the district has been expressed in per cent. The period from 1987-88 to 2001-02 has been divided into five blocks of three years each i.e. A (1987-88 to 1989-90), B (1990-91 to 1992-93), C (1993-94 to 1995-96), D

(1996-1997 to 1998-99) and E (1999-2000 to 2001-2002). The block wise variation of land use has been calculated as follows:

100(B-A)/A= Variation during B block over A block

100(C-B)/B= Variation during C block over B block

100(D-C)/C= Variation during D block over C block

100(E-D)/D= Variation during E block over D block

100(E-A)/A= Variation during E block over A block

4.3 Analysis of secondary data on area, production and yield of agricultural crops

Agricultural crops were categorized as foodgrains, oilseeds and horticultural crops. The long-term average was calculated with respect to area, production and yield of different categories of agricultural crops. Average annual change (%) of area, production and yield of agricultural crops was calculated as follows:

$$\text{Average annual change(\%)} = \sum_{i}^{n}\left[\frac{\text{Area/Production/Yield of (a given year - previous year)} * 100}{\text{Area/Production/Yield of previous year}}\right]/n$$

Where,

n = Number of years

Percentage of net sown area occupied by different crops has been calculated. Block wise variation of area, production and yield of different crops have been calculated with the same procedure followed for land utilization.

4.4 Analysis of physico-chemical properties of soil of study area

Soil samples were collected using cores from the rice fields of three coal mining sites of Jaintia Hills District namely Dkhiah, Lad-Rymbai and Bapung. All sampling locations are situated at a height of about 1,200-1,300 m above mean sea level. Composite soil samples were collected from the field before experimentation to a depth of 0-15 cm and subjected to various physical and chemical analysis such as soil texture, soil pH, available nutrients (kg/ha) and organic carbon (%) following standard procedures (Table 4.1) separately for all the locations. Available nutrients were determined in parts per million (ppm), which were later converted in to kg/ha by multiplying with a factor 2.24 (Subbiah and Asija, 1956; Bray and Kurtz, 1945).

Table 4.1: Methods followed for analysis of various parameters of soil

Parameters	Methods used
Soil texture	Hydrometer method (Bouyoucos, 1962)
Soil pH	pH meter (1:2.5 :: soil: water)
Available Nitrogen	Alkaline Potassium Permanganate method (Subbiah and Asija, 1956)
Available Phosphorous	Bray's method (Bray and Kurtz,1945)
Available Potassium	Ammonium Acetate extraction for exchangeable potassium (Flame photometric method)
Organic carbon	Titrimetric method (Walkley and Black,1934)

4.5 Evaluation of rice varieties in mine affected soil

A pot experiment was conducted to evaluate tolerant rice varieties for cultivation on mine affected soil under various remedial measures. The experiment was conducted in ICAR Research Complex for NEH Region, Umiam, Meghalaya during kharif seasons (June-September) of 2005 and 2006. Meteorological data of study area (Jaintia Hills) and experimental site (Umiam) for 2005 and 2006 is given in Appendix 1 and Appendix 2, respectively.

4.5.1 Selection of rice varieties

Three different rice varieties namely Khaw Saw, Bhalum-1 and Bhalum-2 were selected for growing in pots. Out of the three varieties Khaw Saw is widely grown in Jaintia Hills. The yield of this variety is only 1-2 tonnes/ha as reported by the local farmers. Other two varieties namely Bhalum-1 (RCPL 1-27) and Bhalum-2 (RCPL 1-29) have been collected from ICAR Research Complex for NEH Region, Umiam (Shillong). These two varieties were recommended for upland conditions of medium altitude (800-1,300 above mean sea level) areas of Meghalaya (Anonymous, 2001).

4.5.2 Treatments

Soil samples obtained from mining area were treated with organic matter and lime in different combination as given below:

1. **T_1**: Control (Without application of any soil amendment)
2. **T_2**: Organic matter (10 t/ha or 178.6 g/pot)
3. **T_3**: Lime (4.08 t/ha or 72.9 g/pot)
4. **T_4:** Organic matter (10 t/ha) + Lime (4.08 t/ha)

4.5.3 Experimental Design and layout

The layout (Table 4.2) consisted of 36 pots laid out in a Completely Randomized Design (CRD) with three replications.

Variety 3

Treatments 4

Replications 3

Total number of pots 3x4x3 = 36

Table 4.2: The experimental layout with different treatments

V1F0L0	V2F0L0	V3F0L0
V1F0L1	V2F0L1	V3F0L1
V1F1L0	V2F1L0	V3F1L0
V1F1L1	V2F1L1	V3F1L1

Where,

V1 = Khaw Saw rice variety

V2 = Bhalum 1 (RCPL 1-27)

V3 = Bhalum 2 (RCPL 1-29)

F0 = No application of FYM

F1 = FYM (178.6 g/pot)

L0 = No application of lime

L1 = Lime (4.08 g/pot)

4.5.4 Seed treatment

Seeds were soaked with 0.1% Bavistin prior to sowing as preventive measures against diseases. Crops were sprayed with 0.05% Monocrotophos to reduce the insect population.

4.5.5 Sowing

Each pot was filled with 4 kg of soil. 5-6 seeds were sown per pot. Sowing was done on 28/05/2005 and 8/5/2006 for the two years of experiments, respectively.

4.5.6 Cultural operations

Cultural operations like weeding and thinning were carried out manually. Weeding was done at regular intervals during the crop growth and the thinning was carried out 20-25 days after sowing to maintain required plant population of one plant per pot.

4.5.7 Watering

The pots were continuously watered to maintain about 5 cm of standing water throughout the growth period till reaching maturity stage.

4.5.8 Fertilizer application

In all treatments common doses of fertilizer (60kg N: 60kg P: 40kg K) were applied (Table 4.3). Nitrogenous, phosphatic and potassic fertilizers were applied in the forms of urea, single super phosphate (SSP) and muriate of potash (MoP), respectively. Amount of fertilizer required for each pot was calculated for 4 kg soil per pot, considering weight of soil for 1 ha land is equivalent to 2.26×10^6 kg.

Table 4.3: Amount of fertilizer applied in pots

Fertilizer	kg/ha	g/pot
Urea	130.43	0.23
Single Super Phosphate (SSP)	375.00	0.67
Muriate of Potash (MoP)	67.00	0.12

Half dose of urea and full doses of SSP and MoP were applied at the time of filling the pots with soil, i.e. just before sowing, while remaining urea was top-dressed at panicle initiation stage of the crop growth.

4.5.9 Farmyard Manure (FYM): The basic ingredient of this manure is animal excreta. Content of major nutrients in FYM is 0.5% Nitrogen, 0.3% P_2O_5 and 0.5% K_2O (Biswas and Mukherjee, 1997). FYM was applied at the rate of 10 t/ha or 178.6 g/pot before sowing of seeds.

4.5.9.1 Calculation for amount of FYM applied in the treatment

1 ha land is equivalent to 2.26×10^6 kg soil.

Again, 2.26×10^6 kg soil requires 10 tonnes of FYM.

Hence, 4 kg soil (per pot) requires $(10 \times 4)/(2.26 \times 10^6)$ tonnes FYM or 178.6 g FYM.

4.5.10 Lime

Calcium Carbonate ($CaCO_3$) was applied as liming material. Lime was applied at the rate of 4.08 t/ha or 72.9 g/pot to bring the pH of the soil up to 6 (Shoemaker *et al.*, 1961).

4.5.10.1 Calculation for lime application

1 ha land is equivalent to 2.26×10^6 kg soil.

2.26×10^6 kg soil requires 4.08 tonnes of $CaCO_3$.

So, 4 kg soil (per pot) requires $(4.08 \times 4)/(2.26 \times 10^6)$ tonnes Lime or 72.9 g lime.

4.6 Measurement of growth and yield parameters

Measurement of various growth and yield parameters such as phenological stages, plant height, Leaf area Index (LAI), biomass yield, various yield components and grain yield were periodically recorded using standard procedure (Table 4.4).

4.6.1 Phenology: The standing crop was observed periodically to determine the occurrence and duration of various phenological stages. From these observations, seedling emergence (SE), start tillering (ST), panicle emergence (PE), milk, dough and maturity stages were identified. The first two stages make the vegetative phase of rice. Other stages from panicle emergence to maturity correspond to ripening stage of the crop.

4.6.2 Plant height: Plant height was measured with the help of a meter scale at 7 days interval from tillering to physiological maturity.

4.6.3 Leaf Area Index (LAI): This is the ratio between total green leaf area to ground area occupied by the plants. LAI was measured with plant canopy imager (CI-110) at various crop stages (Anonymous, 2003).

4.6.4 Yield components: Yield components of rice recorded are as given below:

a) Number of effective tillers: These are the tillers with filled grains.

b) Number of filled grains per panicle

c) 1,000 grain weight (g): This is the weight of 1,000 grains of a particular treatment.

Above parameters were measured by manual method (Yoshida *et al.*, 1976).

Table 4.4: Measurement of various plant growth parameters:

Parameters	Methodology	Time interval
Phenological stages	Visual observation	From seedling emergence to yellow maturity
Plant height	Manual method (Yoshida *et al.*, 1976)	From tillering to physiological maturity on weekly basis
Leaf Area Index	Plant Canopy Imager (CI-110) (Anonymous, 2003)	At various crop growth stages
Yield components	Manual method (Yoshida *et al.*, 1976)	At maturity
Grain yield	Physical balance (Yoshida *et al.*, 1976)	At maturity
Dry matter production	Conventional oven drying method (Yoshida *et al.*, 1976)	At maturity

4.6.5 Measurement of grain yield

The grains obtained from a particular pot were threshed, cleaned, dried and weighed. Total weight of all the grains of a particular pot gives the grain yield per pot.

4.6.5.1 Conversion of grain yield per pot to grain yield for one ha area (kg/ha)

It is assumed that plant density of 1 m^2 area is 25 with 20cm x 20cm spacing. Hence, 1 ha (10,000 m^2) area has a plant density of 2,50,000 with same spacing.

$$\text{Grain yield (kg/ha)} = \frac{\text{Grain yield per pot x 2,50,000}}{\text{1,000}}$$

4.6.6 Biomass: Above ground plant materials were collected after harvest and oven dried at 65 °C until a constant weight was obtained to determine dry biomass production.

4.6.7 Harvest Index: Harvest index of crop is a good indicator of its productivity performance. It is calculated using the following formula:

$$\text{Harvest Index (HI)} = \frac{\text{Total grain yield}}{\text{Total dry matter production}}$$

4.7 Statistical analysis

Standard statistical procedures were employed for analysis and interpretation of data (Gomez and Gomez, 1984). ANOVA analysis was done using MSTAC software developed by International Rice Research Institute (IRRI), Philippines.

4.8 Comparison of different varieties

From the analysis of different growth and yield parameters, the varieties have been ranked according to their performance as obtained from standard statistical analysis. The three ranks *viz.* 1, 2 and 3 were assigned to the varieties pertaining to any given parameter depending on their recorded level in descending order of magnitude, except, in case of attainment of yellow maturity. Here, the shorter duration to attain maturity has been considered as a positive character and no. 1 ranking is given to the variety, which has shown shortest duration of crop cycle. Again, in certain cases same ranking has been assigned to two or more varieties, which indicate that for that particular parameter the varieties do not differ significantly. The variety which ranked first (1^{st}) in maximum number of parameters has been considered best and recommended for cultivation in coal mine affected soil of the study area.

RESULTS AND DISCUSSION

Chapter 5

Agriculture is the main occupation of the people of Jaintia Hills and rice is the major agricultural crop grown in the area. During recent years agricultural activity of this area is being threatened by multiple environmental problems caused by unscientific mining of coal. Under such situations, it is extremely important to evaluate the overall scenario of agricultural production of the area and to find out some remedial measures so that the crop sustainability can be maintained by improving the existing situation. The results discussed in this chapter are the outcome of the study undertaken during 2004-2008.

Changes in land utilization and agricultural production in Jaintia Hills since 1987 till 2002 have been analysed to know the agricultural impact of coal mining in the area. Physico- chemical analysis of soils collected from various coal mining sites of Jaintia Hills was done to know the extent of land degradation and to reveal underlying causes of such degradation. Treatment of such soil was done with lime and organic matter to see the changes of various soil properties over control (without any treatment). Performance of different rice varieties were studied through a pot culture experiment conducted on soil collected from coal mining site under the treatment with lime and organic matter. Based on the experiment, suitable rice variety with proper soil ameliorant has been recommended for cultivation on coal mining sites of Jaintia Hills.

5.1 Land Utilization Pattern in Jaintia Hills

Land is the essence of life through sustenance for food, clothes and shelter. Nevertheless, of late the pressure on this vital resource has increased to such an extent that resulted in various kinds of land degradation, environmental pollution and decline in crop productivity and sustainability. The information on land utilization pattern is important to manage and improve the present use of land for better productivity and sustainable management.

Jaintia Hills district of Meghalaya has a total geographical area of 3, 81,900 ha. However, the total reporting area of the district is only 3, 81,100 ha for which data on land use classification is available (Directorate of Economics and Statistics, 2003). Major land uses in Jaintia Hills include 'Forest', 'Area not available for cultivation', 'Barren and Uncultivated land', 'Land under miscellaneous tree crops and groves', 'Cultivable wasteland', 'Fallow land other than current fallow', 'Current Fallow', 'Net sown area', 'Area sown more than once' and 'Total cropped area' (Table 5.1).

Forest area ranged from 1,52,120 to 1,54,093 ha since 1987-88 till 2001-02. It was approximately 40.07% of total geographical area of the district (Table 5.1, Table 5.2). Again 31.57% of total geographical area of Jaintia Hills is lying as 'cultivable wasteland', which is also available for cultivation but not taken up for cultivation for last five years or more in succession (Table 5.2). This category of land ranged from 1, 19,570 to 1, 21,085 ha since 1987-88 to 2001-2002 (Table 5.1). Only 8.64% of the total geographical area of Jaintia Hills is 'total cropped area' (Table 5.2). This area ranged from 32,333 to 37,433 ha during the period of 1987 to 2002 (Table 5.1). 'Total cropped area' includes both 'net sown area' and the areas where crops are cultivated more than once during the agricultural years. Both these two categories occupy around 8.56% and 0.06% of total geographical area of the district, respectively (Table 5.2). Area under 'current fallow' occupies 2.36% of total geographical area (Table 5.2). Area under 'current fallow' ranged from 8,715 ha to 9,470 ha from 1987-88 to 2001-02 (Table 5.1). On the other hand 4.55% of total area is 'fallow land other than current fallow' (Table 5.2). It ranged from 17,110 ha to 20,151 ha from the period from 1987-88 to 2001-02 (Table 5.1). This category of land includes all lands that are kept for cultivation but are temporarily out of cultivation for a period not less than one year and not more than five years. 'Land under non-

Table 5.1: Land Utilization trend in Jaintia Hills district (1987-88 to 2001-02)

Year	Forest	Area not available for agriculture	Barren and uncultivated	Land under misc. tree crop and groves	Cultivable waste	Fallow land other than current fallow	Current fallow	Net area sown	Area sown more than once	Total cropped area
	Area (ha)									
1987-88	153611	15840	15010	14354	120521	20151	9438	32175	164	32339
1988-89	153553	15864	15030	17376	120842	17150	9123	32162	171	32333
1989-90	153386	15874	15011	17252	121091	17165	9136	32185	190	32375
1990-91	152155	16020	15340	17577	121212	17167	8766	32863	207	33070
1991-92	152138	16035	15320	17554	121257	17177	8715	32863	207	33070
1992-93	152120	16045	15340	17595	121145	17190	8765	32900	210	33110
1993-94	152120	16065	15340	17615	121066	17210	8785	32900	207	33107
1994-95	152270	16000	15340	17620	121000	17230	8790	32850	306	33156
1995-96	152082	16070	15313	17634	121085	17207	8796	32923	220	33143
1996-97	152155	16135	15138	27685	121080	17165	8790	32960	240	33200
1997-98	154140	16120	15041	17439	119570	17110	8760	33010	240	33250
1998-99	154076	16096	15075	17127	119919	17290	9470	33047	315	33362
1999-00	154085	16093	15072	17135	119909	17285	9457	33049	325	33374
2000-01	154090	17088	14875	17156	119958	17283	9423	32415	332	32747
2001-02	154093	17011	14872	17152	119946	17283	9427	32416	357	32773
Mean	153072	16157	15141	17885	120640	17404	9043	32715	246	32961

Table 5.2: Distribution of various types of land uses in Jaintia Hills District (1987-88 to 2001-02)

Year	Forest	Area not available for agriculture	Barren and unculturable land	Land under misc. tree crop and groves	Cultivable waste	Fallow land other than current fallow	Current fallow	Net area sown	Area sown more than once	Total cropped area
Per cent contribution										
1987-88	40.22	4.14	3.93	3.75	31.55	5.27	2.47	8.42	0.04	8.46
1988-89	40.20	4.15	3.94	4.55	31.64	4.49	2.39	8.42	0.04	8.46
1989-90	40.15	4.15	3.93	4.51	31.67	4.49	2.39	8.43	0.04	8.47
1990-91	39.84	4.19	4.01	4.60	31.70	4.49	2.30	8.60	0.05	8.65
1991-92	39.83	4.19	4.01	4.59	31.70	4.49	2.28	8.60	0.05	8.65
1992-93	39.82	4.20	4.01	4.60	31.60	4.49	2.29	8.61	0.05	8.66
1993-94	39.82	4.20	4.01	4.61	31.70	4.50	2.29	8.60	0.05	8.65
1994-95	39.86	4.18	4.01	4.61	31.70	4.51	2.30	8.60	0.07	8.67
1995-96	39.81	4.20	4.01	4.61	31.7o	4.49	2.30	8.62	0.05	8.67
1996-97	39.83	4.22	3.96	7.25	31.70	4.49	2.30	8.63	0.06	8.69
1997-98	40.36	4.22	3.94	4.56	31.30	4.48	2.29	8.64	0.06	8.70
1998-99	40.34	4.21	3.94	4.48	31.40	4.52	2.48	8.65	0.08	8.73
1999-00	40.34	4.21	3.68	4.48	31.39	4.52	2.47	8.65	0.08	8.73
2000-01	40.35	4.47	3.63	4.49	31.41	4.52	2.46	8.48	0.08	8.56
2001-02	40.35	4.45	3.63	4.49	31.41	4.52	2.46	8.48	0.09	8.53
Mean	40.07	4.23	3.91	4.68	31.57	4.55	2.36	8.56	0.06	8.62

agricultural uses' comprises of 4.23% of total geographical area of Jaintia Hills district (Table 5.2). This area ranged from 15,840 to17, 088 ha during the study period (Table 5.1). It includes lands occupied by buildings, roads, rivers and canals and any other uses except agriculture. 'Barren and uncultivated land' occupies 3.91 % of total geographical area of Jaintia Hills district (Table 5.2). It covers land under mountains and area that can not be brought under cultivation except at a very high cost. It ranged from 14,872-15,340 ha during 1987-88 to 2001-02 (Table 5.1). 'Land under Miscellaneous tree crops and grooves' occupy an area of 4.68% of the total geographical area (Table 5.2). It includes all cultivable land not included in 'net sown area'. Land under Casurina trees, thatching grasses, bamboo bushes, and other grooves for fuel etc. which are not included under 'orchards' have been contributing to this category.

From the above results it is clear that maximum area under land utilization in Jaintia Hills is occupied by forest. A considerable proportion of total geographical area is under cultivable wasteland which is much higher than total cropped area of the district.

Although forest area is high in Jaintia Hills, still it is far below the national norm of 60% recommended for hilly areas (Directorate of Agriculture, Meghalaya, 2002). This may be due to heavy deforestation of the region. Forest ecosystems of hills are being threatened by a number of factors such as shifting cultivation, industries, infrastructures, human settlements etc. Shifting cultivation (Jhum) is the single largest factor for the loss of forest cover in North Eastern Hill region (Forest Survey of India, 1997). Further, the forests of Jaintia Hills are the greatest victims of coal mining activities (Jha and Singh, 1990; Baig, 1992). Based on a study done on the impact of coal mining on the vegetation characteristics of the Nokrek Biosphere Reserve of Meghalaya Sarma *et al.* (2005) reported that the composition of vegetation reduces in the mined areas with that of the adjacent unmined areas. Based on a remote sensing study, Sarma (2005) reported that 13 to 45 km^2 of forests of Jaintia Hills were diminished due to mining activity from the period of 1975 to 2001.

