The physiological parameters like PBH, SBH, PH, PAPP and TDM were increased with the advancement of plant age while LWR, CGR and RGR decreased with the increase of plant age. The plants under irrigated conditions produced significantly better performances in all the characters tested than those of the rainfed plants except LWR, CGR and RGR. Most of the yield contributing characters were influenced by irrigation applied at two stages of growth. Primary branch height and relative growth rate were the highest as influenced by irrigation applied at one stage of growth. Some growth attributes like leaf weight ratio and crop growth rate were the highest under rainfed conditions. Correlation and path coefficient analysis revealed that plant area per plant showed the highest positive direct contribution on grain yield and it was followed by pod number per plant and seed number per plant. Stability parameters indicated that Barimasur 6 showed the highest grand mean, regression value nearly one (bi= 1.00) and stability nearly zero at most of the characters. Out of the six genotypes of lentil, Barimasur 6 gave very good grain yield under irrigated and rainfed conditions.

Abu Bakkar Siddiq

Abu Bakkar Siddiq, MPhil: Studied Botany at Rajshahi Univ, Bangladesh. Monzur Hossain, PhD: Studied Botany at Rajshahi Univ, Bangladesh. Prof of Botany, Rajshahi Univ. Rafiul Islam, Mphil, Phd: Studied Botany at Rajshahi Univ, Rajshahi, Bangladesh. Prof of Botany, Rajshahi Univ.

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GENOTYPE ENVIRONMENT INTERACTION IN LENTIL

Abu Bakkar Siddiq
Rafiul Islam
Monzur Hossain

CONTENTS

Chapter 1

Introduction

The development of science and technology has reached human civilization at the golden top of development. Without the touch of the science and technology the modern world cannot run for a moment. The modern world means a great mysterious island of science and technology. Science has made human civilization like divine. The basic requirements of people as food, cloth, shelter and medicine are rapidly increasing day by day. The research of science and technology has been possible to complete this basic demand of human beings. To maintain the continuous supply of these basic requirements to the mankind various techniques are evolved in numerous research institutes, laboratories and organization throughout the world. Researches in plant, science play an important role in this respect. The modern effectiveness of the research has been experimented on plants in every country of the world, which have saved the world from the face of destruction. For this reason, people have gained superiority from the world to world.

1.1. General Account

Pulses, called the "protein particles" are the important source of protein nutrition for the people of Bangladesh (Mian 1976). But unfortunately, Bangladesh has been facing an acute shortage of pulses for the last several decades. Present consumption is about 1.00 million tons against the production of about 0.54 million tons. Import is about 0.44 million tons. The annual requirement will be about 2.50 million tons considering 45 g per capita per day consumption. To meet the annual requirements of pulses and to reduce import, it is necessary to give immediate attention to increase the pulses productivity (Bakr *et al.*, 2007).

Lentil plays an important role in the agro-economy and national health of Bangladesh. Nutritionally, lentil supplies about four times as much protein and eight times as much riboflavin as does rice, the calorie value of it is equal to rice (Anonymous, 1966). Erskine and Witcombe (1984) after analyzing 1985 germplasm lines reported a mean seed protein content of 25.78%. As a legume crop lentil has the ability to improve soil health. Bangladesh soils are generally poor in nitrogen and carbon content. The

incorporation of any pulse crop such as lentil in the cropping pattern of such soils is essential to maintain an equilibrium when the nitrogen fixed through rhizobia and the organic matter deposited through crop residues. Not only are the carbon and nitrogen essential for optimum crop growth, they can also useful to maintain the microflora population in the soil.

In spite of the importance of lentil as an important pulse crop, little attention has been paid to improve yield potential of this crop. Moreover, the crop has faced tough competition in the recent past from cereals, particularly wheat and boro rice because of high yielding varieties now available to the farmers. There has been as tremendous diversion of land from winter pulses to wheat/boro rice. The low yield potential of the existing pulses varieties with unstable yield is one of the important reasons for poor production level of lentil. Therefore, there is a need to increase productivity of lentil so that it becomes remunerative to the farmers.

Pulses are excellent sources of protein, but they are treated as minor crops and receive little attention from farmers and policymakers. With the expansion of irrigation facilities, the area of production of cereal crops has increased significantly, while pulses have been pushed to marginal lands of low productivity. In 1988 the GOB approved the Crop Diversification Perfect, of which pulses were a major component. In 1996-97, the government also approved the lentil, blackgram and mungbean Development Pilot Project (Khatun, 1997).

For the last three decades different organizations under NARS have developed a number of modern varieties and technologies for improving the pulse crops. Breeders, agronomist and other scientists have taken a challenge for increasing yield and expanding area of pulse crops. Now we have to increase and strong the research-extension-farmers linkage to transfer the technology at root level. Crop improvement is never ending activity and this is well recognized by researchers in Bangladesh. These achievements need to be supplemented by new traits and variability. Developments in biological sciences provide new tools for creating and utilizing genetic variability that plant breeders may adopt to bring about improvement in the productivity of pulse crops. Scientists of different national and international institutions engaged in pulse research will present their findings in the workshop. Their presentation and sharing knowledge

will make a treasure of information that will help to do future of work for the improvement and stabilizing pulse production in Bangladesh and stimulate further research.

The stable production of lentil and chickpea, and increased area and production of mungbean has largely been considered due to the extensive activities of lentil, black gram and mungbean Development Pilot Project and of the ACIAR financed Integrated Management of Botrytis Grey Mould of chickpea in Bangladesh and Australia project. These projects made a head way in expanding area and increasing yield of these important pulses during the past several years through a concerted effort of BARI, DAE, BSMRAU, BADC and BINA. Following the precedence of these projects further research and development activity may be planned for up scaling of pulses in Bangladesh.

1.2. Origin and history

Research on lentil was initiated during the early 1950s where efforts were confined to the collection and evaluation of local germplasm (Gowda and Kaul, 1982). A few lines were tested over locations during the early 1960s, but the research virtually stopped, as germplasm was not properly maintained. To halt steady decline and to attain self-sufficiency in pulses production, an intensive research effort was launched at the BARI in 1979 under a research grant project of the International Development Research Center (IDRC), Canada. Eventually the pulses improvement programme transformed into a Pulses Research Center (PRC), in mid eighties with its 4-5 testing stations at major pulses-growing zones of the country (Afzal *et al.,* 2003).

Pulses Research Center, BARI has been working to improve lentil through conventional breeding approaches. Strategies were adapted to develop high yielding lentil varieties, within a short span of time, through introduction from exotic sources, particularly from ICARDA. Top properties were given to the collection of local and exotic germplasm, to their evaluation under Bangladesh conditions, and to the selection of desirable ones. Simultaneously, attempts were initiated to improve production packages, including pest and disease management, agronomic and cultural management also received due emphasis.

Informal collaboration between BARI and ICARDA started in the early 1980s. As started earlier, ICARDA has been collaborating with the Pulses Research Center in supplying improved genetic materials, segregating populations, sources of quality traits and resistance to various stresses. The major containts to lentil improvement were lack of genetic variability in traits of importance in local germplasm (Afzal *et al.,* 2003).

To date, PRC, BARI have received more than 2000 germplasm accessions and breeding lines, with specific valuable traits, including biotic and abiotic stress resistance from ICARDA. Only limited success was achieved, however, in selecting or developing promising genotypes through direct introduction. The breeding strategy was revised to include hybridization, and ICARDA was requested to make crosses for PRC, BARI using landraces (Afzal *et al.*, 2003).

During last two decades, the pulse scientists have collected and evaluated about 500 indigenous and more than 2000 exotic germplasm. The first local collection mission was conducted in 1981 in collaboration with the University of Southamton, UK, where collection was done from the lentil growing Northwestern region of Bangladesh (greater Kustia, Jessore, Faridpur, Khulna and Pabna districts). The second expedition was organized under CIDA grant in 1993 to collect indigenous germplasm from Rajshahi, Bogra, Dinajpur and Rangpur districts and 83 accessions were collected. In 1994, under the same grant, lentil germplasm was collected from saline-prone southern districts (Barishal, Noakhali, Chittagong and Comilla) and a total of 166 accessions were added with the earlier collection. The Genetic Resources Unit of ICARDA made another expedition in 1997 to collect lentil germplasm from Tangail, Manikgonj, Jamalpur and Gajipur districts and 62 accessions were collected. Under the material transfer agreement, ICARDA supplied early maturing germplasm of various origins. About 2045 germplasm and breeding lines have been maintained at BARI Genetic Resources Center.

Lentil (*Lens culinaris* Medic.) as a crop is known to be used by the ancient lake dwellers and is thought to be one of the earliest domesticated crops (Zohary and Hopf, 1973; Cubero, 1981). The lentil was grown from early times throughout the eastern Mediterranean region as well as in the Nile valley. Now a days, it is cultivated throughout the world (Aykroyd and Doughly, 1964). The mountainous region between Hindukush and the Himalayas was first suggested as the center of origin but evidence

acquired later supports the Near Estern origin, (Zohary, 1972; Cubero, 1984) in a detailed review, concluded that the region between Western Turkey and Kurdistan could be its places of origin. Earliest Neolithic farming village of the Near-East about 7000-8500 years B.C. (Cubero, 1981). It is now one of the important pulse crops in the south Asian countries being used as "Dhal" by majority of people in Bangladesh.

Lentil is supposed to have originated in Southern Turkey (Ladizinsky, 1979). It spread quickly to Greece, Central and Southern Europe, Egypt, Ethiopia, Mediterranean, Afghanistan, Indian sub continent, China and the new World including Latin America (Cubero, 1981; Duke, 1981; Ladizinsky, 1979). It is probably the oldest of grain legume domesticated (Bahl *et al.* 1993). It is now cultivated in most subtropical and also in the Northern hemisphere such as Canada and Pacific North West regions. It is now also cultivated in Argentina, Canada, Chile, Colombia, Mexico, Peru, Syria and USA.

Barimasur 1 is the first improved lentil variety in Bangladesh. Germplasms of pulse crops were collected from different pulse producing region and foreign countries since 1979. The production capability, adaptability, disease resistance power, insect infestation and life duration of those germplasms either cultivable to present cropping pattern or not is evaluated. Some traits were invented by selecting single plant from some germplasms. In that way, the variety Utfala was invented by selecting single plant from that germplasm collected from Pabna region. It was evolved as more high yielding variety in different advanced and more regional test of different places of the country for several years. Considering the productivity, adaptability, disease resistance power, insect infestation and life duration, it was approved as Barimasur 1 by National Seed Board (NSB) in 1991 as the variety was considered as better than local variety. The National accession number of Barimasur 1 is BLL-79694 (Afzal *et al*., 1997, 1999 and 2003).

Twenty nine F-3 population were brought in Pulses Research Center (PRC) Ishurdi, Pabna to test from ICARDA, Syria in 1984. Primarily, ninety (90) single plants were selected. Considering the productivity, adaptability, disease resistance power, insect infestation and life duration, 51 lines were selected in the next. Selected lines were evaluated by primary, advanced and multi-spacious experiment in different pulse producing region of the country. The yield of the line ILX 113-55 was considered as satisfactory after multi-spacious examination for five years. Since the variety was

considered as more productive than local and Utfala one, it was approved as Barimasur 2 by National Seed Board (NSB) in 1993 (Afzal *et al*., 1997, 1999 and 2003).

Barimasur 3 is a high yielding variety evolved in Bangladesh in 1996. It is the most popular modern variety and increasing its area day by day. Barimasu 3 was developed through single plant selection from progenies of a cross between BLL 79666 (India) and Pabna local variety in 1985. Selected lines were evaluated by primary, advanced and multi-spacious experiment in different pulse producing region of the country. The yield of the line BLX 8405 – 46 was considered as satisfactory after multi-spacious examination for five years. Since the variety was considered as more productive than local and Utfala one, it was approved as Barimasur 3 by National Seed Board (NSB) in 1996 (Afzal *et al.,* 1997, 1999 and 2003).

Barimasur 4 is a high yielding variety evolved in Bangladesh in 1996. Originally the variety was developed in ICARDA through single plant selection from progenies of a cross between ILL-7888 and ILL-5782 made at ICARDA, Syria specifically for Bangladesh in 1985. Obtained F-3 population was tested in the soil and weather of Bangladesh, from Syria in 1987. Primarily, 51 single plants were selected. Considering the productivity, adaptability, disease resistance power, insect infestation and life duration, eight (8) lines were selected in the next. Selected lines were evaluated by primary, advanced and multi-spacious experiment in different pulse producing region of the country. The yield of the line ILX 872-47 was considered as satisfactory after multi-spacious examination. Since the variety was considered as more productive than local and Utfala one, it was approved as Barimasur 4 by National Seed Board (NSB) in 1993 (Afzal *et al,.* 1997, 1999 and 2003).

Barimasur 5 was evolved in Bangladesh in 2006. It was developed through single plant selection from progenies of a cross between ILL-2501 (India) and ILL-7616 (ICARDA) in 1995. Obtained F-3 population was tasted in the soil and weather of Bangladesh, from Syria in 1999. Primarily 60 single plants were selected. Next, 51 lines were selected and evaluated by primary, advanced and multi-spacious experiment in different pulse producing region of the country. The yield of the line SX 136-95 was considered as satisfactory and it was approved as Barimasur 5 by National Seed Board (NSB) in 2006 (Uddin *et al.,* 2007).

Barimasur 6 was evolved in Bangladesh in 2006. It was developed through single plant selection from progenies of a cross between ILL-7667 (advanced line) and EDOLIB-1 (ICADRA) in 1997. Obtained F-3 was tasted in the soil and weather of Bangladesh, from Syria in 2000. Primarily, 58 single plants were selected. After 11 lines were selected and evaluated by primary, advanced and multi-spacious experiment in different pulse producing region of the country. The yield of the line SX 167-95 was considered as satisfactory and it was approved as Barimasur 6 by National Seed Board (NSB) in 2006 (Afzal *et al*., 2007).

Five hundred and eighteen lentil germplasm lines originating from as many as 21 countries are included for studies. They all, except some Bangladesh one, were received through the office of the International Center for Agricultural Research in the Dry Area (ICARDA), Syria. Most of the lines are of Indian origin. Of the 27 Bangladesh lines, 9 already belonged to ICARDA assossins, and the rest 18 collected locally in Bangladesh, 12 from BINA's regional station at Ishurdi, Pabna; 5 from Jessore and one from Mymensingh (Rasul, 1988).

1.3. Botanical Aspects

Lentil is diploid in nature, cytologically containing seven (7) pairs of chromosomes (2n=14). Lentil belongs to the family Fabaceae (Leguminosae), sub family Papilionaseae and tribe Vicieae (Barulina, 1980). Previously, lentil was included in the genus *Ervum*. Medikus suggested the botanical name *Lens culinaris* for lentil in 1787. Monench called it *Lens esculentus* in 1798. Both the nomenclature can be found in the literature but the name given by Medikus is now internationally accepted and approved.

The plant is erect, herb with much branched, square stems and annual grass in nature. It grows quickly, plant height ranges from 38-50 cm, flowers in 6-7 weeks after planting and mature within 3-4 months. It has a slender tap root and a mass of fibrous lateral roots with very small, round or elongated nodules.

Leaves size is medium with dark green color, short petiole and rachis that ending in a short tendrils. The alternate, pinnate leaves have up to seven pairs of narrow leaflets and terminal bristle or tendril. They are subtended by upward pointing, linear stipules, but

there are no stipules. Each sessile leaflet is oval and about 12 mm long. The pairs of leaflets are not always opposite.

The flowers are small and consist of five sepals, five petals consisting of one standard, two keels and two wings. It tinged with purple, occur in groups of 2-3 at the ends of long and very slender peduncles. Lentil plants flower the bottom of the plant and the flowering progress is upward. The flowers range in color from white to pale blue.

Lentil (English) is called by different names in different countries of the world, i.e Adas (Arabic), Mercimek Messer (Ethiopia), Heramane (Japanese), Lentil (*Lens culinaris* Medic.) Turkey and Masur (Bangladesh).

1.4. The Performance of Agricultural Production in Bangladesh

Bangladesh is a land of fertile and well known agricultural country of the world. Agriculture is a major sector and it contributes 25% to GDP of Bangladesh economy. Agriculture is the major source of livelihood in the rural areas where over 78% of the population lives. Approximately two-thirds of the labour force is employed in agriculture. The food crops (mainly rice and wheat) play a dominant role representing about 72% of the value added in agriculture. Agricultural activities are carried out in increasingly fragmented and smaller holdings (BARI, 2001).

The strategy for increasing cereal production over the years has emphasized the adoption of a package programme of "seed-water-fertilizer-insecticide" technology, widely known as the 'green revolution' for rapid transformation of the crop sector. Although substantial emphasis was put on the cereals, the available evidence (Clay and Khan, 1977: Morshed, 1983: Parthasarathy and Chowdhury, 1989) suggests only moderate growth rates in food grain production at different time periods. The production performance of the cereals is sometimes used as or not, however, be a good indicator because a number of studies (Hossain, 1980: Morshed, 1983) observed that inspite of moderate growth in cereal production, the over all crops output is recent years in marked (Hossain, 1991).

Wheat is the second major cereal crop in Bangladesh. The yield of wheat is very low in Bangladesh in comparison to other wheat growing countries of the world. In

Bangladesh the average yield is only 1930 kg/hectare: which is even lower than the world average (FAO, 1987). The production of wheat in 2006 was one million metric tons but requirement was 3.0-3.51 million metric tons and consumption is increasing at 3% per year (Sufian, 2005). About 844145 metric tons of wheat grain was produced in the year of 2007-2008 in Bangladesh (BBS, 2008). The modern varieties of wheat do not give satisfactory yield in this non-irrigated land. As a matter of fact total production is decreased severely (Haque, 1993).

Lentil is one of the oldest and popular food legumes in Bangladesh. It is the second most important pulse crop in area and production, but stands first in the consumers preference in this country (BARI, 2007). Due to adoption of improved varieties combined with appropriate production technologies, average global productivity has increased from 611 kg/hac to 1007 kg/hac and total production from 1.3 million tones to 4.06 million tones in last three decades (Bakr *et al.*, 2007). The production of lentil in 2004 was 752 kg/hac (FAO, 2004). BARI (2003) to incorporate resistance to major stress and to enhance earliness and yield potential in lentil, which provide an approximately 15%-20% yield advance. To date, a total of nine varieties have been developed in Bangladesh of which six by BARI and three by BINA and they are being cultivated by farmers. About 72 metric tons of lentil grain was produced in the year 2007–2008 in Bangladesh (BBS, 2008).

BINA has released/registered 39 mutant varieties of different crops. Of which, 16 varieties are pulse crops, out of these, seven mungbean, three lentil, four chickpea, one blackgram and one grass pea varieties. For mungbean most of the varieties are high yielding, synchronous in pod maturity and tolerant to major diseases (Bakr *et al.,* 2007).

Oilseed is being cultivated in Bangladesh since long but the present production is not sufficient enough to extract oil profitably. Almost every year produce about 480 thousand metric tons of oilseeds. Average per hectare yield in only 700 kg, which is very low as compared to other oilseeds growing countries of the world. In 2006 –2007 Bangladesh produced 701 metric tons oil seed (BBS, 2008).

The principle agricultural production crop of Bangladesh is rice. It is the staple food of Bangladeshis. About 28931 metric tons of rice was produced in the year of 2007–2008 in Bangladesh (BBS, 2008).

The total production of crops in 2007–2008, Jute 839 metric tons, Sugarcane 4984 metric tons, Tea 128 metric tons, Oil seed 701 metric tons, Tobacco 40 metric tons, Maize 13216 metric tons, Barley 1.00 metric tons, Moungbean 21 metric tons, Gram 7.0 metric tons, Lentil 72 metric tons, Arhar 1.0 metric tons and other pulses 83 metric tons (BBS, 2008).

Bangladesh is one of the "pulses-development" countries, where it's people rely on pulses for their nutritional security in rice-pulses' daily diet . In the recent year the total production of the lines have been identified as promising which might give 10% -12% higher seed yield than the released varieties with resistance or tolerance to different biotic and abiotic factors in Bangladesh (Bakr *et al.*, 2007).

1.5. Cropping Patterns in Bangladesh

Bangladesh is well known monsoon seasonal country of the world. Different kinds of crops grow well here. But the crop yield depends on a number of factors such a climate (rainfall, temperature, solar radiation and flooding), topography of soil, soil structure, fertility and other socio-economic conditions. The crops in this country are grown throughout the year in three distinct growing seasons; the first kharif season (K1) lasting from the end of March to May, hot with moderate humidity, the second kharif season (K 2) hot and humid with monsoon rain from May to September and the Rabi season (R) lasting from October to early March which is a cool and dry winter period.

The farmers through their experience and knowledge, cultivate crops in each season selected mostly on the basis of soil-plant-water condition of the place concerned. Flood depth and duration, fragmentation of land prevailing system of share cropping availability of capital, labour and renting of land influence the farmers to arrange various cropping patterns to suit their needs. They prefer the patterns which involve fewer risks and offer the best economic returns for investment.

The people of Bangladesh now a days have become accustomed to lentil as a substitute of fish and meat. The advantage of lentil is that it required less water than rice, wheat, maize and barley and it traditionally grown during the dry winter months (rabi season) on residual soil moisture under rainfed conditions. Lentil faces serious competition with boro rice, wheat, barley, maize, potatoes, pea, kalai, redish, brinjal, oilseeds and other profitable winter crops, particularly where irrigation is available. As a result, the crop has been pushed to marginal and sub-marginal lands (Afzal *et al.,* 2003).

Rice is the major crop of Bangladesh and is grown extensively throughout the country over the years. Hence, all the major cropping patterns are rice based. A wide variety of cropping patterns are followed in different agro-ecological zones of Bangladesh depending on land characteristics and soils moisture regimes.

Ahmed *et al.* (1987) conducted an experiment on mixed cropping of wheat and lentil under variable seedling ratios. The most compatible, promising and economically profitable seeding ratios for wheat and lentil were found to be 100:50 and 50:100. Rahman and Shamsuddin (1981) conducted an experiment on intercropping of lentil and wheat and obtained on the highest total productivity, land equivalent ratio (LER) and net return when 30% of wheat seed rate was sown in between lentil rows spaced 30 cm apart.

Lentil is grown both as a mixed crop and as pure culture. The practice of mixed cropping and intercropping of lentil with crops such as wheat, mustard, linseed and sugarcane is being followed in some parts of the country. This practice seems to have developed as an insurance against complete crop failure and is characteristics of subsistence farming. For Bangladesh there are nine base cropping practices as recognized by Hossain 1991 **(Table 1).**

Table 1: Cropping practices in Bangladesh.

Kharif-1	Kharif-2	Rabi
1. Rice / Jute	Fallow	Rabi crops
2. Rice / Jute	Rice	Fallow
3. Rice / Jute	Rice	Rabi crops
4. Fallow	Rice	Fallow
5. Mixed Rice	.. .. ..	Rabi crops
6. Rice (Boro Aman)	Fallow	Rice (Boro)
7. Rice (Boro Aman)	Fallow	
8. Rice (Boro Aman)	Rice (T. Aman)	
9. Mixed Aus Rice and other kharif crops. (Jhum cultivation)	Rice (T. Aman)	

1. Broad cast Aus-Fallow-Lentil

Areas of Kustia, Rajbari, Magura and Jessore districts are medium hight topography lands with sandy-loamy soil. Sometimes, lentil is grown as mixed crop with mustard, wheat, linseed. Lentil varieties, Barimasur 2, Barimasur 3 and Barimasur 4 are being cultivated in these areas.

2. Jute-Fallow-Lentil

In medium low topography areas of Pabna, Kustia and Natore where C*orchorus capsularis* jute is grown in water stagnated condition in rainy season. Lentil is grown after receding flood water in clay-loam soil. Barimasur 2 is better adapted here.

3. Broad cast Amon rice (long season) -Lentil-Fallow

Lentil is grown in low-lying areas of Faridpur, Kustia, Rajbari, Pabna and Natore districts in heavy clay soil. Barimasur 4 an improved variety is better adapted in these areas.

4. T. Amon rice-Lentil-Jute/Upland rice

In medium topography areas of Jessore, Chauadanga, Magura, Meherpur, Kustia and Rajshahi districts in sandy-loam soil.

5. Tussa Aman rice-Lentil+Mustard

In some areas like Faridpur, Madaripur, Shariatpur, Pabna, after harvesting T. aman, relay and mixed crop of lentil with khesari, mustard, chickpea and linseed are normally grown. In this practice, the yield of lentil can be increased by growing suitable varieties of Barimasur 4 an improved variety (Wahhab *et al*. 2002).

6. Jute-Chickpea/Lentil/Wheat/Aus/Jute

Pabna, Rajshahi, Jessose, Faridpur and Kustia districts after harvesting *Chorchorus capsularis* jute, relay and mixed crop of lentil with chickpea and wheat are normally grown.

The present analysis clearly suggest more attention is needed on a diversified cropping system during the dry Rabi season than boro rice. The study emphasizes the need giving a greater impetus to the growth of wheat, maize, barley, pulses, vegetable and species to reduce irrigation dependence. Obviously, boro rice should be grown where easily managed irrigation is available.

1.6. Environment and Agriculture of Bangladesh

Environmental issues may have local, national and global ramifications, but in all cases they indicate significant concerns about the sustainability of economic means of agricultural production and the welfare of human kind. Here, the most critical question is how to sustaineconomic growth and development, while preventing degradation of soil, water and other natural resources. This is a process which requires research and understanding of the system and adaptations with local conditions (Pretty, 1995).

The need for environment protection derives in part from the strong interdependence between high levels of agricultural output and the natural means of production. The protection of natural resources is now considered critical for agriculture. In particular, sustaining agricultural production depends on maintaining the quality of water, soil, air and biodiversity. The interdependence is greatly magnified when land is scarce and the pressure on land is high, as in case of many Asian countries like Bangladesh (Karim *et al*., 1997).

Lentil grows well on slightly acidic soils pH 5.5- 6.5 to moderately alkaline soils pH 7.5- 9.0 (Kay, 1979). It grows well in 16^0C–28^0C temperature. The temperature of 15^0C- 20^0C is the best for germination of lentil (Afzal *et al*., 1999). Good yields of lentils have been obtained on soils ranging from heavy clay to loamy sands. Moderately

deep “black cotton soils” are very good for lentil cultivation because of their good retention of moisture although they are not of high fertility (Afzal *et al.,* 2003).

Groundnut requires comparatively high temperature and high moisture condition for normal growth and development. The temperature for normal growth and development lies between 25^0C and 30^0C, but temperature below 20^0C restricts development and above 35^0C adversely affect flower production. At the early stage, the crop faces low temperature. As a result growth of plants becomes very slow. Nevertheless, the crop requires long growing period. In some high land areas groundnut is also grown during summer season, especially for seed production purposes, to meet the shortage of seed and particularly to avoid low viability of seeds over longer time storage (Wahhab *et al*., 2002).

It is reported that optimum temperature range for soybean cultivation is 30^0C-32^0C. Temperature below 15^0C – 20^0C adversely affect flower development, but it has little effect it seed is formed. Required day length is 12 - 16 hours. It is observed that the variety which matures earlier, need longer day length. Water requirement is 5-6 acre inch (Wahhab *et al.,* 2002).

Chickpea grows well in 25^0C-30^0C temperature. The temperature of 28^0C - 31^0C is the best for germination of chickpea. The best growth of chickpea occurs above 20^0C temperature (Afzal *et al*., 2008).

It is learnt that sunflower has heat and light tolerant ability to some extent. However, the optimum range of temperature is 20^0C - 30^0C. Temperature more than 25^0C and less than 16^0C at flowering stage reduces seed yield and oil content in the seed. Water requirement is 6-12 acre inch. In Bangladesh, the best growing season is winter (Rabi season) to avoid natural calamities (Wahhab *et al.,* 2002).

Under ideal field condition wheat yield is unlikely to increase by more than about 10% for a doubled current CO_2 concentration and 5% - 7% increase is more realistic (Pinter *et al.,* 1996).

Mustard requires cool temperature during growing season. The winter in Bangladesh is not very long; temperature starts rising from the month of February. So, mustard harvesting should be completed by middle of February; otherwise the crop faces high

temperature and yield become low. The best growth of mustard occurs above 12^0C and below 25^0C. The optimum temperature for maximum growth and development has been estimated at just over 20^0C and minimum temperature is 5^0C. So, Bangladesh weather allows very short sowing period for mustard (Wahhab *et al.,* 2002).

Sesame requires fairly hot conditions to produce maximum yield and does well in temperature of 25^0C - 27^0C. If temperature falls bellow 20^0C for any length of time, germination of seed and seedling growth will be delayed (Wahhab *et al.,* 2002).

Temperatures above 32^0C reduce rice yield due to spikelet sterility; 5% reduction in yield per 0^0C rise for temperature above 32^0C is suggested (Mitchell, 1996).

Mungbean requires comparatively high temperature and high moisture condition for normal growth and development. The temperature for normal growth and development lies between 25^0C-30^0C, but temperature below 20^0C restricts development. The temperature of 28^0C- 31^0C is the best for germination of mungbean (Wahhab *et al.,* 2002).

Recurrent and regular drought is one major constraints that reduce yield in cereal and other crops in many parts of Bangladesh especially the northern region. Drought has been defined as a period without rain of sufficient duration to cause injury to plants. Agricultural drought is an insufficient supply of moisture from precipitation, irrigation or soil moisture stress for maximum plant growth and yield (Mather, 1968).

Pulse crops are mostly grown in the tropics and sub-tropics. Except low temperature, most of the environmental stress are prevailing in these regions. Drought is a major problem in rainfed agriculture and pulses are mostly grown under such conditions. Opposite to drought, the summer rains or occasional heavy rains create anoxia/hypoxia for pulses. Another concern in agriculture is the increasing of saline areas at an increasing rate. High temperature also limits pulse production during summer season (Bakr *et al.*, 2007).

Pulse crops are damaged by a large number of insect pests. To date, 36 species of insect pests have been recorded on five major and three minor pulse crops in Bangladesh. Among these insect pests, 14 insects are most damaging in the field and two in the store. Most of the pests are external feeders and few of them are internal feeders. Scientists of

BARI have developed some easy, suitable and profitable technologies against the major insect (BARI, 2007).

In Bangladesh 20 diseases of mungbean and 23 diseases of blackgram have been reported and 14 virus diseases have been recorded in eight different pulse crops. Future research strategies to control virus diseases of pulses are discussed in the review (Bakr *et al.*, 2007).

Salt affected pulse plants face concerted effects of water stress and not Na^+ toxicity. The tolerant genotypes maintain higher plant water and K^+/ Na^+ ratio than the salt susceptible ones. Under high temperature conditions the pollen viability becomes the major determinant factor for pod formation. Though the stress tolerance mechanisms of plants are well clarified, little progress has so for been made to develop a stress tolerant variety. This is because, stress tolerance is mostly controlled by multiple genes instead of single gene, and there is a lack of fruitful co-ordination between the concerned physiologists and plant breeders. Screening of tolerant genotypes against environmental stresses is still, therefore, remained the most practical way of increasing crop production under such conditions (Bakr *et al.*, 2007).

Although Bangladesh is not under the arid or semi-arid environment, drought invariably occurs almost every year with varying degree of severity (Brammer, 1994). Infact, the entire South Asia suffers from famines that are preceded by drought (Ghosh, 1982) leading to crop failure. The 1972-73 drought was labeled as "the worst in recent history" while those of 1978-79 and 1979-80 were doubled as the worst in lining memory in Bangladesh (Morshed, 1987). This indicates that drought is one of the prime factors that severely reducs the crop production. Drought, therefore, is responsible for a much higher economic loss than normally indicated by only loss on yield (Fischer *et al.,* 1983).

Bangladesh includes a wide range of agriculture environments, altogether 30 agro-ecological zones (Brammer, 1994) naturally providing a range of opportunities and limitations to agricultural development (Mahtab and karim, 1992). Environmental diversity is evident not only at national and regional levels but also at the local and village levels. The small scale complexity of soils and of hydrology is a characteristics of the flood plains of Bangladesh pointing to a diversified cropping system.

1.7. Land Utilization

The position of Bangladesh is 90th according to the area and the first on the density of population in the World. The quantity of land is very little according to the demand of population in Bangladesh. The area of Bangladesh is 1,47,570 squares kilometer. The total land of Bangladesh is 366.69 lac acre. Uncultivable area 88.35 lac acre, cultivable waste land 6.34 lac acre and current fallow area 15014 lac acre. Net cultivable land 192.66 lac acre, where the amount of single cropped land 70.27 lac acre, double cropped area 98.22 lac acre and triple cropped land 24.17 lac acre (BBS, 2008). Due to decreasing of land and increasing of population, the amount of land per head is being decreased.

Rice is the staple food of Bangladesh. Among the cultivable lands, rice cultivation for 261.30 lac acre that is around 70% of total cropped area (BBS, 2008). Moreover, modern rice varieties have been grown in large areas since 1972-1973 at the expense of other crops which are losing the ground gradually (BBS, 2000). Even without systematic adoption of HYV rice culture and extensive use of ground water, fertilizers and pesticides productivity of cultivable land had been decreasing (Andel Vander *et al.,* 1994).

Wheat is a grass that is cultivated world wide. Globally, wheat is the most important human food grain and ranks the second in total area and production as a cereal crop (FAOSTAT, 2006). About 50 countries of the world, wheat is regarded as the staple food. The statistical reports indicate that the irrigated area for wheat cultivation was 2,7236 hectare in Bangladesh in 1992-93 (BBS, 1994). At present, the total area for wheat cultivation was 3,8799.84 hectare in 2007–2008 (BBS, 2008).

Forest play an important role in the economical side of Bangladesh. The total forest areas of Bangladesh are covered about 2599190.28 hectare of total area. Among the total forest 3.8% Sunderban, 9.05% hill forest, 5.02% shal forest and 0.82% rural forest (BBS, 2008)

The total cultivable land of the world are utilized with irrigated and rainfed conditions. Some of 0.3 million hectare of land in New Zealand (Diprose, 1980), about three-fourth of the entire Argentina (Mockel, 1980) most of the part of Australia (Mc William, 1980), about 177 million hectare of land in India (Singh and Raj, 1980) and about 70% cultivable land of Bangladesh in Robi season (BBS, 1999) are under dry land rainfed forming.

Lentil is the second most important pulse crop in area and production of Bangladesh (BARI, 2003). Cultivation of lentil is mainly concentrated within gangetic flood plains in the northern and southern districts in Bangladesh (BARI, 2007). Lentil was grown in India 1390 hectare, Nepal 182 hectare, Pakistan 46 hectare, China 90 hectare, Australia 128 hectare and Bangladesh 154 hectare (FAO, 2004). Lentil was cultivated 1,70,000 acre area of Bangladesh in 2007-2008 (BBS, 2008).

Out of the total cropped land, Jute 440890.69 hectare, sugarcane 129554.66 hectare, Tea 59514.17 hectare, Tobacco 30769.23 hectare, Maize 223886.64 hectare, Barley 68825.91 hectare, Moungbean 24291.50 hectare, Gram 9311.74 hectare, Mashkkalai 23886.64 hectare, Arhar 1214.58 hectare and oil seed 353846.15 hectare used for cultivation (BBS, 2008).

Among the total land 77% used for urban and rural settlement, market places, roads, canals and water bodies. The hill area of Bangladesh cover about 12% of the total area and 8% are flood plain area. The remaining 80% nearly 6.00 million hectare are subjected to flooding annually and the flooding depth ranges from 30 cm to more than 2 meters.

Almost all available of arable land has long been under cultivation. The land of human ratio will decline more rapidly though the passage of time with the further increased population rapid.

1.8. Uses and Nutritional composition

Pulse is the most important nutritious food of the modern human civilization. Every country of the world is very suitable place for the growth of pulse. Lentil is the first ranks in total production as a pulse crop. It contains more protein material than any other vegetable products. Protein is the basis of life. For balanced diet optimum content is very much essential in people daily food with other components. It is the main component of different organ of human body. It is more easily digestible than animal flesh. Pulse is the cheapest source of protein. It contains adequate quantity of protein. In pulse particularly lentil is called the meat of poor in this country.

Lentil is not only rich in protein but also carbohydrates, fats, fiber, ash, vitamin B, vitamin C and minerals are also present. From the nutritional point of view it is superior and rich in all respects except for niacin. The seed of lentil contains about 25% protein, 55.8% carbohydrate, 11.2% water, 10% fat, 3.7% fiber, 3.3% ash, vitamin B and C, calories, calcium, phosphorous and iron (BARI, 2002).

Domestic pulse production satisfies less than half of the country's needs. The rest, some 140000 tones, is imported at a cost of about US 32.2 million per annum (MOA, 2002). The resulting high prices have led to wide spread protein malnutrition especially among vulnerable groups such as rural children aged. Bangladesh consume about 10.5 g per day recommended by FAO/WHO (Islam and Ali, 2002). Meat production, including fish, has declined consistently in recent years, so animal sources of protein are also priced beyond the reach of the poor.

Lentil is nutritionally superior to most other food in many ways in value. Lentil compares very well in nutritive value with fish and meat. It is high in protein, carbohydrate, fat, fiber, ash and iron.

Table 2 : Nutritional value of Barimasur.

Variety	Protein %	Carbohydrate %
Barimasur 1	27.88	48.10
Barimasur 2	28.31	46.50
Barimasur 3	25.50	59.60
Barimasur 4	25.80	59.80
Barimasur 5	26.00	58.80
Barimasur 6	26.00	59.90

Source: Afzal *et al.,* 2003 and 2007; Uddin *et al.,* 2007.

Thousands of children die every year in our country because of malnutrition. Children up to five years of age are nutritionally vulnerable section of the society who are likely to suffer most due to protein deficiency. The protein calorie malnutrition become established as a cause of intellectual dwarfism in a nation.

Table 3: Amount of pulse intake (gram per capita per day) by different age groups in Bangladesh.

Age group	Year	Pulses (g)
Children	1 – 3	1.71
	4 – 6	4.00
	7 – 9	4.99
Adolescent	10 – 12	4.98
	13 – 15	7.50
	16 – 19	6.13
Adults	20 – 39	7.02
	40 – 49	5.83
	50 – 59	7.97
Adults	60 – 69	9.98
	70 – above	10.8
Pregnant		5.14
Lactating		4.93
Average		6.31

Source : INFS. University of Dhaka, Bangladesh, 2000.

Protein of pulses are commonly known as vegetables proteins. Vegetable protein appears to be superior to animal protein. It also contains more protein of weight basis than eggs, meat and fish. Protein is the main component of brain, blood, bone, muscle and skin. Pulses are also a good source of vitamin B (except riboflavin), vitamin C and fair amount of minerals. The nutrition values are shown in **Table 4.**

Table 4 : Nutritive value of different pulses with other proteinacious food.

Food staff	Energy (k. cal)	Protein (g)	Fat (g)	Carbohy (mg)	Calcium (mg)	Iron (mg)	Thiamin (mg)	Riboflavin (G)	B-Carotene
Lentil	347.00	24.50	1.40	59.60	154.00	9.10	0.42	0.37	38.00
Blackgram	343.00	25.10	0.60	59.00	69.00	4.80	0.45	0.49	270.00
Mungbean	348.00	24.50	1.20	59.90	75.00	8.50	0.72	0.15	49.00
Chickpea	372.00	20.80	5.60	59.80	56.00	9.10	0.48	0.18	129.00
Grasspea	345.00	28.20	0.60	56.60	90.00	6.30	0.39	0.41	120.00
Rice	356.00	6.40	0.40	79.00	9.00	4.00	0.21	0.09	-
Wheat flour	341.00	12.10	1.70	69.40	48.00	11.50	0.49	0.29	29.00
Wheat	348.00	11.00	0.90	73.90	23.00	2.50	0.12	0.70	25.00
Soybean	432.00	43.20	19.50	20.90	240.00	11.50	0.73	0.76	426.00
Groundnut	567.00	25.30	40.90	26.10	90.00	2.80	0.45	0.13	37.00
Goose egg	181.00	13.50	13.70	0.80	70.00	3.00	0.90	0.26	540.00
Cow milk	67.00	3.20	4.10	4.40	120.00	0.20	0.12	0.19	20.00
Ruhita fish	97.00	16.60	1.40	4.40	650.00	1.00	0.50	0.70	-
Chicken	109.00	25.90	0.60	-	25.00	-	-	0.14	145.00

Source : Afzal *et al.,* 2003.

Lentil is used in cakes mixed with cereals. It is a good food for invalids and infants. Its young pods are used as vegetables. Lentil seed is eaten by boiling. Its plant and straw are used as food of cattle.

1.9. Aims and objectives

Bangladesh has become a chronic food deficit country mainly due to the rise in population and the frequent occurrence of natural hazards. As crop production risk is comparatively less in the winter months, more emphasis has been given on intensive crop production programme during this season. Very little work has been done to develop the package of improved management practices required to achieve higher yield

potential cereal crop. The yield per location has not increased significantly during the last decade. Attempt should be made to have simultaneous increase in yield per unit area. New varieties must be developed that can with stand adverse climatic conditions.

In Bangladesh, the production of fish and meat to the population is frustratingly low. Beside, meat and fishes are beyond the purchasing capacity of the common people due to high price. In this situation it would be better to improve pulses for high yield like gram and lentil, which is low cost. This certainly bears impact in socio-economic development of the country, development of high yielding lentil and popularization of "Dhal Bhat'' programme among the people suffering from protein deficiency (malnutrition) can relieve the problem to some extent. For this reason, analysis of lentil is very necessary for populous country like green Bangladesh.

The present study was undertaken with the following objectives :

1. Study of genotypic and phenotypic variability of different growth attributes, grain yield and yield components of lentil.
2. Study of path coefficient and character association to estimate direct and indirect effects of component traits on grain yield under different environmental conditions.
3. Study of genotype-environment (G×E) interaction to select variety with good general adaptation in a wide range of environments.
4. Estimation of response and stability parameters and identification of stable genotypes.

CHAPTER 2

REVIEW OF LITERATURE

2.1. Genotype–Environment Interaction

Many scientist of the world put forward the idea about the relationship between genotypes and environments since many years ago. The fundamental nature of gene action and interaction involved in the inheritance of quantitative characters were not understood until genetically assumption and biometrical methods developed in the early days of 20th century were brought together. The development of genetics began with the rediscovery of Mandel's work in 1900. Johannsen (1909) for the first time put forward the idea of the relationship between heritable and non heritable (environmental) effects and that the variation in a pure line was due to environment. Many papers have already been published in various crops and a few in lentil concerning with the problem of genotype-environment (G×E) interaction at different times and some of these papers are reviewed below.

East (1915) observed that the continuous variation in the segregating generation was due to both genotype and environment interaction.

Mather (1949), **Mather and Jones (1958)** separately and combindly improved the techniques of the genotype-environment interaction based on the mathematical model of Fisher *et al.* (1932). It involved the partitioning of the variation of quantitative data into genotypic and environmental interaction.

Fejer (1958) carried out that the variation of population was contributed not only by environmental effect but also by the genotype-environment interaction. He observed that the environmental variance composed of two components viz., a true environmental effect and genotype-environment interaction.

Gandhi *et al.* (1964) worked on the genotype-environment interaction in wheat to obtain estimates of the magnitude of the variety×location, variety×year and variety×location×year interaction. They considered the implications of these interactions for obtaining information on the optimum number and allocation of location

and years and these tests were conducted over a three years period at five locations under normal sowing conditions.

Ananda (1968) worked on the relationship between genotypes and environments in wheat. Analysis of data of variance from trials involving 12 varieties at 4 locations for 3 years showed variety×locality×year and variety×locality interaction to be significant, indicating that the performance of varieties varied with the environments. The interaction variances were found to decrease with the increase in the number of location.

Baker (1969) carried out the pattern of grain production of six cultivars of hard red spring wheat grown at each of nine locations in five different years to evaluate genotype-environment interaction. He reported that all the genotype×environment interaction except genotype × year were significant and important.

Westerman and Lawrence (1970) carried out an experiment to determine the interaction between genotypes and environments. They observed that the evolutionary role of genotype-environment interaction in the population of a species may be take in one or two mutually exclusive forms ; the expression of a metrical character may be buffered against the environment or may vary in an adaptive manner with the environment. Westerman (1971) worked on the same problems and mentioned that both linear and non-linear response to environment controlled by additive and non- additive variation.

Chowdhury and Singh (1970) worked on the kodo-millets under three environments at 2 levels of fertility. They reported that the environmental effect was highly significant for all the characters. Interaction variance was significant for plant height and the number of tillers per plant. Environment contributed to maximum of the variability in all characters. Variety and variety-environment (V×E) interactions were also statistically significant for all the characters. The environmental effect, as well as variety-environment (V×E) interaction showed that varieties had differential behaviour in different environments.

Khaleque (1975) worked on genotype-environment interaction for eighteen quantitative characters in a 5×5 diallel progenies of rice over two seasons.

Zuberi and Gale (1975) worked on the influence of soil nutrients on the expression of eleven metrical traits of P*apaver dubium* and mentioned significant effect of all nutrients and calcium had the greatest single effect. Both linear and non-linear relationship between genotype-environment (G×E) interaction and environmental mean were found for all traits**.**

Byth et al. (1976) worked on the genotype - environment (G×E) interaction on yield characters of 49 wheat cultivars grown in each of 63 environments. They mentioned the presence of genotype-environment (G×E) interaction in wheat cultivars for the characters. They studied regression analysis and showed differential response of varieties under different environmental effects.

Joarder and Eunus (1977) worked on the genotype-environment (G×E) interaction shown by heading and harvesting time of Brassica campestries. They reported that genotype-environment (G×E) interactions were operative in both parental and F_2 generations and that a significant portion of these interaction was accounted for by the linear function of the environmental means.

Joarder et al. (1978) studied the genotype-environment (G×E) interaction of some quantitative characters of four varieties of Brassica campestries L. They mentioned that genotype -environment interaction item was highly significant for all the characters. They studied all the six generations and showed that all items were significant at 1% level except environment.

Uddin, Joarder and Khaleque (1979) studied the genotype - environment (G×E) interaction for two quantitative characters viz., flowering time and tiller number of five parental and F_2 generations of four crosses of rice and showed that genotype - environment (G×E) interactions were operative in both parental and F_2 generations. A significant portion of these interaction was accounted by the linear function of the environmental mean. A real difference existed between the populations and there was also a real effect of different does of nitrogen among the characters. Higher does of urea

delayed flowering and increased tiller number per plant but IR-8 showed early heading in high doses of urea.

Freeman and Crisp (1979) studied on the related varieties in explaining genotype - environment (G×E) interaction. Regressing one character on to another may not only give useful information about the relation between them but also help to explain genotype-environment (G×E) interaction observed in the characters of primary test.

Galvez (1980) studied the genotype–environment (G×E) interaction for yield and brix in eight traits with 20 genotypes of sugarcane. The traits were carried out in two locations during there harvesting periods. The genotype – environment (G×E) interactions were significant at both the locations. In order to determine stability or adaptability, data were analyzed by 3 methods such as linear regression, covariance and coefficient of determination. All the methods were used verified in its own way the discrimination of genotypes their stability in relation to environmental changes.

Jatasra and Paroda (1980) worked on the genotype–environment (G×E) interaction of grain yield and its component in 40 genotypes of wheat including Mexican, Indian and their derivatives. They found both linear and non- linear components of genotype–environment interaction (G×E) were significant for grain yield. Stability for grain yield appeared to have been imparted by the stability of the grain yield components.

Islam *et al.* (1981) carried out an experiment to determine the variety × seedling date interaction on field and other economic traits. They mentioned that the variety significantly interacted with the environment and this interaction was accounted for by the linear function of environmental mean. Genotypes with higher mean performance had regression coefficient greater than unit compared to the genotypes with the lower mean performances.

Rangaswamy *et al.* (1984) tested five sunflower genotypes under ten different environments. Significant differences for grain and oil yield per hectare were observed. With reference to environment also the character expression differed significantly. Variety–environment (linear) interaction was however, non significant. All the varieties

behaved uniformly with reference to different environment exhibited unit regression coefficient with estimate of $\overline{S}_{di}^2$ not different from zero and thus proved stable over all the environments tested.

Jain *et al.* (1984) conducted an experiment consisted of 32 genotypes of chickpea under three environments. Pooled analysis of variance revealed the existence of high genotype-environment (G×E) interaction for all the characters. Inspite of the non significance of linear component of genotype-environment (G×E) interaction, few genotypes exhibited b>1 or b<1 for seed yield per plant, seeds per pod and harvest index. The regression analysis of Eberhart and Russell (1966) has been useful in assessing the adaptation of various genotypes. Accordingly, the genotypes showing wide adaptability and specific adaptation were identified. K- 4 was found suitable for better management conditions. Plant G-110 showed promise for moderate input management, and kaka, NEC- 240 and pink-2 appeared worthwhile for poor environmental conditions.

Kackar and Henry (1984) investigated the genotype–environment (G×E) interaction under rainfed conditions over three years for seed yield in respect of 24 genotypes of cluster bean. There were significant variations for genotypes and genotype – environment interaction for seed yield. The genotypes HG-182, FS-277, D 39-1, 1260/17 and Durgapura appeared to be best suited for favourable growing season, whereas genotypes 2470/12 and 4210/16 gave stable performance under fluctuating environmental conditions.

Kirby *et al.* (1985) studied the effect of sowing date and variety on main shoot leaf emergence and number of leaves of barley and wheat. They found that the final number of leaves per plant decreased with advance in sowing date, except for the winter varieties with the last date, when the number rose. Differences in final number of leaves were observed among the varieties and there was a strong variety × sowing date interaction, which is attributed to differences in vernalization response. Leaf emergence rate rose with the delay in sowing date in both crops and differences in the rate were observed among the varieties, although there was no marked variety × sowing date interaction. In both crops, winter

varieties tended to have higher rate. Rate of leaf emergence was correlated with rate of change of the day length at different sowing dates.

Uddin *et al.* (1986) studied the variety × sowing date interaction in mustard and rapeseed. They showed that the effects of sowing dates were significant for all the characters. The genotypes interacted significantly with the environments in most of the cases. This interaction was accounted for by both linear and non linear function of the environmental means. The genotype with above average phenotypic stability was generally low in mean performance, with high mean yield, high regression coefficient and average $\overline{S}_{di}^2$ values, SS-75 would be suitable for all environment owing to high mean yield below average response (b<1.0) and low $\overline{S}_{di}^2$ values.

Parth and Khan (1987) worked on the genotype-environment (G×E) interaction on 20 wheat cultivars under four sowing dates. They observed that the genotype-environment (G×E) interaction for all the characters were significant.

Henry and Daulay (1987) worked on the genotype–environment (G×E) interaction under four rainfed conditions in 14 genotypes of *sesamum*. They mentioned that the genotypes and genotype–environment (G×E) interactions were significant for seed yield.

Ho and Chang (1987) studied the genotype–environment (G×E) interaction of 15 sugarcane varieties grown at 4 regions in Taiwan over 2 crop years. Significant genotype–environment (G×E) interaction showed for all the traits in both plant and ratoon crops. Ro C-1 performed well in both crops and observed the highest stability compared to the popular varieties Ro C-5 and F-160.

Alam (1987) studied the genotype-environment interaction in tussah jute. He mentioned that significant variations due to sowing and year components. Genotypes interacted with year for base diameter and green weight. Genotype × year × sowing interaction were significant for all the characters except plant height. Major portion of the interaction was due to regression.

Brandle *et al.* (1988) carried out a field experiment to determine the genotype–environment (G×E) interaction and stability analysis of seed yield of *Brassia napus*

cultivar, which were grown at 9 different sites for 3 years. They mentioned that the genotype × year and genotype × year × site interaction were significant, but the genotype × site interaction was non significant. They also reported years, sites and replications in that order and the greatest effects on the standard error of mean of cultivars.

Sarker *et al.* (1988) studied the genotype-environment (G×E) interaction in groundnut. Twenty five genotypes of groundnut were evaluated at three different locations to determine the genotype - environment (G×E) interaction vis-a-vis stability over a wide range of environment. They showed that the genotype environment (G×E) interaction was significant for all the characters. The line ICG (FDRS)-33 showed average response, which was most stable more than yield and suitable for over all the locations. Highest stability of pods per plant conferred the highest stability for pod yield in ICG (FDRS) – 33, stability varied among the genotypes in respect of different characters.

Naidu and Satyanarayana (1991) worked on forty nine mungbean genotypes in three environments to understand the genetic diversity and to study the influence of genotype-environment (G×E) interactions. They observed differential response of different genotypes in varying environmental conditions.

Samad (1991) studied the genotype-environment (G×E) interaction of six agronomical characters in fifteen rapeseed (*Brassca campestris* L.) cultivars in six consecutive years. He showed that genotype - environment (G×E) interaction significantly operative in the experiment. He also mentioned all the genotypes for plant height and number of pods per plant failed to show the stable performance, while some of the genotypes like Polar, Tori -9 and Tori- 7 were predicted to show the stable performances in regard to the agronomical characters such as number of secondary branches, number of seeds per pod and yield per plant.

Deb (1994) worked on the genotype - environment (G×E) interaction on 7 chilli varieties using 5 quantitative characters under 4 consecutive years. He mentioned that the performance of different characters in 7 chilli varieties where was significant due to response in different years. Joint regression analysis indicated that both linear and non linear relationship exist with environment. He also reported that none of the genotypes fulfilled the criteria of stable genotype for a particular character. However, var-6 for

NLIF, var-2 for NLMF, var- 6 for NPBIF and var- 3 and var- 6 for 100 fruit weight/ plant showed stable performances.

Kumar *et al.* (1996) studied the genotype - environment (G×E) interaction and stability of 16 genotypes of desi and kabuli chickpea. They mention that mean squares for locations, genotypes and genotype-location (G×L) interaction were significant. Genotypes exhibited relatively more interaction with winter sown locations than with spring sown locations. Desi types showed more variation than the kabuli types. They found seed size did not appear to influence yield performance and stability.

Nahar (1997) studied the genotype-environment (G×E) interaction of eight quantitative characters of ten sugarcane clones under two different locations. She showed that the genotype -environment (G×E) interactions were signified. She also found that linear and non- linear components of genotype-environment (G×E) interactions were controlled by different gene systems. In her investigation, she recorded the stability performances of different clones were different for different characters.

Hoque (1997) worked on the genotype -environment (G×E) interaction of some morphological characters under soil moisture stress condition in chickpea. He showed genotype and environmental items were significant for all the characters. Join regression analysis indicated that the linear portion of genotype-environment (G×E) interactions were not signified for most of the characters. The above average regression value for most of the genotypes showed that they would likely respond in better environment only, however, varieties ICCV-92133 in 1993-94, PAO- 299/3603 in 1993-94 for PHFF, ICCL- 83105 for PHMF in 1993-1994 and all the genotypes for NSBFF in two years (1993-94 and 1994-95) with average regression value and less standard error indicated that they are likely to be stable in varied environmental conditions.

Nanak Chand *et al.* (2008) assessed thirty diverse elite lines of barley along with six checks in three environments with two replications for three characters i.e. 1000 grain weight (g), harvest index (%) and grain yield per plant (g). The genotype ×environment (G ×E) interactions were significant for all the traits. A stable variety was defined as "one with unit regression (b_i=1) and low deviation from linearity ($\overline{S}^2_{di}$=0)". Among

twenty three average yielding genotypes. Only sixteen genotypes showed suitability for wide adaptation. Better phenotypic stability were observed in four genotypes having high yield mean performance, b_i =1 and $\overline{S}_{di}^2$ =0. These were found promising for wide adaptation over sites across environments. Twelve genotypes had average mean performance with bi=1 and $\overline{S}_{di}^2$ =0 showing stability over wider range of environments. Only two genotypes had average mean associated with b_i <1 and $\overline{S}_{di}^2$ =0 was found stability for poor environments.

2.2. Correlation, Path Coefficient and Stability

Eberhart and Russell (1966) carried out an experiment to find out that genotype with a regression coefficient (b) about 1.0 shows average stability over all environments tested. When b<1.0 there is deficiency in yielding ability under these conditions. They again showed that a variety with mean > grand mean, unit regression coefficient (b =1.0) and least deviation from regression ($\overline{S}_{di}^2$ =0) is considered as a stable genotype.

Malhotra *et al.* (1973) carried out stability analysis with 75 genotypes of lentil at 4 locations and found that the genotype-environment interaction was more pronounced for seed yield and number of pods/plant than number of branches per plant and 100 seed weight.

Khurana and Yadav (1982) studied the stability and adaptability of 55 genotypes of soybean (*Glycine max* L.) in six artificially created environments. They observed high significant differences among genotypes, environments and genotype–environment (G×E) interactions for six agronomic and eight quality traits.

Ahmed and Pandey (1983) worked on ten lentil genotypes in four different environments in India. They showed that the stability parameters were derived from linear and non-linear components of genotype-environment interactions. According to their findings genotype LL-30, LL-1, LL-19 and LL-56 were stable and adaptable.