Large proportion of cultivable waste land in Jaintia Hills may be due to both shifting cultivation and extensive unscientific mining of coal. Similar was reported by Sharma (2003b). Shifting cultivation, involving the cutting and burning of forest covers, caused large scale land degradation, soil erosion and loss of soil fertility (Rao, 1989; Munda, 1998; Sharma, 1998). Due to extensive coal mining, large area of the district has been turned into degraded land. Physico-chemical degradation of land due to rat hole mining of coal in Jaintia Hills has been reported by Das Gupta *et al.* (2002). Deposition of coal particles is another reason for land degradation in coal mining areas (Schejbal, 1995). The study of the impact of coal mining on land degradation has been carried out world wide (Rathore and Wright, 1993; Ghosh, 1998; Prakash and Gupta, 1998).

The loss of soil fertility may be the reason for low cropped area in Jaintia Hills. Nath and Ahmed (2005) reported that paddy fields close to mining sites in Jaintia Hills have become unfit for cultivation due to contamination from coal mine drainage. As a result many farmers abandoned their traditionally cultivated lands. Soil contamination with Acid Mine Drainage (AMD) which is the acidic mine water with high concentrations of heavy metals in nearby areas of coal mining sites have been reported by many workers (Dudka and Adriano, 1997; Van Green *et al.*, 1999; Tiwary, 2001). Heavy metals severely affect the growth, morphology and metabolism of microorganisms in bulk soils, through functional disturbance, protein denaturation or destruction of the integrity of cell membranes (Leita *et al.*, 1995). The results of soil analysis of a coal mining site in Taiwan indicated that the soils were extremely acidic (pH 3.2) associated with nutrient deficiency due to contamination with large amount of coal debris (Lin, 1999). Adler and Sibrell (2003) reported that solubilization and transport of phosphorous to the water environment from soil and manure caused by AMD is a critical environmental issue associated with agricultural productivity in coal mining areas.

5.1.1 Variation of land utilization pattern in Jaintia Hills District in different block years (1987-88 to 2001-02)

For analysis of variation of land utilization pattern in Jaintia Hills District, the time period from 1987-88 to 2001-02 was divided in to five block years such as A (1987-88 to 1989-90), B (1990-91 to 1992-93), C (1993-94 to 1995-96), D (1996-97 to 1998-99) and E (1999-2000 to 2001-2002). Both average and percentage variation of land utilization were seen from block A to block E.

Table 5.3: Variation (Average) of land utilization in Jaintia Hills district in different block years

Land utilization pattern	Block years				
	A 1987-88 to 1989-90	B 1990-91 to 1992-93	C 1993-94 to 1995-96	D 1996-97 to 1998-99	E 1999-00 to 2001-02
	Area (ha)				
Forest	1,53,516.6	1,52,137.6	1,52,157.3	1,53,457.0	1,54,089.3
Area under non agricultural uses	15,859.3	16,033.3	16,045.0	16,117.0	16,730.7
Barren and uncultivated land	15,017.0	15,333.3	15,331.0	14,751.3	14,939.7
Land under misc. tree crop and groves	16,327.3	17,575.3	17,623.0	20,750.3	17,147.7
Cultivable waste	1,20,818.0	1,21,204.6	1,21,050.3	1,20,189.7	1,19,937.7
Fallow land other than current fallow	18,155.3	16,178.0	17,215.6	17,188.3	17,283.7
Current fallow	9,232.3	8,748.6	8,790.3	9,006.6	9,435.7
Net area sown	32,174.0	32,877.0	32,891.0	33,005.6	32,626.7
Area sown more than once	175.0	208.0	242.3	265.0	338.0
Total cropped area	32,349.0	33,085.0	33,133.3	33,270.6	34,317.3

Table 5.4: Variation (Percentage) of land use pattern in Jaintia Hills district in different block years

Land utilization pattern	100(B-A)/A	100(C-B)/B	100(D-C)/C	100 (E-D)/D	Overall Change
	(%)				
Forest	-0.89	0.012	0.854	0.41	0.39
Area under non agricultural uses	0.91	0.073	0.45	3.80	5.23
Barren and uncultivated land	2.10	-0.015	-3.78	1.28	-0.41
Land under misc. tree crop and groves	7.64	0.27	17.70	-17.30	8.31
Cultivable waste	0.32	-0.13	-0.71	-0.21	-0.73
Fallow land other than current fallow	-10.80	6.40	-0.16	0.55	-4.01
Current fallow	-5.90	0.48	-2.40	4.70	-3.12
Net area sown	2.18	0.43	0.35	-1.10	1.86
Area sown more than once	18.80	16.50	9.36	27.50	72.16
Total cropped area	2.75	0.15	0.41	3.14	6.45

The area under 'forest' which was recorded as 1, 53,516.6 ha in block period A, has gone up to 1, 54,089.3 in block period E (Table 5.3). There was an increase of 0.39% of forest area during the whole period (Table 5.4). The area under non agricultural uses was recorded as 15,859.3 ha in block period A, has gone up to 16,730.7 ha in block period E at a rate of increase of 5.23% (Table 5.3, Table 5.4). Area under this category showed maximum increase (3.8%) from block period D to block period E. 'Net sown area' was recorded as 32, 174 ha in block period A, has gone up to 32, 626 ha in block period E (Table 5.3). Overall increase of this category of land use was 1.86% during this period (Table 5.4). However, area under this category declined by 1.1% from block period D to block period E (Table 5.4). 'Total cropped area' which was recorded as 32,349 ha in block period A has gone up to 34,317.3 ha in block period E at a rate of increase of 6.45% (Tables 5.3 and 5.4). 'Area sown more than once' increased by 72.16% from block period A to block period E (Table 5.4).

Above results reveal that there was a rapid growth (5.23%) of 'area under non agricultural uses' during the period from 1987-88 to 2001-2002. Rate of increase of this category of land use was much higher as compared to increase of 'net sown area' (1.86%) during the same period. Again, highest increase of 'area under nonagricultural uses' (3.8%) was recorded from block period D to block period E. During the same period 'net sown area' went down by 1.1%. This may be due to conversion of farmlands into non agricultural uses such as industries, roads, buildings etc. Progressive coal mining activities in the region is one of the important causes of such conversion. Decrease of agricultural area in Jaintia Hills district due to coal mining activities was reported by Semwal *et al.* (2004) and Sarma (2005). Unavailability of 'net sown area' may cause tremendous increase of 'area sown more than once' which ultimately resulted in increase of 'total cropped area' during the period from 1987-88 to 2001-2002.

5.2 Cultivation of rice and other crops in Jaintia Hills District (1987-88 to 2001-02)

Agriculture is the main occupation of 75% population of Jaintia Hills district (JHD), Meghalaya (Survey of India, 2003). For an uncomplicated analysis of scenario of agricultural sector in Jaintia Hills, the crops grown in the district have been grouped in to three distinct categories such as food grains, oilseeds and horticultural crops (Table 5.5). Per cent of net sown area occupied by different agricultural crops grown in Jaintia Hills are given in Table 5.6. Rice, maize, other cereals and small millets, rabi and other pulses are the foodgrain crops which occupy 50.5%, 10.3%, 1.13% and 0.3%, respectively, of total net sown area in the district. Oilseed crops such as sesame, rapeseed and mustard and soybean together occupy 17.83% of net sown area in the district. 19.94% of net sown area of the district is occupied by horticultural crops which include Potato, Banana, Papaya, Pine apple, Citrus fruit, Sweet potato, Tapioca, Chilies, Turmeric, Ginger, Arecanut, tobacco and vegetables.

From the above results it is clear that rice is the major agricultural crop grown in Jaintia Hills. It occupies half of the net sown area of the district. Kar (1998) reported that rice-based monocropping is the rule rather than the exception in North Eastern Hill (NEH) region. Sharma and Singh (1998) reported that nearly 89% of area under total foodgrains in NEH region is occupied by rice.

Table 5.5: Types of agricultural crops grown in Jaintia Hills District

Categories	Crops
Food grain crops	Rice, Maize, other cereals and small millets and rabi and pulses
Oilseed crops	Sesame, Rapeseed and mustard, soybean
Horticultural crops	Potato, Banana, Papaya, Pine apple, Citrus fruit, Sweet potato, Tapioca, Chilies, Turmeric, Ginger, Arecanut, tobacco and vegetables

Table 5.6: Per cent of net sown area occupied by different agricultural crops grown in Jaintia Hills District

Crops	% of net sown area
Rice	50.5
Maize	10.3
Potato	1.23
Other cereals and small millets	1.13
Rabi and other pulses	0.14
Oilseed crops	17.83
Banana	0.94
Papaya	0.28
Pine apple	0.85
Citrus fruit	2.90
Sweet potato	5.50
Tapioca	0.13
Chilies	0.35
Turmeric	2.48
Ginger	0.28
Areca nut	4.02
Tobacco	0.03
Vegetables	0.95

5.2.1 Distribution of area under rice and other agricultural crops in Jaintia Hills district, Meghalaya (1987-88 to 2001-2002)

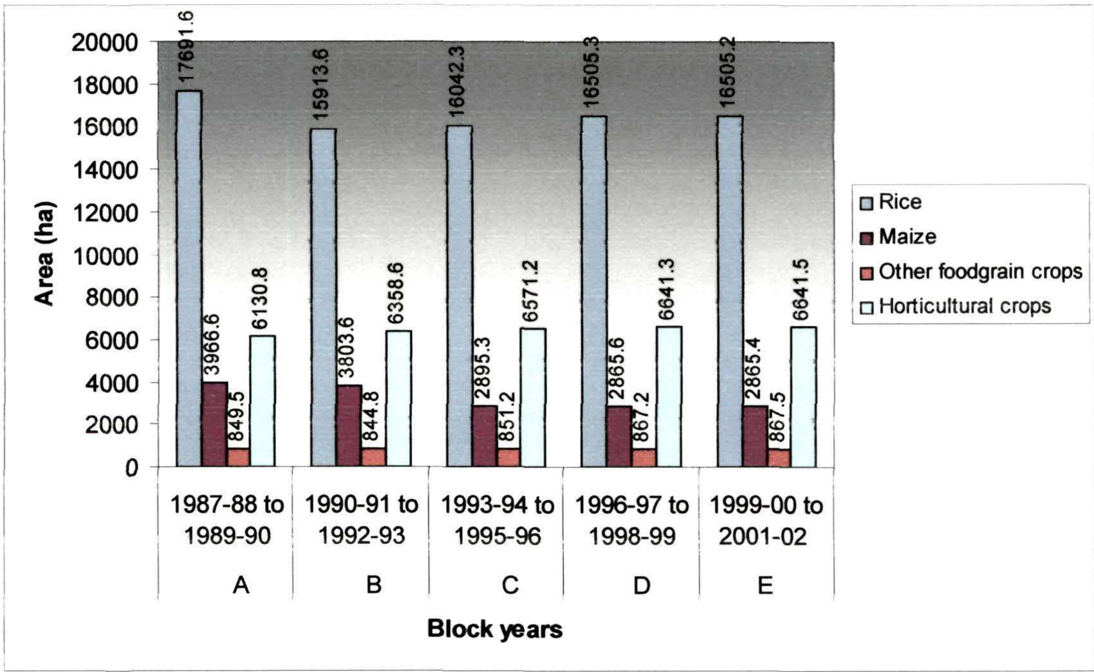
A perusal of the Table 5.7 indicates that the region registered a negative growth in both rice and maize area by -0.83 and -1.2%, respectively, during the period from 1987-88 to 2001-02. Other foodgrains including oilseeds and horticultural crops show increase in acreage by 0.63 and 0.88%, respectively, during the same time period.

Variation of area in different block years shows that area under rice was found to be 17,691.6 ha in block period A, which decreased to 15,913.6 ha in block period B. Area under maize decreased continuously from 3966.6 ha in block period A to 2865.4 ha in block period E. Other foodgrain crops including oilseeds show increase in acreage from 849.5 ha in block period A to 867.5 ha in block period E (Fig.5.1).

Table 5.7: Annual average (ha) and average annual change (%) of area of different agricultural crops grown in Jaintia Hills District, Meghalaya (1987-2002)

Crops	Annual average (ha)	Average annual change (%)
Rice	16,538.20	-0.83
Maize	3,373.80	-1.20
Other foodgrain including oilseeds	852.68	0.63
Horticultural crops	6,592.20	0.88

Figure 5.1: Variation of area under agricultural crops grown in Jaintia Hills District from block period A (1987-88 to 1989-90) to block period E (1999-00 to 2001-02)



This decrease of area under major foodgrain crops may be due to soil degradation and conversion of agricultural lands to non-agricultural uses. Nath and Ahmed (2005) reported that paddy fields close to mining sites in Jaintia Hills district have become unfit for cultivation due to contamination of coal forcing farmers to abandon their fields. Slight increase of area under other foodgrains and horticultural crops during the period indicates crop diversification. Farmers may convert some amount of their rice area into these crops in a view to get more economic benefit.

5.2.2 Production and productivity status of agricultural crops in Jaintia Hills district (1987-88 to 2001-2002)

Analysis of production and productivity scenario of agricultural crops of Jaintia Hills shows that the area recorded an increase of 4.03% and 4.18% in rice production and productivity, respectively, during the period from 1987-88 to 2001-02 (Table 5.8). Analysis of production scenario in various block years since 1987-88 till 2001-02 shows that highest level of rice production was recorded in the block period of 1999-00 to 2001-02 (24,551.2 tonnes) as compared to 19,416.6 tonnes recorded in 1987-88 to 1989-90 block period (Fig. 5.2). Similarly yield of rice has been increased from 1,105.6 kg/ha in block A to in block E (Fig. 5.3).

Table 5.8: Annual average and average annual change of production and productivity of different agricultural crops grown in Jaintia Hills District, Meghalaya (1987-2002)

Crops	Annual average		Average Annual change	
	Production (tones)	Yield (kg/ha)	Production (%)	Yield (%)
Rice	20,192.4	1,231.3	4.03	4.18
Maize	3,722.2	1,097.8	-0.29	1.34
Other foodgrain including oilseeds	873.53	810.74	0.17	0.80
Horticultural crops	25,072.9	5,495.9	0.70	0.49

Total maize production in block period A was 4,095.6 tonnes which has reduced to 3,397.3 tonnes in block period E (Fig.5.2). Annual growth rate of production of maize was negative (-0.29%) during the same period (Table 5.8). Production level of other foodgrain crops has increased from 818.9 tonnes in block period A to 915.9 tonnes in block period E with an annual increase of only 0.17% (Fig. 5.2, Table 5.8). Yield of maize and other foodgrain crops showed annual increment of 1.34% and 0.80%, respectively, during the period of study (Table 5.8). At the last block period of 1999-00 to 2001-02 the yield of maize and other foodgrain crops stands at 1,185.6 and 805.66 kg/ha, respectively, in comparison to 1,015.3 kg/ha (maize) and 779.53 kg/ha (other foodgrain crops) recorded in 1987-88 to 1989-90 block period (Fig. 5.3).

Figure 5.2: Distribution of production of agricultural crops grown in Jaintia Hills District in different block years

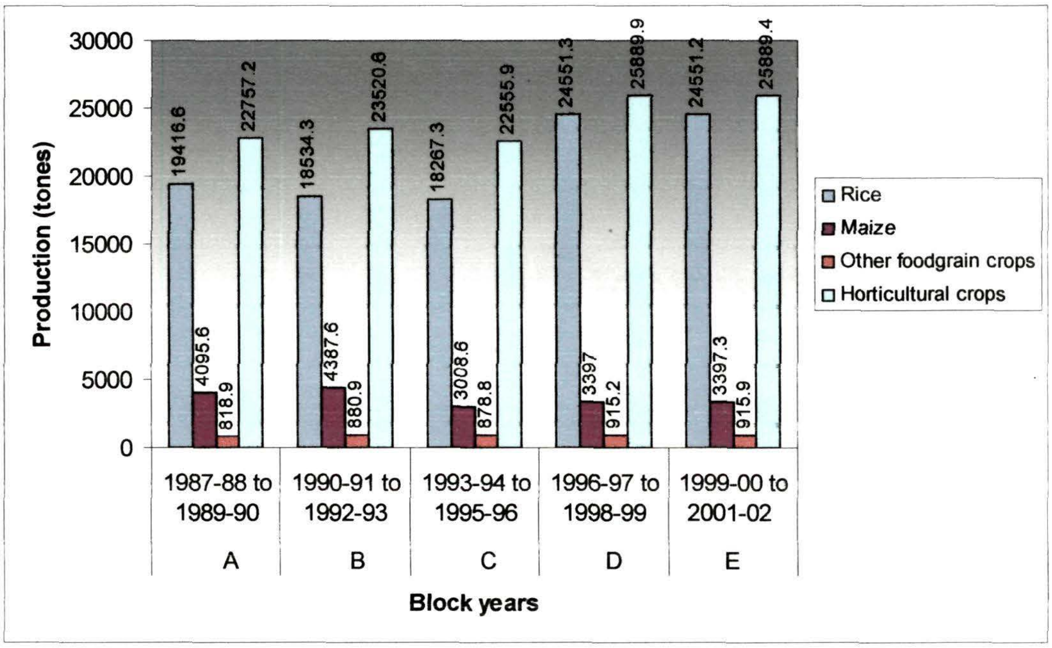
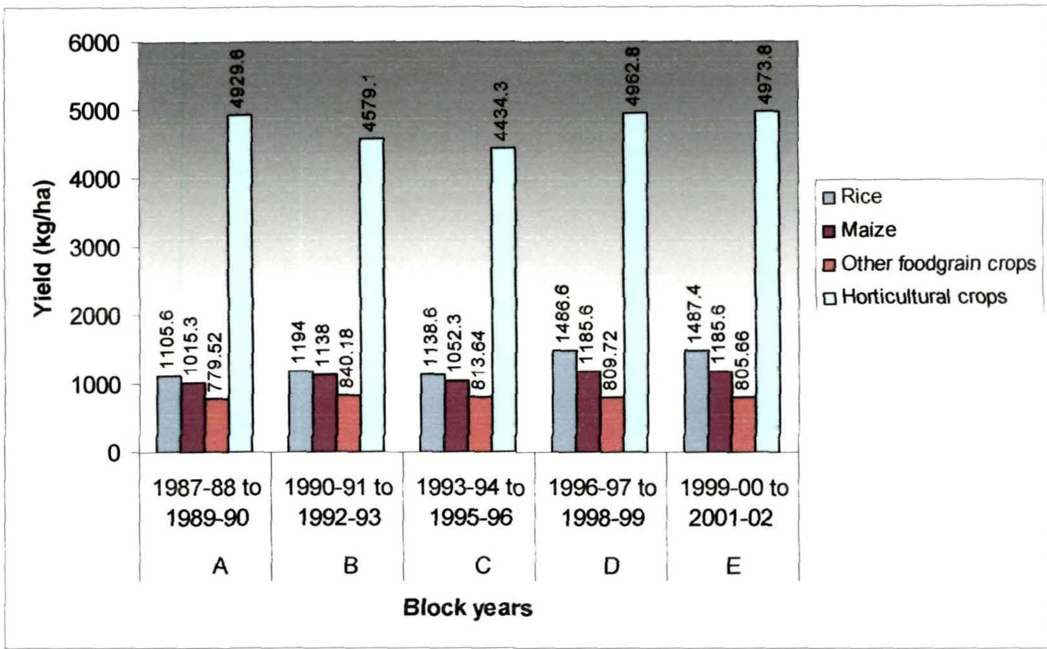


Figure 5.3: Distribution of yield levels of agricultural crops grown in Jaintia Hills District in different block years



Total production of all horticultural crops increased from 1987-88 to 2001-02 with annual increment of 0.70% (Table 5.8). The total production of horticultural crops in block period A was 22,757.2 tonnes, which increased to 25,889.4 tonnes in block period E (Fig. 5.2). Yield of horticultural crops increased from 4,929.6 kg/ha in block period A to 4,973.8 ha in block period B (Fig 5.4).

Results of long term analysis of production and productivity of agricultural crops grown in Jaintia Hills show that although there was overall increase in production and productivity of agricultural crops, but the trend of increase was marginal. Yield of rice is still far below the national average of 1,728.8 kg/ha (Basic Statistics of NER, 2002). This marginal trend of increase of agricultural production/ productivity may be due to various factors. Continuous use of traditional varieties due to lack of awareness of farmers about high yielding varieties, low soil fertility, poor adoption of improved crop production technologies due to economic backwardness of the farmers may be the major constraints. Further, increase in coal mining activity in Jaintia Hills district may also be a major cause of low production and productivity. Balanced nutrition is considered as one of the basic factors which can increase 50% agricultural production (Singh *et al.*, 1997). But the soils of coal mining areas of Jaintia Hills district are highly acidic with low available soil nutrients which are not sufficient for growth and development of crops (Das Gupta *et al.*, 2002).