Yadav and Kumar (1983) evaluated thirty one cultivars of black gram for stability of seed boldness under three environments. Eighteen genotypes showed stable performance, whereas rest of the genotypes were unstable for this trait. Bold seeded strains were appreciably stable, nevertheless, indicated their response to poor

environment. The smallest seeded cultivars (FU-26) were on the other extreme and average response (b =1.04) of the variety reflects its suitability for wider environments.

Sugiyarta *et al.* (1984) obtained stability in sugarcane following Finlay, Wilkinson and Eberhart and Russell's model. The trait was conducted at 27 sites in Java 1975-76 involving 6 cultivars. The analysis indicated that PS-41, PS-46, PS-47 and PS-48 (according to Finlay and Wilkinson) and PS-47 and PS-48 (according to Eberhart and Russell) were most stable genotypes.

Razzaque *et al.* (1984) studied correlation and path analysis in 80 wheat cultivars for days to flower, grain filling period, days to mature, ears /plant, ear length, grains/ear, 100 grain weight and yield/plant. Genotypic correlation coefficients were higher than the corresponding phenotypic correlations in almost all the cases. Days to flower and grain filling period showed negative direct effects on yield, but total days to maturity had a moderately positive direct effect. Of the yield component, 100 grain weight was found to be the most important component of yield and grain/ear was next in importance.

An experiment with 10 cowpea cultivars in nine environments was conducted by **Kandasamy *et al.* (1985)** to determine the stability for yield component characters over environments. The analysis of variance showed that both genotypes and environmental differences were significant. The non linear components $\overline{S}^2_{di}$ was significant for traits. The mean squares due to regression (linear component of genotype –environment interaction) were also significant for pods/ cluster, pod length, seeds/pod and 100 grain weight, indicated that genotypes differed in their regression on the

Twenty genotypes of lentil with different seed sizes were evaluated in three seasons by **Waldia *et al.* (1988)** to study the stability parameters and reported that genotypes with 100 seed weight of about 2.0 g had a comparatively high mean yield, an average response to their environment and non significant deviation around unit regression. They concluded that small seeded types exhibited more stable performance. Genotype-environment interaction was also found by **Sundaram *et al.* (1986*)*** for 100 seed weight in ragi (*Eleusine coracana* Gaortn.).

Singh and Singh (1990) studied the stability of grain yield per plant and harvest index in 66 genotypes of chickpea (*Cicer arietinum* L.) grown in nine environments. Highly significant difference were observed due to genotypes, environments and genotype-environment (G×E) interaction. Significant linear mean square were observed for yield per plant and harvest index. Stable genotypes for yield/plant and harvest index were 52 and 54 respectively. Genotypes ICC 7719, F-6, wilt -115 and NEC -2305 (with high mean, regression coefficient bi>1 and deviation from regression $\overline{S}_{di}^2 = 0$) were suitable for high yielding environments. Genotypes P-1786 and HMS- 17 (with average yield bi<1 and $\overline{S}_{di}^2 = 0$) maintained their inherent potentialities fully well under low yielding environments. Twenty genotypes showing high yield (high mean than grand mean over environments) and stability for yield per plant and harvest index are expected to yield better in the environments represented by a given set of environmental conditions.

Singh *et al.* (1991) evaluated 66 genotypes of chickpea (C*icer arietinum*) in nine micro environments for stability of nine characters. Variations due to genotypes, environments and genotype-environment (G×E) interactions were highly significant for all traits. Forty eight genotypes were stable for plant height, 37 for days to flower, 56 for days to maturity, 46 for pods per plant, 38 for 100 grain weight and 52 for yield per plant. Plant height, secondary branches and harvest index were attributed to their low percentage of linear component of genotype-environment interaction, i.e. being non predictive in nature.

Baisakh and Nayak (1991) conducted an experiment with 17 genotypes of chickpea to study the stability parameters for yield and maturity. Significant differences were observed due to genotypes, environments and genotype environment (G×E) interaction. Linear and non linear components were predominant in genotype-environment (G×E) interaction in maturity, whereas non linear component in yield. ICCC- 6 was the most stable genotype for yield and maturity.

Sharma and Godawat (1991) worked on phenotypic stability in 30 genotypes of foxtail millet **(***setaria italica* L.) under four different environments. The results were analyzed on the basis of stability parameters for days to flower, days to maturity and plant height. Highly significant mean squares were observed for genotypes,

environments and genotype - environment (G×E) interaction. CZS-5 and SN-6 were the most stable genotypes with respect to flower, SN-27 was highly stable for maturity and SIC-9 for plant height.

Niwas *et al.* (1993) worked on 31 genotypes of chickpea (*pisum sativum* L.) in three agronomical different environments for their stability. Characters like pods per plant, seeds per pod, 100 seed weight and seed yield per plant were studied. Significant difference were observed for all the characters among the genotypes. The genotype - environment (G×E) interaction was present for all the traits and both linear and non linear components were presents and equal in magnitude. Line no. 3 was found to have a high mean and a stable performance for the grain yield.

Roy *et al.* (1999) studied the stability analysis for days to 50% silking, plant height, ear height, days to maturity and grain yield per hectare with 20 exotic and local genotypes of maize across three different locations of Bangladesh. Genotype -environment (G×E) interaction was not significant for all the characters. The reaction of the genotypes were different at different locations and stability varied among the genotypes in respect of different characters. None of the genotype was found to be suitable for all the environments for all the characters, significant regression coefficients showed for days to 50% silking and days to maturity in all the genotypes. The genotypes Poza Rica - 9227, Poza-9227 and EV 89345-1 were found to be suitable for grain yield per hectare whereas, Jalna – 9128, Poza Rica 9227 and Poza Rica- 9227 were found to be suitable for plant height. The genotypes across 9128 and across 9136 were observed more or less stable performance over locations.

Ara *et al.* (2000) worked on the stability analysis in five advanced genotypes of tomato for yield and some of the yield component under three different environments. Genotype - environment (G×E) interaction was observed to be signified for all the characters. Linear component contributes positively for wards genotype - environment (G×E) interaction for yield while non-linear component contributed towards the rest of the characters. On the basis of three stability parameters, genotypes, AH (OH)-2 was identified as stable, and genotype, AH (OH)-1 might be suitable cultivation in unfavorable environment.

Hasan (2001) worked on stability parameters regarding irrigation treatments on six yield components of six chickpea (C.A) lines. In regression analysis, he observed that genotype was highly significant for all the characters and the $\overline{S}^2di$ value was also found to be non significant for all the characters. Some of the lines (genotypes) having non-significant $\overline{S}^2di$ values and average regression coefficient values with less standard error indicated that they would likely to show stable performance in different environmental conditions. Besides, some of the lines exhibited above average regression coefficient values which indicated that these lines would likely to perform well in better environment only.

Sarker (2002) carried out an experiment at BARI, Regional Station, Rangpur during boro and T. aman seasons in 1998-1999. The stability parameters, mean ($\bar{X}$), phenotypic index (Pi), regression coefficient (b_i) and deviation from regression ($\overline{S}^2_{di}$) were calculated for yield of different genotypes. Genotype-environment interaction as well as stability performance were determined for grain yield in eight boro and T. aman varieties of rice across eight different planting times. Highly significant estimates for genotypes, environments and genotype environment interactions were observed. Non linear comment (pooled deviation) was found highly significant for grain yield. All the varieties were stable for favourable environment except BARI dhan 32, BR 24 and BARI dhan 33. High mean and phenotypic index with significant regression coefficient ($b_i > 1$) and non significant deviation from regression ($\overline{S}^2_{di}$) was observed in BARI dhan 29 and BARI dhan 28 which might be predicted as suitable for favourable environments. BRRI dhan 29 was observed to be top yielder due to its high mean (5.29) and phenotypic index (1.27) followed by BRRI dhan 28, BRRI dhan 27 and BRRI dhan 36. These varieties were favourable for 9 January planting.

Amiruzzaman *et al*. (2003) reported that the highest direct positive effect was contributed by number of tillers per plant followed by number of grains per spike on grain yield. Path analysis showed that number of tillers per plant and number of grains per spike directly contributed to grain yield but 1000 grain weight and spike length also accelerated the increase of yield.

Anisuzzaman *et al.* (2007) observed that among all the variables in most of the cases, the magnitude of the variance components due to environment (irrigation treatment) was substantially larger than the other effects. Grain weight, extrusion length and spike length were affected mainly by its genetic potential lies within. Therefore, most of the variations in the performance of barley genotypes in these traits were due to environmental and not due to genotype-environment interactions. Differential fitness of genotypes to the environments is reported in different trials world wide.

Riaz-ud-Din *et al.* (2007) studied the effects of heat stress, genetic variability and character association in wheat. Twelve wheat genotypes were evaluated under normal and heat stress condition. Morphological characters were affected due to heat stress when planting was delayed by 60 days. Decline was recorded for grain yield (48.87%), number of spikes/m² (29.61%), days to anthesis (28.24%), days to maturity (28.89%), 1000 grain weight (24.80%), plant height (9.96%) and grains per spike (8.24%). Phenotypic and genotypic coefficients of variability indicated higher moderate genetic variability for grain yield, 1000 grain weight, grains per spike, spikes/m^2 and plant height in both conditions, while moderate genetic variability for days to anthesis in heat stress. Days to anthesis exerted negative direct effect on grain yield and highest positive direct effect was for spikes m^{-2} followed by days to maturity. All the characters had shown non-significant association with grain yield in heat stress.

Debnath *et al.* (2008) carried out at the experimental field to study the variability and their interrelationship and direct and indirect effects to different characters on yield. They worked with 21 local genotypes of buckwheat. Correlation coefficient between seed yield (kg/rn^2) with number of inflorescence per plant and grain setting raceme per plant were significant and positive. Highly significant and positive correlation was observed between grain setting raceme per plant vs. Inflorescence per plant. Path coefficient analysis revealed that grains per raceme had the highest positive direct effect on yield followed by inflorescence per plant and seed yield per plant. The direct effect of inflorescence per plant was almost equal to the correlation coefficient implies that there was a true relationship between inflorescence per plant and yield. Path coefficients indicated that maximum direct contribution towards seed yield (kg/rn^2) was obtained

through grains per raceme which indicated that this trait should he considered as primary component of yield.

Singh *et al.* (2008) observed that estimate of genetic parameters for eight quantitative characters viz. tillers per plant, plant height, spikes per plant, seeds per spike, 100 grain weight, grain yield per plant, spike length and days to maturity in 18 genotypes of barley (*Hordeum vulgare* L.) revealed significant variability for all the traits. The estimates of genotypic and phenotypic coefficient of variation were high for grain yield per plant, the broad sense heritability estimates coupled with high genetic advance for plant height and grain yield per plant. Correlation studies indicated that grain yield per plant exhibited stable positive association with spikes per plant followed by 100 grain weight and tillers per plant. Path analysis revealed high positive and direct influence of 100 grain weight towards grain yield per plant followed by spike per plant and tillers per plant. Spikes per plant also contributed to grain yield mainly through indirect effect via tillers per plant.

Adhikary *et al.* (2009) conducted an experiment in the research field of Rajshahi University Campus, Bangladesh to study the grain growth pattern of eight cultivars of wheat and to find out association and linear regression of spike weight and grain weight with time. Linear regression and correlation coefficients reveled that the association between both spike weight and grain weight with time were highly positively significant among the cultivars but their regression coefficients were non-significant.

CHAPTER 3

MATERIALS AND METHODS

3.1. Materials

The materials of the study comprised six lentil (*Lens culinaris* Madic.) genotypes collected from Ishurdi Pulse Research Center (IPRC), Pabna, Bangladesh. The six modern lentil genotypes are as follows:

1. Barimasur 1 (Indicated herein as G1)
2. Barimasur 2 (Indicated herein as G 2)
3. Barimasur 3 (Indicated herein as G 3)
4. Barimasur 4 (Indicated herein as G 4)
5. Barimasur 5 (Indicated herein as G 5)
6. Barimasur 6 (Indicated herein as G 6)

1. Barimasur 1 (G1)

Barimasur 1 is the first improved lentil variety in Bangladesh. It was released by the National Seed Board in 1991. Barimasur 1 was selected from landrace, Pabna local with its national accession number BLL 79694. It is a medium statured and semi erect cultivar with basal primary and secondary branches. Plant height ranges from 45-50 cm. Stem pigmentation is absent at the seedling stage, but it becomes light green at the late vegetative stage. Leaves are dark green with slightly pubescence. Leaves size is medium with dark green color, short petiole and rachis that from no tendrils. Its seed coat is ash and testa pattern is dotted with smooth seed surface and cotyledon color is red. One thousand seed weight is 15.40 g. Barimasur 1 matures within 105-110 days. Its flowers are white. Its stem, pods and leaves turn into straw. It is good both at optimum and late sown conditions. This variety is resistant to rust and stemphylium blight diseases. Barimasur 1 produced a mean seed yield of 1700- 1800 kg/ hac (Afzal *et al.,* 1997, 1999 and 2003).

2. Barimasur 2 (G 2)

Barimasur 2 is a high yielding variety evolved in Bangladesh in 1993. Originally the variety was developed in ICARDA through single plant selection from progenies of a

cross between ILL 4353 (India) and ILL 353 (Mexico) types. It is a medium statured and semi erect cultivar with basal primary and secondary branches. Mean plant height ranges are 40 cm. Stem pigmentation is absent at seedling stage, but, it becomes light green at the late vegetative stage. Leaves are gray green and pubescence. Leaves size is medium with narrow terminal leaflets and ending in a short tendril. Seed coat color is light grey without patterns and cotyledon color is bright orange. One thousand seed weight is 12.50 g. Barimasur 2 matures within 105-110 days. Its flowers are white. This variety is resistant to rust and stemphylium blight diseases. Barimasur 2 produced a mean seed yield of 1800- 1900 kg/ hac (Afzal *et al.,* 1997, 1999 and 2003).

3. Barimasur 3 (G 3)

Barimasur 3 is a high yielding variety evolved in Bangladesh in 1996. It is the most popular modern variety and increasing its area day by day. Barimasur 3 was developed through single plant selection from progenies of a cross between BLL 79666 (India) and Pabna local made at PRC. It is a medium statured and semi erect cultivar with basal primary and Secondary branches. Plant height ranges from 42-44 cm. The stem is pigmentation and it remains green at maturity. Leaves are dark green with broad leaflets without tendrils. The pods and leaves turn into straw color. Seed coat color is dark grey and cotyledons are bright orange. One thousand seed weight is 23.80 g. Barimasur 3 matures within 100-105 days, which is earlier to Barimasur 1, Barimasur 4 and Barimasur 5. Its flowers are white. This variety is resistant to rust and stemphylium diseases. Barimasur 3 produced a mean seed yield of 2000 kg/ hac (Afzal *et al.,* 1997, 1999 and 2003).

4. Barimasur 4 (G 4)

Barimasur 4 is a high yielding variety evolved in Bangladesh in 1996. Originally the variety was made at ICARDA, Syria specially for Bangladesh. It was developed through single plant selection from progenies of a cross between ILL 77888 (India) and ILL 5782 (ICARDA) in 1995. It is a medium statured and semi erect cultivar with basal primary and secondary branches. The plant height ranges from 42-44 cm. The stem remains green at maturity. Leaves are dark green, with broad leaflets without tendrils. The pods and leaves turn into straw color. Seed coat color is dark grey and cotyledons are bright orange. One thousand seed weight is 19.84 g. The cultivars matures within 110-115 days, which is later to Barimasur 1 and traditional landraces. It flowers are white. This variety is resistant

to rust and stemphylium blight diseases. The variety produces an average seed yield of 2300 kg / hac (Afzal *et al.,* 1997, 1999 and 2003).

5. Barimasur 5 (G 5)

Barimasur 5 is a high yielding variety evolved in Bangladesh in 2007. It is a popular modern lentil variety. Barimasur 5 was developed through single plant selection from progenies of a cross between ILL 2501 (India) and ILL 7616 (ICARDA) in 1995. It is a medium statured and semi erect cultivars with basal primary and secondary branches. Mean plant height ranges are 38 cm. The stem is pigmentation and it remains green at maturity. Leaves are green, with broad leaflets with tendrils. The pods and leaves turn into straw color. Seed coat color is purple and cotyledons are bright orange. One thousand seed weight is 19.00 g. The cultivars matures within 110-115 days and traditional landraces. It flowers are light violent. This variety is resistant to rust and stemphylium blight diseases. Barimasur 5 produces seed yield of 2000-2200 kg/ hac (Udddin *et al.,* 2007).

6. Barimasur 6 (G 6)

Barimasur 6 is a high yielding variety evolved in Bangladesh in 2007. It is a popular modern lentil variety. Barimasur 6 was developed through single plant selection from progenies of a cross between ILL 7667 (Advance lines) and IDOLIB-1 (ICARDA) in 1997. It is a medium statured and semi erect cultivars with basal primary and secondary branches. The plant height ranges from 35-40 cm. The stem is pigmentation and it remains green at maturity. Leaves are dark green, with broad leaflets without tendrils. The pods and leaves turn into straw color. Seed coat color is dark gray and cotyledons are bright orange. One thousand seed weight is 19.80 g. Barimasur 6 matures within 105-110 days and traditional landraces. It flowers are white. This variety is resistant to rust and stemphylium blight diseases. Barimasur 6 produces seed yield of 2000-2300 kg/ hac (Afzal *et al.,* 2007).

3.2. Methods

3.2.1. Experimental Site and Period

The experiment was conducted in the experimental field of Botany Department at Rajshahi University campus during the period from November 2009 to February 2010 and November 2010 to February 2011. The global position site (GPS) of the

experimental area is $24^0 17^/$- $24^0 31^/$ N latitude and $88^0 28^/$ - $88^0 43^/$ E longitude with a height of 20 meter above the sea level (Anisuzzaman, 2003).

3.2.2. Experimental design and layout

Experiment was arranged in split plot design with four environments (treatment). Each treatment was divided into three replications. Each replication was divided into six sub plots or split plots. Total number of plots was 72.

3.2.3. Treatment /Environment

The following four treatment/environment were tested in this investigation

1. Treatment 1 (Indicated herein as E1)
2. Treatment 2 (Indicated herein as E 2)
3. Treatment 3 (Indicated herein as E 3)
4. Treatment 4 (Indicated herein as E 4)

1. Environment 1 (E1)

No irrigation, lentil plants were grown under non-irrigation and rainfed condition. This environment was considered as double stress. One stress at initiative stage and another stress at heading stage.

2. Environment 2 (E 2)

Irrigation at flowers initiation stage. One irrigation was applied after 50 days of sowing (DAS), when lentil plants showed first flowers.

3. Environment 3 (E 3)

Irrigation at early pods stage. One irrigation was applied after 71 days of sowing, when lentil plants showed first pods.

4. Environment 4 (E 4)

Lentil was grown with two irrigations. One irrigation was applied after 50 days of sowing (DAS), when lentil plants showed first flowers. The second irrigation was applied after 71 days of sowing (DAS), when lentil plants showed first pods. The amount of water was added to moist to surface soil and care taken so that no water logging condition was prevailed. This environment was considered as no stress.

G1	G2	G3	G4	G5	G6	G3	G4	G5	G6	G1	G2	G5	G6	G1	G2	G3	G4
III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III
III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III
Replication - 1						Replication - 2						Replication - 3					

TREATMENT / ENVIRONMENT-1

G1	G2	G3	G4	G5	G6	G3	G4	G5	G6	G1	G2	G5	G6	G1	G2	G3	G4
III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III
III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III
Replication - 1						Replication - 2						Replication - 3					

TREATMENT / ENVIRONMENT-2

G1	G2	G3	G4	G5	G6	G3	G4	G5	G6	G1	G2	G5	G6	G1	G2	G3	G4
III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III
III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III
Replication - 1						Replication - 2						Replication - 3					

TREATMENT / ENVIRONMENT-3

G1	G2	G3	G4	G5	G6	G3	G4	G5	G6	G1	G2	G5	G6	G1	G2	G3	G4
III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III
III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III
Replication - 1						Replication - 2						Replication - 3					

TREATMENT / ENVIRONMENT-4

Figure 1. Design of experimental field

3.2.4. Soil and soil conditions

Lentil shows adaptability to a wide range of soil types. Good yields of lentils have been obtained on soil ranging from heavy clay to loamy sands. The crop performs well on land of moderate to low fertility. On soils with very high natural fertility and excessive soil moisture, the crop might make excessive vegetative growth at the cost of reproductive growth. Moderately deep "black cotton soils" are very good for lentil cultivation because of their good retention of moisture although they are not of high fertility.

Lentil grows well on the slightly acidic soils pH 5.5 - pH 6.5 (Kay 1979) to moderately alkaline soils pH 7.9 – pH 9.0. Delayed nodulation and decreased yields have been obtained when the pH of the soil increased.

3.2.5. Land preparation

Land preparation is a key factor to achieve higher yield of any crop. Traditionally the crop has been cultivated as intercrop, mixed crop and relay crop with other crops and particularly with cereal crops.

The nature and extent of land preparation depends on the soil type and cropping system in which lentils are being grown. The purpose of preparatory tillage is to have a friable but compact seed bed free from weeds ensuring good and rapid germination of seed and good retention of moisture. In Midwestern region, where the moisture conserved during the preceding monsoon season is critical, the land preparation is minimum on light soils and is done with a non-turning country plough which ensures minimum loss of soil moisture.

The land of the experimental plot was prepared by bullock driven country plough followed by laddering. The land was prepared by giving four ploughings followed by four laddering. During land preparation large piece of land were melted and weeds and stubble removed were from the field. After preparation the experiment was conducted in split plot design with three replications in each treatment (environment). The moisture treatment was on the main plots and the genotypes were in the sub plots. Each plot was 8.70 meter long and 1.50 meter wide ($8.70 \times 1.50 = 13.05 m^2$). Two border lines were used to eliminate border effects and were considered as non-experimental. The land was prepared on 28 October in 2009-2010 (first year) and 29 October in 2010-2011 (Second year). The seeds

were sown in furrows 30 cm distance and covered by fine soil. The seeds were sown on 2 November in 2009-2010 (first year) and 3 November in 2010-2011 (Second year).

3.2.6. Fertilizer application

The lentil cultivars have little response to fertilizers. It is known that genetic erosion has occurred in most of the pulses due to continuous cultivation in marginal and poor soil. So, the importance of balance fertilization has long been recognized to achieve high productivity and fertilizer use efficiency. Due to its ability of nitrogen fixation from the atmosphere legumes require less nitrogen application. But for initial establishment of plants up to the stage of nodule formation a starter dose of 20-40-20 NPK respectively should be applied. For good production 45 kg urea, 85kg TSP and 35 kg MP were applied per hectare in the experimental field. All the fertilizers were applied during the final land preparation and incorporated with the soil through ploughing and laddering.

3.2.7. Seed rate and seed sowing

Seed rate of crop depends on mainly seed size, seed quality, soil moisture and soil type. Proper establishment is another important factor that determines the yield of lentil. Lack of optimum stand in farmers field is one of the constraints of low yield. A plant density of 250-300 plants/m^2 provides to produce higher yield in lentil in the country (Rahman and Miah, 1989). To achieve higher yield from optimum plant population, seed of 35-40 kg/hac for Barimasur 1, Barimasur 2, Barimasur 4, Barimasur 5 and Barimasur 6 and 40–45 kg/hac for Barimasur 3 have been recommended, and are being practiced by farmers.

Sowing time markedly influences the performance of lentil cultivars because of the change in those environmental conditions to which the crop is exposed at various stages of phenological development under variable dates. Delayed sowing, therefore, hampers proper growth resulting in poor yield (Khan and Mia, 1986). The farmers in Bangladesh are advised to sow lentil within first week of November. For obtaining maximum income from the crop it is advisable to sow as a sole crop using line-sowing method of seeding. The line to line distance was maintained 30 cm.

3.2.8. Weeding and thinning

Weeds cause heavy loss to the lentil crop as they rob the soil of its nutrients and moisture. The magnitude of loss depends upon weed species and their intensity,

growing conditions, soil fertility and soil moisture. Rahman and Miah (1989), in an experiment on the weed control of lentil using different herbicides and manual weed control methods observed that control of weeds either manual or by herbicides are very effective for high yield realization. To obtain optimum yield from the crop it is essential to make the crop free from weed. For a good economic return one weeding between 20-25 days after seeding emergence should be sufficient.

Two weeding one at 20 DAS and other at 41 DAS were done with the help of a hoe. Different weeds infested the crops among them "Bathva grass" (*Cheropodium album*) and "Mutha grass" (*Cyperus rotundus*) were prominent and thinning was done after 30 DAS to maintain plant to distance approximately 10 cm (Afzal *et al.,* 2003).

3.2.9. Level of irrigation

Lentil requires as much as water as wheat or other cereals. However, over 90% of the lentil is grown on conserved or residual moisture. Generally no irrigation is required for cultivation of lentil except the case of severe drought during growing season. However, for good stand establishment pre-sowing irrigation may be applied if the soil moisture seems to be stress condition.

Two recommended irrigations were applied in the experimental field. One irrigation was applied at 50 DAS in the environment 2 and environment 4, when lentil plants showed first flowers. The second irrigation was applied at 71 DAS in the environment 3 and environment 4, when lentil plants showed first pods.

3.2.10. Collection of Data (Growth attributes)

For growth analysis, different plant parts of lentil were recorded from eight harvests in 2009-2010 (first year) and nine harvests in 2010-2011 (second year) at equal interval of seven days. Three plants were selected for each genotype (variety) from each replication at each growth stage. The first harvest was taken at 50 days after sowing (DAS) when lentil plants showed first flowers. At each harvest, plants were cut at the ground level and tops were separated into leaves, stem and pods (when present). The samples were packed separately in labeled brown paper bags. Before weighing the plant parts were dried separately in an oven at about 65˚C for 72 hours till they reached constant weight. Then

the sample weights were taken separately with an electrical balance in the Department of Botany, University of Rajshahi, Rajshahi. The following characters were recorded.

1. Primary branch height (PBH)

Three plants were selected randomly for each genotype and primary branch height was measured in centimeter (cm) from ground level to the top of the terminal leaflets and the mean primary branch height was determined.

2. Secondary branch height (SBH)

Three plants were selected randomly for each genotype and secondary branch height was measured in centimeter (cm) from base level to the top of the terminal leaflets and the mean secondary branch height was determined.

3. Plant height (PH)

Three plants were selected randomly for each genotype and plant height was measured in centimeter (cm) from ground level to the top of the terminal leaflets and the mean plant height was determined and recorded.

4. Plant area per plant (PAPP)

Three plants were selected randomly for each genotype from each replication and first the diameter of each plant was measured at the position of maximum spread of the plant. Then the diameter was divided into two and calculated the radius (r). At last, the plant area per plant was found out from the formula πr^2.

5. Total dry matter (TDM)

Three selected plants of each genotype from each replication were uprooted and packed separately in labeled brown paper bags and dried in an oven at about 65˚C for 72 hours till they reached constant weight. Then the sample weights were taken separately with an electrical balance and total dry matter was recorded.

6. Leaf weight ratio (LWR)

Three selected plants of each genotype from each replication were uprooted and packed separately in labeled brown paper bags. Then each plant was dried in an oven at about 65˚C for 72 hours till it reached constant weight. At first the leaves of each plant and later the total plant with leaves weights were taken separately with an electrical balance

and recorded. At last, the weight of leaves was divided by total plant weight and calculation of leaf weight ratio (LWR) was determined.

$$\text{Leaf Weight Ratio (LWR)} = \frac{\text{Leaf dry weight}}{\text{Total dry weight}}$$

7. Crop growth rate (CGR)

Three selected plants of each genotype from each replication were uprooted and packed separately in labeled brown paper bags. Each plant was dried in an oven at about 65˚C for 72 hours till it reached constant weight. Then the simple weights were taken separately with an electrical balance that is the former harvest weight W_1 and the duration of the former time t_1. After one week, the later harvest weight W_2 and the later time t_2 was found out in the same way. Then the values $W_2 - W_1$ and t_2-t_1 were determined. At last, the crop growth rate was measured from the formula $\frac{W_2 - W_1}{t_2 - t_1}$.

8. Relative growth rate (RGR)

Three selected plants of each genotype from each replication were uprooted and packed separately in labeled brown paper bags. Each plant was dried in an oven at about 65˚C for 72 hours till it reached constant weight. Then the simple weights were taken separately with an electrical balance that is the former harvest weight W_1 and the duration of the former time t_1. After one week, the later harvest weight W_2 and the later time t_2 was found out in the same way. Then the values $\log_e W_2 - \log_e W_1$ and t_2-t_1 were determined. At last, the relative growth rate was measured from the formula $\frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$.

3.2.11. Harvesting and threshing

Harvesting is the main stage for the production of crops. Post harvest processing plays an important role in the production of lentils. The highest returns depend on the successful processing of the crop, which can stabilize the marked system. The lentil passes through several processes after harvesting until they become ready for consumption. The processes include plant uprooted, drying, threshing, cleaning and

weighing. Each of these steps deserves proper care to reduce post harvest loss and to maintain the quality of grain.

Drying and threshing should be done. Drying of seed should be at a level that it contains 8%-9% moisture. Final harvest of all six genotypes were made after 110 days of sowing. The plants were uprooted at harvest when 80% of the plant and pod became straw colored and threshing was done for each genotype from each sub plot. The harvested plants were staged and laid out on a concrete floor and dried for five days over night to bring down the temperature at normal level. Threshing was done manually by beating with a stick. Then the seeds were dried, cleaned and weighed.

3.2.12. Growth analysis

The classical method of growth was followed to determine the various growth attributes like crop growth rate and relative growth rate from the dry weight of different plants between two successive harvests. Plant area per plant and leaf weight ratio were calculated separately for each harvest (Radford, 1967)

1. Plant Area Per Plant (PAPP) = πr^2 (r = Radius)

2. Leaf Weight Ratio (LWR) $= \frac{\text{Leaf dry weight}}{\text{Total dry weight}}$

3. Crop Growth Rate (CGR) $= \frac{W_2 - W_1}{t_2 - t_1}$

4. Relative Growth Rate (RGR) $= \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$

Where, W_2 and W_1 are the total dry weight of later and former harvest and t_2 and t_1 are the later and former harvest time, respectively.

3.2.13. Grain yield and its components

The final harvest was done for Barimasur 1 (G1), Barimasur 2 (G 2), Barimasur 3 (G 3), Barimasur 4 (G 4), Barimasur 5 (G 5) and Barimasur 6 (G 6) at 110 days after sowing (DAS). Three plants per genotype per replication were harvested and measurements of yield and its components were made. The following characters were recorded.

1. Plant height (PH)

Three plants per genotype per replication were harvested and plant height was measured in centimeter (cm) from ground level to the top of the terminal leaflets and the mean plant height was determined.

2. Branch number per plant (BNPP)

The selected plants were uprooted at final harvest and the total branches from each plant were separated. Then the total number of branch was counted and recorded.

3. Plant area per plant (PAPP)

Three plants were selected randomly for each genotype from each replication and first the diameter of each plant was measured at the position of maximum spread of the plant. Then the diameter was divided into two and the radius (r) was calculated. At last, the plant area per plant was found out from the formula πr^2.

4. Days to 50% flower (D 50% F)

Counted when 50% of the lentil plants of a plot produced flowers from seedling to opening of buds. Expressed as number of days per genotype and recorded.

5. Days to maturity (DM)

Counted when 75% -80% of the pods in lentil plants turned into brown and matured. At that time, expressed as number of days per genotype and recorded.

6. Pod number per plant (PNPP)

The selected plants per genotype per replication were uprooted at final harvest and the total pods from each plant were separated. Then the number of pods per plant was calculated and recorded.

7. Seed number per pant (SNPP)

The selected plants were uprooted at final harvest and the total pods from each plant were separated. Then the number of seeds per plant was calculated and recorded.

8. 1000 seed weight (g)

The selected plants were uprooted at final harvest from each genotype and were collected from each sub plot. The harvested plants were tagged and laid out on a

concrete floor and sun dried for five days. Then 1000 seed weights were measured with an electrical balance and recorded.

9. Total dry matter (TDM)

Three selected plants of each genotype from each replication were uprooted at final harvest and packed separately in labeled brown paper bags and dried in an Oven at about 65˚C for 72 hours till they reached constant weight. Then the sample weights were taken separately with an electrical balance and total dry matter was recorded.

10. Grain yield (kg/ha)

Total grain yield for each genotype was collected from each sub plot. The harvest plants was tagged and laid out on a concrete floor and sun dried for five days, threshed, the grains were cleaned and weighted with an electrical balance. Then total grain of yield each genotype was recoded in kilogram and converted into kg/hac.

3.2.14. Statistical analysis of data

The techniques used for analysis of data are described under the following sub-heads:

1. Mean

Data on individual plant basis were added together than divided by the total number of observations and the mean was obtained as follows.

$$\text{Mean } (\overline{X}) = \frac{1}{n}\sum_{i=1}^{n} X_i$$

Where,

$\overline{X}$ = Arithmetic mean

X_i = The individual reading was recorded on each plant

$\sum X_i$ = Summation of variable

n = Number of observations

i =1, 2, 3..... n

2. Standard deviation (SD)

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

$$SD = \sqrt{\partial^2}$$

Where,

SD = Standard deviation

∂^2 = Variance

3. Standard error of mean (SE)

If several samples are considered instead of taking one, it will be found that the standard deviations of the different samples also vary. This variation was measured by the standard error mean, which was calculated as follows.

$$SE = \frac{SD}{\sqrt{n}}$$

Where,

SD = Standard deviation

SE = Standard error of mean

n = Total number of individual

4. Analysis of variance

Variance analysis is a measure of dispersion of among the population. Variance analysis for each of the characters was carried out separately on mean value of three plants.

The variance due to different sources such as genotype (G), replication (R), G×E interaction and error (E) of population were calculated as per the standard skeleton of analysis.

5. Test of least significant differences (LSD)

The experimental design was a split plot design and the analysis of variance was done accordingly. Least significant difference (LSD) at 5% level was calculated according to

following formula (Gomez and Gomez, 1984) where the values for variance ratio (F) for each item viz., genotype (G), environment (E) and genotype-environment (G×E) interaction were significant.

The following formula were used (According to Gomoz and Gomez, 1984)

Genotype (G) = $\sqrt{\frac{2E_1}{rbc}}$

Environment (E) = $\sqrt{\frac{2E_2}{rac}}$

LSD = (ta) ($\bar{s}d$)

Here,

E_1 = Genotype error mean square

E_2 = Environment error mean square

ta = Tabulated value (5% level)

$\bar{s}d$ = Calculated value

3.2.15. Correlation coefficient

The degree of relationship can be established by calculating a coefficient called the correlation coefficient, which gives a quantitative measure of the degree of closeness of the linear relationship between the two variables. Simple correlation coefficients were calculated between pairs of characters according to standard procedure (Steel and Torrie 1960) as follows:

$$r = \frac{\sum dx.dy}{\sqrt{\sum dx^2 \sum dy^2}}$$

Where,

r is the correlation coefficient between x and y

$\sum dx.dy$ is the covariance between x and y

$\sum dx^2$ is the variance of x

$\sum dy^2$ is the variance of y

3.2.16. Path coefficient analysis

The path coefficient analysis was carried out using the formula of Wright (1923) as illustrated by Dewey and Lu (1959). The path coefficient analysis was done at both the phenotypic and genotypic levels by solving the simultaneous equation using matrix method.

The form of equation is as follows:

$r_{xy} = P_{xy} + r_{x2} P_{2y} + r_{x3} P_{3y} + \ldots\ldots\ldots\ldots r_{xn} P_{ny}$

r_{xy} = Correlation between one component character and yield.

P_{xy} = Path coefficient between the same character and yield.

r_{x2} r_{x3} ..... r_{xn} = Represent correlation coefficient between that character and each of the other yield components in turn.

The above equation was written in a matrix form as:

A		B			C
r1y	= r11	r12	r13	r1j	p1y
r2y	= r21	r22	r23	r2j	p2y
r3y	= r31	r32	r33	r3j	p3y
riy	= ri1	ri2	ri3	rij	piy

$A = B \times C$; Then $C = B^{-1}A$

Where ,

Pry = Direct effect of the character I on the dependent trait y (yield)

The indirect effect of a particular character through other characters was obtained by multiplication of direct path and particular correlation coefficient between those two characters respectively.

Indirect effect = $R_{ij} \times P_{ij}$

Where,

i = 1 .....n,

J = 1 .....n,

$p_{iy} = P_{1y} \ldots\ldots\ldots\ldots P_{ny}$

Where,

R_{ij} = Correlation coefficient between two independent characters.

The residual effect is assumed to be independent to the remaining variables. It was calculated from the formula as proposed by Wright (1923).

Residual effect (x) =1-R_2

$R_2 = P_{1y}+P_{2y}r_{2y}+.....+P_{ny}\,R_{ny}$

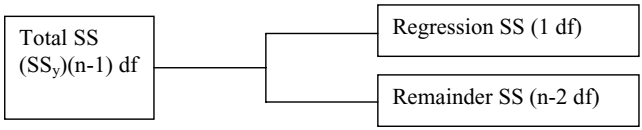
R_2 is the required multiple correlation coefficient and is the amount of variation in yield that can be accounted for by the component character.

3.2.17. Regression coefficient

To study the genotype-environment interaction, the data were analysed by the following techniques of analysis as developed and used by Finlay and Wilkinson (1963) in barley; Eberhart and Russell (1966) in maize; Bucio Alanis and Hill (1966), Perkins and Jinks (1968) in *Nicotiana Rustica* L. and Breese (1969) in grasses. In this study the following analyses were computed:

Regression Analysis:

Regression analyses were done by following Eberhart and Russell's (1966) models. The primary analysis of regression was done as follows:



Where,

n = Number of observation

Regression SS = $(SP_{xy})^2/SS_x$

Remainder SS = Total SS (SSy) – Regression SS

Where,

$SSx = \sum x^2 - (\sum x)^2 \quad /n$

$SPxy = \sum xy - \sum x.\sum y/n$

$SSy = \sum y^2 - (\sum y)^2 \quad /n$

Regression coefficient (1+ bi) : The response of each genotype under different environments of the environmental means over all the genotypes are measured by regression coefficient. This was estimated as follows:

$$b_i = \frac{SPxy}{SSx}$$

Study of stability parameters according to Eberhart and Russell's model:

In this approach, the regression coefficient and the deviation from regression are used as parameters of stability. As the regression of d_i on e_j is one, and regression of g_{ij} on e_j is βi, therefore, the b_i value of **Eberhart and Russell's model** is

$$b_i = 1+ \beta_i$$

$$\beta_i = \beta_1\text{-}1$$

Eberhart and Russell (1966) used the following model to study stability of the varieties under different environments :

$$Y_{ij} = m+ \beta_i I_j+\sigma_{ij}$$

Where,

i varies from 1 to L, the number of lines and
J varies from 1 to I, the number of environment
yij = Mean of ith lines over all the environments
m = Mean of all the lines over all the environments

β_i = The regression coefficient of the ith lines on the environmental index which measures the response of these lines to varying environments.

Ij = The environmental index which is defined as the deviation of mean of all the varieties at a given environment from the over all mean.

$$= \frac{\sum Yij}{i} - \frac{\sum_i \sum_j Yij}{LI} \quad \text{with} = \sum_j I_j = 0$$

And σ_{ij} = The deviation from the regression of ith lines at the jth environment.

Two parameters of stability were calculated:

1. The regression coefficient which is the regression of the performance of each variety under different environment on the environmental mean over all the genotypes. This was estimated as follows:

$$b_i = \sum_i Y_{ij} Ij / \sum_j I_j^2$$

Where,

$\sum_i Y_{ij}$ is the sum of products and

$\sum_j I_j^2$ is the sum of squares

2. Mean square deviation and stability ($\overline{S}_{di}^2$) from linear regression:

It is calculated from the following formula.

$$\overline{S}_{di}^2 = \frac{\sum_j \sigma ij\, 2}{(IY-2)} - \frac{S_e^2}{r}$$

where,

$$\sum_j \sigma^{\,2} ij = \left[\sum Y_{ij}^{\,2} - \frac{Y_i^{\,2}}{L}\right] - \frac{\left[\sum_j Y_{ij} I_j\right]}{\sum_j I_j^{\,2}}$$

$\sum \sigma^{\,2} ij =$ The variance due to deviation from regression, i.e., remainder sum of square.

$\sum_j Y_{ij}^{\,2} - \frac{Y_i^2}{L} =$ The variance due to dependent variable (SSy)

$\frac{\left[\sum Y_{ij} Ij\right]^2}{\sum I_j^2} =$ The variance due to regression

$S_e^{\,2} =$ the estimate of pooled error and

r = the number of replications.

The various computational steps involved in the estimation are as follow:

1. Computation of environmental index (I_j):

It is calculated as follows:

$$I_j = \frac{\sum_j Y_{ij}}{L} - \frac{\sum_i \sum_j Y_{ij}}{YI}$$

$$= \frac{\text{Total of the lines at the environment}}{\text{Number of lines}} - \frac{\text{Grand total}}{\text{Total number of observations}}$$

2. Computation of regression coefficient (b_i) **for each line:**

$$bi = \frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$$

Where, $\sum_j Y_{ij} I_j$ for each line is the sum of products of environment index (I_j) with the corresponding mean ($\bar{x}$) of that line at each environment. These values may be obtained in the following manner:

Where,

($\bar{x}$) = Matrix of mean
I_j = Vector of environment index
[S] = Vector of sum of products
i.e. $\sum_j Y_{ij}$

3. Computation of $\bar{S}_{di}^2$ in general, it is obtained by subtracting the variance due to regression from σ^2_y. It is calculated as follows.

$$\bar{S}^2 di = \left[\sum \sigma^2 ij / (IY - 2)\right] - (S^2 e / r)$$

4. Standard error b_i was calculated as follows:

$$Sb = \sqrt{\frac{\text{Remainder SS}}{SSx}}$$

3.2.18. Meteorological data

Weekly average maximum and minimum temperature (^{0}C), relative humidity, sunshine hours and total rainfall (mm) during the experimental years were collected from the Regional Meteorological Station, Shympur, Rajshahi-6205, Bangladesh.

Air temperature (maximum and minimum), relative humidity, sunshine hours, total rainfall from sowing to the final harvest are shown in **Table 5** for 2009-2010 and 2010-2011 growing seasons. It was observed that the temperature was higher in November and February in both the experimental seasons than in January. The highest temperature was found at third week (31.00) of November in 2009-2010 and second week (31.10) of November in 2010-2011. The lowest temperature was observed at third week (7.00) of December in 2009-2010 and second week (6.70) of December in 2010-2011. At the beginning in February, temperature increased gradually and remained increasing up to the final harvest in both the growing seasons.

Relative humidity had higher value in January and lower in February in both the experimental years. The highest humidity was observed second week 84.10% of January in 2009-2010 and second week 85.00% of January in 2010-2011. The lowest humidity was found at last week 67.00% of February in 2009-2010 and last week 65.00% of February in 2010-2011.

Higher bright sunshine hours were observed in November in both the growing seasons. The highest sunshine hours was found in second week (8.87) of November in 2009-2010 and last week (9.42) of February in 2010-2011. Lower bright sunshine hours were observed in January in both the experimental periods. The lowest sunshine hours were found in second week of January in both the years. Sunshine hours increased sharply and gradually in both the growing seasons up to the final harvest.

During the growing period all the plots received 20.80 mm natural rainfall in 2009-2010 season. Of these 2.50 mm in November, 15.30 mm in December, 1.60 mm in January and 1.40 mm in February. But, in the second seasons in 2010-2011, all the plots received 42.70 mm natural rainfall. Of these 3.10 mm in November, 38.40 mm in December and 1.20 mm in January. So, the fluctuation in total rainfall was high in 2010-2011 than in 2009-2010.

Table 5 : Temperature (maximum and minimum) , humidity, sunshine hours and total rainfall during the crop seasons.

Session time	Week	Maximum temperature	Minimum temperature	Humidity (%)	Sunshine hours	Rainfall (mm)
November 2009	First	30.40	19.70	82	7.51	000
	Second	30.90	19.00	81	8.87	000
	Third	31.00	19.10	81	7.20	2.50
	Fourth	28.50	16.70	80	6.40	000
December 2009	First	27.00	14.50	78	6.20	000
	Second	24.50	15.80	82	4.46	000
	Third	25.00	11.00	79	7.32	000
	Fourth	24.70	8.80	80	6.57	15.30
January 2010	First	23.00	10.50	82	6.10	000
	Second	20.00	7.10	84	5.20	000
	Third	22.10	7.00	80	5.72	000
	Fourth	24.80	9.90	81	5.71	1.60
February 2010	First	27.50	11.20	77	7.55	000
	Second	28.80	11.20	71	8.81	000
	Third	27.10	15.60	80	4.10	1.40
	Fourth	29.50	12.60	67	8.66	000

Session time	Week	Maximum temperature	Minimum temperature	Humidity (%)	Sunshine hours	Rainfall (mm)
November 2010	First	30.00	19.90	83	7.46	3.10
	Second	31.10	18.90	80	9.30	000
	Third	30.40	19.20	81	7.00	000
	Fourth	28.30	16.20	80	6.30	000
December 2010	First	26.60	14.40	77	6.30	000
	Second	24.70	15.50	82	4.41	38.40
	Third	24.80	10.40	78	7.51	000
	Fourth	24.50	8.60	81	6.51	000
January 2011	First	22.40	10.30	82	5.90	000
	Second	19.90	6.70	85	5.10	000
	Third	22.30	7.10	79	5.50	000
	Fourth	24.90	9.80	80	5.69	1.20
February 2011	First	27.40	11.10	76	7.60	000
	Second	29.00	11.20	72	8.76	000
	Third	27.20	15.70	81	3.47	000
	Fourth	29.40	12.40	65	9.42	000

Source: Regional Meteorological Station, Shympur, Rajshahi-6205, Bangladesh.

Chapter 4

RESULTS

4.1. Choice of growth analysis technique

Growth analysis has long been established as a standard technique for the study of plant growth and development. There are two different approaches of plant growth analysis – classical technique and functional technique. Out of these two approaches, classical technique was followed in the present experiment.

4.2. Primary branch height (PBH)

Experiment for 2009 – 2010

The results of analysis of variance for primary branch height of lentil are shown in **Table 6.** The results show that the item genotype (G) was highly significant at all the harvesting stages, indicating that the cultivars strongly responded in different soil moisture regimes. The item environment (E) was significant at most of the harvesting periods except at 57 DAS, which indicated that the varieties were highly affected by different soil moisture conditions.

Mean values on primary branch height of all six genotypes **(Table 8)** of lentil starting from a lower value at the early stages of growth, increased rapidly with the advancements of time and reached their highest value at the last harvest at 99 DAS. Among the genotypes, Barimasur 2 (G 2) showed the highest value and Barimasur 4 (G 4) was found to show the lowest value of primary branch height at all the growth phases.

Mean values on primary branch height of all four environments **(Table 8)** starting from a lower value at the early harvests, increased sharply with the age of plants and reached their highest value at the last harvest at 99 DAS. In all the environments, environment 2 (E 2) plants were observed to show the highest primary branch height at 57, 64, 71 and 78 DAS and environment 4 (E 4) plants showed the highest primary branch height at 85, 92 and 99 DAS. Environment 1 (E1) plants showed the lowest primary branch height at most of the growth stages except at 50 and 57 DAS.

The mean effect between genotypes and environments on primary branch height (**Table 8)** of lentil starting from a lower value at the early stages of growth and reached their

highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, G2×E4 showed the highest primary branch height at most of the growth stages except at 50, 57 and 71 DAS. On the other hand, G4×E1 was found to show the lowest primary branch height at 78, 85, 92 and 99 DAS and G4×E4 showed the lowest primary branch height at 50, 57, 64 and 71 DAS.

The overall interaction effects between genotypes and environments on primary branch height of lentil at different stages of growth are graphically shown in **Fig 2A**. The graphical presentation shows that all the genotypes and environments starting from a lower value, increased with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. In all the genotypes, at the last harvest (99 DAS) the highest peak was found in Barimasur 2 (G 2) and the lowest peak was observed in Barimasur 4 (G4). Barimasur 2 (G2) produced more primary branch height than the other genotypes and it was followed by Barimasur 1, Barimasur 3, Barimasur 4, Barimasur 5 and Barimasur 6. In all the environments, at the last harvest (99 DAS) the highest peak was found in environment 4 (E 4) plants and the lowest peak was found in environment 1(E1) plants. In all the environments, environment 4 (E4) plants showed the highest value at 85, 92 and 99 DAS and environment 2 (E 2) plants showed the highest primary branch height at 57, 64, 71 and 78 DAS. On the other hand, environment 1 (E1) plants showed the lowest peak at most of the harvesting dates except at 50 and 57 DAS.

Experiment for 2010 – 2011

Mean squares from the analysis of variance for primary branch height of lentil are shown in **Table 7.** The results show that the item genotype (G) was highly significant at all the harvesting stages, indicating that the cultivars were strongly affected in different soil moisture conditions. The item environment (E) was significant at most of the harvesting periods except at 57 DAS, which indicated that the varieties were highly affected by different soil moisture regimes.

Mean values on primary branch height of all six genotypes **(Table 9)** of lentil starting from a lower value at the early stages of growth, increased rapidly with the advancements of time and reached their highest value at the last harvest at 99 DAS. In

all the genotypes, Barimasur 2 (G 2) showed the highest value and Barimasur 4 (G 4) showed the lowest value of primary branch height at all the growth stages.

Mean values on primary branch height of all four environments **(Table 9)** starting from a lower value at the early stages of growth and reached their highest peak at the last harvest at 99 DAS. In all the environment, environment 2 (E 2) plants showed the highest primary branch height at 57, 64, 71 and 78 DAS. Environment 4 (E 4) plants were found to show the highest primary branch height at 85, 92 and 99 DAS. But, the environment 1 (E 1) plants showed the lowest primary branch height at most of the growth stages except only at 50 DAS.

The mean effect between genotypes and environments on primary branch height (**Table 9)** of lentil starting from a lower value at the early stages of growth and reached their highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, G2×E4 showed the highest primary branch height at most of the growth stages except at 50, 57 and 71 DAS. On the other hand, G4×E1 was observed to show the lowest primary branch height at 78, 85, 92 and 99 DAS and G4×E4 was observed to show the lowest primary branch height at 50, 57, 64 and 71 DAS.

The overall interaction effects between genotypes and environments on primary branch height of lentil at different stages of growth are graphically shown in **Fig 2B**. The graphical results showed that all the genotypes and environments starting from a lower value, increased with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. In all the genotypes, at the last harvest (99 DAS) the highest peak was found in Barimasur 2 (G 2) and the lowest peak was found in Barimasur 4 (G 4). Barimasur 2 (G 2) showed the highest peak and Barimasur 4 showed the lowest peak at all the growth stages. In all the environments, at the last harvest (99 DAS) the highest peak was found in environment 4 (E 4) plants and the lowest peak was found in environment 1 (E 1) plants. Among the environments, environment 4 (E 4) plants showed the highest value at 85, 92 and 99 DAS and environment 2 (E 2) plants showed the maximum peak at 57, 64, 71 and 78 DAS. On the other hand, environment 1 (E 1) plants showed the lowest peak at most of the harvesting stages except only at 50 DAS.

Table 6 : Mean squares (MS) from the analysis of variance for primary branch height (cm) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2009– 2010.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	1.454	3.587	1.724	2.538	2.413	2.302	5.963	6.820
Genotype (G)	5	10.542**	14.275**	15.928**	17.009**	11.927**	12.983**	13.872**	28.010**
Error - 1	10	0.933	0.974	0.992	0.767	0.786	0.742	0.972	0.953
Environment (E)	3	5.796**	1.930	8.278**	17.98**	19.183**	30.864**	42.821**	52.924**
G × E	15	1.753	1.841	1.521	2.828	3.691	1.483	2.467	2.423
Error - 2	36	1.588	2.145	3.058	2.487	2.503	2.477	2.702	2.086

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 7 : Mean squares (MS) from the analysis of variance for primary branch height (cm) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2010– 2011.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	0.468	2.669	0.617	1.347	1.459	1.258	3.417	4.355
Genotype (G)	5	9.708**	11.05**	14.74**	13.097**	14.444**	16.049**	16.223**	17.201**
Error - 1	10	0.934	0.976	0.994	0.771	0.792	0.737	0.981	0.971
Environment (E)	3	4.813*	0.921	5.368*	19.696**	17.395**	33.679**	46.536**	49.616**
G × E	15	1.647	1.738	1.447	2.674	3.756	1.395	1.396	1.38
Error - 2	36	1.698	2.056	3.167	2.699	2.645	2.688	2.541	2.374

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 8 : Mean values of primary branch height (cm) of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2009 – 2010.

Genotype (G)	50 DAS	57DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	15.13	18.42	21.96	25.20	28.53	31.13	33.08	33.59
Barimasur 2 (G2)	16.28	19.84	23.69	26.24	29.89	32.47	34.35	34.84
Barimasur 3 (G3)	15.73	19.09	21.95	25.70	28.41	31.96	33.06	33.58
Barimasur 4 (G4)	13.74	17.02	20.22	23.26	26.53	29.20	30.84	31.38
Barimasur 5 (G5)	14.38	18.33	21.73	24.88	28.52	30.93	32.68	33.18
Barimasur 6 (G6)	14.59	18.29	21.62	24.54	28.27	30.60	32.38	32.95
LSD 5%	0.868	0.879	0.905	0.801	0.806	0.793	0.884	0.902
Environment (E)								
Environment 1 (E1)	15.33	18.35	21.34	24.14	27.01	29.07	30.52	31.46
Environment 2 (E2)	14.96	18.83	22.49	26.32	29.38	31.57	33.05	33.57
Environment 3 (E3)	15.01	18.29	21.58	24.31	28.54	31.44	33.56	34.09
Environment 4 (E4)	14.60	18.52	22.04	25.10	28.50	32.09	34.12	34.64
LSD 5%	0.846	0.927	1.194	1.215	1.162	1.100	1.087	1.195
(G×E)								
G1×E1	16.07	18.77	22.03	24.73	27.23	29.43	31.03	31.57
G1×E2	14.77	18.60	22.33	26.20	29.13	31.47	32.93	33.43
G1×E3	15.27	18.07	21.43	24.37	28.13	31.67	33.67	34.17
G1×E4	14.40	18.23	22.03	25.50	29.60	31.93	34.67	35.20
G2× E1	16.43	19.63	22.67	23.93	27.77	29.77	31.13	31.70
G2×E2	16.37	20.50	24.17	27.73	30.83	32.90	34.43	34.90
G2×E3	16.57	19.70	23.37	25.70	29.30	32.33	35.13	35.63
G2×E4	15.73	19.53	24.57	27.60	31.67	34.87	36.70	37.13
G3× E1	15.50	18.43	21.50	24.73	28.00	30.17	31.50	32.07
G3×E2	15.63	19.67	23.27	27.00	29.97	32.10	33.50	34.07
G3×E3	15.17	17.83	21.13	24.53	29.60	32.50	34.23	34.83
G3×E4	16.60	20.43	21.90	26.53	29.80	33.07	35.00	35.50
G4× E1	14.00	16.93	19.70	22.67	25.23	27.33	28.67	29.23
G4×E2	14.20	18.00	21.50	25.57	28.40	30.50	31.97	32.47
G4×E3	14.27	16.97	20.20	22.87	26.37	29.70	31.67	32.20
G4×E4	12.50	16.17	19.47	21.93	26.13	29.27	31.07	31.63
G5×E1	14.17	17.30	20.10	23.60	26.07	28.20	29.83	30.37
G5×E2	14.43	18.23	21.93	25.90	29.13	31.40	32.93	33.43
G5×E3	14.40	19.05	22.33	24.73	29.60	32.00	33.87	34530
G5×E4	14.53	18.73	22.57	25.27	29.27	32.13	34.10	34.63
G6× E1	15.83	19.03	22.03	25.20	27.73	29.53	30.97	31.50
G6×E2	14.30	17.97	21.73	25.53	28.80	31.03	32.53	33.13
G6×E3	14.40	18.13	21.00	23.67	28.27	30.47	32.85	33.40
G6×E4	13.83	18.03	21.70	23.77	28.27	31.30	33.20	33.77
LSD 5%	2.255	2.297	2.888	2.816	2.507	2.574	2.799	2.605