5.2.3 Comparison of average Area, Production and Yield of rice of Jaintia Hills district with other districts of Meghalaya (1992-93 to 2001-02)

Area, production and yield of rice for Jaintia Hills district has been compared with other districts of Meghalaya for the duration of 1992-93 to 2001-02 (Table 5.9). It has been observed that though Jaintia hills occupies second position in area under rice (16,102 ha) but its yield is much lower (1139.8 kg/ha) in comparison to the other districts of Meghalaya. Extensive mining of coal may be the major reason for it. Although coal mining is done in all three regions of the state, Jaintia Hills contribute maximum in terms of production. From the year 1991-2002 the district alone contributed about 27,230.62 thousand tonnes which is 74.27% of the total coal production of the state (Dkhar and Rai, 2005).

Table 5.9: Average Area, Production and Yield of rice for different districts of Meghalaya (1992-93 to 2001-02)

District	Area (ha)	Production (tonnes)	Yield (kg/ha)
Ri-bhoi	11,977	15,611	1,309
East Khasi Hills	4,993	6,304	1,257
West Khasi Hills	8,895	10,406	1,158
Jaintia Hills	16,102	20,697	1,139
East Garo Hills	6,906	10,343	1,497
West Garo Hills	17,688	24,634	1,395
South Garo Hills	3,346	4,364	1,179

5.3 Impact of coal mining on agriculture of Jaintia Hills district of Meghalaya

Agriculture is the backbone of economy of Jaintia Hills district, Meghalaya. Nearly 75% of total population of the district is engaged in agricultural activities (Survey of India, 2003). Agriculture is supplemented by other major and minor industries for generation of livelihood in the area. Coal mining is one of the major industrial sources of income in Jaintia Hills district. The district has been most extensively exploited in terms of extraction of coal among all the districts of Meghalaya. The district contributes more than 74% of the total coal production of the state. Important coal deposits of the district are Bapung, Lakadong, Jarain-Shkentalang, Lumshnong, Malwar-Musiang-Lamare, Sutnga, Ioksi and Mutang (Dkhar and Rai, 2005)

Mining activities in Jaintia Hills district are small scale ventures controlled by individual owners of the land. Coal extraction is done by primitive sub-surface mining method commonly known as 'rat-hole' mining. In this method, the land is first cleared by cutting and removing the ground vegetation and then pits ranging from 5 to 100 m^2 are dug into the ground to reach the coal seam. Thereafter, tunnels are made into the seam sideways to extract coal which is first brought into the pit by using a conical basket or a wheel barrow and then taken out and dumped on nearby unmined area. Finally, the coal is carried by trucks to the larger dumping places near highways for its trade and transportation. Entire road sides in and around mining areas are used for piling of coal which is a major source of air, water and soil pollution. Off road movement of trucks and other vehicles in the area causes further damage to the ecology of the area. Hence, a large extent of the land is spoiled and denuded of vegetal cover not only by mining but also by dumping and storage of coal and associated vehicular movement. Mining operation, undoubtedly has brought wealth and employment opportunity in the area, but simultaneously has lead to extensive degradation of healthy ecosystem. Large-scale denudation of forest cover, scarcity of water, pollution of air, water and soil, and degradation of agricultural lands are some of the conspicuous environmental implications of coal mining in Jaintia Hills (Swer and Singh, 2003).

The disturbed and haphazardly mixed infertile, consolidated and unconsolidated materials overlying a coal seam are known as overburdens. These overburdens when dumped in unmined areas in the vicinity of the coal mines create mine spoils. Nutrient deficient sandy spoils are generally hostile to plant growth (Sarma, 2005). Again Iron pyrite present in coal mining areas when exposed to oxygen and water forms sulfuric acid and iron sulphate which results in large quantities of Acid Mine Drainage being formed (Thompson, 1980). Inundation of such highly acidic mine water is responsible for large scale degradation of agricultural lands of the area (Singh, 2005). Chemicals released from the coal mines, overburden and tailings also contain high concentration of metals such as Cu, Cd, Fe, Hg and Zn, which also affect the plant growth adversely (Long Peng *et al.*, 2004).

The land tenure system in Meghalaya is typically different from the rest of the country. Here, the ownership of the land is vested on the individuals rather than the state. No proper land records are maintained by the state land revenue department and exact information on mining and other industrial activities are also found inadequate to generate a clear picture of the impact of mining activities on agriculture of the region. Lands are usually given on lease by rich individuals to poor farmers for carrying out farm activities. Hence, the emotional attachment of people to the land is very limited which leads to over exploitation and subsequent degradation of farm lands.

A primary survey was conducted in three representative coal mining areas of Jaintia Hills district, namely, Dkhiah, Lad Rymbai and Bapung to have an onsite scenario of the impact of coal mining on agriculture of the region. Surveyed area falls in coal mining areas where large scale mining was going on in and around the area. Nearly 75-80% of total population of the area is engaged in agricultural activities. Although both shifting and settled cultivations are practiced in the region, but settled cultivation of rice is mostly practiced with traditional varieties. Next to agriculture, coal mining is the major industrial source of income in the area. Approximately 10-15% of total population of the area is engaged in various activities related to coal mining. The entire area is very much under environmental concern due to large scale coal mining in the area. Majority of farmers are marginal farmers with per capita land holdings less than 4 ha. Again, 1/3rd of total agricultural lands occupied by each farmer is lost every year due to adverse effect of coal mining activities going in and around the area. More than 50% of loss of agricultural lands are due to deposition of coal particles and rest due to inundation of mine water from near by coal mines. The drainage of water from various coal mines has made the agricultural fields of the area highly unproductive. Farmers are getting only 0.5-0.6 tonnes/ha of yield from their traditional rice varieties having yield potential of 3-4 tonnes/ha. Over the years the population of the region is increasing to create a pressure on available land for cultivation and that ultimately reduces the chance for rejuvenation. Hence, soil is subjected to over exploitation and the degradation occurs in an irreversible way leading to barren and uncultivable lands. Cultivation in hill terraces is one of the main features of agriculture in this region. But nowadays terrace cultivation is greatly hampered because of heavy deforestation due to mining activities. Surface water is the main source of irrigation in the crop fields of these sites. But this water is contaminated with coal particles. As a result this is no longer suitable for agricultural use nowadays. Coal mining activities in different sites of Jaintia Hills have been shown in Figures 5.4 (a)-5.4 (d).

Figure 5.4 (a): Large scale mining and dumping of coal at Lad Rymbai

Figure 5.4 (b): Loading of coal in carriage from dumping sites for transportation

Figure 5.4 (c): Degradation of land and forests due to coal mining at Bapung

Figure 5.4 (d): Abandoned crop field near coal mine and dumping sites at Dkhiah

5.4 Physico-chemical analysis of soils from coal mining area

Physico-chemical properties of soils collected from three representative coal mining sites namely Dkhiah, Lad Rymbai and Bapung of Jaintia Hills district were analyzed and compared with soil collected from unmined site (Jowai) of the district. This study was done to know the impact of coal mining on soil quality of the area. Three soil samples were collected from rice fields of each site. Surface soil samples (0-15 cm) collected from each site were mixed, sieved and homogenized for analysis of various physico-chemical properties of soil such as soil texture, soil pH, organic carbon and available nutrients by following standard procedures. Results of physico-chemical analysis of soil are discussed below.

5.4.1 Soil texture

Soil texture is expressed as percentages of sand, silt and clay present in soil. Soil texture governs plant growth either directly or indirectly by its influence on aeration, available water holding capacity, cation exchange, availability of nutrients, soil structure, infiltration and drainage condition. So, analysis of soil texture is very important to know the suitability of a particular soil for cultivation (Singh *et al.*, 1999).

Table 5.10: Soil texture of coal mining sites and unmined site

Soil Parameters	Dkhiah		Lad Rymbai		Bapung		Jowai	
	Mean*	Range	Mean*	Range	Mean*	Range	Mean*	Range
Sand (%)	63.67	63.14-64.31	60.27	60.21-60.30	60.67	60.10-60.68	58.32	58.10-58.39
Silt (%)	18.67	18.52-18.74	19.00	18.40-19.10	21.67	21.50-21.78	18.93	18.46-19.82
Clay (%)	17.67	17.50-18.00	20.33	20.24-20.44	17.67	17.48-17.88	19.42	19.32-19.54

*Mean of three samples

5.4.2 Soil pH

Soil pH is a convenient measure of soil reaction. pH is measured on a scale from 0 to 14 with a pH of 7 referred to as neutral, neither acidic nor alkaline. Soil with a pH below 7 is considered as acidic and soil with pH above 7 is considered alkaline. Again, soil with a pH less than 4 is considered as highly acidic whereas soil with pH more than 7 is considered as highly alkaline soil

(Tan, 1980). Soil reaction governs the availability of several micro and macro nutrients along with micro organism population in a particular soil environment. Its measurement is also helpful in suggesting ameliorative measures for better land use (Singh *et al.*, 1999).

Table 5.11 shows that soil pH of all the coal mining sites ranged from 3.3 to 4.1. On the other hand soil pH of unmined site was 5.1. Among all the coal mining sites, soil pH of Bapung was lower (3.3) than that of Lad Rymbai (3.8) and Dkhiah (4.1).

Above results reveal that soils of coal mining sites were highly acidic. Moreover, soil pH of all the mining sites were lower than that of unmined site. Lowering of soil pH of coal mining sites may be due to inundation of highly acidic mine water from nearby coal mines. Iron pyrite present in coal mining areas when exposed to oxygen and water forms sulfuric acid and iron sulphate which results in large quantities of Acid Mine Drainage being formed (Thompson, 1980). Drop of soil pH in coal mining sites due to Acid Mine Drainage has been reported by many researchers in different parts of the world (Monterroso *et al.*, 1996; Lin, 1999; Tedesco, 1999; Nath and Ahmed, 2005; Darmody *et al.*, 1989; Haigh, 1992; Bai *et al.*, 1998; Das Gupta *et al.*, 2002; Adler and Sibrell, 2003).

Table 5.11: Soil pH and organic carbon of experimental soils

Soil Parameters	Dkhiah		Lad Rymbai		Bapung		Jowai	
	Mean*	Range	Mean*	Range	Mean*	Range	Mean*	Range
pH	4.1	4.0-4.2	3.8	3.6-4.1	3.30	3.2-3.4	5.1	4.9-5.2
Org. C (%)	0.53	0.51-0.55	0.67	0.65-0.71	0.21	0.20-0.23	3.3	3.1-3.4

*Mean of three samples

5.4.3 Organic carbon

Estimation of soil organic carbon is widely used as a measure of organic matter content of soil. Soil organic matter, measured through organic carbon estimation, has got immense influence in controlling physical and chemical properties of soil. It also accounts for much of cation exchange capacity, especially of the surface soil and is responsible for stability and structure of soil aggregates. It also helps in building of micro organism population in soil (Sahrawat, 2005). Three classes of organic matter contents such as low (<0.5%), medium (0.5-0.75% and high (>0.75%) were identified (Muhr *et al.*, 1965).

Table 5.11 shows that the percentage of organic carbon of soils of coal mining areas of Jaintia Hills ranged from 0.21% to 0.67%. On the other hand organic carbon of unmined site was 3.3%. Percentage of organic carbon was highest in Lad Rymbai (0.67%) followed by Dkhiah (0.53%) and Bapung (0.21%).

Above results reveal that organic carbon of soils of all the mining sites were less than the upper limit of organic carbon (0.75) for plant growth (Table 5.13). Moreover percentages of soil organic carbon of all these sites were lower than that of unmined area of Jaintia Hills. Poor vegetal cover is the main cause of low organic carbon content of coal mining regions of Jaintia Hills (Das Gupta *et al.*, 2002). Natural vegetation, when it accumulates on the soil surface, contributes to the organic carbon of soil (Walse *et al.*, 1998). Vegetation gets lost due to the spread out of waste materials haphazardly in the areas of coal mining, which were very unhealthy for its growth. Similar findings were reported by Koster and Slob (1994) and Schejbal (1995). Large scale degradation of vegetation in coal mining regions of Jaintia Hills were reported by many workers (Lyngdoh, 1995; Sarma, 2005).

5.4.4 Available nutrients

Only a small fraction of the total nutrient contents of soil can be utilized by plants. Estimation of nutrient availability of soil is very essential to know the fertility status of soil (Biswas and Mukharjee, 1999). Availability of three major nutrients such as nitrogen, phosphorous and potassium of experimental soils was analyzed and presented in Table 5.12.

5.4.4.1 Available nitrogen

Nitrogen is an essential constituent of metabolically active compounds such as amino acids, proteins, enzymes and some non proteinous compounds. When nitrogen is a limiting factor, the rate and extent of protein synthesis are depressed and as a result plant growth is affected (Sahrawat, 2005). Three classes of available soil nitrogen such as low (<125 kg/ha) medium (125-250 kg/ha) and high (>250 kg/ha) were identified (Muhr *et al.*, 1965)

Table 5.12 shows that available nitrogen of soils of coal mining areas of Jaintia Hills ranged from 94.08 ppm (210.73 kg/ha) to 110.46 ppm (247.43 kg/ha) whereas that of unmined site was 127.36 ppm (285.28 kg/ha). Nitrogen availability of Bapung soil (94.08 ppm) was lower as compared to available nitrogen of Lad Rymbai (99.50 ppm) and Dkhiah (110.46 ppm).

Above results reveal that nitrogen availability of soils collected from all the coal mining sites were lower than the upper limit of available nitrogen (250 kg/ha) for plant growth (Table 5.13). Moreover contents of available nitrogen of all these sites were lower than that of unmined area of Jaintia Hills. Highly acidic soil pH of coal mining sites may be one of the reasons of low availability of soil nitrogen in coal mining sites. Because, soil pH is an important factor in controlling nitrogen availability from soil organic matter (Bandick and Dick, 1999; Pascual *et al.*, 2000). Ammonifying and nitrifying bacteria which convert organic form of nitrogen into easily available ammonical and nitrate nitrogen, respectively, are inactive below pH 5.5 (Biswas and Mukharjee, 1999). Effect of soil acidity on nitrogen availability in coal mining regions has been reported by many workers (Darmody *et al.*, 1989; Jha and Singh, 1991; Haigh, 1992; Springob and Lebert, 1995; Bai *et al.*, 1998; Lin, 1999; Tedesco *et al.*, 1999; Das Gupta *et al*, 2002).

Table 5.12: Available nutrients of experimental soils

Soil Parameters		Dkhiah		Lad Rymbai		Bapung		Jowai	
		Mean*	Range	Mean*	Range	Mean*	Range	Mean*	Range
Available Nitrogen	N (ppm)	110.46	109.18-111.22	99.50	99.08-99.78	94.08	93.06-94.32	127.36	126.42-128.32
	N (kg/ha)	247.43	244.56-249.13	222.87	221.93-223.50	210.73	208.45-211.27	285.28	283.18-287.43
Available Phosphorus	P (ppm)	6.48	6.23-6.93	4.95	4.43-5.34	4.20	4.05-4.29	5.13	4.95-5.13
	P_2O_5 (kg/ha)	33.23	31.95-35.54	25.40	22.72-27.39	21.53	20.77-22.00	26.30	25.39-26.31
Available Potassium	K (ppm)	78.17	77.97-78.20	65.66	65.00-66.56	54.02	53.96-54.10	110.26	110.10-110.34
	K_2O (kg/ha)	210.13	209.58-210.20	176.50	174.72-178.91	145.20	145.04-145.42	296.38	295.94-296.59

*Mean of three samples

Table 5.13: Rating of chemical fertility status of Soil by Standard Soil-Test-Rating-Chart (Muhr *et al.*, 1965)

Parameters	Low	Medium	High
Organic carbon (%)	<0.50	0.50-0.75	>0.75
Available N (kg/ha)	<125	125-250	>250
Available P (kg/ha)	<11	11-25	>25
Available K (kg/ha)	<120	120-280	>280

5.4.4.2 Available phosphorous

Phosphorus plays an important role in energy transformations and metabolic processes in plants. It also stimulates root growth (Classens *et al.*, 2005). Three classes of available soil phosphorus such as low (<11 kg/ha) medium (11-25 kg/ha) and high (>25 kg/ha) were identified (Muhr *et al.*, 1965).

A perusal of the Table 5.12 shows that phosphorous availability of soils collected from coal mining areas of Jaintia Hills ranged from 4.2 ppm (21.53 kg/ha P_2O_5) to 6.48 ppm (33.23 kg/ha P_2O_5) whereas that of unmined site was 5.13 ppm (26.3 kg/ha P_2O_5). Phosphorous availability of Bapung soil (4.20 ppm) was lower in comparison to that of Lad Rymbai (4.95 ppm) and Dkhiah (6.48 ppm).

Above results reveal that content of available soil phosphorous at Bapung was lower than the optimum available phosphorous (25 kg/ha P_2O_5) for plant growth (Table 5.13).The availability of phosphorous of soils from Bapung and Lad Rymbai was lower than phosphorous availability (26 kg/ha P_2O_5) of soil of unmined area of Jaintia Hills. This may be due to fixation of phosphorous in highly acidic soil of coal mining sites. Acid soils usually contain significant amounts of soluble Al^{3+}, Fe^{3+} and Mn^{2+} ions. The phosphate ions present in such soils can enter into a chemical reaction with these free metal ions to form less soluble metal phosphates which are less available to plants (Tan, 1980).

Monterroso *et al.* (1996) has also reported that acidic pH (2.4) of agricultural soils near coal mine of Glacia, Spain was associated with low available phosphorous concentration (1 mg/kg). Moreover, phosphorous is depleted due to leaching in such soils (Tan, 1980). Adler and Sibrell (2003) reported that solubilization and transport of phosphorous to the water environment from soil and manure caused by Acid Mine Drainage is a critical environmental issue associated with agricultural productivity in coal mining areas.

5.4.4.3 Available potassium

Potassium activates the enzymes in protein and carbohydrate metabolism and translocation of carbohydrates. It also imparts resistance to plants against fungal and bacterial diseases (Tan, 1980). Three classes of available soil potassium such as low (<120 kg/ha) medium (120-280 kg/ha) and high (>280 kg/ha) were identified (Muhr *et al.*, 1965).

Results presented in Table 5.12 show that potassium availability of soils collected from coal mining areas of Jaintia Hills ranged from 54.02 ppm (145.20 kg/ha K_2O) to 78.17 ppm (210.13 kg/ha K_2O) whereas that of unmined site was 110.26 ppm (296.38 kg/ha K_2O). Potassium availability of Bapung soil (54.02 ppm) was lower than that of Dkhiah (78.17 ppm) and Lad Rymbai (65.66 ppm).

Above results reveal that potassium availability of soils of all the coal mining sites were lower than the optimum available potassium (280 kg/ha K_2O) for plant growth (Table 5.13). More over contents of available potassium of all the coal mining sites were lower than potassium availability of soil collected from unmined area of Jaintia Hills. Lower potassium availability in highly acidic soil of coal mined sites as compared to unmined site may be due to lower base saturation as well as depletion due to leaching. Potassium is available in cationic form. At pH less than 6.0, soil is partly base saturated which causes low availability of potassium in such soils (Tan, 1982). Depletion of potassium due to leaching in highly acidic soil of coal mining areas was reported by Das Gupta *et al.* (2002). Effect of Acid Mine Drainage in potassium availability in soils of coal mining areas has been reported by Jha and Singh (1991) and Springob and Lebert (1995).

5.5 Treatment of soil to improve its quality

Analysis of physico-chemical properties of soil of different coal mining sites of Jaintia Hills district, Meghalaya revealed that soils were highly acidic with insufficient levels of organic carbon and available nutrients (N, P and K) for plant growth. Soil samples collected from Bapung had lowest pH along with lowest levels of organic carbon and available nutrients among three coal mining sites (Table 5.11, Table 5.12). So, this soil was selected for experimental purpose. This soil was treated with organic matter and lime to improve the soil quality for cultivation of rice. Liming is a general practice to alleviate acidity hazards (Nhung and Ponnamperuma, 1966; Sahrawat, 2005).The convergence of soil pH to neutrality benefits crop production in acidic soils through better availability of nutrients (Sahrawat, 2005). On the other hand organic matter maintains a threshold level of soil organic carbon which is crucial for maintaining physical, chemical and biological integrity of the soil and also for the soil to perform agricultural production (Singh *et al.*, 1999)

5.5.1 Sources of lime

The most common material used for liming agricultural soil is finely ground calcitic ($CaCO_3$) and dolomitic [$CaMg(CO_3)_2$] limestones. But for the purpose of study, finely ground calcitic limestone was selected due to its faster reaction than dolomitic limestone (Wolf *et al.*, 1994).