Table 9: Mean values of primary branch height (cm) of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2010 - 2011.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	15.37	18.70	22.31	25.63	28.93	31.46	33.44	34.00
Barimasur 2 (G2)	16.33	20.06	24.03	26.68	30.25	32.83	34.73	35.43
Barimasur 3 (G3)	16.01	19.28	22.29	25.86	29.72	32.32	33.45	33.99
Barimasur 4 (G4)	13.98	17.16	20.55	23.58	26.82	29.51	31.18	31.72
Barimasur 5 (G5)	14.49	18.58	22.10	25.22	28.79	31.30	33.02	33.65
Barimasur 6 (G6)	14.88	18.53	21.96	24.86	28.59	30.93	32.73	33.42
LSD 5%	0.879	0.899	0.907	0.799	0.810	0.781	0.901	0.896
Environment (E)								
Environment 1 (E1)	15.85	18.49	21.67	24.46	27.34	29.39	30.78	31.26
Environment 2 (E2)	15.22	18.98	22.91	26.68	29.70	31.94	33.40	34.25
Environment 3 (E3)	15.03	18.58	21.90	24.53	29.44	31.78	33.70	34.33
Environment 4 (E4)	14.61	18.82	22.34	25.54	28.79	32.46	34.48	34.96
LSD 5%	0.881	0.969	1.203	1.111	1.099	1.108	1.078	1.042
(G×E)								
G1×E1	16.53	19.00	22.33	25.13	27.57	29.73	31.43	31.70
G1×E2	15.30	18.80	22.77	26.57	29.50	31.80	33.30	34.00
G1×E3	15.23	18.43	21.80	24.80	28.70	32.00	34.00	34.73
G1×E4	14.40	18.57	22.33	26.00	29.93	32.30	35.03	35.57
G2× E1	16.40	19.70	22.97	24.20	28.17	30.04	31.53	32.10
G2×E2	16.23	20.67	24.60	28.37	31.20	33.40	34.80	35.47
G2×E3	16.80	19.97	23.67	26.03	29.63	32.67	35.53	36.67
G2×E4	15.90	19.90	24.87	28.10	32.00	35.20	37.07	37.47
G3× E1	16.17	18.53	21.83	25.07	28.40	30.50	31.23	31.80
G3×E2	16.03	19.77	23.63	27.30	30.30	32.50	33.90	34.57
G3×E3	15.20	18.13	21.47	24.13	29.90	32.83	33.23	33.67
G3×E4	16.63	20.70	22.23	26.93	30.20	33.43	35.43	35.93
G4× E1	15.07	17.07	20.07	22.97	25.50	27.60	29.00	29.60
G4×E2	14.27	18.07	21.93	25.80	28.67	30.87	32.27	32.87
G4×E3	14.20	17.20	20.50	23.17	26.73	30.00	32.00	32.53
G4×E4	12.40	16.30	19.70	22.40	26.37	29.57	31.43	31.87
G5×E1	14.17	17.37	20.47	23.83	26.30	28.57	30.17	30.83
G5×E2	14.73	18.47	22.40	26.23	29.47	31.73	33.27	34.20
G5×E3	14.50	19.40	22.63	25.10	29.90	32.37	34.27	34.70
G5×E4	14.57	19.10	22.90	25.70	29.50	32.53	34.37	34.87
G6× E1	16.77	19.27	22.37	25.53	28.10	29.87	31.30	31.90
G6×E2	14.77	18.13	22.13	25.83	29.07	31.37	32.87	33.40
G6×E3	14.27	18.33	21.33	23.93	28.53	30.80	33.17	33.70
G6×E4	13.73	18.37	22.00	24.13	28.67	31.70	33.57	34.07
LSD 5%	2.158	2.374	2.947	2.720	2.693	2.715	2.640	2.551

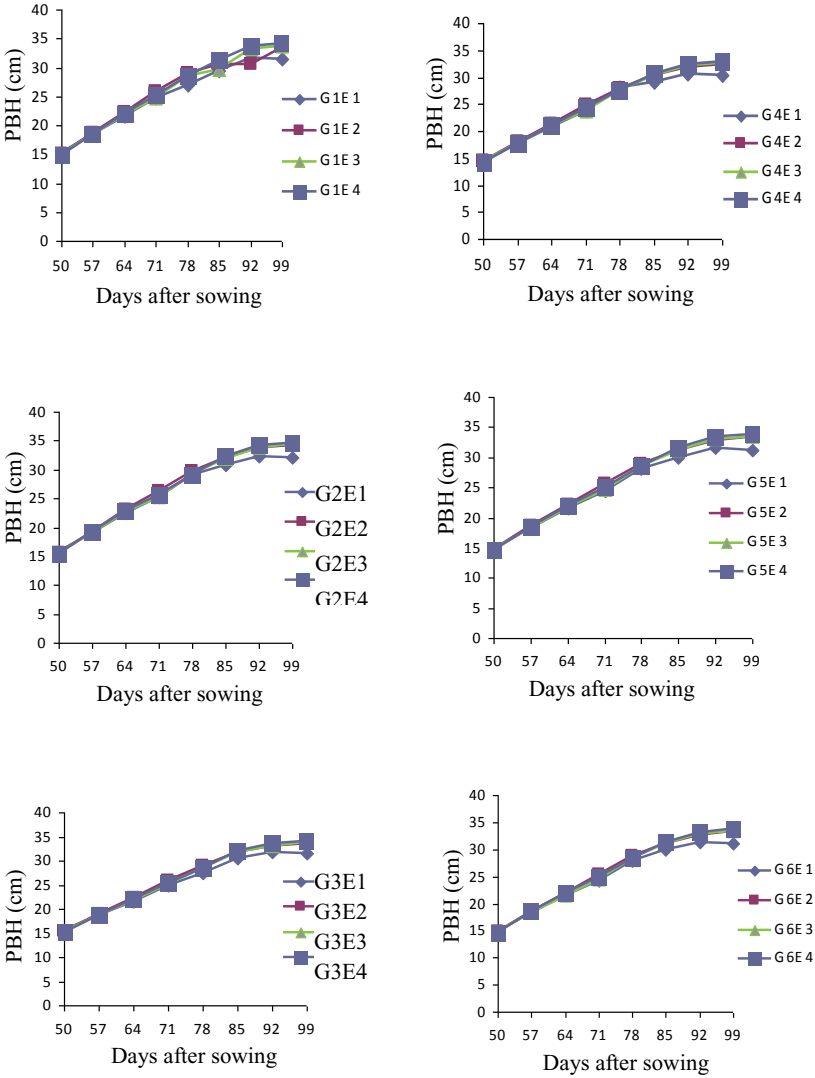


Figure. 2A: Interaction between genotypes and environments on primary branch height (PBH) of six lentil genotypes at different growth stages for experiment 2009-2010.

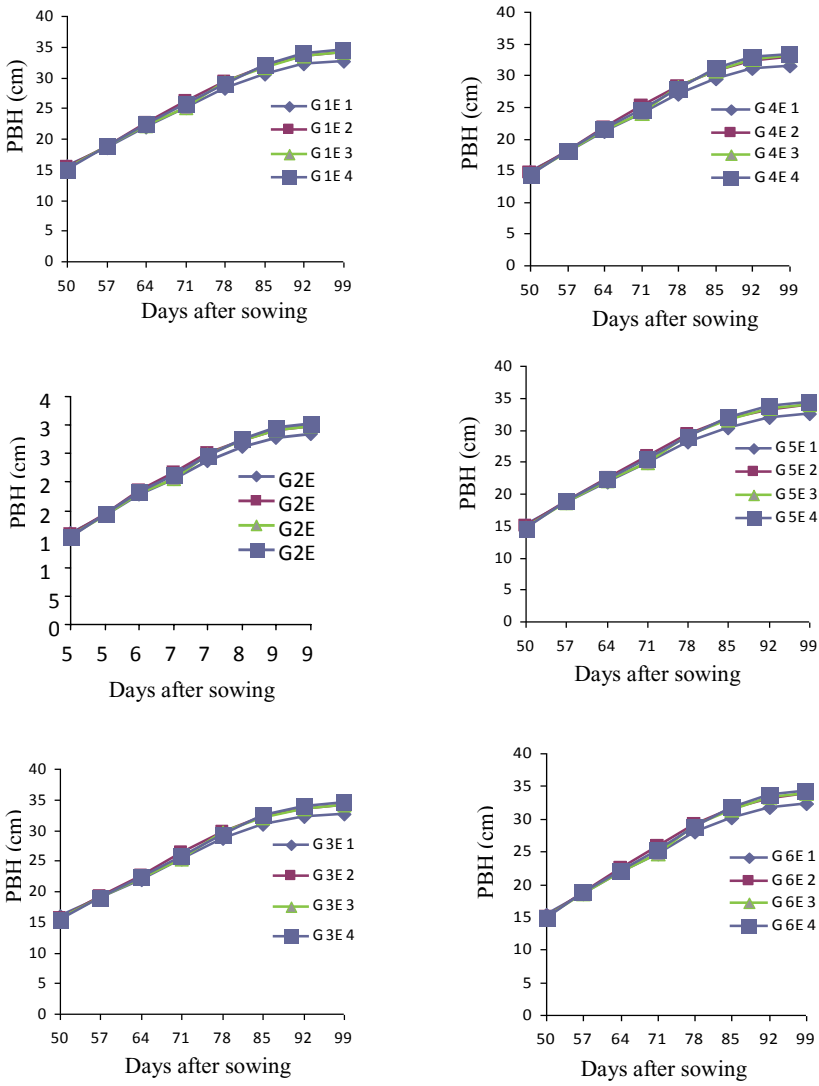


Figure. 2B: Interaction between genotypes and environments on primary branch height (PBH) of six lentil genotypes at different growth stages for experiment 2010-2011.

4.3. Secondary branch height (SBH)

Experiment for 2009 – 2010

The results of analysis of variance for secondary branch height of lentil are shown in **Table 10.** The results show that the item genotype (G) was highly significant at all the harvesting dates, indicating that the cultivars were strongly affected by the soil moisture conditions. The item environment (E) was significant at most of the harvesting periods except at 50 DAS, which indicated that the varieties were highly affected by different soil moisture regimes.

Mean values on secondary branch height of all six genotypes **(Table 12)** of lentil starting from a lower value at the early stages of growth, increased with the advancement of time and reached their highest value at the last harvest at 99 DAS. In all the genotypes, Barimasur 2 (G 2) showed the highest secondary branch height at all the growth stages. Barimasur 4 (G 4) showed the lowest secondary branch height at most of the growth phases except at 50 and 57 DAS.

Mean values on secondary branch height of all four environments **(Table 12)** of lentil starting from a lower value at the early stages of growth and reached their highest value at the last harvest at 99 DAS. Of all the environments, environment 4 (E 4) plants were found to show the highest value at most of the growth stages except at 50 and 57 DAS. Environment 1 (E1) plants showed the lowest secondary branch height at most of the growth phases except at 50, 57 and 71 DAS.

The mean effect between genotypes and environments on secondary branch height of lentil **(Table 12)** starting from a lower value at the early stages of growth and reached their highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, G2×E4 showed the highest value at most of the growth stages except at 50 and 57 DAS. G4×E1 was found to show the lowest secondary branch height at most of the growth phases except at 50 and 57 DAS.

The overall interaction effects between genotypes and environments on secondary branch height of lentil at different stages of growth are graphically present in **Fig 3A**. The graphical results show that all the genotypes and environments on secondary branch

height of lentil indicated that starting from a lower value, increased sharply with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. Barimasur 2 (G 2) had the highest value and Barimasur 4 (G 4) had the lowest value at the last harvest at 99 DAS. In all the genotypes, Barimasur 2 (G 2) showed the highest peak at all the growth stages. Barimasur 4 (G 4) showed the lowest secondary branch height at most of the growth stages except at 50 and 57 DAS. Of all the environments, at the last harvest (99 DAS) the highest peak was found in environment 4 (E 4) plants and the lowest peak was observed in environment 1 (E1) plants. On average, environment 4 (E 4) plants showed the highest peak at most of the growth stages except at 50 and 57 DAS and environment 1 (E1) plants showed the lowest secondary branch height at most of the growth stages except at 50, 57 and 71 DAS.

Experiment for 2010 – 2011

Mean squares from the analysis of variance for secondary branch height of lentil are shown in **Table 11.** The results show that the item genotype (G) was highly significant at all the harvesting dates, indicating that the cultivars were strongly affected by different soil moisture conditions. The item environment (E) was significant at most of the harvesting periods except at 50, 57 and 64 DAS, which indicated that the varieties were highly affected by different soil moisture regimes.

Mean values on secondary branch height of all six genotypes **(Table 13)** of lentil starting from a lower value increased with the increasing growth periods and reached their highest value at the last harvest at 99 DAS. Among the genotypes, Barimasur 2 (G 2) showed the highest value and Barimasur 4 (G 4) was found to show the lowest value of secondary branch height at all the growth phases.

Mean values on secondary branch height of all four environments **(Table 13)** of lentil starting from a lower value at the early stages of growth, increased with the advancement of time and reached their highest value at the last harvest at 99 DAS. In all the environments, environment 4 (E 4) plants showed the highest value at most of the harvesting dates except at 50 and 71 DAS. Environment 1 (E1) plants was found to show the lowest secondary branch height at most of the growth stages except at 50 DAS.

The mean effect between genotypes and environments on secondary branch height of lentil **(Table 13)** starting from a lower value at the early stages of growth and reached their highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, G2×E4 showed the highest value at most of the growth stages except at 50, 57 and 71 DAS. G4×E1 was observed to show the lowest secondary branch height at most of the growth phases except only at 50 DAS.

The overall interaction effects between genotypes and environments on secondary branch height of lentil at different stages of growth are graphically present in **Fig 3B**. The graphical results show that all the genotypes and environments on secondary branch height of lentil indicated that starting from a lower value, increased sharply with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. A close study of the six genotypes revealed that Barimasur 2 (G 2) had the highest value and Barimasur 4 (G $4_{)}$ had the lowest value at the last harvest at 99 DAS. On average, Barimasur 2 (G 2) showed the highest peak and Barimasur 4 (G 4) showed the lowest secondary branch height at all the growth stages. In all the environments, at the last harvest (99 DAS) the highest peak was found in environment 4 (E 4) plants and the lowest peak was observed in environment 1(E 1) plants. On average, environment 4 (E 4) plants showed the highest peak at most of the growth phases except at 50 and 71 DAS. Environment 1 (E1) plants were found to show the lowest secondary branch height at most of the growth stages except only at 50 DAS.

Table 10 : Mean squares (MS) from the analysis of variance for secondary branch height (cm) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2009 – 2010.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	1.394	3.371	1.746	1.264	2.468	3.073	5.831	5.482
Genotype (G)	5	14.689**	12.013**	14.638**	15.07**	16.073**	16.052**	18.873**	18.034**
Error - 1	10	1.204	0.910	1.303	1.206	0.944	0.924	0.966	1.123
Environment (E)	3	1.701	7.457**	8.58**	16.556**	25.887**	45.937**	61.995**	61.837**
G × E	15	1.122	2.306	0.408	1.921	1.965	1.237	1.887	1.864
Error - 2	36	1.791	2.304	3.062	3.101	2.427	2.227	2.416	2.235

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 11: Mean squares (MS) from the analysis of variance for secondary branch height (cm) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2010 - 2011.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	0.289	2.462	0.552	0.907	1.657	2.327	3.643	4.253
Genotype (G)	5	11.448**	11.292**	13.11**	11.69**	14.134**	14.115**	15.544**	15.189**
Error - 1	10	1.186	0.802	1.02	1.195	0.938	0.892	0.951	1.023
Environment (E)	3	0.685	4.882	7.873	18.304**	28.916**	47.793**	65.007**	68.364**
G × E	15	1.054	1.242	0.911	1.519	1.656	1.106	0.864	0.816
Error - 2	36	1.98	2.157	3.205	2.918	2.776	2.572	2.555	2.281

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 12: Mean values of secondary branch height (cm) of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2009 – 2010.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	15.74	19.18	22.73	26.00	29.33	32.04	33.08	34.42
Barimasur 2 (G2)	17.32	20.93	24.80	27.40	30.98	33.64	35.59	35.90
Barimasur 3 (G3)	17.07	20.33	23.33	26.84	30.30	32.90	34.38	35.04
Barimasur 4 (G4)	14.99	18.22	21.65	25.18	27.78	30.48	32.12	32.57
Barimasur 5 (G5)	15.41	19.55	22.73	25.92	29.43	31.98	33.65	34.15
Barimasur 6 (G6)	14.31	17.77	22.77	25.93	29.47	31.85	33.38	33.97
LSD 5%	0.983	0. 866	0.954	0.867	0.908	0.966	0.979	0.903
Environment (E)								
Environment 1 (E1)	16.96	19.86	21.63	25.76	27.64	29.82	31.97	32.53
Environment 2 (E2)	15.19	18.99	23.06	27.51	29.67	31.86	33.84	34.36
Environment 3 (E3)	15.82	18.76	22.87	25.09	29.81	31.38	34.08	34.66
Environment 4 (E4)	16.46	19.65	23.86	26.38	29.95	32.08	34.37	35.12
LSD 5%	0.975	0.969	1.301	1.262	1.308	1.135	1.163	1.102
(G×E)								
G1×E1	16.23	19.27	22.60	25.23	27.83	29.93	31.33	31.80
G1×E2	15.57	19.10	22.70	26.30	29.47	32.17	33.73	34.23
G1×E3	15.43	18.87	22.43	25.53	29.33	32.33	34.17	34.63
G1×E4	15.73	19.50	23.20	26.93	30.87	33.97	35.90	36.33
G2× E1	17.70	20.87	24.20	25.27	29.17	31.20	32.26	32.80
G2×E2	18.13	21.30	25.17	28.63	31.80	34.33	36.47	36.97
G2×E3	16.77	20.50	24.13	26.80	30.17	33.10	35.40	35.83
G2×E4	16.67	21.07	25.70	28.90	32.77	35.93	37.83	38.30
G3× E1	16.73	19.50	22.80	26.00	29.27	31.37	32.17	32.70
G3×E2	16.57	19.90	23.80	27.07	30.17	32.77	34.27	34.80
G3×E3	16.60	19.63	22.87	25.80	29.50	32.53	34.23	34.73
G3×E4	18.37	22.37	23.87	28.50	32.27	34.93	36.83	37.27
G4× E1	14.90	17.97	20.77	23.77	26.37	28.40	29.83	30.33
G4×E2	14.83	18.17	21.77	25.00	28.13	30.70	32.20	32.70
G4×E3	15.67	18.87	22.47	25.63	28.80	31.77	33.53	34.07
G4×E4	14.53	17.87	21.60	23.97	27.83	31.03	32.90	33.40
G5×E1	15.17	18.33	21.03	24.53	27.00	29.27	30.87	31.33
G5×E2	15.03	18.97	22.37	25.97	29.87	32.17	33.73	34.27
G5×E3	15.60	19.87	23.77	26.43	30.50	32.97	34.63	35.13
G5×E4	15.83	20.33	23.83	26.73	30.33	33.50	35.37	35.40
G6× E1	16.20	19.57	22.53	25.70	28.30	30.13	31.50	32.00
G6×E2	14.50	18.47	21.67	25.10	29.47	31.37	32.70	33.23
G6×E3	16.10	19.73	23.30	26.20	30.13	32.77	34.40	34.93
G6×E4	15.70	20.00	23.57	26.73	30.03	33.13	34.93	35.37
LSD 5%	2.265	2.218	2.995	2.934	2.866	2.872	2.408	2.822

Table 13: Mean values of secondary branch height (cm) of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2010 - 2011.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	15.95	19.55	23.14	26.45	29.77	32.49	34.19	34.88
Barimasur 2 (G2)	17.51	21.30	25.16	27.78	31.40	34.08	36.02	36.64
Barimasur 3 (G3)	17.22	20.68	23.69	27.38	30.71	33.33	34.82	35.44
Barimasur 4 (G4)	15.04	18.53	21.94	24.98	28.18	30.88	32.55	33.19
Barimasur 5 (G5)	15.57	19.53	23.18	26.14	29.84	32.37	34.09	34.73
Barimasur 6 (G6)	15.73	19.76	23.18	26.33	29.83	32.23	33.91	34.66
LSD 5%	0.991	0.815	0.919	0.994	0.881	0.859	0.887	0.910
Environment (E)								
Environment 1 (E1)	16.37	19.48	22.62	25.54	28.29	30.37	31.67	32.21
Environment 2 (E2)	15.91	19.87	23.80	27.57	30.59	32.83	34.28	35.13
Environment 3 (E3)	16.14	19.59	23.06	25.77	29.72	32.75	34.91	35.54
Environment 4 (E4)	16.24	20.63	24.06	27.17	31.21	34.31	36.19	36.82
LSD 5%	0.951	0.993	1.210	1.155	1.126	1.084	1.081	1.021
(G×E)								
G1×E1	16.50	19.53	22.83	25.60	28.10	30.20	31.60	32.20
G1×E2	15.43	19.40	23.37	27.17	30.10	32.40	33.90	34.60
G1×E3	16.07	19.27	22.63	25.60	29.53	32.83	34.83	35.57
G1×E4	15.80	20.00	23.73	27.43	31.33	34.53	36.43	37.13
G2× E1	18.00	21.10	24.37	25.90	29.53	31.53	32.93	33.50
G2×E2	17.57	21.67	25.60	29.37	32.20	34.40	35.80	36.47
G2×E3	17.70	20.90	24.57	27.60	30.53	33.83	36.90	37.57
G2×E4	16.77	21.53	26.10	28.27	33.33	36.53	38.43	39.03
G3× E1	16.97	19.73	23.03	26.80	29.60	31.80	32.43	33.00
G3×E2	16.53	20.57	24.43	28.10	31.10	33.30	34.70	35.37
G3×E3	16.70	19.63	22.97	25.63	29.43	32.73	34.73	35.40
G3×E4	18.67	22.77	24.33	28.97	32.70	35.50	37.40	38.00
G4× E1	15.00	18.17	21.17	24.07	26.60	28.70	30.10	30.70
G4×E2	15.27	19.17	23.07	26.90	29.77	31.97	33.37	33.97
G4×E3	15.43	18.50	21.80	24.47	28.00	31.30	33.30	34.00
G4×E4	14.47	18.30	21.73	24.50	28.33	31.53	33.43	34.10
G5×E1	15.33	18.53	21.47	24.83	27.30	29.57	31.17	31.83
G5×E2	15.40	19.27	23.20	27.03	30.27	32.53	34.07	35.00
G5×E3	15.50	19.57	23.70	26.10	30.87	33.33	35.27	35.63
G5×E4	16.03	20.77	24.37	26.60	30.93	34.03	35.87	36.47
G6× E1	16.43	19.80	22.87	26.03	28.60	30.40	31.80	32.00
G6×E2	15.27	19.13	23.13	26.83	30.13	32.37	33.87	35.40
G6×E3	15.47	19.67	22.67	25.20	29.93	32.47	34.40	35.07
G6×E4	15.73	20.43	24.07	27.27	30.63	33.70	35.57	36.17
LSD 5%	2.330	2.432	2.965	2.829	2.759	2.656	2.647	2.501

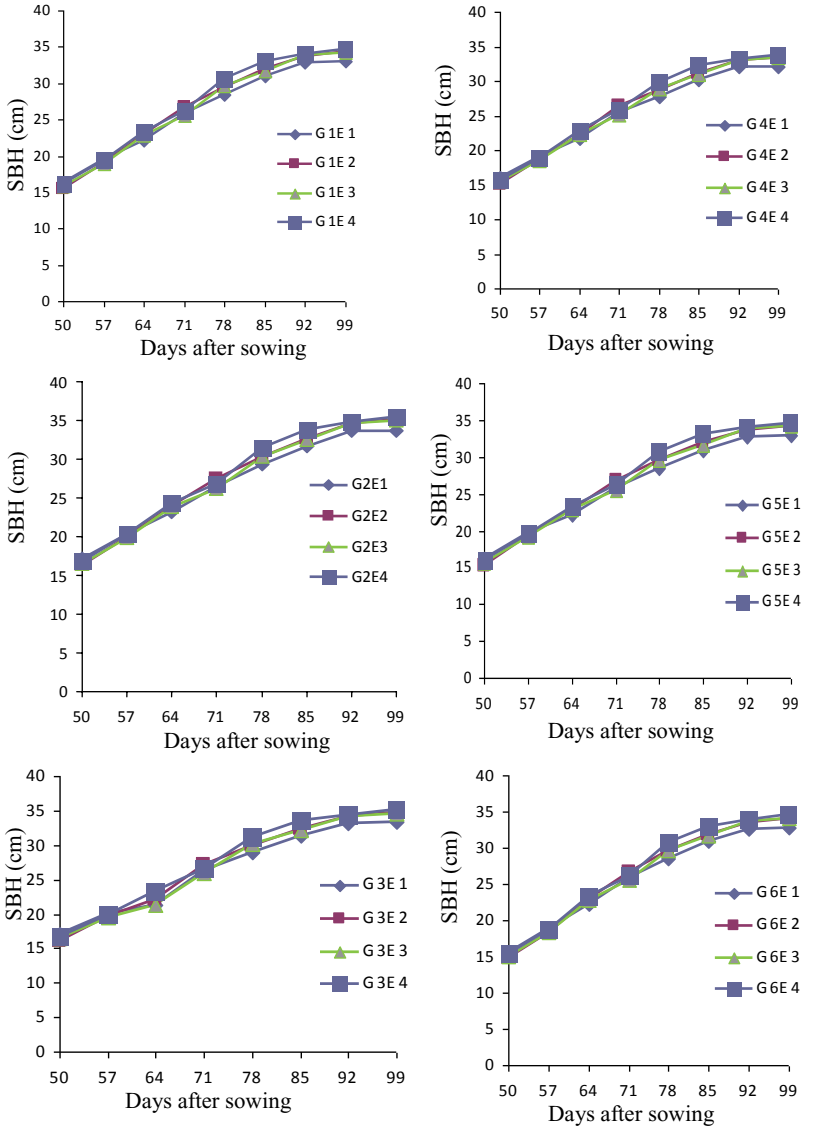


Figure 3A: Interaction between genotypes and environments on secondary branch height (SBH) of six lentil genotypes at different growth stages for experiment 2009-2010.

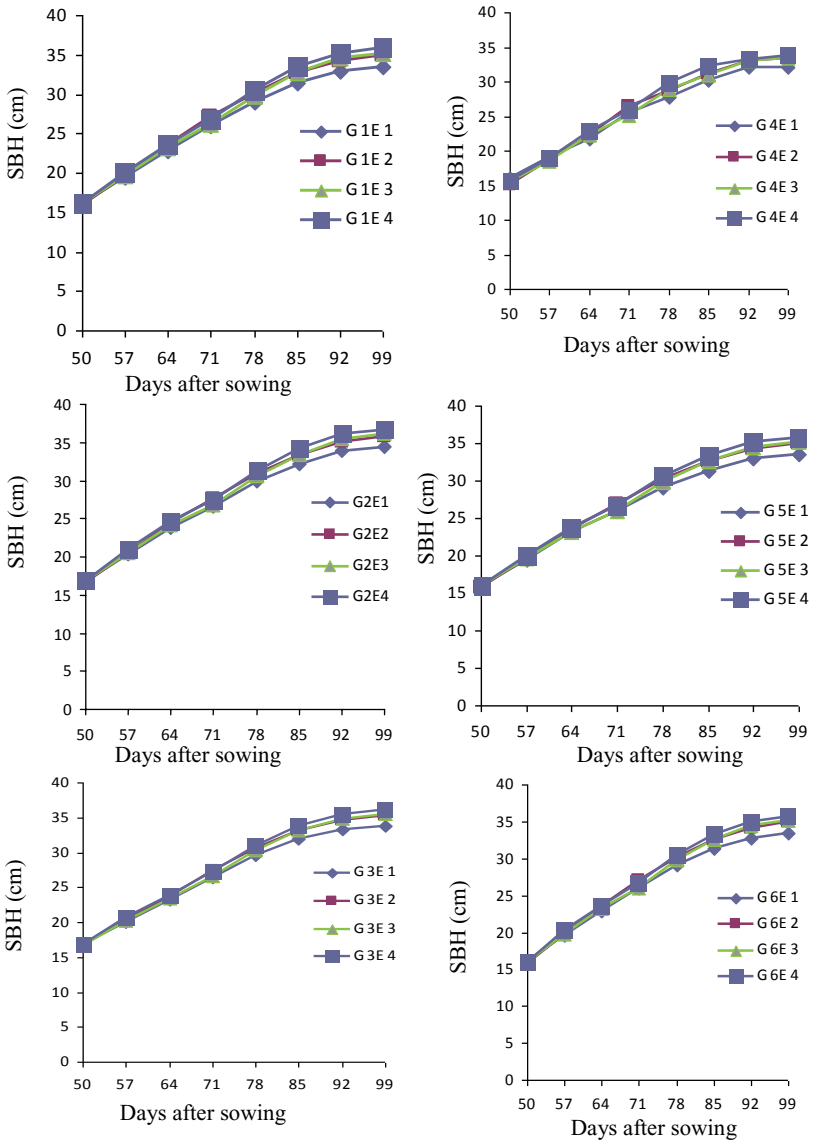


Figure. 3B: Interaction between genotypes and environments on secondary branch height (SBH) of six lentil genotypes at different growth stages for experiment 2010-2011.