5.5.2 Sources of organic matter

Although various types of organic matter such as compost, cowdung, cattledung, Farm Yard Manure (FYM) etc. are available but FYM was used to treat the soil due to its high C: N (100:1) ratio and rapid mineralization (Cassman, 1996).

5.5.3 Doses of different treatments

Doses of different treatments applied to soil were as follows:

a) 4.08 tonnes/ha of lime (72.9 g/pot)

b) 10 tonnes/ha of Farm Yard Manure (178.6 g/pot)

c) 4.08 tonnes of lime (72.9 g/pot) + 10 tonnes/ha of Farm Yard Manure (178.6 g/pot)

d) Control

Dose of lime required to ameliorate soil acidity for cultivation of a particular crop depends on initial soil pH and optimum pH for that crop. In this study soil was treated with lime for cultivation of rice which has optimum pH requirement of 6.0. Hence the dose of lime required to convert initial pH to 6.0 was calculated by using the method given by Shoemaker *et al.* (1961) and the dose was recorded to be 4.08 t/ha. On the other hand dose of Farm Yard Manure was determined based on the previous study done by Bridgit and Potty (2002) and Salem (2006).

5.5.4 Effect of different treatments on soil pH

A perusal of the data of Table 5.14 shows that treatment with lime increased soil pH from 3.3 to 6.0. Treatment with Farm Yard Manure also increased soil pH by 1.4 over control. However, highest value of soil pH (6.2) was recorded due to combined application of lime and Farm Yard Manure.

Table 5.14: Effect of different treatments on soil pH

Treatments	Soil pH
Control	3.3
Lime (72.9 g/pot)	6.0
FYM (178.6 g/pot)	4.7
Lime (72.9 g/pot) + FYM (178.6 g/pot)	6.2
S. D.	1.3

S. D. = Standard deviation

From the above results it is clear that effect of liming in increasing soil pH was more than that of Farm Yard Manure. However, combined effect of lime and Farm Yard Manure was more than their individual effect. Lime reduces soil acidity (increases pH) by changing some of the hydrogen ions into water and carbon dioxide (CO_2). A Ca^{++} ion from the lime replaces two H^+ ions on the cation exchange complex of soil. The carbonate (CO_3^{2-}) reacts with water to form bicarbonate (HCO_3^-) which reacts with H^+ to form H_2O and CO_2. The pH increases because the H^+ concentration has been reduced (Tan, 1980). Increase of soil pH with application of lime in acid soil has been reported by many researchers (Mamaril *et al.*, 1990; Mongia *et al.*, 1991; Ono, 1991; Mitra *et al.*, 1992; Fageria *et al.*, 1995; Dwivedi, 1996).

Application of FYM (F1L0) also helped in increasing the pH of the soil in between 3.3 to 4.7. Organic matter has a chelating (binding) effect on acidic cationis such as Al^{3+} and Fe^{3+} and makes them unavailable and thereby increases soil PH (Biswas and Mukharjee, 1999). Similar results have been reported by Hegde (1997), Roy *et al.* (1997) and Panda (2000). The application of lime and organic matter together improved pH from 3.3 to 6.2. Significant increase of soil pH due to combined application of lime and FYM in an acidic soil of Tamil Nadu has been reported by Shanmugam and Rathnasamy (1995). Similar results have also been reported by Lebedinskaya *et al.* (1988), Sharma and Sinha (1989) and Vy *et al.* (1989).

5.5.5 Effect of different treatments on soil organic carbon

Table 5.15 shows that treatment of lime did not have any effect on organic carbon content of soil. On the other hand treatment with Farm Yard Manure increased organic carbon of soil by 3.5% over control which was statistically significant at 5% level of confidence. Treatment with both FYM and lime increased organic carbon up to 4.05%, which was 3.84% higher than control. Increase of organic carbon after application of Farm Yard Manure may be due to high Carbon: Nitrogen (100:1) of FYM which added carbon into the soil. Similar observations were reported by Yadav and Kumar (1993), Das *et al.* (2001) and Parihar (2004).

Table 5.15: Effect of different treatments on soil organic carbon

Treatments	Organic carbon (%)
Control	0.21
Lime (72.9 g/pot)	0.23
FYM (178.6 g/pot)	3.71
Lime (72.9 g/pot) + FYM (178.6 g/pot)	4.05
S. D.	2.12

S. D.= Standard deviation

5.5.6 Effect of different treatments on available nutrients in soil

A perusal of the Table 5.16 shows that treatment with lime increased available nitrogen (N), phosphorous (P), and potassium (K) levels by 24.15 ppm, 1.31 ppm and 28.03 ppm, respectively, over control. Similarly treatment with Farm Yard Manure also increased the availability of nitrogen, phosphorous and potassium by 34.92 ppm, 2.97 ppm and 43.11 ppm, respectively, over control. However, highest levels of available nitrogen, phosphorous and potassium (139.47 ppm N, 10.15 ppm P and 111.03 ppm K) were recorded after combined application of lime and Farm Yard Manure.

Table 5.16: Effect of different treatments on available Nitrogen, Phosphorous and Potassium of soil

Treatments	Nitrogen		Phosphorous		Potassium	
	ppm (N)	kg/ha (N)	ppm (P)	kg/ha (P_2O_5)	ppm (K)	kg/ha (K_2O)
Control	94.07	210.73	4.20	21.53	53.94	145.00
Lime (72.9 g/pot)	118.22	264.82	5.51	28.24	81.97	220.34
FYM (178.6 g/pot)	128.99	288.93	7.17	36.78	97.05	260.87
Lime (72.9 g/pot) + FYM (178.6 g/pot)	139.47	312.42	10.15	52.08	111.03	298.45
S. D.	19.45	43.57	2.57	13.19	24.45	65.70

S. D.= Standard deviation

Above results revealed that the effect of Farm Yard Manure in increasing available nutrients was higher than the effect of lime. However, combined effect of both lime and Farm Yard Manure was more than their individual effect.

Farm Yard Manure after decomposition releases nutrients into soil and thereby improves available nutrient status of soil. Similar results were reported by many workers (Nour, 1998; Bassal and Zahran, 2000; Channabasavanna *et al.*, 2001; Das *et al.*, 2001; Parihar, 2004).

Liming enhances mineralization of soil organic matter and thereby increases available soil nutrient status. Similar results were reported by He-Dy (1991), Manguiat *et al.* (1997), Subbaiah and Mittra (1997) and Biswas and Dravid (1998). Activity of Nitrogen fixing bacteria in acidic soil could also be improved by liming. Effect of liming in increasing efficiency of nitrogen fixing bacteria was reported by Tripathy and Dacayo (1988) and Panda (2000). Liming also inactivates Phosphorus and Potassium fixation in acid soil and thereby increases their availability. Improvement in the availability of soil Phosphorus and potassium in acidic soil due to liming has been reported by many workers (Lee *et al.*, 1986; Tripathy and Dacayo, 1988; Chidanandappa *et al.*, 1996; Ithayarajan *et al.*, 1997; Subbaiah and Mittra, 1997; Biswas and Dravid, 1998; Mongia *et al.*, 1998; Ntamatungiro *et al.*, 1998).

5.6 Varietal trial under different remediation options

Soil samples were collected from rice fields of three representative coal mining sites of Jaintia Hills district, Meghalaya, namely, Dkhiah, Lad Rymbai and Bapung. Physico-chemical analysis of the collected soil samples revealed that the soils were strongly acidic in reaction (pH: 3.3-4.1) with medium ranges of organic carbon (0.21-0.67%), available nitrogen (93.75-110.26 ppm), available Phosphorous (4.09-6.43 ppm) and available potassium (53.94-78.12 ppm). Ranges of various nutrients in terms of kg/ha were 210-247 kg/ha nitrogen, 21-33 kg/ha phosphorous and 145-210 kg/ha potassium. Among all the sampling sites, Bapung soils exhibited lowest pH and soil fertility status.

A pot culture experiment was conducted with soils collected from Bapung area during kharif seasons (June-September) of 2005 and 2006 in ICAR Complex for NEH Region, Umiam, Meghalaya. Experiment comprised of Control (F0L0), 72.9 g/pot of lime treatment (F0L1), 178.6 g/pot of farm Yard Manure (F1L0) treatment and combination of 72.9 g/pot of lime and 178.6 g/pot of Farm Yard Manure treatment (F1L1) for three rice varieties, namely, Khaw Shaw (a traditional variety widely grown by the farmers of Jaintia Hills), Bhalum-1 (RCPL 1- 27) and Bhalum-2 (RCPL 1-29). Both of two varieties were developed by ICAR Complex, Umiam, Meghalaya and released by the State Variety Release Committee, Meghalaya in 2002. These two varieties were recommended for mid-altitude areas of Meghalaya for June-July sowing. Recommended seed rate for sowing of each of these varieties is 60-80 kg/ha. Each of them is semi-dwarf in nature with yield potential of 4-5 tonnes/ha (Pattanayak *et al.*, 2006).

The experiments were performed in Completely Randomized Design (CRD) with three replications for each treatment. Common fertilizer dose of 60 kg N: 60 kg P_2O_5: 40 kg K_2O were applied in the forms of urea, SSP and MoP, respectively, which is also the recommended dose of inorganic fertilizer for rice in Meghalaya.

The responses of three different rice varieties to various treatments applied were quantified through various plant parameters such as phenology, plant height (cm), Leaf Area Index, dry biomass (g/plant), number of effective tillers/plant, number of grains per panicle, grain weight per plant (g/plant), grain yield (kg/ha) and Harvest Index (HI). Statistical analyses were performed following standard procedures (Gomez and Gomez, 1984).

5.6.1 Test of data on different growth and yield parameters for homogeneity

Test of homogeneity for the error mean square (EMS) from individual year (2005 and 2006) analysis of variance (ANOVA) has been done through the application of F-test. The F-value was calculated using the following formula:

$$F = \frac{\text{Larger error mean square}}{\text{Smaller error mean square}}$$

The computed F-value has been compared with the table F-value for given error degree of freedom (d. f.) at 5% level of confidence. If the computed F-value is larger than table F-value, the difference of individual set of data is significant and ANOVA is to be carried out individually. In reverse condition, the individual data set can be pooled and ANOVA is done for pooled average data. Under this study the test for homogeneity has been done and it has been presented in Table 5.17.

Table 5.17: Test of homogeneity for different growth and yield parameters of rice

Parameters	Error MS		F-computed	F-table	Remarks
	2005	2006			
Dry biomass (g/plant)	92.14	220.50	2.39	2.66	Pooled
No. of grain per panicle	103.75	99.22	1.05		Pooled
Grain weight per plant (g)	14.64	13.90	1.05		Pooled
Plant height (cm)	18.11	23.35	1.28		Pooled
Harvest index	0.01	0.01	1.20		Pooled
LAI	0.10	0.10	1.04		Pooled
No. of effective tillers	6.06	6.47	1.07		Pooled
Grain yield (kg/ha)	1641768.04	1046966.53	1.56		Pooled

(* Significant at 5% level of confidence) (Error degree of freedom (d. f.) = 24)

After the analysis of homogeneity it was found that the recorded plant parameters did not differ significantly from 2005 to 2006 at 24 error degrees of freedom and 5% level of confidence. So, pooled mean of the two years' data were taken for analysis.

5.6.2 Effect of Farm Yard Manure (FYM) and lime on attainment of different phenological stages

The scientific study of cyclical biological events in relation to environmental conditions is called phenology (Pandey and Sinha, 1972). Every crop has its own distinct stages of growth and development, both vegetative and reproductive, which are called phenological stages. In case of rice the major phenological stages are seedling emergence, start tillering, panicle initiation, flowering, milk, dough and yellow maturity (Cheema *et al.*, 1998). Phenological records of the dates on which seasonal phenomena occur provide important information on how change in environment affects ecosystems over time. Durations of phenological stages in rice show a wide range of diversity, depending on genotype and environment, and have a significant influence on growth and yield (Salisbury, 1996).

Effect of Farm Yard Manure and lime on attainment of different phenological stages of the local variety (Khaw Shaw) is depicted in Fig. 5.5 and Table 5.18(a). The local variety exhibited a total duration of around 152 days for completing its life cycle under control i.e. when no Farm Yard Manure (FYM) and lime were applied (F0L0). Treatment with lime (F0L1), Farm Yard Manure (F1L0) and their combination (F1L1) reduced number of days to attain each phenological stage except for seedling emergence and start tillering. Both of these stages were attained at 3 and 12 days after sowing under all the above treatments. Treatment with lime (F0L1) reduced number of days to attain panicle emergence, flowering, milk as well as dough stages of the variety by 10, 10, 11, 11 and 9 days over control. Similarly treatment with Farm Yard Manure (F1L0) also reduced total duration to attain above stages by 17, 15, 15, 14 and 9 days over control.

Figure 5.5: Effect of organic matter and lime on attainment of various phenological stages of 'Khaw Shaw'

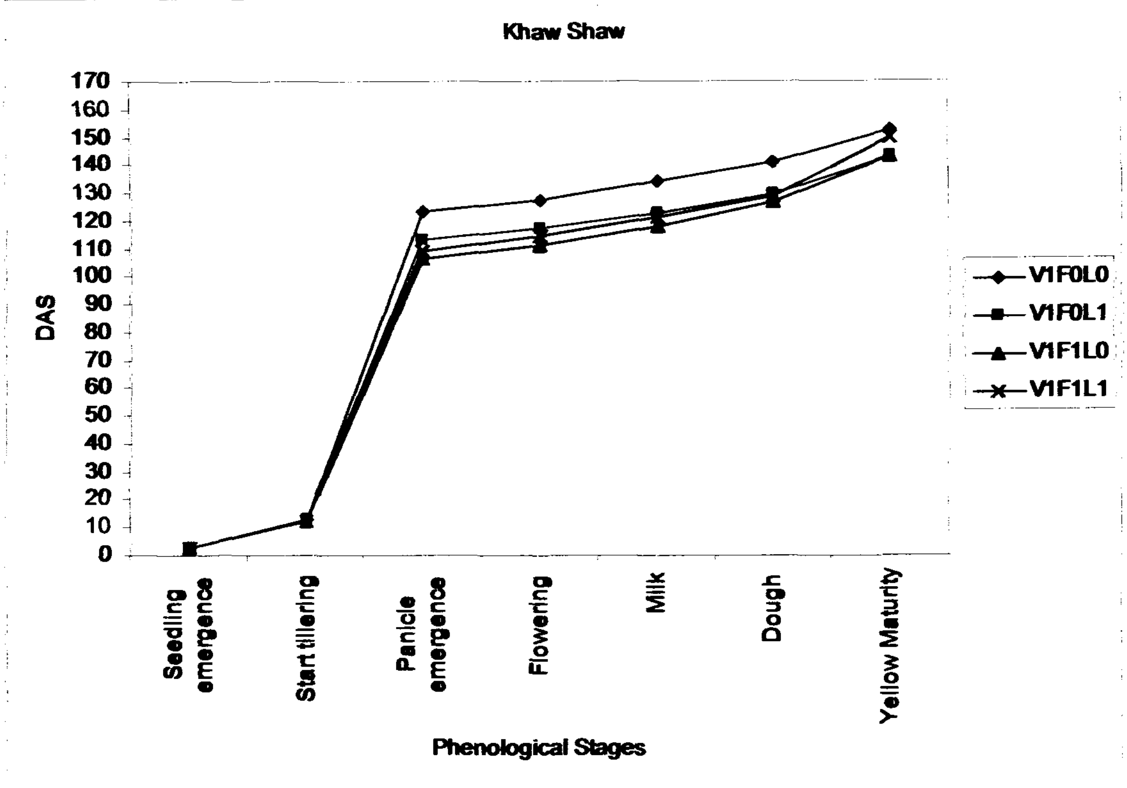


Table 5.18 (a): Effect of organic matter and lime on attainment of phenological stages of 'Khaw Shaw'

Phenological stages	Treatments			
	F0L0	F0L1	F1L0	F1L1
	Days after sowing			
Seedling emergence	3.0	3.0	3.0	3.0
Start tillering	12.8	12.6	12.3	12.1
Panicle emergence	123.5	112.8	106.0	108.8
Flowering	127.0	116.8	111.3	114.6
Milk	133.8	122.6	118.1	121.5
Dough	141.1	129.5	126.8	129.0
Yellow maturity	152.5	143.0	143.0	149.5

Effect of Farm Yard Manure and lime on attainment of different phenological stages of Bhalum-1 is depicted in Fig. 5.6 and Table 5.18(b). Bhalum-1 exhibited a total duration of 126 days for completing its life cycle under control i.e. when no Farm Yard Manure (FYM) and lime were applied (F0L0). Treatment with lime (F0L1), Farm Yard Manure (F1L0) and their combination (F1L1) reduced number of days to attain each phenological stage except for seedling emergence. Seedling emergence of the variety was attained around 2-3 days after sowing under all the above treatments. Treatment with lime (F0L1) reduced number of days to attain panicle emergence, flowering, milk as well as dough stages of the variety by 6, 6, 4 and 3 days over control. Similarly treatment with Farm Yard Manure (F1L0) also reduced total duration to attain above stages by 15, 5, 4 and 6 days over control.

Figure 5.6: Effect of organic matter and lime on attainment of various phenological stages of Bhalum-1

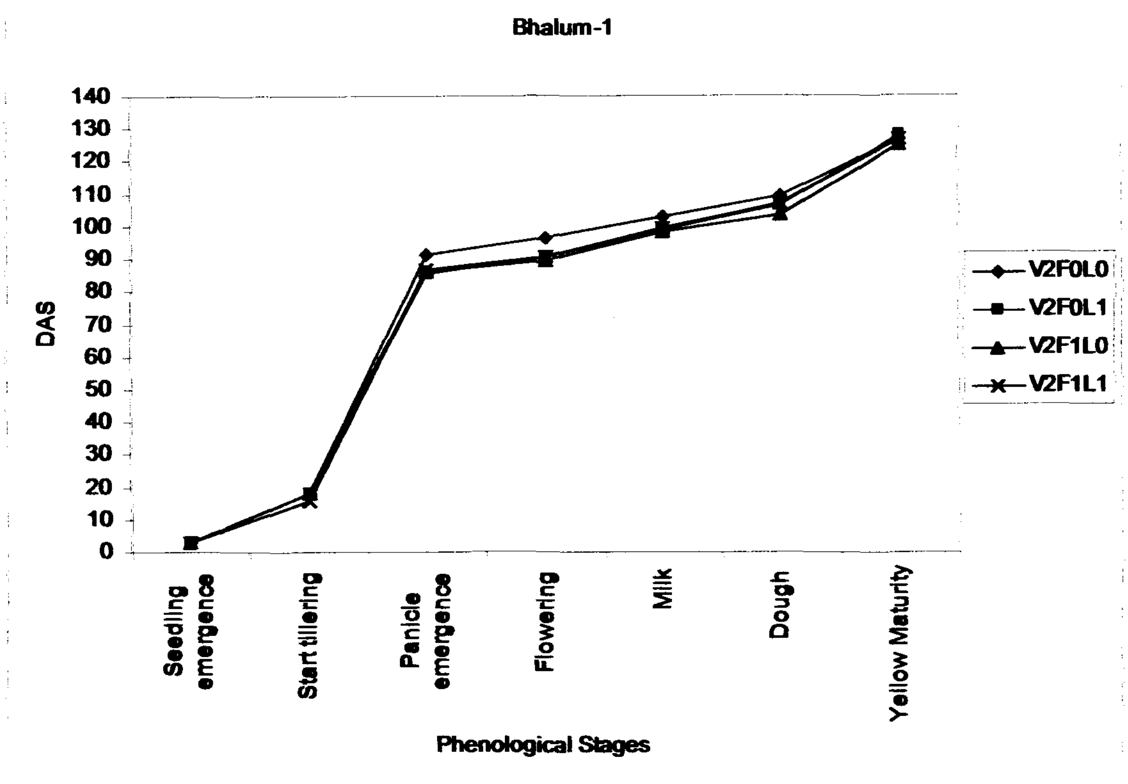


Table 5.18 (b): Effect of organic matter and lime on attainment of phenological stages of 'Bhalum-1'

Phenological stages	Treatments			
	F0L0	F0L1	F1L0	F1L1
	Days after sowing			
Seedling emergence	3.0	2.8	3.0	2.8
Start tillering	17.8	18.0	17.8	15.5
Panicle emergence	91.3	85.3	86.0	86.5
Flowering	96.5	90.6	89.6	90.5
Milk	102.8	98.6	98.1	99.5
Dough	109.15	106.5	103.6	106.6
Yellow maturity	126.8	127.7	124.6	126.8

Effect of Farm Yard Manure and lime on attainment of different phenological stages of Bhalum-2 is depicted in Fig. 5.7 and Table 5.18(c). Bhalum-2 exhibited a total duration of around 127 days for completing its life cycle under control i.e. when no Farm Yard Manure (FYM) and lime were applied (F0L0). Treatment with lime (F0L1) reduced number of days to attain panicle emergence and flowering stages of the variety by 4 and 3 days, respectively over control. Similarly treatment with Farm Yard Manure (F1L0) also reduced total duration to attain above stages by 4 and 2 days over control. Treatment effects were not significant on all other stages of the variety.

Figure 5.7: Effect of organic matter and lime on attainment of various phenological stages of Bhalum-2

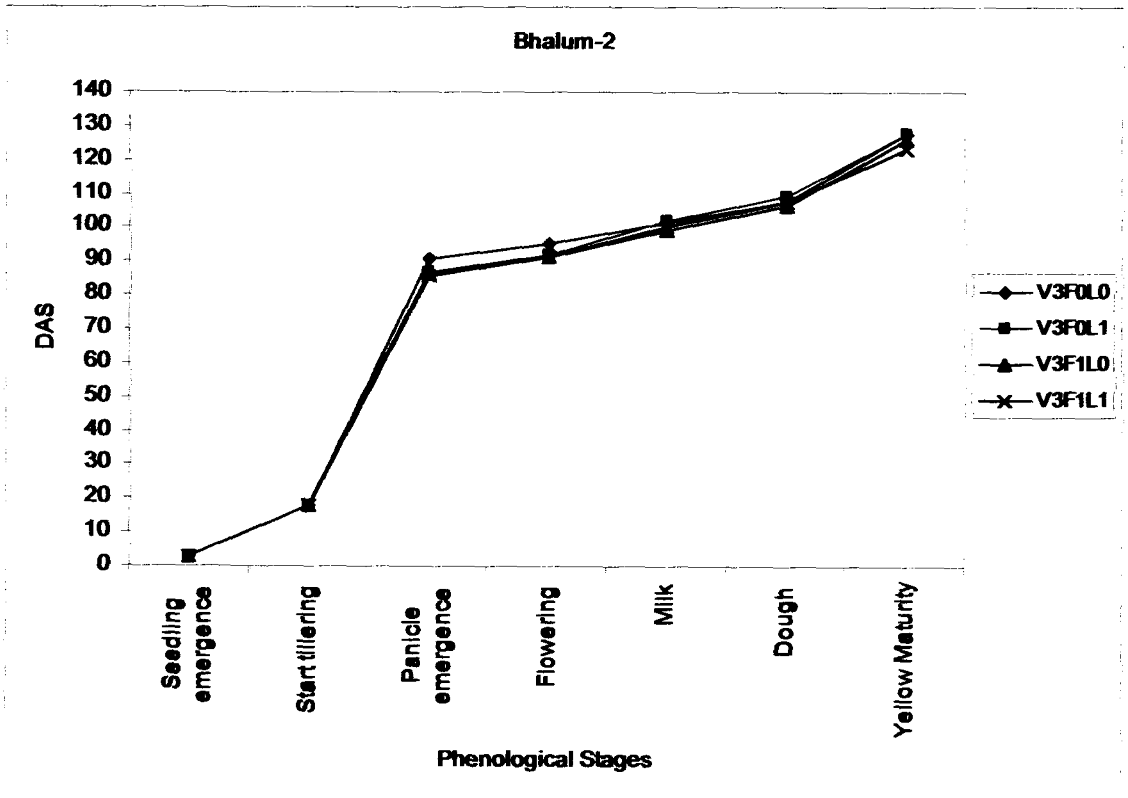


Table 5.18 (c): Effect of organic matter and lime on attainment of phenological stages of 'Bhalum-2'

Phenological stages	Treatments			
	F0L0	F0L1	F1L0	F1L1
	Days after sowing			
Seedling emergence	3.0	3.0	3.0	3.0
Start tillering	17.65	17.85	18.0	18.15
Panicle emergence	90.8	86.7	86.0	85.5
Flowering	95.35	91.85	91.7	91.5
Milk	101.5	101.7	99.3	100.2
Dough	107.65	109.35	105.7	107.35
Yellow maturity	127.8	127.65	125.7	123.35

From the above results it comes into view that both Bhalum-1 and Bhalum-2 showed earlier development of various phenological stages as compared to the local variety (Khaw Shaw). This may be due to the fact that both Bhalum-1 and Bhalum-2 were genetically short duration in nature (Pattanayak *et al.*, 2006). Moreover application of lime and Farm Yard Manure caused early attainment of various phenological stages of each of the three varieties. Both lime and Farm Yard Manure increased availability of nutrients in soil which resulted in early development of various phenological stages of the crop. Effect of FYM in decreasing time period for attaining various phenological stages of rice in acidic soil has been reported by Salem (2006). Similarly Zhang and Zhang (1998) reported that application of lime up to pH 6.2 resulted early development of rice grown in acidic soil of South China. Organic matter and lime has substantial impact on overall plant growth and development, input economy and soil nutrient balance (Hegde, 1997).

5.6.3 Effect of Farm Yard Manure (FYM) and lime on plant height

Plant height is a plant growth parameter which goes through three distinct phases such as cell formation, cell elongation and cell differentiation (Pandey and Sinha, 1999).

Analysis of Variance (ANOVA) for the effects of different treatments on plant height at maturity of the tested varieties (Khaw Shaw, Bhalum-1 and Bhalum-2) shows that plant height attained by Bhalum-2 was highest (102.7 cm) followed by Bhalum-1 (100.1 cm) and Khaw Shaw (99.4 cm). Again application of FYM and lime has significantly improved plant height by 5.25 and 3.12 cm over their respective controls (Table 5.19).

`Table 5.19: Analysis of variance (ANOVA) for effect of organic matter and lime on plant height at maturity (cm) of different rice varieties

Variables		Mean Plant Height (cm)
Variety		
	Bhalum-1	100.133
	Bhalum-2	102.733
	Khaw Shaw	99.417
	SEm ±	1.043
	CD (0.05)	3.044
Organic Matter		
	No Organic matter	98.183
	10 t/ha	103.339
	SEm ±	0.851
	CD (0.05)	2.484
Lime		
	No Lime	99.200
	With lime	102.322
	SEm ±	0.851
	CD (0.05)	2.484
Interaction		
	Variety x Organic matter	NS
	Variety x Lime	NS
	Organic matter x Lime	NS
	Variety x Organic matter x Lime	NS

NS- Non Significant

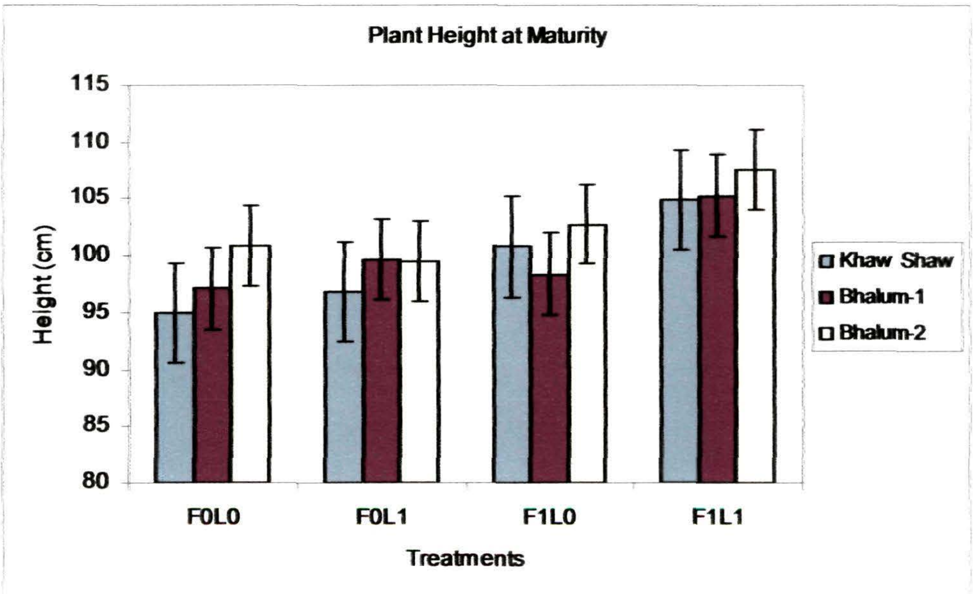
Effect of different treatments on plant height at maturity of the tested varieties (Khaw Shaw, Bhalum-1 and Bhalum-2) is shown in Table 5.20 and Figure 5.8. Treatment of lime (F0L1) increased plant height of the local variety (Khaw Shaw) and Bhalum-1 by 1.8 and 2.6 cm, respectively over control. However, there was no positive effect of this treatment on plant height of Bhalum-1. Similarly treatment with Farm Yard Manure (F1L0) increased plant height of the local variety (Khaw Shaw) by 5.8 cm over control. Similar treatment increased plant heights of Bhalum-1 and Bhalum-2 by 1.3 and 1.9 cm, respectively, over control. Again, combined treatment with lime and Farm Yard Manure (F1L1) increased plant heights of Khaw Shaw, Bhalum-1 and Bhalum-2 by 9.9, 8.2 and 6.7 cm, respectively over control.

Table 5.20: Effect of organic matter and lime on plant height (cm) at yellow maturity stage of different varieties of rice

Treatments	Varieties		
	Khaw Shaw	Bhalum-1	Bhalum-2
	Plant height (cm)		
F0L0	95.0	97.1	100.9
F0L1	96.8	99.7	99.5
F1L0	100.8	98.4	102.8
F1L1	104.9	105.3	107.6
S. D.	4.4	3.6	3.5

S. D.= Standard deviation

Fig. 5.8: Effect of organic matter and lime on plant height at yellow maturity stage of different rice varieties



Effect of various treatments on plant height of the tested varieties (Khaw Shaw, Bhalum-1 and Bhalum-2) at different stages of crop growth is shown in the Figures 5.9(a)-5.9(c) and Tables 5.21(a)-5.21(c). Plant height of all the varieties increased rapidly during 25-96 days after sowing and after that the increase in height was almost stable. Maximum plant heights of all the varieties such as Khaw Shaw (104.9 cm), Bhalum-1 (105.3 cm) and Bhalum-2 (107.6 cm) were recorded at 116 days after sowing under combined treatment with lime and Farm Yard Manure (F1L1). This particular treatment resulted in higher values of plant height as compared to other treatments at all stages of plant growth for all the varieties.

Table 5.21 (a): Effect of organic matter and lime on plant height (cm) of 'Khaw Shaw'

Days after sowing	Treatments			
	F0L0	F0L1	F1L0	F1L1
	Plant height (cm)			
15 DAS	9.6	12.9	9.5	13.3
25 DAS	39.0	38.8	42.0	44.2
35 DAS	47.4	48.3	50.6	49.2
47 DAS	52.5	51.9	54.1	53.8
55 DAS	58.3	59.0	61.5	59.5
66 DAS	67.8	71.8	73.7	74.4
76 DAS	71.0	73.7	76.7	78.8
85 DAS	78.1	83.8	88.1	87.3
96 DAS	81.2	85.9	92.7	92.0
106 DAS	87.8	91.6	98.5	99.6
116 DAS	95.0	96.8	100.8	104.9
S. D.	24.7	25.5	27.9	27.6

S. D.= Standard deviation

Figure 5.9 (a): Effect of organic matter and lime on plant height of 'Khaw Shaw'

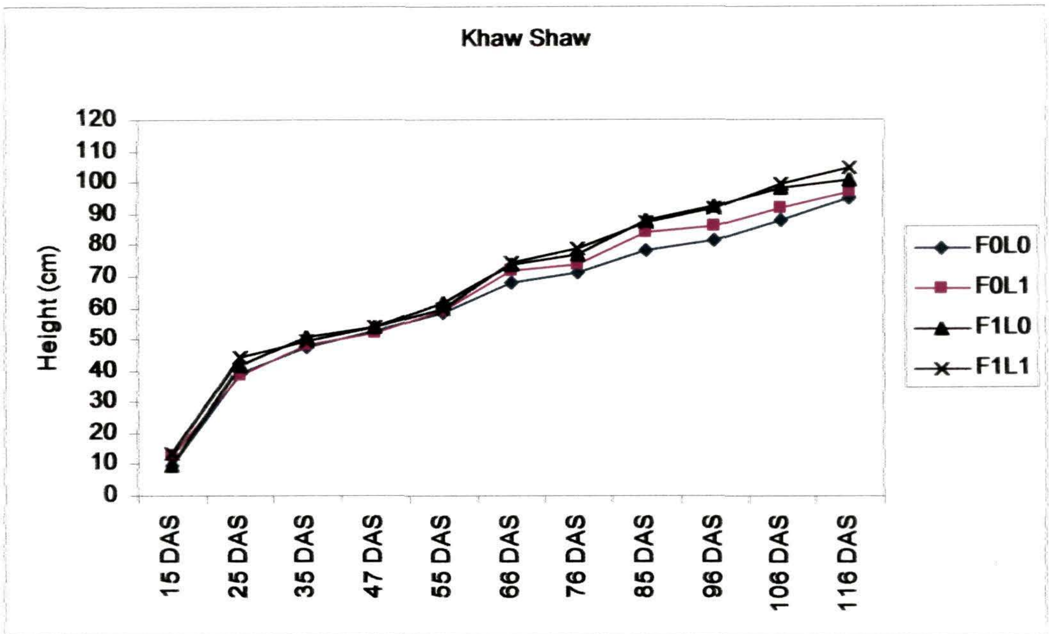


Table 5.21 (b): Effect of organic matter and lime on plant height of 'Bhalum-1'

Days after sowing	Treatments			
	F0L0	F0L1	F1L0	F1L1
	Plant height (cm)			
15 DAS	8.8	10.4	11.6	12.6
25 DAS	39.4	42.0	40.4	43.6
35 DAS	48.2	49.4	48.9	54.9
47 DAS	52.2	54.0	52.2	57.9
55 DAS	60.3	60.4	59.9	63.5
66 DAS	74.4	72.3	74.3	75.8
76 DAS	79.2	76.5	77.8	81.0
85 DAS	85.5	82.2	84.5	91.4
96 DAS	90.3	86.1	90.1	94.6
106 DAS	94.1	93.1	95.0	103.1
116 DAS	97.1	99.7	98.4	105.3
S. D.	27.4	26.1	26.7	28.2

S. D.= Standard deviation

Figure 5.9 (b): Effect of organic matter and lime on plant height (cm) of 'Bhalum-1'

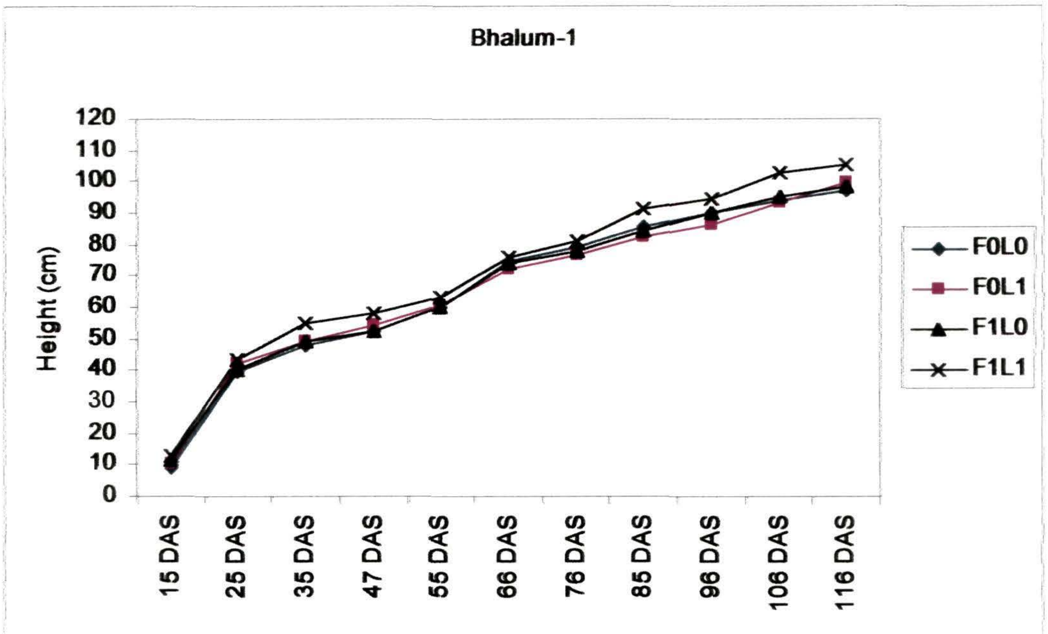
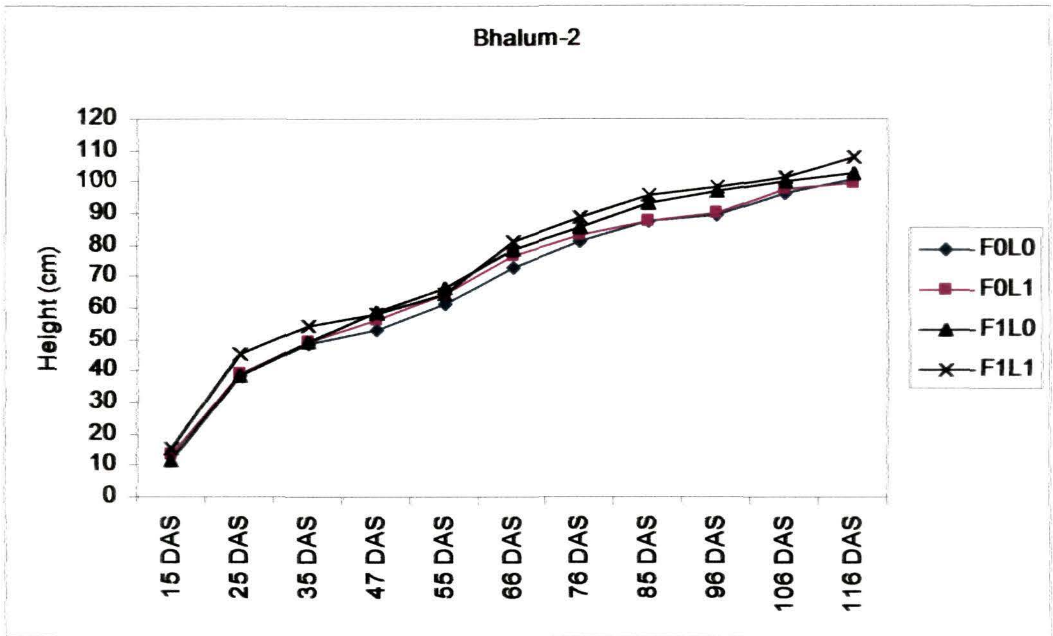


Table 5.21 (c): Effect of organic matter and lime on plant height (cm) of 'Bhalum-2'

Days after Sowing	Treatments			
	F0L0	F0L1	F1L0	F1L1
	Plant height (cm)			
15 DAS	13.1	13.6	11.4	15.3
25 DAS	38.6	38.9	38.3	45.2
35 DAS	48.4	49.4	49.0	54.5
47 DAS	53.1	56.0	58.8	58.0
55 DAS	61.2	64.3	66.1	64.4
66 DAS	73.0	76.5	78.7	81.3
76 DAS	81.2	82.9	85.8	88.9
85 DAS	87.2	87.5	93.2	95.9
96 DAS	89.6	90.3	97.3	98.3
106 DAS	96.2	97.6	100.5	101.4
116 DAS	100.9	99.5	102.8	107.6
S. D.	27.3	27.1	29.4	28.7

S. D.= Standard deviation

Figure 5.9 (c): Effect of organic matter and lime on plant height of 'Bhalum-2'



Above results reveal that all the three varieties showed similar trend of increase in plant height throughout the growth period. In case of all the varieties, plant height increased rapidly from 25 days after sowing up to 96 days after sowing and after that the increase in height was almost stable. Treatment of lime as well as Farm Yard Manure improved plant height of all the three varieties.