4.4. Plant height (PH)

Experiment for 2009 – 2010

The results of analysis of variance for plant height of lentil are shown in **Table 14.** The results show that the item genotype (G) was highly significant at all the growth stages, indicating that the cultivars were highly responded by soil moisture conditions. The item environment (E) was highly significant at all the harvesting periods, which indicated that highly affected by different soil moisture regimes. The item G×E interaction was significant at most of the growth stages except at 64 and 78 DAS.

Mean values on plant height of all six genotypes **(Table 16)** of lentil starting from a lower value at the early stages of growth, increased with the advancement of time and very sharply reached their highest peak at the last harvest at 99 DAS. In all the genotypes, Barimasur 1 (G 1) showed the highest plant height at all the growth stages. Barimasur 6 (G 6) was found the lowest plant height at most of the growth stages except at 50, 57 and 78 DAS. On the other hand, Barimasur 4 (G 4) showed the lowest plant height at 50 and 57 DAS.

Mean values on plant height of all four environments **(Table 16)** of lentil starting from a lower value at the early stages of growth and rapidly reached their highest value at the last harvest at 99 DAS. In all the environments, environment 4 (E 4) plants showed the highest value at most of the growth stages except at 50, 57 and 64 DAS and environment 2 (E 2) plants were observed to show the highest value at 50, 57 and 64 DAS. Environment 1 (E1) plants showed the lowest plant height at most of the growth stages except only at 50 DAS.

The mean effect between genotypes and environments on plant height of lentil **(Table 16)** starting from a lower value, increased with the increasing growth stages and reached their highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, G1×E4 showed the maximum value at all the growth stages. G5×E3 showed the minimum plant height at 50, 57, 64 and 71 DAS and G2×E1 was found to show the lowest plant height at 85, 92 and 99 DAS .

The overall interaction effects between genotypes and environments on plant height of lentil at different stages of growth are graphically shown in **Fig 4A**. The graphical presentation shows that all the genotypes and environments starting from a lower value, increased with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. In all the genotypes, at the last harvest (99 DAS) the highest peak was found in Barimasur 1 (G1) and the lowest peak was observed in Barimasur 6 (G 6). Barimasur 1 (G1) produced more plant height at all the harvesting dates. Barimasur 6 produced less plant height at most of the harvesting stages except at 50, 57 and 78 DAS. Among the environments, at the last harvest (99 DAS) the highest peak was found in environment 4 (E 4) plants and the lowest peak was found in environment 1(E1) plants. Environment 4 (E 4) plants showed the highest plant height at most of the growth stages except at 50, 57 and 64 DAS and Environment 2 (E 2) plants was found to show the highest value at 50, 57 and 64 DAS. Environment 1 (E1)plants showed the lowest plant height at most of the growth stages except only at 50 DAS.

Experiment for 2010 – 2011

Mean squares from the analysis of variance for plant height of lentil are shown in **Table 15.** The results show that the item genotype (G) was highly significant at all the growth stages, indicated that the cultivars were strongly responded by different soil moisture conditions. The item environment (E) was highly significant at all the harvesting periods, which indicated that the varieties were highly affected by different soil moisture regimes. The item G×E interaction was significant at most of the growth stages except at 57 and 78 DAS.

Mean values on plant height of all six genotypes **(Table 17)** of lentil starting from a lower value at the early stages of growth and reached their highest peak at the last harvest at 99 DAS. In all the genotypes, Barimasur 1 (G1) showed the highest plant height at all the growth stages. Barimasur 5 (G 5) showed the lowest plant height at most of the growth stages except at 50, 57 and 78 DAS. But, Barimasur 4 (G 4) showed the lowest plant height at 50 and 57 DAS.

Mean values on plant height of all four environments **(Table 17)** of lentil starting from a lower value at the early stages of growth and reached their highest value at the last

harvest at 99 DAS. In all the environments, environment 4 (E 4) plants showed the highest value at most the growth stages except at 50, 57 and 64 DAS and environment 2 (E 2) plants was found to show the highest value at 50, 57 and 64 DAS. Environment 1 (E1) plants showed the lowest plant height at most of the growth stages except at 50, 57 and 64 DAS and environment 3 (E 3) plants were observed to show the lowest plant height at 50, 57 and 64 DAS.

The mean effect between genotypes and environments on plant height of lentil **(Table 17)** starting from a lower value, increased with the increasing growth stages and reached their highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, G1×E4 showed the maximum value at all the growth stages. The minimum plant height was found in G4×E1 at 57 and 85 DAS, in G5×E3 at 64 and 71 DAS and in G2×E1 at 92 and 99 DAS.

The overall interaction effects between genotypes and environments on plant height of lentil at different stages of growth are graphically shown in **Fig 4B**. The graphical presentation shows that all the genotypes and environments starting from a lower value, increased with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. In all the genotypes, at the last harvest (99 DAS) the highest peak was found in Barimasur 1 (G1) and the lowest peak was found in Barimasur 5 (G5). Barimasur 1 (G1) produced more plant height at all the harvesting dates. Barimasur 5 (G 5) produced less plant height at most of the growth stages except at 50, 57 and 78 DAS. Among the environments, at the last harvest (99 DAS) the highest peak was found in environment 4 (E 4) plants and the lowest peak was found in environment 1 (E1) plants. Environment 4 (E 4) plants showed the highest peak at most of the growth phases except at 50, 57 and 64 DAS and environment 2 (E 2) plants produced more plant height at 50, 57 and 64 DAS. Environment 1 (E1) plants showed the lowest plant height at most of the growth stages except at 50, 57 and 64 DAS and environment 3 (E 3) plants produced less plant height at 50, 57 and 64 DAS.

Table 14: Mean squares (MS) from the analysis of variance for plant height (cm) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2009 - 2010.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	1.139	2.150	1.202	1.942	2.513	0.912	5.670	0.209
Genotype (G)	5	10.062**	13.001**	18.043**	17.945**	32.642**	51.895**	82.078**	14.087**
Error - 1	10	0.351	0.310	0.341	1.216	3.460	1.805	2.513	0.406
Environment (E)	3	6.413**	36.947**	101.78**	121.87**	217.013**	218.01**	208.95**	16.248**
G × E	15	2.174**	2.937**	1.033	8.073**	3.710	12.126**	18.972**	2.346**
Error - 2	36	0.636	0.742	0.939	1.984	2.301	2.504	3.358	0.691

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 15: Mean squares (MS) from the analysis of variance for plant height (cm) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2010 - 2011.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	0.144	1.13	0.117	1.516	1.402	0.201	4.14	0.144
Genotype (G)	5	9.174**	11.087**	16.038**	14.389**	24.116**	44.787**	70.686**	9.174**
Error - 1	10	0.353	0.32	0.322	1.087	2.45	1.751	2.494	0.353
Environment(E)	3	5.267**	41.616**	96.469**	114.17**	206.432**	187.953**	205.028**	5.267**
G × E	15	1.231**	1.226	1.847**	5.537**	2.69	11.956**	17.652**	1.231**
Error - 2	36	0.637	0.711	0.948	1.875	2.244	2.422	3.345	0.637

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 16: Mean values of plant height (cm) of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2009 – 2010.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	21.26	25.79	30.30	32.74	37.63	40.55	42.74	43.31
Barimasur 2 (G2)	19.82	23.75	28.08	31.47	34.81	36.76	38.41	39.47
Barimasur 3 (G3)	19.50	23.65	27.80	31.97	35.16	38.48	40.30	40.88
Barimasur 4 (G4)	19.12	23.33	27.51	31.30	35.14	38.03	39.69	40.42
Barimasur 5 (G5)	19.14	23.37	28.13	30.19	34.26	35.74	37.53	38.08
Barimasur 6 (G6)	19.26	23.53	27.35	30.18	34.33	35.31	36.88	37.47
LSD 5%	0.652	0.643	0.523	0.797	1.505	1.348	1.262	0.499
Environment (E)								
Environment 1 (E1)	19.53	22.64	26.08	28.80	31.51	32.92	34.86	35.42
Environment 2 (E2)	20.52	25.75	30.58	32.91	36.34	38.66	39.52	40.04
Environment 3 (E3)	19.26	22.65	26.09	29.09	34.08	36.86	39.47	40.04
Environment 4 (E4)	19.44	24.58	29.16	34.01	39.25	41.08	43.00	43.57
LSD 5%	0.527	0.504	0.701	0.913	1.147	1.106	1.441	0.806
(G×E)								
G1×E1	20.97	24.37	28.00	30.63	31.53	35.90	37.83	38.43
G1×E2	21.37	26.97	31.27	35.50	38.93	42.03	44.53	45.07
G1×E3	21.00	24.33	28.17	31.40	36.53	40.00	42.50	43.07
G1×E4	21.93	27.50	32.77	37.43	42.53	46.27	48.43	49.00
G2× E1	19.90	22.50	25.87	28.47	30.97	32.53	33.80	34.33
G2×E2	20.23	25.23	30.03	34.10	37.07	39.07	40.37	40.93
G2×E3	19.53	22.63	25.93	28.73	33.03	37.03	39.00	39.57
G2×E4	19.60	24.63	29.50	33.23	38.00	39.07	41.13	41.70
G3× E1	18.37	21.87	25.03	28.30	31.03	33.13	34.27	34.83
G3×E2	20.40	25.37	30.33	33.83	36.83	39.10	40.43	41.00
G3×E3	19.43	22.83	26.37	29.43	34.10	37.63	39.17	39.77
G3×E4	19.43	24.53	29.50	35.63	40.37	44.03	46.00	46.60
G4× E1	18.33	21.63	25.10	29.63	30.90	32.87	34.13	34.67
G4×E2	20.90	26.20	30.87	32.73	35.77	38.00	39.10	39.67
G4×E3	19.13	22.40	25.90	29.00	34.00	37.53	39.60	40.20
G4×E4	18.07	23.10	28.17	35.20	39.90	41.63	42.70	43.30
G5×E1	19.83	22.90	26.37	28.83	31.43	33.40	34.60	35.13
G5×E2	20.33	25.57	30.73	32.80	35.47	38.23	39.23	39.80
G5×E3	18.03	21.60	24.80	27.40	33.10	35.90	38.10	38.63
G5×E4	18.37	23.40	27.27	30.03	33.03	35.43	38.17	38.73
G6× E1	19.43	22.60	26.10	28.30	31.20	33.03	34.53	35.13
G6×E2	19.90	25.17	30.27	32.47	35.00	37.87	38.83	39.43
G6×E3	18.43	22.03	25.30	28.10	33.47	36.03	38.47	39.03
G6×E4	19.27	24.30	27.73	31.53	37.67	40.63	42.70	43.30
LSD 5%	1.408	1.409	1.596	2.005	2.612	2.685	3.232	1.952

Table 17: Mean values of plant height (cm) of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2010 – 2011.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	21.43	25.92	30.41	33.88	37.81	40.75	43.77	44.47
Barimasur 2 (G2)	19.70	23.87	27.93	31.33	35.03	37.04	38.58	39.23
Barimasur 3 (G3)	19.48	23.73	27.92	31.93	35.73	37.04	39.24	40.96
Barimasur 4 (G4)	19.11	23.38	27.58	30.61	35.21	38.15	39.83	40.53
Barimasur 5 (G5)	19.19	23.45	27.36	30.19	34.37	36.13	37.66	38.23
Barimasur 6 (G6)	19.27	23.60	27.42	30.21	34.02	36.33	37.84	38.49
LSD 5%	0.540	0.515	0.516	0.948	1.424	1.204	1.437	0.575
Environment (E)								
Environment 1 (E1)	19.49	22.75	26.23	28.94	31.61	33.60	34.97	35.60
Environment 2 (E2)	20.49	25.81	30.79	33.01	36.47	38.74	40.67	41.18
Environment 3 (E3)	19.30	22.72	26.11	29.13	33.72	37.01	39.66	40.61
Environment 4 (E4)	19.49	24.68	29.28	33.73	39.42	41.52	43.20	43.89
LSD 5%	0.540	0.570	0.658	0.926	1.013	1.052	1.236	0.714
(G×E)								
G1×E1	21.10	24.47	28.13	30.87	33.63	36.03	38.00	38.67
G1×E2	21.50	27.13	32.37	35.33	38.10	43.20	45.67	46.30
G1×E3	21.07	24.47	28.27	31.63	36.77	37.13	42.73	43.57
G1×E4	22.03	27.60	32.87	37.70	42.73	46.63	48.67	49.33
G2× E1	19.50	22.70	26.03	28.63	31.13	32.63	33.93	34.57
G2×E2	20.10	25.37	30.10	34.23	37.23	39.20	40.53	41.10
G2×E3	19.57	22.70	25.97	28.93	33.57	37.20	39.20	39.87
G2×E4	19.63	24.70	29.63	33.50	38.17	39.88	41.33	41.70
G3× E1	18.67	21.97	25.27	28.43	31.10	33.23	34.33	35.07
G3×E2	20.43	25.37	30.37	33.90	37.00	39.20	40.87	41.03
G3×E3	19.33	22.90	26.37	29.50	34.27	37.80	39.97	40.83
G3×E4	19.47	24.67	29.67	35.90	40.57	44.27	46.20	46.90
G4× E1	18.33	21.63	25.23	28.30	30.90	33.03	34.27	34.97
G4×E2	20.90	26.27	30.90	32.87	35.87	38.00	39.20	39.80
G4×E3	19.17	22.43	25.97	29.10	34.07	37.67	39.77	40.67
G4×E4	18.03	23.17	28.20	32.17	40.00	43.90	46.10	46.70
G5×E1	19.83	23.03	26.50	28.93	31.60	33.50	34.73	35.23
G5×E2	20.23	25.57	30.73	32.90	35.57	38.30	39.27	39.43
G5×E3	18.27	21.70	24.77	27.57	33.10	36.07	38.30	39.20
G5×E4	18.43	23.50	27.43	31.37	37.20	36.63	38.33	39.07
G6× E1	19.50	22.70	26.20	28.50	31.30	33.17	34.53	35.10
G6×E2	19.80	25.13	30.27	32.53	35.03	37.87	38.90	39.70
G6×E3	18.40	22.10	25.33	28.07	30.57	36.17	38.90	39.50
G6×E4	19.37	24.47	27.87	31.73	36.17	38.33	39.27	39.97
LSD 5%	1.322	1.396	1.612	2.267	2.481	2.577	3.029	1.749

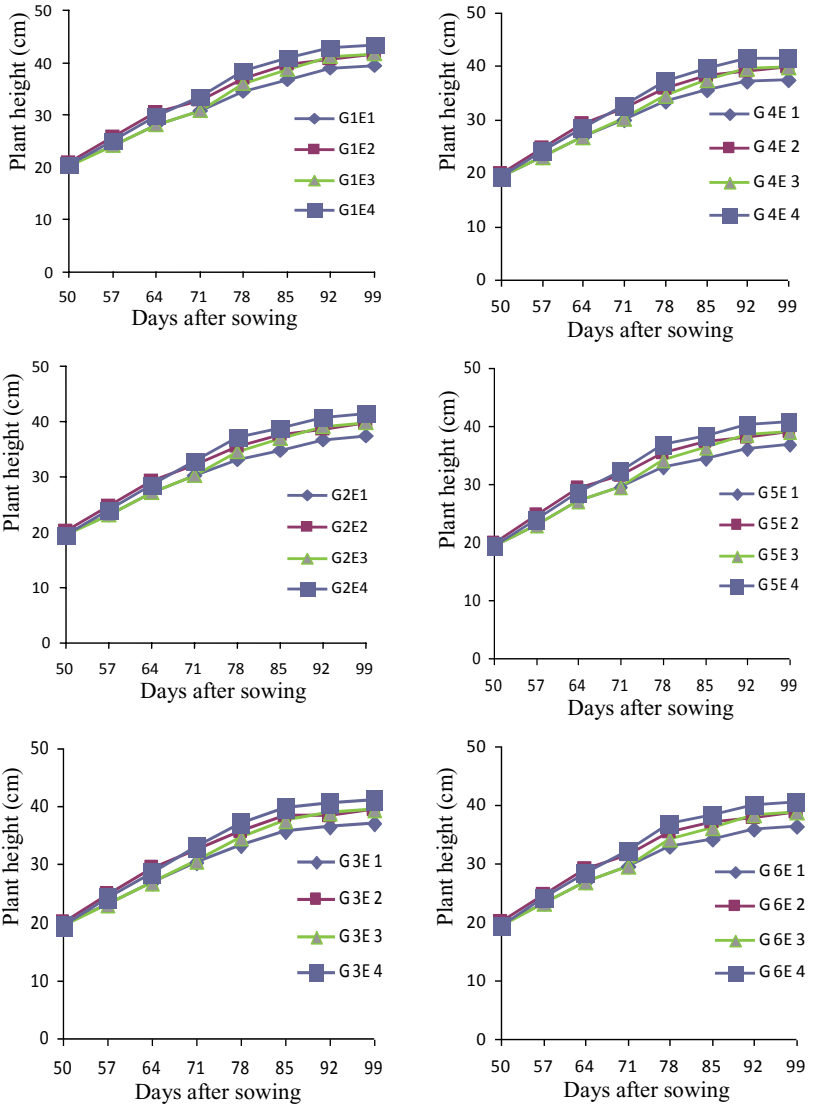


Figure 4A: Interaction between genotypes and environments on plant height (PH) of six lentil genotypes at different growth stages in 2009-2010 experiment.

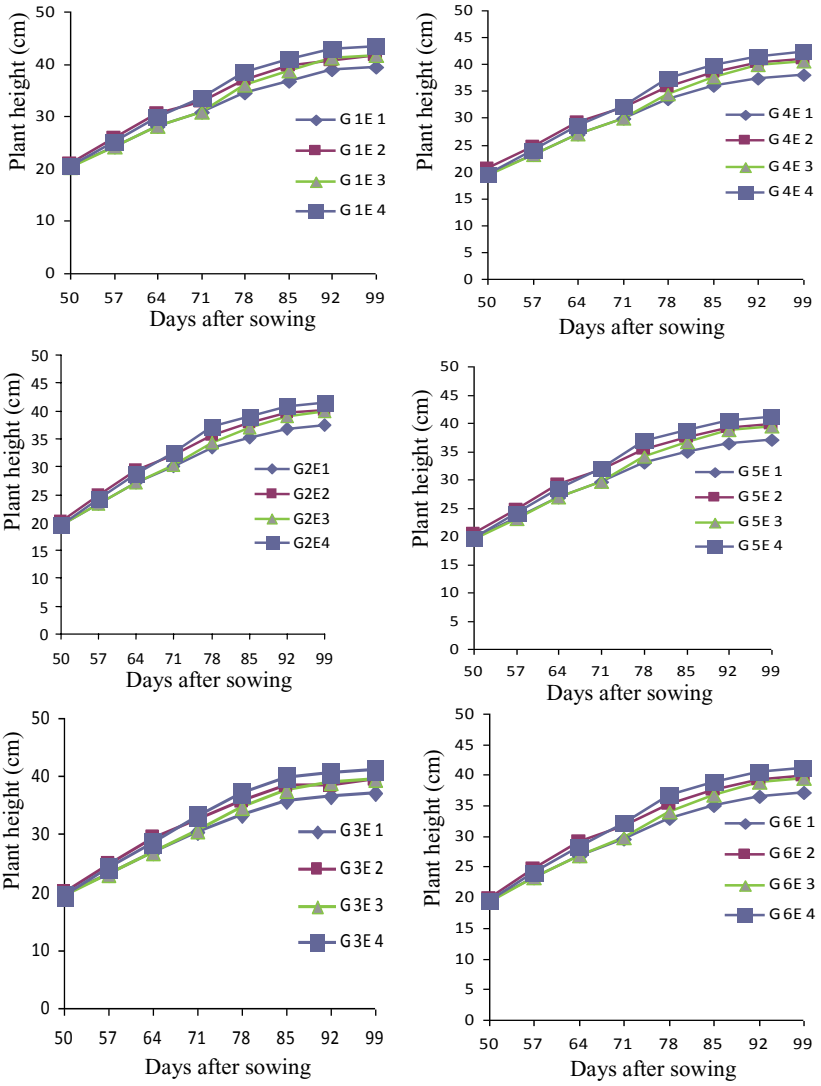


Figure 4B: Interaction between genotypes and environments on plant height (PH) of six lentil genotypes at different growth stages in 2010-2011 experiment.

4.5. Plant area per plant

Experiment for 2009 – 2010

The results of analysis of variance for plant area per plant of lentil are shown in **Table 18.** The results show that the item genotype (G) was highly significant at all the growth stages, indicating that the cultivars were highly responded by soil moisture conditions. The item environment (E) was strongly significant at all the harvesting periods, which indicated that the varieties were highly affected by different soil moisture regimes. The item G×E interaction was also significant at all the growth stages.

Mean values on plant area per plant of all six genotypes **(Table 20)** of lentil starting from a lower value, increased sharply with the age of plants and rapidly reached their highest value at the last harvest at 99 DAS. In all the genotypes, Barimasur 4 (G 4) showed the highest plant area per plant at most of the growth stages except only at 64 DAS. Barimasur 1 (G1) showed the lowest plant area per plant at all the growth phases.

Mean values on plant area per plant of all four environments **(Table 20)** of lentil starting from a lower value, increased sharply with the advancement of time and rapidly reached their highest value at the last harvest at 99 DAS. In all the environments, environment 2 (E 2) plants showed the highest plant area per plant at most of the growth stages except at 78, 92 and 99 DAS. Environment 3 (E 3) plants also showed the highest value at 78, 92 and 99 DAS. Environment 1 (E1) plants showed the lowest plant area per plant at all the growth stages.

The mean effect between genotypes and environments on plant area per plant of lentil (**Table 20)** starting from a lower value, increased sharply with the age of plants and reached their highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, G5× E2 showed the maximum value at 50, 57, 64 and 71 DAS and G6× E3 showed the maximum value at 78, 92 and 99 DAS. G2×E1 showed the minimum plant area per plant at most of the growth phases except only at 64 DAS.

The overall interaction effects between genotypes and environments on plant area per plant of lentil at different stages of growth are graphically shown in **Fig 5A**. The

graphical results show that all the genotypes and environments starting from a lower value, increased with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. In all the genotypes, at the last harvest (99 DAS) Barimasur 4 (G 4) showed the highest value and Barimasur 1 (G1) showed the lowest value. Barimasur 4 (G 4) showed the highest peak at most of the growth stages except at 64 DAS. Barimasur 1 (G1) showed the lowest plant area per plant at all the growth stages. Of all the environments, at the last harvest (99 DAS) environment 3 (E 3) plants had the highest peak and environment 1 (E 1) plants showed the lowest peak. Environment 2 (E 2) plants showed the highest peak at most of the growth stages except at 78, 92 and 99 DAS. Esnvironment 1 (E 1) plants showed the lowest peak at all the growth phases.

Experiment for 2010 – 2011

Mean squares from the analysis of variance for plant area per plant of lentil are shown in **Table 19.** The results show that the item genotype (G) was strongly significant at all the growth stages, indicating that the cultivars were highly responded by different soil moisture conditions. The item environment (E) was highly significant at all the harvesting periods, which indicated that the varieries were strongly affected by different soil moisture regimes. The item G×E interaction was significant at all the growth phases.

Mean values on plant area per plant of all six genotypes **(Table 21)** of lentil starting from a lower value, increased sharply with the advancement of time and rapidly reached their highest value at the last harvest at 99 DAS. In all the genotypes, Barimasur 4 (G 4) was found to show the highest plant area per plant at most of the harvesting stages except at 50 and 57 DAS. Barimasur 1 (G1) was found to show the lowest plant area per plant at all the growth stages.

Mean values on plant area per plant of all four environments **(Table 21)** of lentil starting from the lower value, increased sharply with the advancement of time and rapidly reached their highest value at the last harvest at 99 DAS. Of all the environments, environment 2 (E 2) plants showed the highest plant area per plant at 50, 58, 64 and 71 DAS. Environment 3 (E 3) plants showed the highest plant area per plant at 78, 85, 92

and 99 DAS. Environment 1 (E1) plants showed the lowest plant area per plant at all the growth stages.

The mean effect between genotypes and environments on plant area per plant of lentil (**Table 21)** starting from a lower value, increased with sharply increasing growth stages and reached their highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, G5×E2 showed the maximum value at 50, 57, 64 and 71 DAS and G6×E3 showed the highest value at 78, 85, 92 and 99 DAS. G2×E1 showed the lowest plant area per plant at all the growth phases.

The overall interaction effects between genotypes and environments on plant area per plant of lentil at different stages of growth are graphically shown in **Fig 5B**. The graphical results show that all the genotypes and environments starting from a lower value, increased with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. In all the genotypes, at the last harvest (99 DAS) Barimasur 4 (G 4) showed the highest peak and Barimasur 1 (G1) showed the lowest peak. Barimasur 4 (G 4) was found to show the highest plant area per plant at most of the growth stages except at 50 and 57 DAS. Barimasur 1 (G1) was found the lowest plant area per plant at all the growth stages. In all the environments, at the last harvest (99 DAS) environment 3 (E 3) plants had the highest value and environment 1 (E1) plants showed the lowest peak. Environment 2 (E 2) plants showed the highest value at 50, 57, 64 and 71 DAS and Environment 3 (E 3) plants showed the highest peak at 78, 85, 92 and 99 DAS. Esnvironment 1 (E1) plants showed the lowest plant area per plant at all the growth stages.