Rapid increase of plant height from 25 days to 96 days after sowing for all the varieties may be due to fastest cell elongation during this period. Attainment of stable plant height after 96 days of sowing may be due to cell maturation (Pandey and Sinha, 1999). Although pattern of growth is never influenced by any factor, but overall growth may be affected by external or internal factor.

Improvement of plant height due to application of lime and Farm Yard Manure may be due to improvement of soil fertility status. Both of these amendments increased available nitrogen status of soil. Nitrogen enhances cell elongation and cell division which probably resulted in increase of plant height (Salem, 2006). Similar findings were reported by Channabasavanna *et al.* (2001) and Das *et al.* (2001). Liming also increases plant height through increase of available nitrogen statue of soil by increasing soil pH (Sekimoto *et al.*, 1995). Similar result was reported by Wu *et al.* (1994) and Martins *et al.* (1995). Tripathy and Dacayo (1988) reported that liming to pH 6.0 significantly increased plant height of rice as compared to control in acid upland soil of Philippine.

5.6.4 Effect of organic matter and lime on Leaf Area Index (LAI)

Leaf Area Index (LAI) is the ratio of total upper leaf surface of a crop to the surface area of the land on which the crop grows. It is directly proportional to the production of photosynthates (Chen and Black, 1992). Better LAI enhances the capacity of plant to capture more solar energy to produce photosynthates in the process of photosynthesis. LAI at tillering and flowering is positively related to grain yield production of rainfed rice (Singh *et al.*, 1995).

Within different varieties no statistically significant difference in LAI was found. The mean LAI recorded in case of Khaw Shaw (1.41) was higher than Bhalum-

1 (1.16) and Bhalum-2 (1.39) (Table 5.22). Again, treatment with Farm Yard Manure and lime increased Leaf Area Index of all the varieties by 0.22 and 0.018, respectively over their respective controls.

Table 5.22: Analysis of variance (ANOVA) for effect of organic matter and lime on Leaf Area Index (LAI) of different rice varieties

Variables		Mean LAI
Variety		
	Bhalum-1	1.163
	Bhalum-2	1.394
	Khaw Shaw	1.414
	SEm ±	0.092
	CD (0.05)	0.269
Organic Matter		
	No Organic matter	1.214
	10 t/ha	1.434
	SEm ±	0.075
	CD (0.05)	0.219
Lime		
	No Lime	1.341
	With lime	1.359
	SEm ±	0.075
	CD (0.05)	0.219
Interaction		
	Variety x Organic matter	NS
	Variety x Lime	NS
	Organic matter x Lime	NS
	Variety x Organic matter x Lime	NS

NS- Non Significant

Leaf area index (LAI) as a function of application of organic matter and lime for different phenological stages and varieties have been shown in Figures 5.10(a)-5.10(d) and Tables 5.23(a)-5.23(d). Maximum LAI was observed between panicle emergence and ripening stages under different treatments for all the three varieties. Application of lime and organic matter separately and together drastically increased the LAI for all the three varieties. The local variety (Khaw Shaw) had a marked increase in LAI when both lime and organic matter were applied. LAI value was found in the range of 0.6 at active tillering stage to 1.8 in ripening stage, which was even better than the other two varieties. In the control treatment (F0L0) the LAI ranged from 0.45 to 1.45, with lime (F0L1) it ranged from 0.50 to 1.45, with organic matter (F1L0) it ranged from 0.80 to 1.60 where maximum LAI was recorded in ripening stage itself and with both organic matter and lime it ranged from 0.60 to 1.80.

Table 5.23 (a): Leaf area index (LAI) of Khaw Shaw, Bhalum-1 and Bhalum-2 varieties of rice under control in various phenological stages

Treatments	Phenological Stages			
	Active tillering	Maximum tillering	Panicle emergence	Ripening stage
	LAI			
V1F0L0	0.54	0.80	1.18	1.11
V2F0L0	0.48	0.60	1.10	1.19
V3F0L0	0.53	0.77	1.11	1.52
S. D.	0.03	0.10	0.04	0.22

S. D.= Standard deviation

Figure 5.10 (a): Leaf area index (LAI) of Khaw Shaw, Bhalum-1 and Bhalum-2 varieties of rice under control in various phenological stages

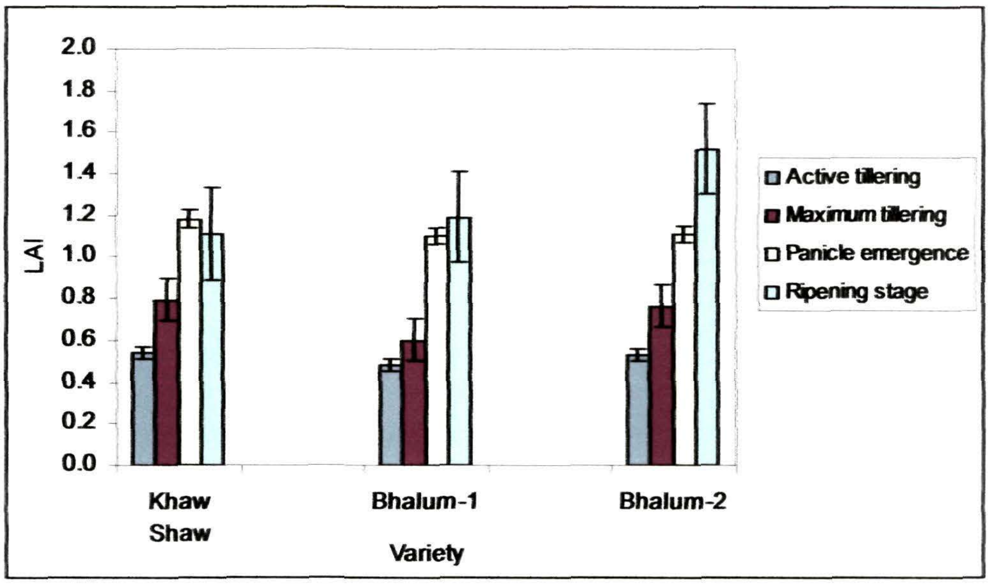


Table 5.23 (b): Effect of lime on leaf area index (LAI) of different varieties of rice in various phenological stages

Treatments	Phenological Stages			
	Active tillering	Maximum tillering	Panicle emergence	Ripening stage
	LAI			
V1F0L1	0.58	0.87	1.32	1.10
V2F0L1	0.69	0.82	1.04	1.44
V3F0L1	0.73	0.92	1.52	1.50
S. D.	0.08	0.05	0.24	0.22

S. D.= Standard deviation

Figure 5.10 (b): Effect of lime on Leaf Area Index (LAI) of different varieties of rice in various phenological stages

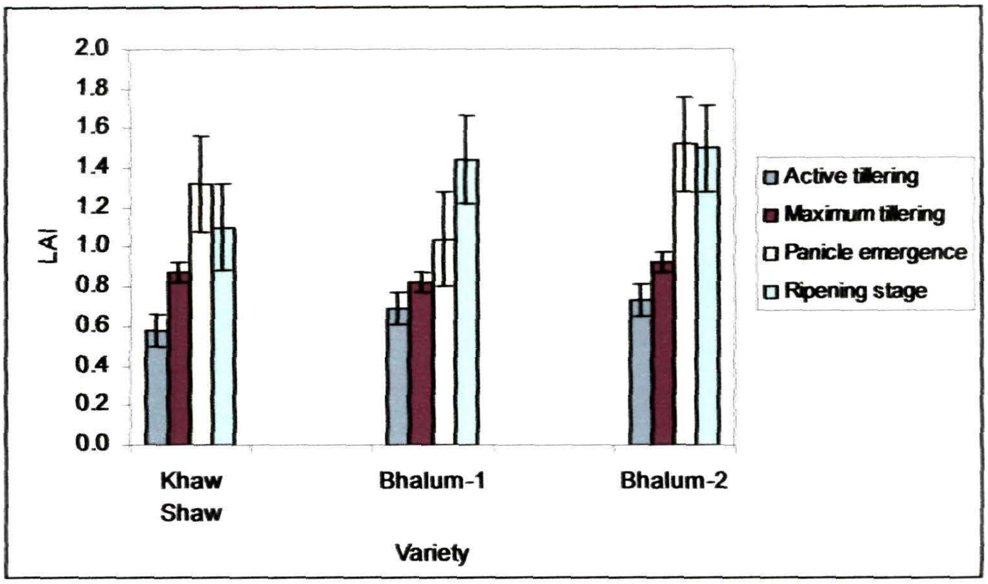


Table 5.23 (c): Effect of organic matter on leaf area index (LAI) of different varieties of rice in various phenological stages

Treatments	Phenological Stages			
	Active tillering	Maximum tillering	Panicle emergence	Ripening stage
	LAI			
V1F1L0	0.87	0.98	1.63	1.29
V2F1L0	0.69	0.87	1.40	1.35
V3F1L0	0.85	0.89	1.61	1.37
S. D.	0.10	0.06	0.13	0.04

S. D.= Standard deviation

Figure 5.10 (c): Effect of organic matter on Leaf Area Index (LAI) of different varieties of rice in various phenological stages

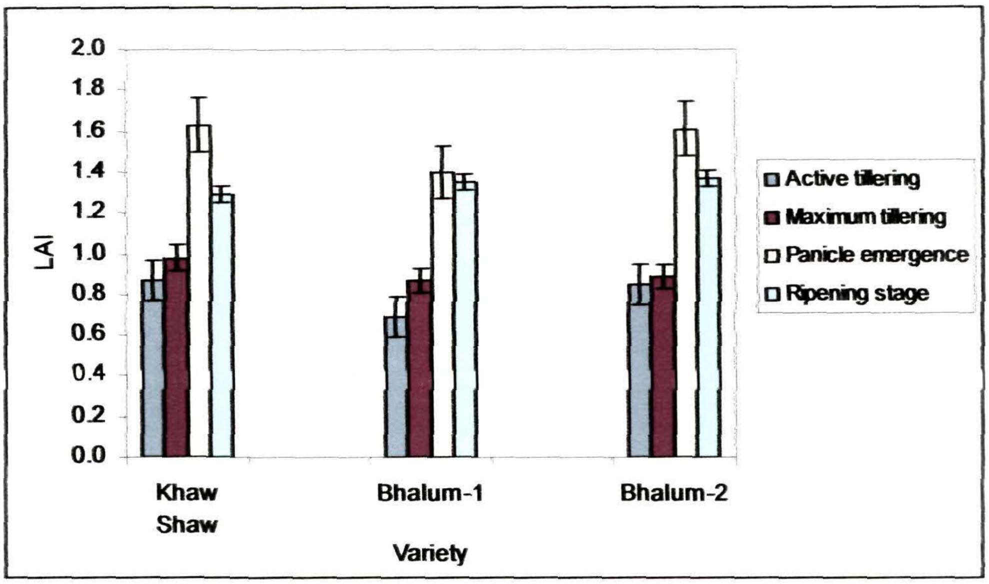
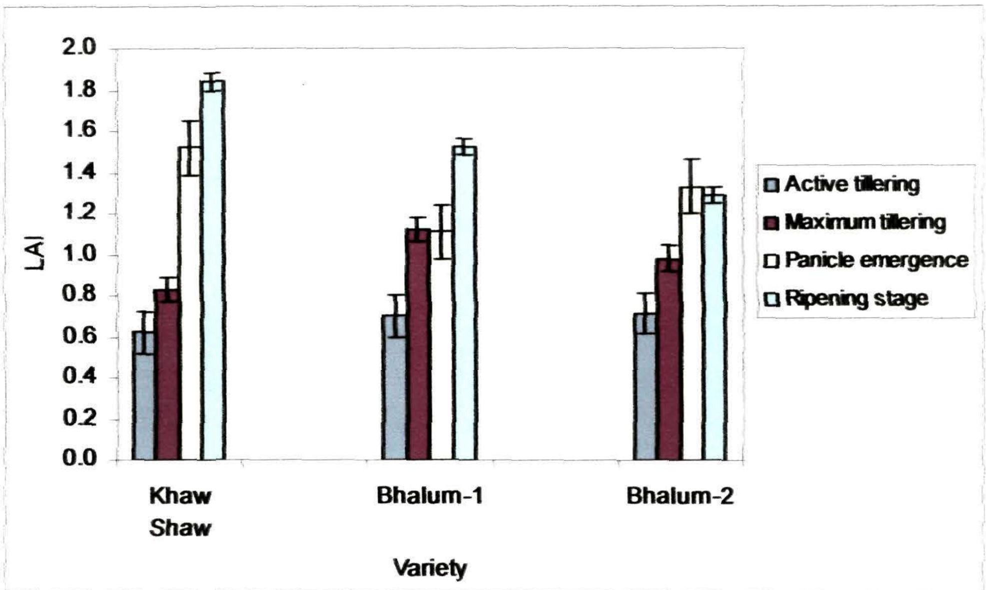


Table 5.23 (d): Effect of organic matter and lime on leaf area index (LAI) of different varieties of rice in various phenological stages

Treatments	Phenological Stages			
	Active tillering	Maximum tillering	Panicle emergence	Ripening stage
	LAI			
V1F1L1	0.62	0.83	1.52	1.84
V2F1L1	0.70	1.12	1.11	1.52
V3F1L1	0.71	0.98	1.33	1.29
S. D.	0.05	0.15	0.21	0.28

S. D.= Standard deviation

Figure 5.10 (d): Effect of organic matter and lime on Leaf Area Index (LAI) of different varieties of rice in various phenological stages



From the above results it is clear that Leaf Area Index (LAI) of Khaw Shaw was better than that of Bhalum-1 and Bhalum-2. Moreover application of both lime and FYM increased LAI of all the varieties at different growth stages. Both of these amendments increased availability of soil nitrogen which enhanced cell elongation and cell division resulting in large Leaf Area Index. Similar results were reported by El-Batal *et al.* (2004). Also increasing nitrogen level might be delaying the early leaf aging, thus leading to large Leaf Area Index (Ebaid and Ghanem, 2000).

5.6.5 Effect of Farm Yard Manure (FYM) on biomass production

Biomass production reflects the vegetative growth that a plant acquires during its entire life cycle. A crop will show higher dry biomass accumulation when the total vegetative phase is longer in duration with high number of tillers.

Analysis of Variance shows that dry biomass produced by Khaw Shaw was 76.37 and 60.56 g/plant higher than Bhalum-1 and Bhalum-2, respectively, which were also significantly different at 5% level of confidence. Again application of Farm Yard Manure and lime produced 30.628 and 16.239 g/plant more dry biomass over their respective controls (Table 5.24).

Table 5.25 and Fig. 5.11 show that treatment with lime (F0L1) increased biomass production of the local variety (Khaw Shaw) by 6.87 g/plant over control. Similar treatment increased biomass production of Bhalum-1 and Bhalum-2 by 1.78 and 13.8 g/plant, respectively. Similarly treatment with Farm Yard Manure (F1L0) increased biomass of the local variety (Khaw Shaw) and Bhalum-2 by 26.32 and 21.44 g/plant, respectively over control. Similar treatment increased biomass of Bhalum-1 only by 0.66 g/plant over control. Again combined treatment with lime and Farm Yard Manure (FYM) increased biomass production of Khaw Shaw, Bhalum-1 and Bhalum-2 by 35.55, 33.04 and 38.69 g/plant, respectively over control.

Table 5.24: Analysis of variance (ANOVA) for effect of organic matter and lime on dry biomass (g/plant) of different rice varieties

Variables		Mean Dry Biomass (g/plant)
Variety		
	Bhalum-1	50.750
	Bhalum-2	66.617
	Khaw Shaw	127.175
	SEm ±	5.367
	CD (0.05)	15.664
Organic Matter		
	No Organic matter	66.200
	10 t/ha	96.828
	SEm ±	4.382
	CD (0.05)	12.789
Lime		
	No Lime	73.394
	With lime	89.633
	SEm ±	4.382
	CD (0.05)	12.789
Interaction		
	Variety x Organic matter	NS
	Variety x Lime	NS
	Organic matter x Lime	NS
	Variety x Organic matter x Lime	NS

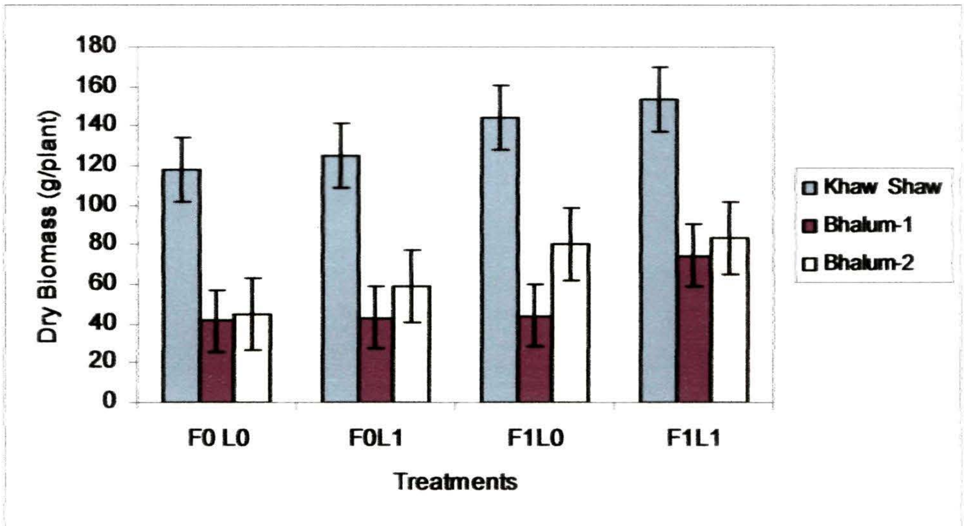
NS- Non Significant

Table 5.25: Effect of organic matter and lime on dry biomass (g/plant) of different varieties of rice

Treatments	Varieties		
	Khaw Shaw	Bhalum-1	Bhalum-2
	Dry biomass (g/plant)		
F0L0	118.03	41.44	44.68
F0L1	124.90	43.22	58.48
F1L0	144.35	43.88	79.92
F1L1	153.58	74.48	83.37
S. D.	16.56	5.85	18.30

S. D.= Standard deviation

Figure 5.11: Effect of organic matter and lime on dry biomass (g/plant) of different varieties of rice



Above results indicate that (Khaw Shaw) produced higher biomass as compared to Bhalum-1 and Bhalum-2. Again treatment with lime and Farm Yard Manure increased production of biomass of all the three varieties over control.

Higher production of biomass by the local variety (Khaw Shaw) as compared to Bhalum-1 and Bhalum-2 may be due to its longer vegetative phase as well as better partitioning of photosynthates towards straw as compared to others. Treatment with lime increases base saturation of acidic soil resulting in increase of dry matter production of crop in such soil (Borges *et al.*, 1998). Zaini *et al.* (1997) reported that liming as $CaCO_3$ tends to increase ca contents in rice straw. Improvement of biomass yield of the three varieties due to treatment with Farm Yard Manure may be due to its nutrient supplying capacity to soil. Moreover Farm Yard Manure improves physical condition of soil resulting in better plant growth (Parihar, 2004). Bridgit and Potty (2002) reported application of FYM @ 10 tonnes/ha increased dry biomass of rice by 6.8% as compared to control. Similar results have been reported by other workers (Bassal and Zahran, 2000; Das *et al.*, 2001; Salem, 2006).

5.6.6 Effect of organic matter and lime on number of Effective Tillers

Factors in high rice production include the attainment of a suitable tiller number and full tiller development. An effective tiller rate of 80% or more is needed to give a high-yielding crop (Xu *et al.*, 1996). Number of effective tiller is a direct and positive contributors towards grain yield (Dash *et al.*, 1996).

Table 5.26 shows that number of effective tillers per plant of Bhalum-2 (11.875) was highest followed by Bhalum-1 (11.75) and Khaw shaw (9.083). Number of effective tillers per plant of both Bhalum-1 and Bhalum-2 were significantly higher than the local variety (Khaw Shaw). However there was no significant difference of mean number of effective tillers between Bhalum-1 and Bhalum-2. Again application of Farm Yard Manure and lime has improved number of effective tillers by 0.694 and 1.417 over their respective controls.

Table 5.26: Analysis of variance (ANOVA) for effect of organic matter and lime on number of effective tillers per plant of different rice varieties

Variables		Mean No. of Effective Tiller
Variety		
	Bhalum-1	11.750
	Bhalum-2	11.875
	Khaw Shaw	9.083
	SEm ±	0.416
	CD (0.05)	1.214
Organic Matter		
	No Organic matter	10.556
	10 t/ha	11.250
	SEm ±	0.339
	CD (0.05)	0.989
Lime		
	No Lime	10.194
	With lime	11.611
	SEm ±	0.339
	CD (0.05)	0.989
Interaction		
	Variety x Organic matter	NS
	Variety x Lime	NS
	Organic matter x Lime	NS
	Variety x Organic matter x Lime	NS

NS- Non Significant

Table 5.27: Effect of organic matter and lime on number of effective tillers per plant of different varieties of rice

Treatments	Varieties		
	Khaw Shaw	Bhalum-1	Bhalum-2
	Number of effective tillers per plant		
F0L0	7.7	10.8	11.3
F0L1	9.8	11.8	11.8
F1L0	7.5	12.2	11.7
F1L1	11.3	12.2	12.7
S. D.	1.8	0.7	0.6

S. D.= Standard deviation

Figure 5.12: Effect of organic matter and lime on number of effective tillers of different varieties of rice

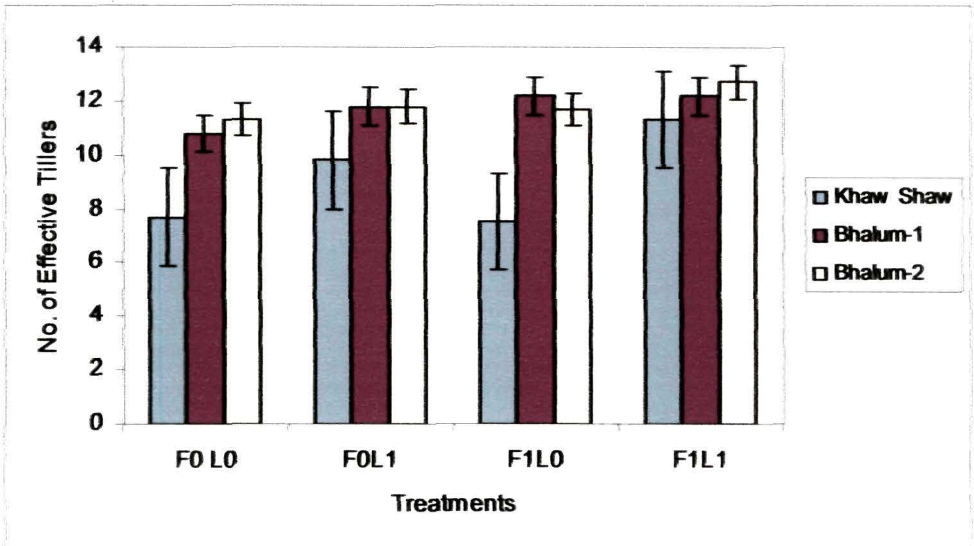


Table 5.27 and Fig. 5.12 show that treatment with lime (F0L1) increased mean number of effective tillers of the local variety (Khaw Shaw) by 2.1 over control. Similar treatment increased effective tillers of both Bhalum-1 and Bhalum-2 by 1 and 0.5 over control. Again treatment with lime+Farm Yard Manure (F1L1) increased mean number of effective tillers of Khaw Shaw, Bhalum-1 and Bhalum-2 by 3.6, 1.4 and 1.4, respectively over control.

Above results reveal that Bhalum-1 and Bhalum-2 produced higher number of reproductive tillers as compared to the local variety (Khaw Shaw). Both lime and Farm Yard Manure increased number of effective tillers of all the three varieties. Higher number of effective tillers of Bhalum-1 and Bhalum-2 as compared to the local variety (Khaw Shaw) may be due to their higher yield potential as compared to the local variety. Organic matter and liming increased the available nitrogen content of soil. Increasing nitrogen level has positive effect on grain filling, which reduces grain sterility and increases number of reproductive tillers (Salem, 2006). Similar findings were reported by Bassal and Zahran (2000) and Parihar (2004).

5.6.7 Effect of organic matter and lime on number of Grains per Panicle

Data presented in Table 5.28 shows that number of grains per panicle of Bhalum-2 is highest (77.5) followed by Bhalum-1 (69.4) and Khaw Shaw (62.9). Again application of FYM and lime significantly improved number of grains per panicle by 16.72 and 5.22, respectively over their controls. Interaction effects of different treatments were found statistically non significant.

Table 5.29 and Fig. 5.13 show that treatment with lime (F0L1) increased number of grains per panicle of the local variety (Khaw Shaw) by 1.8 over control. Similar treatment increased number of grains per panicle of Bhalum-1 and Bhalum-2 by 4.4 and 9.9, respectively over control. Treatment with Farm Yard Manure (F1L0) increased number of panicles of the local variety (Khaw Shaw) by 9.0 over control. Similar treatment increased number of panicles of Bhalum-1 and Bhalum-2 by 18.7 and 24.7, respectively over control. Again treatment with lime+ Farm Yard Manure (F1L1) increased grain yields of Khaw Shaw, Bhalum-1 and Bhalum-2 by 10.8, 18.7 and 31.3 over control.

Table 5.28: Analysis of variance (ANOVA) for effect of organic matter and lime on number of grains per panicle of different rice varieties

Variables		Mean No. of Grain Per Panicle
Variety		
	Bhalum-1	69.417
	Bhalum-2	77.583
	Khaw Shaw	62.917
	SEm ±	1.922
	CD (0.05)	5.609
Organic Matter		
	No Organic matter	61.611
	10 t/ha	78.333
	SEm ±	1.569
	CD (0.05)	4.579
Lime		
	No Lime	67.361
	With lime	72.583
	SEm ±	1.569
	CD (0.05)	4.579
Interaction		
	Variety x Organic matter	NS
	Variety x Lime	NS
	Organic matter x Lime	NS
	Variety x Organic matter x Lime	NS

NS- Non Significant

Above result reveals that number of grains per panicle of Bhalum-1 and Bhalum-2 were higher than that of the local variety (Khaw Shaw). Treatment with Farm Yard Manure and lime had positive effect on number of grains per panicle of each of the aforementioned varieties. Better partitioning of net photosynthates to grains as compared to straw might be the reason behind more number of grains per panicle of Bhalum-1 and Bhalum-2 than Khaw

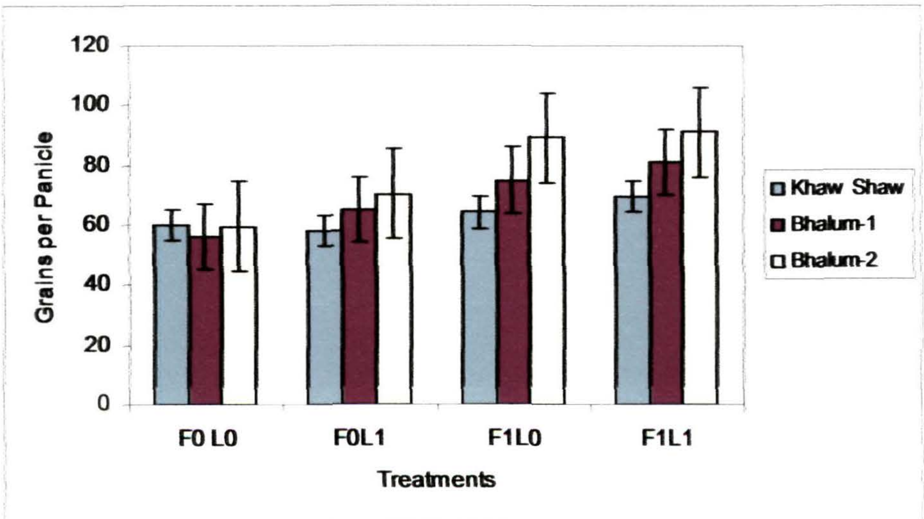
Shaw. Increased number of grains per panicle of the tested varieties due to addition of Farm Yard Manure and lime might be due to their favorable effect on overall soil health and fertility status. Bridgit and Potty (2002) reported that incorporation of Farm Yard Manure facilitates the process of translocation which ultimately results in increasing number of grains/panicle. Positive effects of liming on number of grains/ panicle of rice in acid soil have been reported by Subbaiah and Mitra (1997).

Table 5.29: Effect of organic matter and lime on number of grains per panicle of different varieties of rice

Treatments		Varieties	
	Khaw Shaw	Bhalum-1	Bhalum-2
	Number of grains per panicle		
F0L0	59.8	56.3	59.7
F0L1	58.0	65.3	70.5
F1L0	64.2	75.0	89.2
F1L1	69.7	81.0	91.0
S. D.	5.2	10.9	15.1

S. D.= Standard deviation

Figure 5.13: Effect of organic matter and lime on number of grains per panicles



5.6.8 Effect of organic matter and lime on Grain yield

Grain yield is positively and significantly correlated with grain weight per plant (Dash *et al.*, 1996). Grain yield is one of the most important yield parameters, which determines the performance of crop varieties. It is also called economic yield and strongly influence the overall profitability associated with agricultural practices.

ANOVA (Analysis of Variance) presented in Table 5.30 shows that Bhalum-1 and Bhalum-2 produced respectively 4.9 and 8.9 g/plant more grain yield over the local variety (Khaw Shaw). Again, grain yield of Bhalum-2 was significantly higher than Bhalum-1. Besides, application of Farm Yard Manure and lime produced 7.37 and 5.69 g/plant, respectively more grain yield over the control. No statistically significant relationships were observed in cases of interaction of different treatments.

Table 5.31 and Fig. 5.14 show that treatment with lime (F0L1) increased grain yield of the local variety (Khaw Shaw) by 2.51 g/plant over control. Similar treatment increased grain yields of Bhalum-1 and Bhalum-2 by 6.66 and 5.86 g/plant, respectively over their respective controls. Treatment with Farm Yard Manure (F1L0) increased grain yield of the local variety (Khaw Shaw) by 0.84 g/plant over control. Similar treatment increased grain yields of Bhalum-1 and Bhalum-2 by 7.8 and 11.44 g/plant, respectively over their respective controls.

Again treatment with lime+ Farm Yard Manure (F1L1) increased grain yields of Khaw Shaw, Bhalum-1 and Bhalum-2 by 9.28, 13.99 and 15.91 g/plant, respectively over control.

Table 5.30: Analysis of variance (ANOVA) for effect of organic matter and lime on grain yield of different rice varieties

Variables		Grain yield	
		g/plant	kg/ha
Variety			
	Bhalum-1	18.410	4602.633
	Bhalum-2	22.444	5611.333
	Khaw Shaw	13.468	3366.667
	SEm ±	1.019	254.808
	CD (0.05)	2.975	743.656
Organic Matter			
	No Organic matter	14.420	3605.072
	10 t/ha	21.794	5448.683
	SEm ±	0.832	208.050
	CD (0.05)	2.429	607.193
Lime			
	No Lime	15.262	3815.556
	With lime	20.953	5238.200
	SEm ±	0.832	208.050
	CD (0.05)	2.429	607.193
Interaction			
	Variety x Organic matter	NS	NS
	Variety x Lime	NS	NS
	Organic matter x Lime	NS	NS
	Variety x Organic matter x Lime	NS	NS

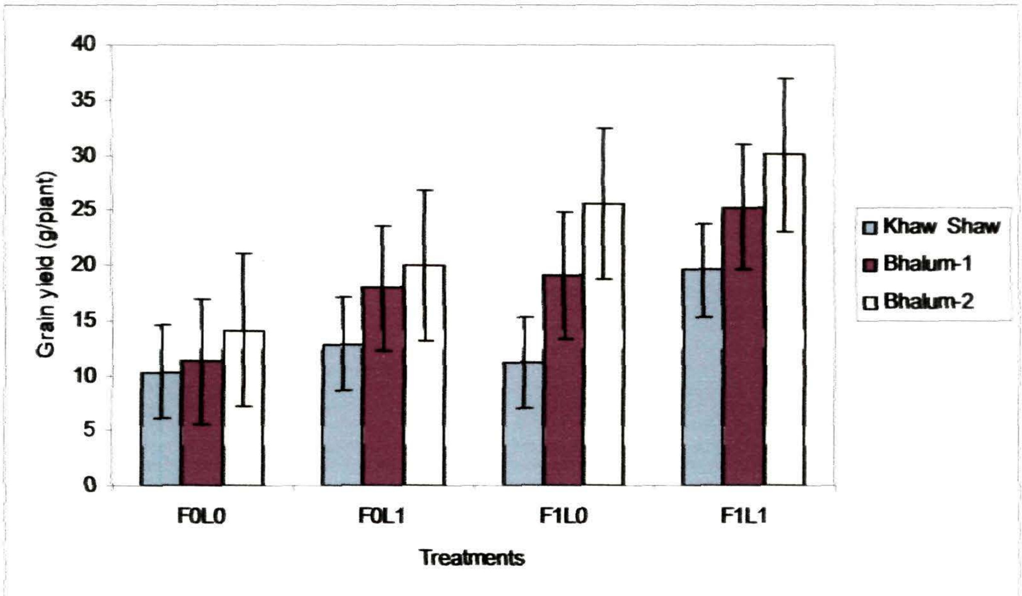
NS- Non Significant

Table 5.31: Effect of organic matter and lime on grain yield (g/plant) of different varieties of rice

Treatments	Varieties		
	Khaw Shaw	Bhalum-1	Bhalum-2
	Grain yield (g/plant)		
F0L0	10.31	11.30	14.14
F0L1	12.82	17.96	20.00
F1L0	11.15	19.10	25.58
F1L1	19.59	25.29	30.05
S. D.	4.21	5.73	6.90

S. D.= Standard deviation

Figure 5.14: Effect of organic matter and lime on grain yield (g/plant) of different rice varieties



From the above results it is clear that grain yields of both Bhalum-1 and Bhalum-2 were higher than the yield of the local variety, Khaw Shaw. Again treatment with lime and Farm Yard Manure produced higher grain yield as compared to control. Though the local variety (Khaw Shaw) had a higher accumulation of dry biomass, it does not reflect in the grain production. It may be due to better partitioning of net photosynthates to straw as compared to grain. Similarly, higher grain yield of Bhalum-1 and Bhalum-2 as compared to the local variety (Khaw Shaw) might be because of better partitioning of net photosynthates to grains in Bhalum-1 and Bhalum-2 as compared to Khaw Shaw. Hence, both Bhalum-1 and Bhalum-2 appear genetically high yielding varieties and also perform better under different treatments.

Application of lime and FYM increased soil pH which resulted in increased availability of various nutrients in soil as increase of soil pH had positive effect on nutrient status of acidic soil. Higher availability of nutrients to plants increased vegetative growth resulting in higher photosynthetic area and thereby higher translocation of photosynthates towards grains (Manguiat *et al.*, 1997). This resulted in increase of grain yield. Bridgit and Potty (2002) got 15% more grain yield of rice with application of FYM @ 10 tonnes/ha over control. Many workers have reported the increase of total grain yield of rice with liming in acidic soil condition (Cassel *et al.*, 1990; Chidanandappa *et al.*, 1996; Saikia and Pathak, 1996; Bastos *et al.*, 1998; Mutanal *et al.*, 1998; Ntamatungiro *et al.*, 1998).

5.6.10 Effect of organic matter and lime on Harvest Index (HI)

Harvest Index (HI) is the ratio between total grain yield to the total dry matter yield (Wilts *et al.*, 2004). It is an important trait associated with success in partitioning of assimilated photosynthates to harvestable product (Chauhan *et al.*, 1999).

Data presented in Table 5.32 shows that Harvest Index of Bhalum-1 was highest (0.372) followed by Bhalum-2 (0.351) and Khaw Shaw (0.098). Although there was no significant difference between Harvest Indices of Bhalum-1 and Bhalum-2, but both of their Harvest Indices differ significantly from Khaw Shaw. Again application of Farm Yard Manure and lime significantly improved average Harvest Indices of all the varieties by 0.014 and 0.037, respectively over respective controls. Interaction effects of different treatments were found statistically non significant.

Table 5.32: Analysis of variance (ANOVA) for effect of organic matter and lime on Harvest Index (HI) of different rice varieties

Variables		Mean Harvest Index
Variety		
	Bhalum-1	0.372
	Bhalum-2	0.351
	Khaw Shaw	0.098
	SEm ±	0.024
	CD (0.05)	0.071
Organic Matter		
	No Organic matter	0.267
	10 t/ha	0.281
	SEm ±	0.019
	CD (0.05)	0.058
Lime		
	No Lime	0.255
	With lime	0.292
	SEm ±	0.019
	CD (0.05)	0.058
Interaction		
	Variety x Organic matter	NS
	Variety x Lime	NS
	Organic matter x Lime	NS
	Variety x Organic matter x Lime	NS

NS- Non Significant

Table 5.33 and Fig. 5.15 show that treatment with lime (F0L1) increased Harvest Index of the local variety (Khaw Shaw) by 0.10 over control. Similar treatment increased Harvest Indices of Bhalum-1 and Bhalum-2 by 0.16 and 0.04, respectively over their controls. Treatment with Farm Yard Manure (F1L0) increased Harvest Index of Bhalum-1 by 0.17 over control. Again treatment with lime+ Farm Yard Manure (F1L1) increased Harvest Indices of Khaw Shaw, Bhalum-1 and Bhalum-2 by 0.04, 0.08 and 0.03, respectively over control.

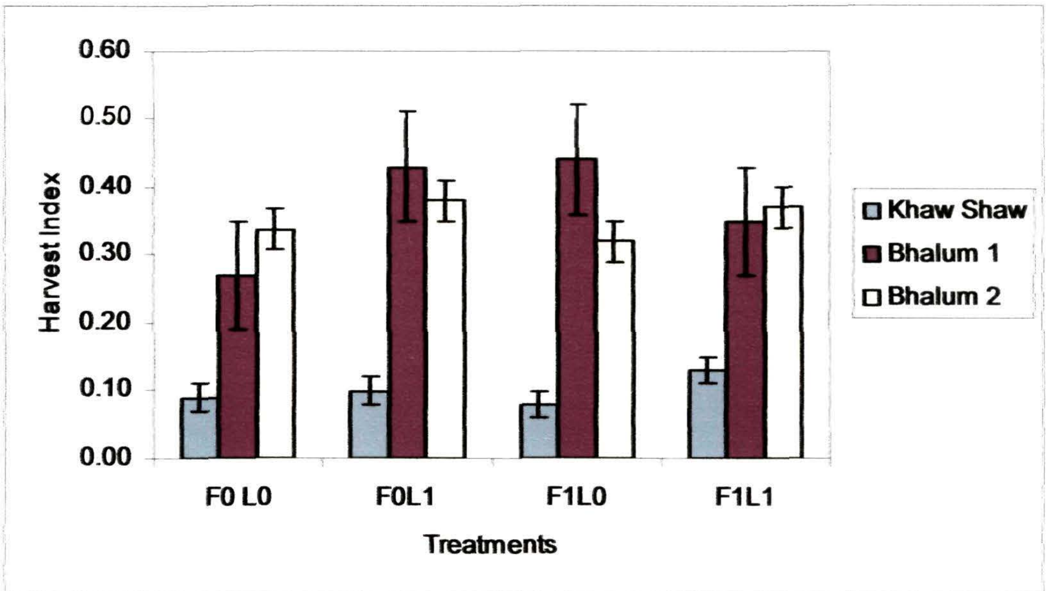
Above results reveal that Harvest Indices of Bhalum-1 and Bhalum-2 were better than the local variety, Khaw Shaw. All these varieties showed positive responses to the treatments of lime and Farm Yard Manure. One factor that influences Harvest Index is the relative value of grain, compared to straw (Sinclair, 1998). Higher grain yield of Bhalum-1 and Bhalum-2 resulted in higher Harvest Index of these varieties as compared to the Khaw Shaw. Similarly Production of quite large quantities of dry biomass of Khaw Shaw is responsible for its low value of Harvest Index. Increase of grain yield resulted from addition of Farm Yard Manure and lime caused subsequent increase of Harvest Indices of all the tested varieties. There is abundant evidence of that harvest Index of grain crops has increased with increasing crop yields (Donald and Hamlin, 1976; Hay, 1995).