Table 18: Mean squares (MS) from the analysis of variance for plant area per plant at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2009 - 2010.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	9465.4	11846.1	12103.5	12965.6	13072.1	13816.4	14012.6	14823.5
Genotype (G)	5	30121.5**	35592.7**	40365.6**	45244.9**	46124.5**	48738.3**	51228.4**	55671.8**
Error - 1	10	5843.8	7004.7	7865.2	8808.2	8913.6	8024.54	9102.7	9211.4
Environment(E)	3	39674.2**	50138.8**	58562.7**	64450.4**	68561.5**	70433.4**	71075.6**	71994.2**
G × E	15	16291.7**	18957.3**	21611.2**	22079.3**	24103.8**	28324.4**	29435.7**	30845.9**
Error - 2	36	4126.2	6024.6	6885.7	7219.9	7182.5	7099.7	7201.9	7093.8

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 19: Mean squares (MS) from the analysis of variance for plant area per plant at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2010 - 2011.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	8912.9	10648.7	11976.3	12624.2	12992.9	13546.6	13942.6	14651.9
Genotype (G)	5	29430.4**	34925.2**	40812.9**	39967.6**	44784.6**	50046.6**	52424.5**	54276.8**
Error - 1	10	5201.7	6816.82	7124.4	86982.7	8774.5	8101.5	8942.9	9059.5
Environment(E)	3	40286.6**	48892.1**	58027.3**	61917.3**	67087.4**	74024.9**	74124.6**	76012.6**
G × E	15	17012.6**	19012.7**	22009.3**	23528.6**	25014.4**	30125.9**	30562.1**	31028.8**
Error - 2	36	4013.4	5884.4	6124.8	6951.7	7004.9	7251.6	7205.4	7104.6

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 20: Mean values of plant area per plant of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2009 – 2010.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	82.57	128.03	187.56	268.57	349.97	407.23	464.80	481.78
Barimasur 2 (G2)	92.82	148.64	209.35	292.80	377.30	454.67	491.95	509.21
Barimasur 3 (G3)	88.33	141.59	202.91	275.87	364.57	438.31	474.74	492.22
Barimasur 4 (G4)	124.91	198.92	266.15	385.53	485.72	584.53	633.59	652.22
Barimasur 5 (G5)	124.63	196.29	276.94	376.20	469.71	539.63	597.68	617.23
Barimasur 6 (G6)	119.20	189.27	275.43	381.05	479.80	568.73	613.48	630.98
LSD 5%	9.98	14.23	15.92	27.02	38.27	42.44	51.07	58.82
Environment (E)								
Environment 1 (E1)	83.09	134.84	186.63	262.58	314.77	371.67	381.15	395.89
Environment 2 (E2)	129.29	206.30	278.50	385.41	464.11	537.40	574.18	592.66
Environment 3 (E3)	106.87	169.01	246.80	349.36	466.12	528.42	632.15	651.46
Environment 4 (E4)	102.39	158.34	233.56	322.65	439.71	532.81	596.68	615.45
LSD 5%	92.82	148.64	209.35	292.80	377.30	454.67	491.95	509.21
(G×E)								
G1×E1	80.11	124.21	185.68	243.35	303.75	344.27	368.81	383.66
G1×E2	73.97	117.53	159.74	248.86	307.88	359.55	393.10	408.46
G1×E3	85.58	131.40	198.56	287.49	389.45	440.70	543.08	559.72
G1×E4	90.61	138.97	206.25	294.58	398.81	484.41	554.23	575.27
G2× E1	68.04	110.16	172.20	231.45	288.47	324.73	348.60	360.85
G2×E2	125.59	193.66	244.96	354.21	421.48	493.44	515.97	533.57
G2×E3	85.58	132.12	192.15	277.68	386.15	499.85	530.89	550.07
G2×E4	90.61	158.62	228.09	307.86	413.08	500.68	572.33	592.33
G3× E1	79.05	126.09	187.08	251.71	305.77	345.20	357.43	373.27
G3×E2	98.63	166.70	213.79	354.21	369.91	427.65	456.16	471.42
G3×E3	81.16	126.08	195.23	277.68	372.06	475.24	515.89	534.82
G3×E4	94.48	147.48	215.54	274.46	410.55	505.17	569.46	589.37
G4× E1	97.57	162.25	211.64	298.59	354.08	418.20	438.25	442.36
G4×E2	155.30	239.10	325.96	446.00	533.41	612.53	671.25	691.25
G4×E3	122.16	194.35	277.95	386.98	513.35	651.55	716.29	738.51
G4×E4	124.63	199.99	295.72	410.59	542.05	655.84	719.24	736.76
G5×E1	86.63	142.47	203.71	266.91	315.08	365.20	386.94	402.21
G5×E2	175.44	278.45	374.43	498.66	585.18	657.16	698.70	720.80
G5×E3	134.33	210.29	300.84	416.69	544.87	610.78	722.56	743.32
G5×E4	102.10	153.96	228.78	322.53	433.72	525.37	582.43	602.59
G6× E1	87.16	143.88	206.11	283.50	321.45	342.42	397.51	412.99
G6×E2	146.80	242.35	352.15	464.98	566.80	674.05	709.82	730.44
G6×E3	138.88	219.81	316.44	449.83	590.87	643.04	764.22	782.31
G6×E4	103.96	151.04	227.00	325.89	440.07	525.41	582.36	598.17
LSD 5%	97.76	142.18	216.46	307.88	351.27	478.72	515.64	588.26

Table 21: Mean values of plant area per plant of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2010 – 2011.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	81.37	131.09	192.69	274.17	356.95	423.52	474.42	489.00
Barimasur 2 (G2)	92.09	151.22	215.13	288.74	385.93	455.60	500.82	516.85
Barimasur 3 (G3)	89.54	144.20	204.57	287.48	372.97	443.78	477.81	499.05
Barimasur 4 (G4)	128.56	192.90	287.74	392.00	495.81	594.56	649.98	664.72
Barimasur 5 (G5)	128.70	196.25	282.26	381.44	479.68	560.35	608.58	623.24
Barimasur 6 (G6)	120.20	192.41	276.12	387.75	488.48	577.38	626.39	646.99
LSD 5%	11.71	20.21	28.21	29.85	36.82	51.83	57.58	58.99
Environment (E)								
Environment 1 (E1)	86.01	138.01	200.80	264.90	322.72	367.05	391.80	402.24
Environment 2(E2)	132.43	205.66	295.93	386.74	473.88	544.72	585.57	605.20
Environment 3 (E3)	98.98	168.20	246.35	355.48	474.68	583.63	643.92	661.10
Environment 4 (E4)	101.73	160.16	229.23	333.94	448.64	541.39	609.04	624.02
LSD 5%	102.37	154.63	231.31	347.47	451.36	529.05	442.57	607.24
(G×E)								
G1×E1	82.32	128.82	189.69	248.91	309.08	351.94	376.75	390.70
G1×E2	71.94	119.27	185.46	253.54	315.18	363.00	401.38	413.35
G1×E3	82.29	135.52	195.28	293.53	397.61	486.94	556.95	576.66
G1×E4	88.93	140.48	200.32	300.68	405.92	492.24	562.60	575.27
G2× E1	64.75	113.92	176.78	230.62	295.54	331.15	355.25	366.51
G2×E2	127.50	199.48	277.66	327.57	434.96	496.04	525.41	545.92
G2×E3	77.55	133.57	190.57	282.65	391.93	483.19	541.77	561.24
G2×E4	98.58	157.89	215.50	314.11	421.48	512.00	580.84	593.72
G3× E1	85.24	129.42	190.33	252.63	317.22	351.81	367.55	379.00
G3×E2	97.32	171.30	229.80	303.92	376.75	433.78	466.31	481.81
G3×E3	81.72	128.66	188.68	282.49	378.92	479.00	528.05	541.74
G3×E4	93.87	147.41	209.49	310.89	418.99	510.52	579.35	593.68
G4× E1	104.43	166.03	231.51	302.72	363.03	426.76	449.10	452.39
G4×E2	159.06	211.28	339.19	453.48	542.02	621.34	685.01	702.13
G4×E3	125.47	189.25	279.54	393.98	524.10	663.65	730.58	748.21
G4×E4	125.30	205.03	300.72	417.80	553.08	666.49	735.24	756.17
G5×E1	89.96	141.72	204.41	266.02	322.48	372.00	392.78	403.39
G5×E2	188.39	285.39	390.44	509.27	596.64	669.33	711.32	728.73
G5×E3	134.92	203.19	309.88	421.54	556.00	666.55	732.12	748.21
G5×E4	101.52	154.68	224.31	328.93	443.61	533.53	598.09	612.63
G6× E1	89.37	148.16	212.10	288.51	328.96	368.65	409.37	421.44
G6×E2	150.38	246.99	353.01	472.65	576.71	684.83	724.01	759.28
G6×E3	138.90	219.00	314.14	458.66	599.51	722.48	774.05	790.55
G6×E4	102.16	155.47	225.25	331.20	448.73	533.57	598.12	612.67
LSD 5%	101.98	130.86	218.28	311.34	414.37	428.75	528.21	541.76

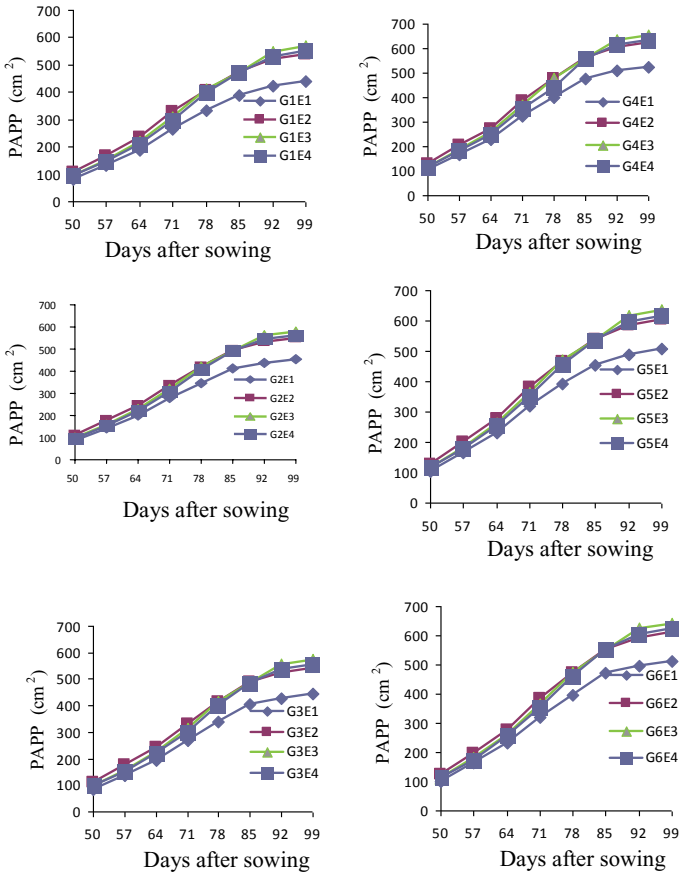


Figure 5A: Interaction between genotypes and environments on plant area per plant (PAPP) of six lentil genotypes at different growth stages in 2009-2010 experiment.

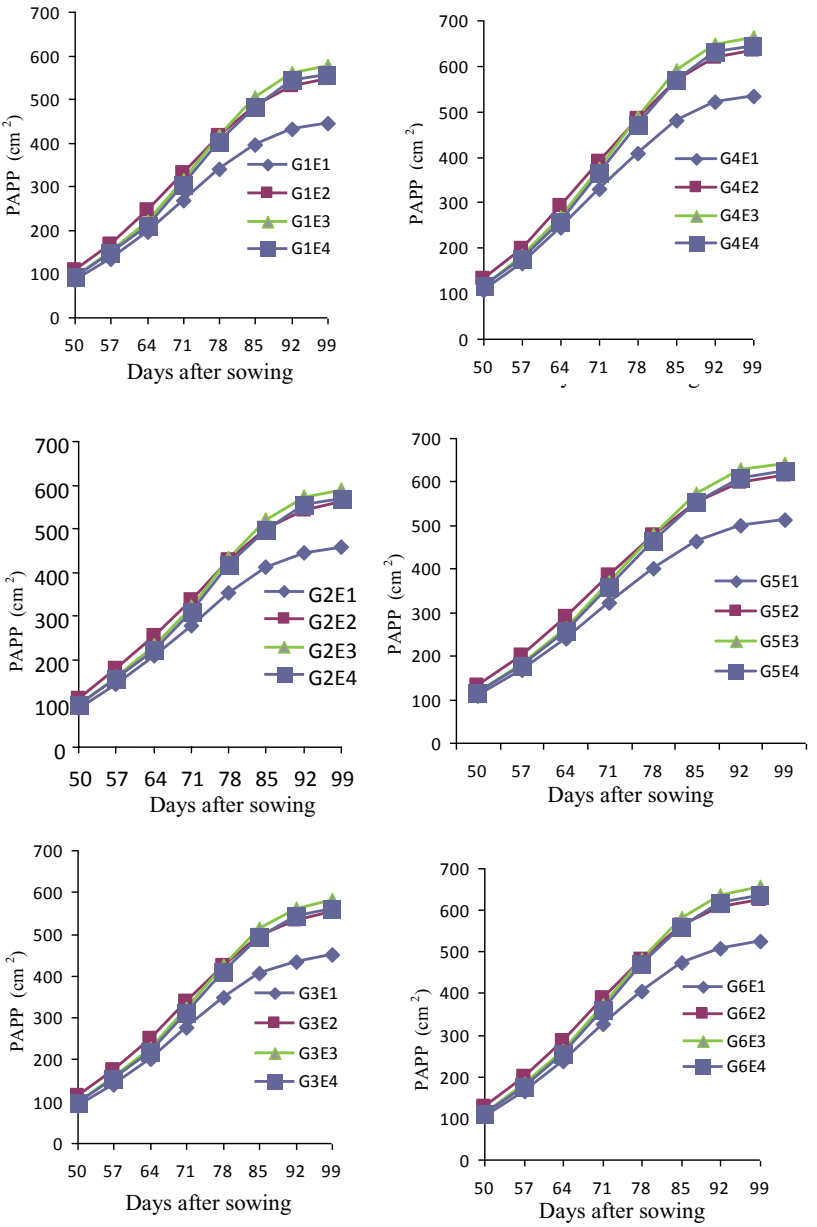


Figure 5B: Interaction between genotypes and environments on plant area per plant (PAPP) of six lentil genotypes at different growth stages in 2010-2011 experiment.

4.6. Total dry matter (TDM)

Experiment for 2009 – 2010

Mean squares from the analysis of variance for total dry matter of lentil are shown in **Table 22.** The results show that the item genotype (G) was significant at most of the growth stages except at 50, 57 and 99 DAS. The item environment (E) was highly significant at most of the harvesting periods except at 50 ADS, which indicated that the varieties were strongly affected by different soil moisture regimes.

Mean values on total dry matter of all six genotypes **(Table 24)** of lentil indicated that starting from a lower value at the early stages of growth, increased with the advancement of time and reached their highest peak at the last harvest at 99 DAS. In all the genotypes, Barimasur 6 (G 6) showed the highest total dry matter at most of the growth stages except only at 99 DAS. Barimasur 1 (G1) showed the lowest value at most of the growth phases except at 92 and 99 DAS.

Mean values on total dry matter of all four environments **(Table 24**) of lentil starting from a lower value, increased sharply with the age of plants and reached their highest value at the last harvest at 99 DAS. In all the environments, environment 4 (E 4) plants showed the highest total dry matter at most of the growth phases except at 50 and 57 DAS. Environment 1 (E1) plants was found to show the lowest total dry matter at most of the growth stages except at 50, 57 and 64 DAS.

The mean effect between genotypes and environments on total dry matter of lentil **(Table 24)** starting from a lower value, increased with the increasing growth stages and reached their highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, the highest value was observed in G6×E4 at 64, 71, 92 and 99 DAS. On the other hand, G1× E1 showed the lowest total dry matter at 71, 78 and 85 DAS.

The overall interaction effects between genotypes and environments on total dry matter of lentil at different stages of growth are graphically shown in **Fig 6**A. The graphical presentation shows that all the genotypes and environments starting from a lower value, increased with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. In all the genotypes, at the last harvest (99 DAS) Barimasur 5

(G 5) showed the highest value and Barimasur 2 (G 2) was found the lowest value. Barimasur 6 (G 6) showed the highest peak at most of the growth stages except at 50 and 99 DAS. Barimasur 1 (G1) showed the lowest value of total dry matter at most of the growth stages except at 92 and 99 DAS. Of all the environments, at the last harvest (99 DAS) environment 4 (E 4) plants were found to show the maximum value and environment 1 (E1) plants were observed to show the minimum value. Environment 4 (E 4) plants showed the highest peak at most of the growth stages except at 50 and 57 DAS. Environment 1 (E1) plants showed the lowest value at most of the growth stages except at 50, 57 and 64 DAS.

Experiment for 2010 – 2011

The results of analysis of variance for total dry matter of lentil are shown in **Table 23.** The results show that the item genotype (G) was significant at 64, 78, 85 and 92 DAS. The item environment (E) was highly significant at most of the harvesting periods except at 50 ADS, which indicated that the varieties were strongly affected by different soil moisture regimes.

Mean values on total dry matter of all six genotypes **(Table 25)** of lentil indicated that starting from a lower value at the early stages of growth, increased sharply with the age of plants and reached their highest peak at the last harvest at 99 DAS. Of all the genotypes, Barimasur 6 (G 6) showed the highest total dry matter at all of the growth stages. Barimasur 1 (G1) showed the lowest value at most of the growth stages except at 64, 85 and 92 DAS and Barimasur 3 (G 3) showed the lowest value at 64, 85 and 92 DAS.

Mean values on total dry matter of all four environments **(Table 25)** of lentil starting from a lower value, increased sharply with the early stages of harvest and reached their highest value at the last harvest at 99 DAS. In all the environments, environment 4 (E 4) plants showed the highest total dry matter at most of the growth stages except at 50 and 57 DAS. Environment 1 (E 1) plants showed the lowest total dry matter at most of the growth stages except at 50, 57 and 64 DAS and Environment 3(E 3) plants showed the lowest total dry matter at 50, 57 and 64 DAS.

The mean effect between genotypes and environments on total dry matter of lentil (**Table 25)** at different growth stages starting from a lower value, increased with the

increasing growth stages and reached their highest value at the last harvest at 99 DAS. The mean effect between genotypes and environments, the highest value was observed in G6×E2 at 50 and 57 DAS, in G6× E4 at 71 and 78 DAS and in G5× E4 at 92 and 99 DAS. G1×E1 showed the lowest total dry matter at 71, 78 and 85 DAS.

The overall interaction effects between genotypes and environments on total dry matter of lentil at different stages of growth are graphically shown in **Fig 6B**. The graphical results show that all the genotypes and environments starting from a lower value, increased with the increasing growth stages and rapidly reached their highest peak at the last harvest at 99 DAS. In all the genotypes, at the last harvest (99 DAS) Barimasur 6 (G 6) was found to show the highest value and Barimasur 1 (G1) was found to show the lowest value. Barimasur 6 (G 6) showed the highest value at all of the growth stages. Barimasur 1 (G1) showed the lowest value of total dry matter at most of the growth stages except at 64, 85 and 92 DAS. Barimasur 3 (G 3) showed the lowest peak at 64, 85 and 92 DAS. In all the environments, at the last harvest (99 DAS) environment 4 (E 4) plants showed the highest value and environment 1 (E1) plants showed the minimum value. Environment 4 (E 4) plants showed the highest peak at most of the growth stages except at 50 and 57 DAS. Environment 1 (E1) plants showed the minimum peak at most of the growth stages except at 50, 57 and 64 DAS.

Table 22: Mean squares (MS) from the analysis of variance for total dry matter at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2009 - 2010.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	0.006	0.028	1.81	0.011	0.062	0.402	0.084	0.104
Genotype (G)	5	0.011	0.039	2.506**	1.057**	5.201**	0.938**	3.108**	0.609
Error - 1	10	0.013	0.005	1.546	0.178	0.196	0.096	0.173	0.587
Environment (E)	3	0.032	0.092**	2.607**	2.179**	13.406**	19.084**	5.013**	9.024**
G × E	15	0.017	0.021	1.346	0.214	0.638	0.365	0.331	0.408
Error - 2	36	0.009	0.009	1.341	0.111	0.126	0.280	0.238	0.702

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 23 : Mean squares (MS) from the analysis of variance for total dry matter at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2010 - 2011.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	0.002	0.022	1.790	0.020	0.061	0.394	0.053	0.086
Genotype (G)	5	0.016	0.031	2.143**	0.806	4.162**	0.913**	1.975**	0.347
Error - 1	10	0.013	0.006	1.529	0.175	0.188	0.094	0.157	0.672
Environment (E)	3	0.027	0.085**	2.298**	2.184**	12.389**	18.972**	4.398**	7.615**
G × E	15	0.016	0.013	1.302	0.203	0.652	0.327	0.315	0.399
Error - 2	36	0.009	0.009	1.338	0.112	0.127	0.276	0.247	0.671

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 24 : Mean values of total dry matter ($gm^{-2}day^{-1}$) of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2009 - 2010.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	0.376	0.503	1.155	4.549	11.548	18.682	26.698	33.834
Barimasur 2 (G2)	0.456	0.581	1.182	4.804	11.822	19.002	26.542	33.759
Barimasur 3 (G3)	0.466	0.580	1.156	4.947	11.805	18.951	26.392	33.857
Barimasur 4 (G4)	0.446	0.553	1.387	5.033	11.581	19.854	27.716	34.167
Barimasur 5 (G5)	0.457	0.551	1.536	5.134	12.795	20.092	27.956	34.659
Barimasur 6 (G6)	0.527	0.639	1.570	5.291	12.878	20.341	28.318	34.636
LSD 5%	0.152	0.102	1.205	0.263	0.401	0.299	0.373	0.821
Environment (E)								
Environment 1 (E1)	0.471	0.567	1.396	4.437	11.216	18.107	26.578	33.365
Environment 2 (E2)	0.491	0.635	1.364	5.149	11.750	19.278	27.111	33.885
Environment 3 (E3)	0.435	0.471	1.144	4.978	12.826	19.842	27.442	34.364
Environment 4 (E4)	0.422	0.610	1.426	5.274	13.080	20.660	27.954	34.929
LSD 5%	0.062	0.071	0.804	0.305	0.248	0.371	0.523	0.604
(G×E)								
G1×E1	0.375	0.470	1.134	3.854	10.099	17.006	26.159	33.225
G1×E2	0.357	0.564	1.119	4.740	10.763	18.186	26.531	33.525
G1×E3	0.400	0.439	1.089	4.687	12.144	18.992	27.035	34.095
G1×E4	0.373	0.576	1.028	4.914	12.822	20.542	27.293	34.468
G2× E1	0.523	0.646	1.166	4.035	10.782	17.303	26.211	32.537
G2×E2	0.497	0.662	1.149	5.346	11.163	18.689	26.254	33.850
G2×E3	0.422	0.485	1.121	4.968	12.743	19.268	26.296	34.019
G2×E4	0.370	0.580	1.294	4.865	12.669	20.741	27.388	34.564
G3× E1	0.411	0.528	1.294	4.097	10.727	17.241	25.453	33.178
G3×E2	0.536	0.611	1.142	5.155	11.159	18.570	26.372	33.396
G3×E3	0.535	0.588	1.082	5.271	12.720	19.694	26.497	33.953
G3×E4	0.380	0.659	1.142	5.264	12.612	20.299	27.271	34.500
G4× E1	0.451	0.559	1.539	4.735	11.713	18.715	26.701	33.627
G4×E2	0.529	0.570	1.501	4.994	12.399	19.791	27.920	33.385
G4×E3	0.384	0.421	1.141	5.021	12.910	19.997	27.795	33.535
G4×E4	0.421	0.657	1.370	5.384	12.970	20.678	28.446	35.086
G5×E1	0.555	0.594	1.523	4.970	11.632	18.993	27.173	33.583
G5×E2	0.453	0.573	1.207	5.335	12.526	19.819	27.691	34.800
G5×E3	0.395	0.467	1.232	4.791	13.273	20.499	28.409	34.940
G5×E4	0.427	0.551	1.679	5.441	13.752	20.913	28.517	35.448
G6× E1	0.513	0.605	1.723	4.929	12.345	19.387	27.833	34.041
G6×E2	0.572	0.832	1.568	5.325	12.489	20.611	27.897	34.356
G6×E3	0.465	0.489	1.197	5.133	13.025	20.603	28.615	34.662
G6×E4	0.557	0.642	1.794	5.776	13.654	20.785	28.891	35.510
LSD 5%	0.203	0.175	2.04	0.579	0.607	0.899	0.846	1.427

Table 25: Mean values of total dry matter ($gm^{-2}day^{-1}$) of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2010 - 2011.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	0.375	0.502	1.151	4.537	11.860	19.674	27.412	33.891
Barimasur 2 (G2)	0.452	0.591	1.152	4.772	11.901	19.681	27.343	34.024
Barimasur 3 (G3)	0.465	0.598	1.141	4.930	12.125	19.534	27.114	33.952
Barimasur 4 (G4)	0.443	0.548	1.383	5.010	12.841	20.021	28.013	34.090
Barimasur 5 (G5)	0.456	0.543	1.563	5.121	13.003	20.133	27.991	34.190
Barimasur 6 (G6)	0.525	0.647	1.585	5.276	13.182	20.180	28.014	34.363
LSD 5%	0.104	0.070	1.125	0.381	0.394	0.279	0.360	0.746
Environment (E)								
Environment 1 (E1)	0.471	0.564	1.383	4.423	11.522	18.763	27.151	33.190
Environment 2 (E2)	0.490	0.634	1.390	5.142	12.070	19.401	27.322	34.102
Environment 3 (E3)	0.430	0.478	1.134	4.951	13.180	20.172	27.882	34.314
Environment 4 (E4)	0.420	0.610	1.972	5.251	13.181	21.144	28.223	34.731
LSD 5%	0.064	0.064	0.782	0.226	0.241	0.355	0.331	0.554
(G×E)								
G1×E1	0.370	0.462	1.130	3.848	10.195	18.003	26.985	32.638
G1×E2	0.354	0.539	1.107	4.735	11.057	19.366	26.782	33.858
G1×E3	0.403	0.435	1.080	4.677	12.704	19.891	27.779	34.460
G1×E4	0.371	0.572	1.268	4.890	13.148	21.403	28.100	34.622
G2× E1	0.538	0.645	1.065	4.025	10.407	18.333	27.252	32.634
G2×E2	0.496	0.657	1.146	5.312	11.496	19.169	27.418	33.767
G2×E3	0.405	0.480	1.113	4.915	13.065	20.352	27.108	33.807
G2×E4	0.370	0.581	1.290	4.834	12.638	20.864	27.570	34.480
G3× E1	0.407	0.529	1.266	4.094	10.950	18.079	26.212	33.310
G3×E2	0.532	0.615	1.133	5.154	11.867	19.368	27.009	33.846
G3×E3	0.537	0.584	1.058	5.235	12.974	19.872	27.136	34.669
G3×E4	0.385	0.662	1.106	5.246	12.782	20.820	28.072	34.411
G4× E1	0.446	0.553	1.549	4.716	12.207	19.353	27.262	32.959
G4×E2	0.531	0.567	1.483	4.988	12.547	19.484	27.863	34.156
G4×E3	0.377	0.419	1.136	4.981	13.431	20.182	28.492	34.147
G4×E4	0.419	0.654	1.166	5.356	13.167	21.050	28.439	34.907
G5×E1	0.554	0.591	1.537	4.950	12.429	19.326	27.619	32.801
G5×E2	0.454	0.568	1.812	5.328	12.642	19.585	27.397	34.348
G5×E3	0.493	0.564	1.222	4.773	13.364	20.270	28.307	34.291
G5×E4	0.422	0.548	1.682	5.432	13.609	21.336	28.627	35.000
G6× E1	0.510	0.603	1.731	4.898	12.923	19.482	27.579	33.425
G6×E2	0.571	0.855	1.642	5.321	12.810	19.418	27.471	34.641
G6×E3	0.462	0.585	1.175	5.132	13.455	20.442	28.466	34.366
G6×E4	0.555	0.644	1.794	5.753	13.628	21.396	28.508	34.988
LSD 5%	0.157	0.157	1.915	0.554	0.590	0.870	0.811	1.356

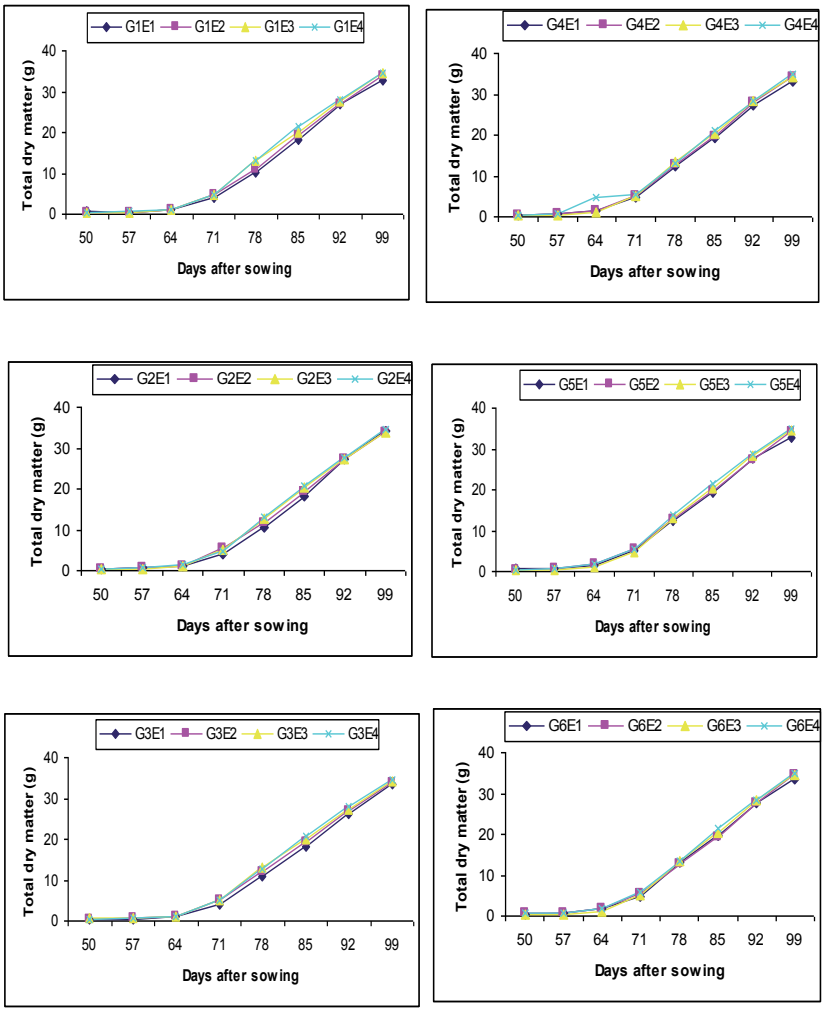


Figure 6A: Interaction between genotypes and environments on total dry matter (TDM) of six lentil genotypes at different growth stages in 2009-2010 experiment.