Table 5.33: Effect of organic matter and lime on Harvest Index (HI) of different varieties of rice

Treatments	Varieties		
	Khaw Shaw	Bhalum-1	Bhalum-2
	Harvest Index		
F0L0	0.09	0.27	0.34
F0L1	0.10	0.43	0.38
F1L0	0.08	0.44	0.32
F1L1	0.13	0.35	0.37
S. D.	0.02	0.08	0.03

S. D.= Standard deviation

Figure 5.15: Effect of organic matter and lime on harvest index (HI) of different rice varieties



Overall Increase of growth and yield of rice in coal mine affected soil with application of lime and Farm Yard Manure may be due to their soil ameliorating effect. Soils collected from coal mining areas of Jaintia Hills district were highly acidic (pH< 5) in reaction. The productivity potential of these soils in general is limited mainly due to poor availability of essential nutrients i.e. Nitrogen, Phosphorus and Potassium and toxicity of Iron, Alumunium and Manganese. All the above mentioned problems could be managed by amelioration through liming which increases nutrient status and inactivates Aluminium, Iron and Manganese of acidic soils (Panda, 2000).

Farm Yard Manure, after decomposition, increases availability of different nutrients which is reflected in growth and yield of plants (Nour, 1998; Das *et al.*, 2001; Parihar, 2004). Hegde (1997) reported that it is possible to substitute 50% of the N needs of rice as organic sources such as farmyard manure (FYM) in acid soils. FYM also improves physical properties of soil by increasing organic carbon percentage of soil (Yadav and Kumar, 1993; Das *et al.*, 2001).

5.6.11 Comparison of different rice varieties for their suitability to grow in coal mine affected soils

On the basis of the standard statistical analysis of different growth and yield parameters, the three tested rice varieties were ranked according to their performances. The three ranks viz. 1, 2 and 3 were assigned to the varieties pertaining to any given parameter depending on their recorded level in descending order of magnitude, Again, in certain cases same ranking has been assigned to two or more varieties, which indicate that for that particular parameter the varieties do not differ significantly (Table 5.34).

After proper ranking of the rice varieties, it has been observed that the variety Bhalum-2 ranked first in six out of seven important plant parameters followed by Bhalum-1, which ranked first and second in three parameters each. The local variety (Khaw Shaw) has lowest performance among the three. A part of the pot experiment has been shown in Figures 5.16-5.19.

Table 5.34: Comparison of ranking of different rice varieties for various parameters

Parameter	Ranking		
	Khaw Shaw	Bhalum-1	Bhalum-2
Plant height (cm)	2	2	1
Leaf Area Index	1	1	1
Dry biomass (g/plant)	1	3	2
Number of effective tillers per plant	2	1	1
Number of grains per panicle	3	2	1
Grain yield (g/plant)	3	2	1
Harvest index	2	1	1

From the present investigation, it can be concluded that utilization of both Farm Yard Manure (10 tonnes/ha) and lime (4.08 tonnes/ha) may improve soil fertility for cultivation of rice in highly acidic soil of coal mining areas of Jaintia Hills district, Meghalaya. Moreover, cultivation of the rice variety, Bhalum-2 (RCPL-1-29) may fetch higher yield as compared to traditional low yielding variety, Khaw Shaw in coal mining areas.

A

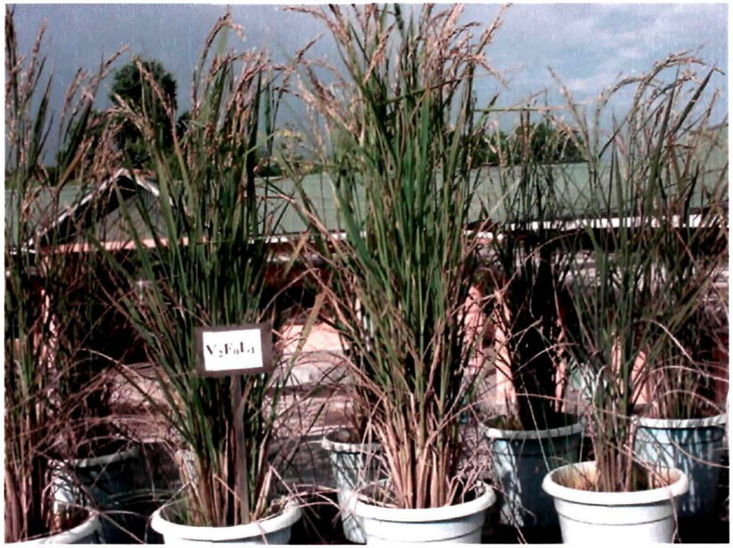
B

C

Figure 5.16: Different rice varieties under control

A: Khaw Shaw
B: Bhalum-1
C: Bhalum-2

A



B

C

Figure 5.17: Different rice varieties under treatment of lime

A: Khaw Shaw
B: Bhalum-1
C: Bhalum-2

A

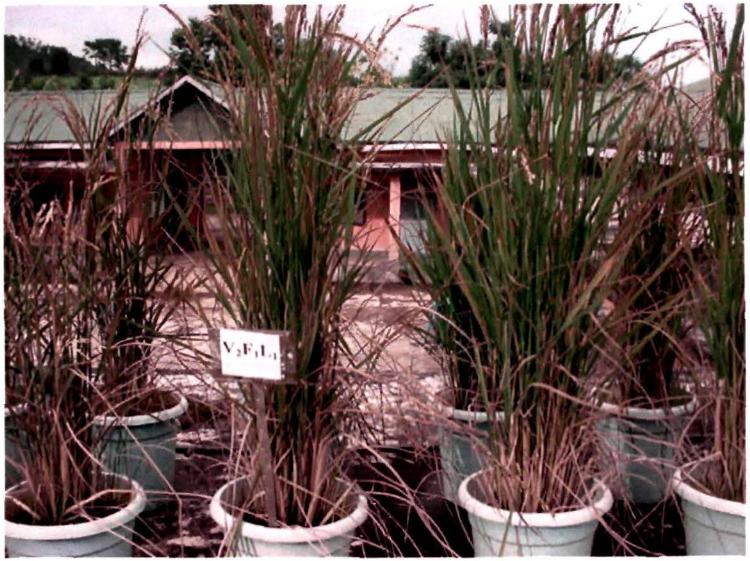
B

C

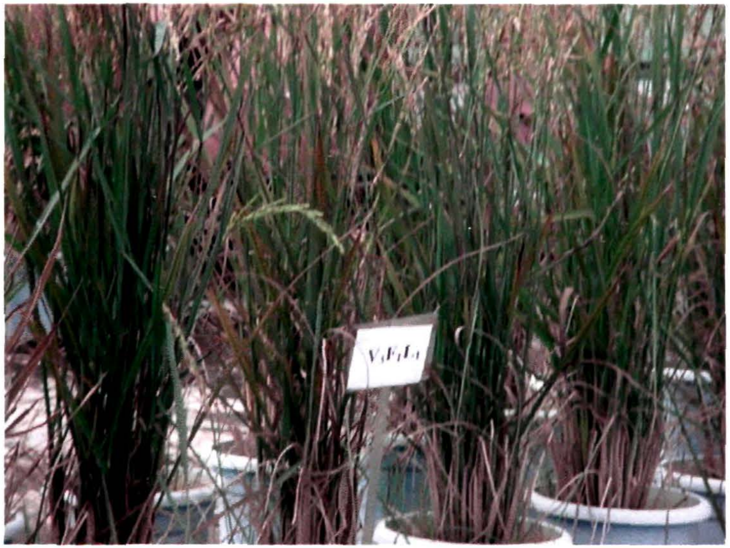
Figure 5.18: Different rice varieties under treatment of Farm Yard Manure

A: Khaw Shaw
B: Bhalum-1
C: Bhalum-2

A



B



C

Figure 5.19: Different rice varieties under treatments of lime and Farm Yard Manure

A: Khaw Shaw
B: Bhalum-1
C: Bhalum-2

SUMMARY

Chapter 6

To attain sustainable development in agriculture, management of vegetation, soil and water resources should be done in an integrated and rational manner. Agriculture alone can not uplift the economic scenario of a region but must be supplemented by other minor and major industries. While pursuing industrial activities, it should be taken in to account that the congenial environment should not be deteriorated as environmental degradation ultimately leads to reduction in production and productivity of crops.

Jaintia Hills district is situated in the eastern part of the state of Meghalaya and lies between 25°5′ to 25°4′ N latitudes and between 91°51′ to 92°45′ E longitudes. Majority of the population of the district depends on agriculture as the source of livelihood. There is a wide range of cropping systems in the district, of which rice based cropping system is dominant.

Next to agriculture, coal mining is the major industrial source of income in Jaintia Hills district of Meghalaya. A sizable amount of population is involved in the process of mining activity. Sutnga, Lakadong, Musiang-Lamare, Khliehriat, Ioksi, Ladrymbai, Rymbai, Byrwai, Chyrmang, Bapung, Jarain, Shkentalang, Lumshnong, Sakynphor etc. are the main coal mining areas of the Jaintia Hills.

It has been observed that coal mining activities in the area is unscientific, unsystematic and primitive in nature. Extraction of coal is carried out by a primitive mining method commonly known as 'rat-hole' mining. Many researchers have reported that deforestation, soil erosion, surface run-off, caving in of the ground and pollution of land, air and water are some of the prominent environmental problems associated with coal mining in the area. The mining activity has also deteriorated the soil quality of the area. As a consequence, many farmers have abandoned the farming activity. Agricultural fields have been adversely affected by acidification of soil as well as by deposition of coal and sand particles on soil surface. Significant increase in soil acidity has negative impact on soil fertility, biological activity and plant productivity.

The availability of the essential nutrients to the plant becomes restricted in highly acidic soil condition and the process of mineralization is also affected because of the diminished microbial activity, mostly bacterial activities in acidic soils. Further, acidity contributes to the build up of detrimental heavy metal concentration in agricultural fields, which ultimately enters in to the biological system through the crops grown in the affected fields.

Rice is the major agricultural crop grown in Jaintia Hills district followed by maize, potato, minor cereals, oilseed crops and vegetables. As the fertility status of crop fields are deteriorating due to both physical and chemical degradation caused by bi-products of coal mining areas including Acid Mine Drainage (AMD), it was felt to evaluate the overall scenario of agricultural production in Jaintia Hills district and to find out some remedial measures so that the crop sustainability can be maintained by improving the existing situations and farmers of the area can earn better economic return from their agriculture.

Thus, considering the seriousness of the problem, present study has been undertaken to assess the effects of coal mining on agriculture and on soil quality in Jaintia Hills district of Meghalaya. Physico-chemical analysis of soils collected from rice fields of three different coal mining sites of Jaintia Hills district, Meghalaya namely Dkhiah, Lad Rymbai and Bapung was done. In order to improve the quality, soils were treated with lime and organic matter (Farm Yard Manure) to see their effects on various soil properties. A pot culture experiment was conducted with soils collected from Bapung area during kharif seasons of 2005 and 2006. Various treatments comprised of control, lime (72.9 g/pot), Farm Yard Manure (178.6 g/pot) and lime (72.9 g/pot) + Farm Yard Manure (178.6 g/pot). The responses of three different rice varieties to various treatments applied were quantified through various plant parameters such as phenology, plant height (cm), Leaf Area Index, dry biomass (g/plant), number of effective tillers/plant, number of grains per panicle, grain weight per plant (g/plant), grain yield (kg/ha) and Harvest Index (HI). Statistical analyses were performed following standard procedures (Gomez, 1984). The results of the study have been summarized as follows:

1. A considerable proportion (31.57%) of total geographical area is under 'cultivable wasteland' which is much higher than total cropped area (8.64%). Rate of increase of net sown area was much slower (1.86%) as compared to 'area under non agricultural uses' (5.23%) during the period from 1987-88 to 2001-2002.

2. Rice is the major agricultural crop grown in Jaintia Hills occupying about 50.5% of net sown area in the district. There was overall decrease of rice area (-0.83%) in the district since 1987-88 till 2001-02. The increase of rice yield in 2001-02 in comparison to 1987-88 was only 381.8 Kg/ha, which is very meager in a span of 15 years. Though Jaintia Hills occupies second

position in area under rice (16,102 ha) but its yield is much lower (1139.8 kg/ha) in comparison to the other districts of Meghalaya.

3. Physico-chemical analysis of soils collected from rice fields of three different coal mining sites of Jaintia Hills district, Meghalaya namely Dkhiah, Lad Rymbai and Bapung revealed that soils were having highest percentage of sand (60-63%) followed by silt (18-21%) and clay (17-20%). Further soils were highly acidic (pH 3.3-4.1) with medium availability of N (94.08-110.46 ppm), P (4.20-6.48 ppm), K (54.02-78.17 ppm) and organic carbon (0.21 - 0.67%). Soil pH, organic carbon and available nutrients of soils of all the coal mining sites of Jaintia Hills were lower than the soil of unmined site of the district. Soil collected from Bapung was having lowest pH (3.3) along with lowest levels of N (94.08 ppm), P (4.20 ppm), K (54.02 ppm) and organic C (0.21%) among three different coal mining sites.

4. To improve the quality of soil, the collected soils (Bapung) were treated with lime (72.9 g/pot), Farm Yard Manure (178.6 g/pot) and lime (72.9 g/pot) + Farm Yard manure (178.6 g/pot). It was found that (a) Application of lime enhanced soil pH up to 6.0; (b) Application of Farm Yard Manure increased soil pH to a level of 4.7; (c) Application of lime + Farm Yard Manure increased soil pH to a level of 6.2 and (d) Highest organic carbon (4.05%) was recorded due to application of both Farm Yard Manure and lime.

5. Application of organic matter increased the availability of nitrogen (N), phosphorous (P) and potassium (K) to the levels of 128.99, 7.17 and 97.05 ppm, respectively as compared to 118.22, 5.51 and 81.97 ppm, respectively due to application of lime. Highest availability of nutrients (139.47 ppm N, 10.15 ppm P and 111.03 ppm K) were recorded after combined application of both lime and Farm Yard Manure.

6. Three varieties of rice namely Khaw Shaw, Bhalum-1 and Bhalum-2 were used for varietal trial under different treatments i. e. lime, Farm Yard Manure and their combination. The study revealed that:

(a) The local variety (Khaw Shaw) exhibited a total duration 152 days for completing its life cycle. On the other hand both Bhalum-1 and Bhalum-2 completed their life cycles by 126 and 127 days, respectively. Treatments with lime and Farm Yard Manure reduced the number of days to attain different phenological stages of Khaw Shaw.

(b) Mean plant height attained at maturity stage for Bhalum-2 was highest (102.7 cm) followed by Bhalum-1 (100.1 cm) and Khaw Shaw (99.4 cm). Maximum plant heights observed were 104.9 cm, 105.3 cm and 107.6 cm, respectively for Khaw Shaw, Bhalum-1 and Bhalum-2 under treatment with both lime and Farm Yard Manure.

(c) Within the different rice varieties no statistically significant difference in Leaf Area Index (LAI) was found. The mean LAI recorded in case of Khaw Shaw (1.41) was higher than Bhalum-1 (1.16) and Bhalum-2 (1.39). Maximum LAI was 1.84 for Khaw Shaw under treatment with both lime and Farm Yard Manure. In case of Bhalum-1, maximum LAI recorded was 1.44 under treatment with lime. Again, Bhalum-2 showed maximum LAI of 1.61 under treatment with Farm Yard Manure.

(d) Total dry biomass produced by Khaw Shaw was 76.37 and 60.56 g/plant higher than Bhalum-1 and Bhalum-2, respectively. Again Bhalum-2 yielded 15.86 g/plant higher drybiomass than Bhalum-1. Maximum dry biomass recorded were 153.58, 74.48 and 83.37 g/plant, respectively under treatment with both lime and Farm Yard Manure.

(e) Mean number of effective tillers per plant produced by Bhalum-2 (11.87) and Bhalum-1 (11.75) were higher than number of effective tillers produced by Khaw Shaw (9.08). Maximum number of effective tillers per plant recorded were 11.3, 12.2 and 12.7, respectively for Khaw Shaw, Bhalum-1 and Bhalum-2 under treatment with both lime and Farm Yard Manure.

(f) Bhalum-2 produced significantly higher number of grains per panicle (77.58) as compared to Bhalum-1 (69.4 nos.) and Khaw Shaw (62.9 nos.).

Maximum number of grains per panicle recorded were 69.7, 81.0 and 91.0 for Khaw Shaw, Bhalum-1 and Bhalum-2, respectively under treatment with both lime and Farm Yard Manure.

(g) Grain yield of Bhalum-2 was highest (22.44 g/plant) followed by Bhalum-1 (18.41 g/plant) and Khaw Shaw (13.46 g/plant). Highest grain yields recorded were 19.59, 25.29 and 30.05 g/plant for Khaw Shaw, Bhalum-1 and Bhalum-2, respectively under treatment with both FYM and lime.

(h) Harvest Index (HI) of Bhalum-1 was higher (0.372) as compared with Bhalum-2 (0.351) and Khaw Shaw (0.098). Maximum Harvest Indices recorded were 0.13 and 0.37, respectively for Khaw Shaw and Bhalum-1 under the treatment of both FYM and lime. However, maximum HI recorded for Bhalum-1 was 0.44 under treatment with Farm Yard Manure.

(i) On the basis of the standard statistical analysis of different growth and yield parameters, the three tested rice varieties were ranked according to their performances. Three ranks viz. 1, 2 and 3 were assigned to the varieties pertaining to any given parameter depending on their recorded level in descending order of magnitude. After proper ranking of the rice varieties, it has been observed that the variety Bhalum-2 ranked first in highest number of recorded plant parameters followed by Bhalum-1 and Khaw Shaw.

From the present investigation, it can be concluded that utilization of both Farm Yard Manure (10 tonnes/ha) and lime (4.08 tonnes/ha) would improve soil fertility for cultivation of rice in highly acidic soil of coal mining areas of Jaintia Hills district, Meghalaya. Further, cultivation of the rice variety, Bhalum-2 (RCPL-1-29) would fetch higher yield as compared to traditional low yielding variety Khaw Shaw in coal mining areas.

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Appendix I

Meteorological data of Study area (Jaintia Hills) and Experimental site (Umiam) of 2005

Month	Rainfall (mm)		Evaporation (mm/day)		Maximum Temperature (^0C)		Minimum Temperature (^0C)	
	Jowai	Umiam	Jowai	Umiam	Jowai	Umiam	Jowai	Umiam
January	4.2	12.6	2.7	2.3	17.7	19.2	9.6	7.2
February	33.2	3.3	2.9	3.7	19.5	23.3	12.3	11.1
March	300.4	161.7	4.2	3.5	22.9	25.8	15.4	14.3
April	239.0	91.4	3.0	3.6	24.0	27.3	16.8	16.0
May	177.7	495.8	3.5	2.9	24.9	27.1	18.3	17.2
June	635.7	298.9	3.1	2.9	24.8	29.2	19.3	20.2
July	358.1	360.9	2.4	2.8	25.4	28.9	19.9	20.8
August	278.1	308.9	2.2	2.5	24.9	29.1	19.7	20.9
September	116.5	333.7	3.4	3.2	25.3	29.1	19.7	19.8
October	54.5	283.4	2.8	2.2	23.8	25.7	17.2	16.3
November	13.8	48.3	2.1	2.6	21.8	23.9	14.9	11.8
December	0.0	10.8	1.9	2.2	19.1	22.1	10.3	7.5

Appendix II

Meteorological data of Study area (Jaintia Hills) and Experimental site (Umiam) of 2006

Month	Rainfall (mm)		Evaporation (mm/day)		Maximum Temperature (^0C)		Minimum Temperature (^0C)	
	Jowai	Umiam	Jowai	Umiam	Jowai	Umiam	Jowai	Umiam
January	0.0	0.0	2.5	2.2	19.9	21.2	9.0	7.0
February	25.8	1.8	2.7	2.9	21.4	24.4	11.5	12.0
March	128.4	4.0	3.6	4.3	25.5	27.2	16.1	13.8
April	326.3	104.9	3.9	4.3	21.0	27.6	16.0	16.4
May	209.7	317.3	3.0	3.3	21.5	27.6	17.0	17.8
June	15.4	343.7	2.8	2.5	21.8	27.5	17.7	19.7
July	245.2	171.1	3.2	3.5	26.5	29.4	19.4	21.0
August	265.7	197.1	2.6	3.5	26.7	29.7	19.2	20.3
September	38.8	390.7	2.7	2.8	27.8	27.8	19.8	19.0
October	105.0	234.0	2.9	3.2	24.5	27.3	16.2	15.6
November	13.6	50.7	2.5	2.3	23.0	23.4	14.3	12.6
December	24.7	14.3	1.8	1.4	21.5	21.0	10.2	8.4

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