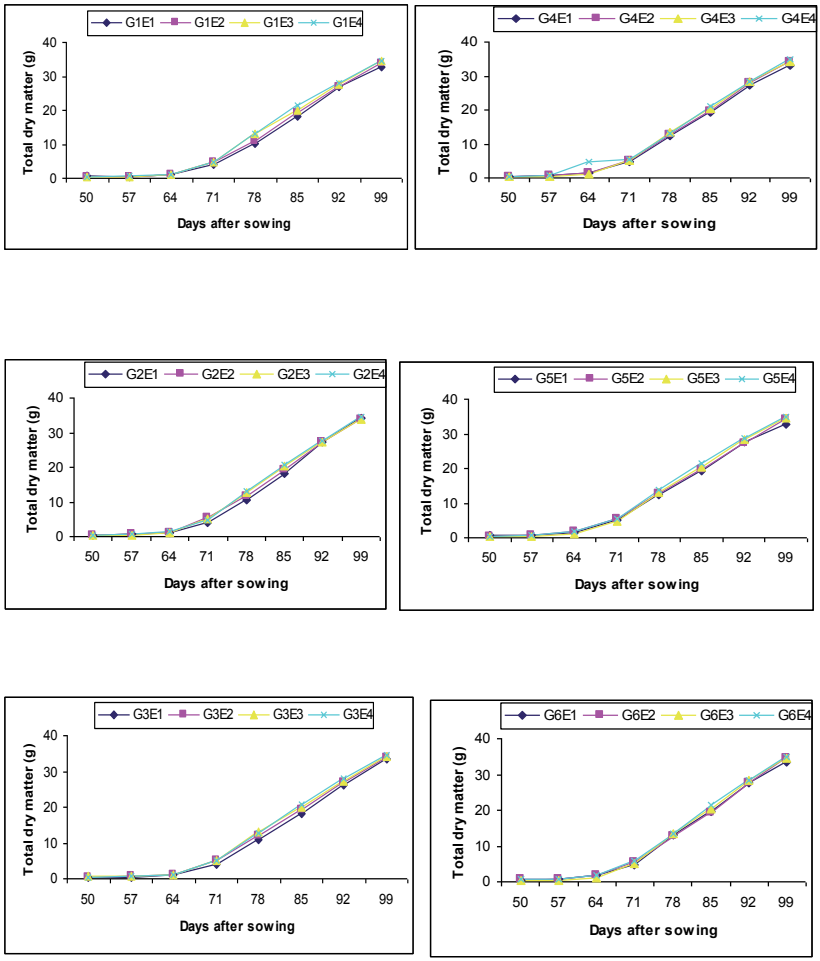


Figure 6B: Interaction between genotypes and environments on total dry matter (TDM) of six lentil genotypes at different growth stages in 2010-2011 experiment.

4.7. Leaf weight ratio (LWR)

Experiment for 2009 – 2010

The results of analysis of variance for leaf weight ratio of lentil are shown in **Table 26**. The results show that the item genotype (G) was highly significant at most of the growth stages except at 71 and 92 DAS, which indicated that the cultivars were highly affected by different soil moisture conditions. The item environment (E) was significant at 64, 71, 78 and 85 DAS. The item G×E interaction was significant at 78 and 85 DAS.

Mean values on leaf weight ratio of all six lentil genotypes **(Table 28)** indicated that starting from a lower value, increased slowly at the early stages of growth, increased with the advancement of time and reached their highest value at the third harvest at 64 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. In all the genotypes, at the third harvest (64 DAS) Barimasur 5 (G 5) showed the highest value and Barimasur 1 (G 1) showed the lowest value of leaf weight ratio. Barimasur 5 (G 5) showed the highest leaf weight ratio at 50, 57 and 64 DAS and Barimasur 1 (G1) showed the highest leaf weight ratio at 71 and 99 DAS. Barimasur 1 (G1) was observed to show the lowest value at 50, 57 and 64 DAS and Barimasur 6 (G 6) showed the lowest value at 92 and 99 DAS.

Mean values on leaf weight ratio of all four environments **(Table 28)** of lentil starting from a lower value, increased slowly at the early harvests and reached their highest value at the third harvest at 64 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. In all the environments, at the third harvest (64 DAS) environment 3 (E 3) plants showed the highest value and environment 2 (E 2) plants were found to show the lowest value of leaf weight ratio. Environment 3 (E 3) plants showed the highest leaf weight ratio at 64, 71 and 85 DAS and Environment 4 (E 4) plants showed the highest leaf weight ratio at 50 and 57 DAS. Environment 1 (E1) plants were observed to show the minimum leaf weight ratio at 50, 57, 71 and 99 DAS and Environment 4 (E 4) plants were observed to show the lowest leaf weight ratio at 85 and 92 DAS.

The mean effect between genotypes and environments on leaf weight ratio of lentil **(Table 28)** also starting from a lower value, increased slowly at the early stages of

growth and reached their highest value at the third harvest at 64 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. The mean effect between genotypes and environments, at the peak harvest (64 DAS) G5×E1 showed the highest value and G1×E2 showed the lowest value. G5×E1 showed the highest peak at 50 and 64 DAS. G1×E2 showed the lowest peak at 50, 57 and 64 DAS and G3×E1 showed the lowest value at 71, 85 and 99 DAS. The highest and the lowest value showed more, less or similar trends at different growth stages.

The overall interaction effects between genotypes and environments on leaf weight ratio of lentil at different stages of growth are graphically shown in **Fig 7A**. The graphical results show that all the genotypes and environments indicated that starting from a lower value, increased slowly at the early harvests and reached their highest value at the third harvest at 64 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the third harvest (64 DAS) Barimasur 5 (G 5) showed the highest value and Barimasur 1 (G 1) showed the lowest value of leaf weight ratio. Barimasur 5 (G 5) was found to show the highest value at 50, 57 and 64 DAS. Barimasur 1 (G1) showed the lowest value at 50, 57 and 64 DAS. In all the environments, at the third harvest (64 DAS) environment 3 (E 3) plants showed the highest peak and environment 2(E 2) plants showed the lowest leaf weight ratio. Environmen 3 (E 3) plants showed the highest peak of leaf weight ratio at 64, 71 and 85 DAS. Environment 1 (E1) plants were found to show the lowest value at 50, 57, 71 and 99 DAS.

Experiment for 2010 – 2011

Mean squares from the analysis of variance for leaf weight ratio of lentil are shown in **Table 27.** The results show that the item genotype (G) was significant at most of the growth stages except at 71 and 92 DAS, indicated that the cultivars were highly affected by the different soil moisture regimes. The item environment (E) was significant at 64, 71, 78 and 85 DAS, which indicated that the the varieties were affected by different soil moisture conditions. The item G×E interaction was significant at only two harvests at 78 and 85 DAS.

Mean values on leaf weight ratio of all six genotypes **(Table 29)** of lentil indicated that starting from a lower value, increased slowly at the early harvest and reached their

highest value at the third harvest at 64 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. In all the genotypes, at the third harvest (64 DAS) Barimasur 3 (G 3) showed the highest value and Barimasur 6 (G 6) showed the lowest value of leaf weight ratio. Barimasur 1 (G1) was found to show the highest leaf weight ratio at 71, 78 and 85 DAS and Barimasur 5 (G 5) was found to show the highest leaf weight ratio at 50 and 57 DAS. Barimasur 6 (G 6) showed the minimum leaf weight ratio at 50 and 64 DAS and Barimasur 1 (G1) showed the lowest leaf weight ratio at 92 and 99 DAS. All the genotypes showed more, less or similar trends at different growth stages.

Mean values on leaf weight ratio of all four environments **(Table 29)** of lentil indicated that starting from a lower value, increased slowly at the early stages of growth and reached their highest value at the third harvest at 64 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. In all the environments, at the third harvest (64 DAS) environment 3 (E 3) plants showed the highest value and environment 2 (E 2) plants were found to show the lowest value of leaf weight ratio. Environment 3 (E 3) plants showed the highest leaf weight ratio at 57, 64 and 92 DAS and environment 1 (E1) plants showed the highest value at 71, 78 and 85 DAS. Environment 2 (E 2) plants showed the minimum leaf weight ratio at 64, 71 and 92 DAS and Environment 4 (E 4) plants showed the lowest leaf weight ratio at 78, 85 and 99 DAS. All the environments showed more, less or similar trends at different growth stages.

The mean effect between genotypes and environments on leaf weight ratio of lentil **(Table 29)** also starting from a lower value, increased slowly at the early stages of growth and reached their highest value at the third harvest at 64 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. The mean effect between genotypes and environments, at the peak harvest (64 DAS) G6**×**E3 showed the maximum value and G6**×**E2 showed the minimum value. G6**×**E3 showed the highest value at 57, 64 and 92 DAS. The highest and the lowest value showed more, less or similar trends at different growth stages.

The overall interaction effects between genotypes and environments on leaf weight ratio of lentil at different stages of growth are graphically shown in **Fig 7B**. The graphical results show that all the genotypes and environments indicated that starting from a lower value, increased slowly at the early harvest and reached their highest value at the third harvest at 64 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the third harvest (64 DAS) Barimasur 3 (G 3) was found to show the highest peak and Barimasur 6 (G 6) showed the lowest peak of leaf weight ratio. Barimasur 1 (G 1) showed the highest value at 71, 78 and 85 DAS. Barimasur 6 (G 6) showed the lowest value at 50 and 64 DAS. In all the environments, at the third harvest (64 DAS) environment 3 (E 3) plants showed the highest peak and environment 2 (E2) plants were found to show the lowest value of leaf weight ratio. Environment 3 (E 3) plants showed the highest peak of leaf weight ratio at 57, 64 and 92 DAS. Environment 2 (E 2) plants were found to show the lowest value at 64,71 and 92 DAS and environment 4 (E 4) plants were found to show the lowest value at 78, 85 and 99 DAS. All the genotypes and environments showed more, less or similar trends at different growth stages.

Table 26: Mean squares (MS) from the analysis of variance for leaf weight ratio (gg^{-1}) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2009 - 2010.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	0.024	0.023	0.004	0.002	0.001	0.002*	0.202	.0042
Genotype (G)	5	0.021**	0.025**	0.018**	0.006	0.0026**	0.0032**	0.179	0.0055**
Error - 1	10	0.003	0.005	0.003	0.003	0.0001	0.0001	0.197	0.0001
Environment (E)	3	0.008	0.024	0.075**	0.007**	0.0136**	0.0034**	0.171	0.00217
G × E	15	0.005	0.008	0.006	0.002	0.0028**	0.0009**	0.186	0.001
Error - 2	36	0.005	0.021	0.007	0.003	0.0002	0.0001	0.176	0.0551

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 27 : Mean squares (MS) from the analysis of variance for leaf weight ratio (gg^{-1}) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2010 - 2011.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Replication (R)	2	0.013	0.021	0.003	0.001	0.001	0.0024	0.186	0.002
Genotype (G)	5	0.012**	0.022**	0.017**	0.005	0.0021**	0.0023**	0.188	0.004**
Error - 1	10	0.003	0.005	0.003	0.003	0.0001	0.0001	0.194	0.0001
Environment (E)	3	0.007	0.022	0.071**	0.008**	0.0123**	0.0024**	0.182	0.001
G × E	15	0.004	0.007	0.005	0.001	0.0012**	0.0001**	0.187	0.001
Error - 2	36	0.005	0.03	0.006	0.002	0.0001	0.0001	0.182	0.051

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 28: Mean values of leaf weight ratio of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2009 - 2010.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	0.5194	0.5388	0.5473	0.5346	0.3830	0.3214	0.2927	0.2705
Barimasur 2 (G2)	0.5552	0.5583	0.5724	0.3779	0.3219	0.3148	0.2996	0.2680
Barimasur 3 (G3)	0.5349	0.5463	0.5852	0.3725	0.3702	0.3275	0.3113	0.2511
Barimasur 4 (G4)	0.5386	0.5497	0.5908	0.3730	0.3728	0.3689	0.2951	0.2524
Barimasur 5 (G5)	0.5555	0.5775	0.6112	0.4101	0.3727	0.3495	0.2861	0.2558
Barimasur 6 (G6)	0.5442	0.5499	0.5964	0.3903	0.3848	0.3356	0.2778	0.2470
LSD 5%	0.059	0.067	0.039	0.036	0.011	0.009	0.411	0.009
Environment (E)								
Environment 1 (E1)	0.5191	0.5381	0.5665	0.3713	0.3077	0.3061	0.2886	0.2387
Environment 2 (E2)	0.5436	0.5494	0.5497	0.3915	0.3995	0.3559	0.2979	0.2576
Environment 3 (E3)	0.5468	0.5511	0.5997	0.4057	0.3747	0.3721	0.2946	0.2678
Environment 4 (E4)	0.5575	0.5814	0.5928	0.3940	0.3851	0.3015	0.2845	0.2688
LSD 5%	0.052	0.051	0.034	0.022	0.007	0.007	0.301	0.032
(G×E)								
G1×E1	0.5101	0.5228	0.5999	0.3807	0.3759	0.2919	0.2906	0.2430
G1×E2	0.4642	0.4708	0.4793	0.4301	0.3864	0.3381	0.2870	0.2832
G1×E3	0.5423	0.5432	0.5443	0.3787	0.3435	0.3350	0.2831	0.2795
G1×E4	0.5513	0.5545	0.5817	0.3725	0.3661	0.3207	0.3030	0.2759
G2× E1	0.5643	0.5698	0.5828	0.4515	0.3748	0.2858	0.2750	0.2566
G2×E2	0.5382	0.5479	0.5485	0.3834	0.3668	0.3615	0.2999	0.2765
G2×E3	0.5374	0.5640	0.5650	0.4058	0.3997	0.3910	0.2965	0.2859
G2×E4	0.5494	0.5578	0.5700	0.5022	0.4251	0.2901	0.2870	0.2529
G3× E1	0.4926	0.5443	0.5803	0.3459	0.3440	0.2763	0.2758	0.2190
G3×E2	0.5582	0.5613	0.5620	0.4589	0.4258	0.3761	0.3435	0.2718
G3×E3	0.5339	0.5393	0.5910	0.4012	0.3639	0.3629	0.3096	0.2572
G3×E4	0.5547	0.5683	0.6201	0.3842	0.3685	0.2947	0.2827	0.2564
G4× E1	0.4929	0.5355	0.5979	0.4640	0.3827	0.3807	0.3249	0.2497
G4×E2	0.5570	0.5685	0.5820	0.4589	0.4035	0.4025	0.2921	0.2480
G4×E3	0.5457	0.5571	0.5960	0.3975	0.3600	0.3507	0.3188	0.2582
G4×E4	0.5518	0.5643	0.6255	0.3713	0.3648	0.2813	0.2755	0.2536
G5×E1	0.5858	0.5882	0.6288	0.3920	0.3626	0.2915	0.2868	0.2375
G5×E2	0.5359	0.5418	0.6031	0.4406	0.3974	0.3758	0.2742	0.2345
G5×E3	0.5551	0.5672	0.6287	0.4261	0.3789	0.3509	0.2808	0.2620
G5×E4	0.5652	0.5709	0.5844	0.3611	0.3520	0.3392	0.2835	0.2821
G6× E1	0.4692	0.5439	0.6038	0.3802	0.3593	0.3101	0.2615	0.2264
G6×E2	0.5386	0.5442	0.5813	0.4771	0.3971	0.3884	0.2905	0.2313
G6×E3	0.5663	0.5719	0.6252	0.4251	0.4114	0.3618	0.2786	0.2643
G6×E4	0.5629	0.5692	0.5754	0.4792	0.4043	0.3821	0.2965	0.2892
LSD 5%	0.121	0.124	0.097	0.058	0.024	0.119	0.155	0.058

Table 29: Mean values of leaf weight ratio of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2010 - 2011.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS	99 DAS
Barimasur 1 (G1)	0.5448	0.5786	0.5888	0.4446	0.3710	0.3171	0.3072	0.2483
Barimasur 2 (G2)	0.5698	0.5797	0.5893	0.4068	0.3654	0.3146	0.3101	0.2622
Barimasur 3 (G3)	0.5483	0.5766	0.6140	0.3858	0.3513	0.3155	0.3104	0.2854
Barimasur 4 (G4)	0.5001	0.5049	0.5797	0.4183	0.3462	0.3152	0.3132	0.2711
Barimasur 5 (G5)	0.5951	0.5973	0.6011	0.4239	0.3421	0.3162	0.3092	0.2843
Barimasur 6 (G6)	0.5385	0.5471	0.5543	0.4207	0.3433	0.3171	0.3083	0.2912
LSD 5%	0.050	0.064	0.050	0.050	0.009	0.009	0.401	0.009
Environment (E)								
Environment 1 (E1)	0.5212	0.5252	0.5801	0.4345	0.3811	0.3182	0.3064	0.2741
Environment 2 (E2)	0.5616	0.5673	0.5732	0.3888	0.3669	0.3093	0.3049	0.2813
Environment 3 (E3)	0.5534	0.5690	0.6934	0.4137	0.3382	0.3147	0.3096	0.2752
Environment 4 (E4)	0.5618	0.5653	0.5752	0.4298	0.3252	0.3083	0.3050	0.2634
LSD 5%	0.052	0.052	0.037	0.021	0.007	0.007	0.295	0.021
(G×E)								
G1×E1	0.5111	0.5580	0.5613	0.4695	0.4117	0.3227	0.3083	0.2423
G1×E2	0.5476	0.5576	0.5612	0.4041	0.3887	0.3423	0.3077	0.2563
G1×E3	0.4515	0.5296	0.6641	0.4480	0.3467	0.3180	0.3127	0.2517
G1×E4	0.5789	0.5892	0.5986	0.4559	0.3357	0.3160	0.2977	0.2410
G2× E1	0.5481	0.5707	0.5884	0.4556	0.4147	0.3033	0.3010	0.2490
G2×E2	0.5091	0.5194	0.5741	0.3582	0.3817	0.2987	0.2949	0.2667
G2×E3	0.5664	0.5787	0.6448	0.4006	0.3400	0.3033	0.3007	0.2780
G2×E4	0.5656	0.5701	0.5800	0.4130	0.3253	0.3107	0.3060	0.2560
G3× E1	0.4936	0.5247	0.5753	0.4254	0.3917	0.3160	0.3043	0.2767
G3×E2	0.5703	0.5742	0.5801	0.3503	0.3487	0.3133	0.3093	0.3063
G3×E3	0.5821	0.5933	0.6677	0.3705	0.3380	0.3267	0.3193	0.2890
G3×E4	0.5476	0.5641	0.6588	0.3968	0.3153	0.3047	0.2973	0.2697
G4× E1	0.4953	0.5156	0.5480	0.4156	0.3540	0.3120	0.3087	0.2993
G4×E2	0.4900	0.5543	0.5716	0.4117	0.3510	0.3183	0.3090	0.2773
G4×E3	0.4538	0.5588	0.6597	0.4157	0.3413	0.3293	0.3220	0.2460
G4×E4	0.5628	0.5710	0.5895	0.4301	0.3360	0.3240	0.3130	0.2610
G5×E1	0.5895	0.6551	0.6652	0.4116	0.3553	0.3093	0.3083	0.2823
G5×E2	0.5648	0.5833	0.6350	0.4010	0.3593	0.3253	0.3048	0.2840
G5×E3	0.5447	0.5986	0.6571	0.4308	0.3377	0.3230	0.3193	0.2853
G5×E4	0.5017	0.5521	0.5869	0.4520	0.3137	0.3057	0.3010	0.2827
G6× E1	0.4697	0.4826	0.4907	0.4292	0.3593	0.3047	0.2947	0.2850
G6×E2	0.4777	0.4852	0.4901	0.4076	0.3620	0.3177	0.2987	0.2973
G6×E3	0.5320	0.6553	0.6855	0.4167	0.3253	0.3280	0.3277	0.3010
G6×E4	0.5345	0.5755	0.5782	0.4301	0.3250	0.3150	0.3093	0.2700
LSD 5%	0.128	0.128	0.091	0.052	0.017	0.017	0.724	0.052

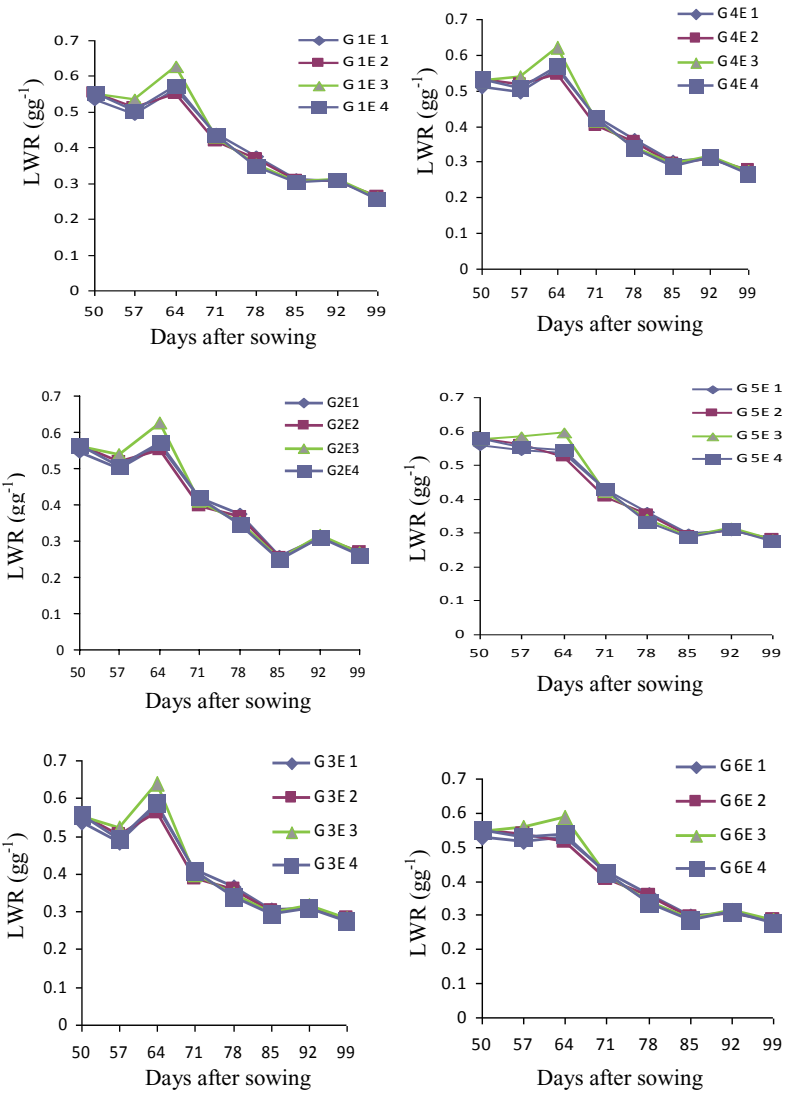


Figure 7A: Interaction between genotypes and environments on leaf weight ratio (LWR) of six lentil genotypes at different growth stages in 2009-2010 experiment.

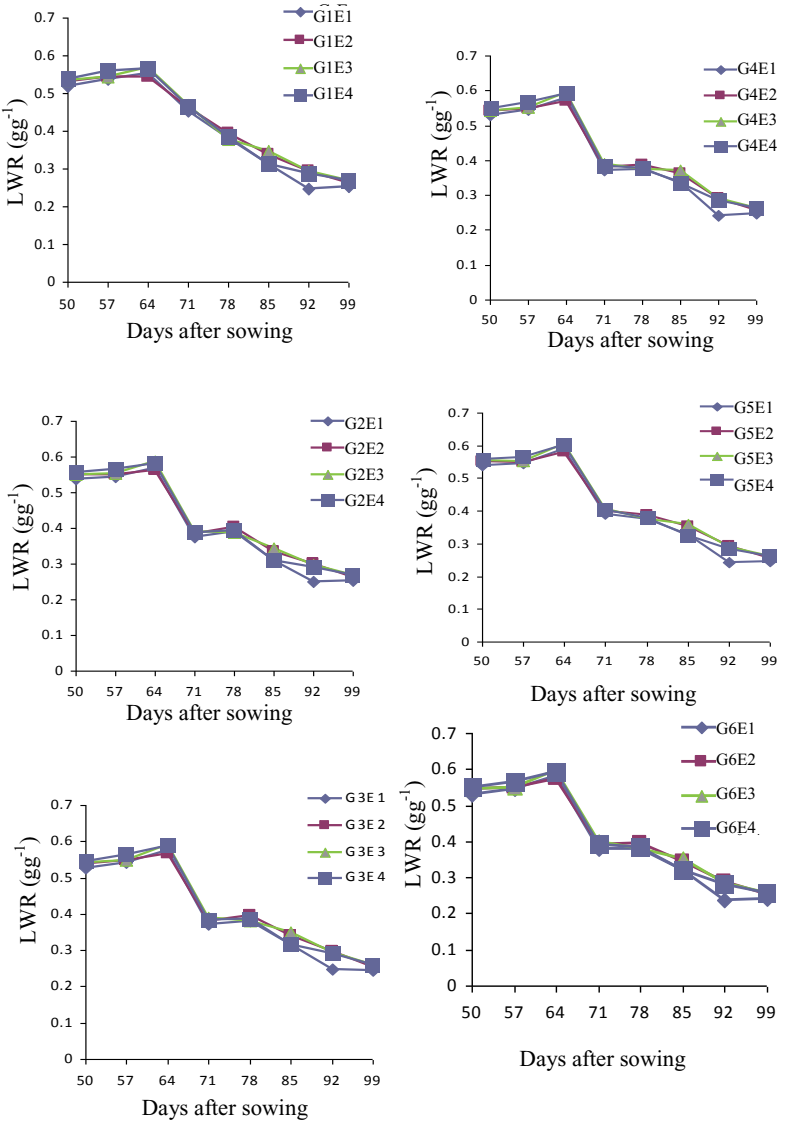


Figure 7B: Interaction between genotypes and environments on leaf weight ratio (LWR) of six lentil genotypes at different growth stages in 2010-2011 experiment.

4.8. Crop growth rate (CGR)

Experiment for 2009 – 2010

The results of analysis of variance for crop growth rate of lentil are shown in **Table 30.** The results show that the item genotype (G) was not significant at any harvest. The item environment (E) was significant at 50, 64, 71 and 85 DAS, which indicated that the cultivars were affected by different soil moisture regimes. The item G×E interaction was significant only at 50 DAS.

Mean values on crop growth rate of all six lentil genotypes **(Table 32)** indicated that starting from a lower value, increased slowly at the early stages of growth and reached their highest value at the fifth harvest at 78 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fifth harvest (78 DAS) the highest crop growth rate was recorded in Barimasur 4 (G 4) and the lowest crop growth rate was recorded in Barimasur 2 (G 2). In all the genotypes, Barimasur 1 (G1) showed the highest value at 85 and 92 DAS, Barimasur 3 (G 3) showed the highest value at 50 and 71 DAS and Barimasur 5 (G 5) showed the highest value at 57 and 64 DAS. On the other hand, Barimasur 4 (G 4) was found to show the lowest crop growth rate at 50, 57, 64 and 85 DAS. All the genotypes showed more, less or similar trends at different growth stages.

Mean values on crop growth rate of all four environments **(Table 32)** of lentil also indicated that starting from a lower value, increased slowly at the early harvests and reached their highest value at the fifth harvest at 78 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fifth harvest (78 DAS) environment 2 (E 2) plants showed the highest and environment 3 (E 3) plants showed the lowest crop growth rate. Among the environments, environment 1 (E1) plants showed the highest value at 85 and 92 DAS, environment 2 (E 2) plants showed the highest value at 50 and 78 DAS and environment 4 (E 4) plants showed the highest value at 64 and 71 DAS. Environment 1 (E1) plants showed the lowest value at 57 and 64 DAS, environment 2 (E 2) plants were found to show the lowest value at 71 and 92 DAS and environment 3 (E 3) plants showed the lowest value of crop growth rate at 50 and 78 DAS. All the environments showed more, less or similar trends at different growth stages.

The mean effect between genotypes and environments on crop growth rate of lentil **(Table 32)** also starting from a lower value, increased slowly at the early harvests and reached their highest value at the fifth harvest at 78 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. The mean effect between genotypes and environments, at the peak harvest (78 DAS) G4×E2 showed the maximum value and G3×E1 showed the minimum value. G6×E4 showed the highest value at 50, 64 and 92 DAS. G1×E1 showed the lowest value at 64 and 92 DAS and G3×E1 showed the lowest value of crop growth rate at 57 and 78 DAS. The highest and the lowest value showed more, less or similar trends at different growth stages.

The overall interaction effects between genotypes and environments on crop growth rate of lentil at different stages of growth are graphically shown in **Fig 8A**. The graphical results show that all the genotypes and environments indicated that starting from a lower value, increased slowly at the early harvests and reached their highest value at the fifth harvest at 78 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fifth harvest (78 DAS) Barimasur 4 (G 4) showed the maximum value and Barimasur 2 (G 2) showed the minimum value of crop growth rate. Among the genotypes, Barimasur 1 (G 1) showed the highest value at 85 and 92 DAS, Barimasur 3 (G3) showed the highest value at 50 and 71 DAS and Barimasur 5 (G 5) showed the highest value of crop growth rate at 57 and 64 DAS. Barimasur 4 (G 4) was found to show the lowest value at 50, 57, 64 and 85 DAS. In all the environments, at the fifth harvest (78 DAS) environment 2 (E 2) plants showed the highest peak and environment 3 (E 3) plants showed the lowest crop growth rate. Of all the environments for crop growth rate, the highest value was found in environment 1 (E1) plants at 85 and 92 DAS, in environment 2 (E 2) plants at 50 and 78 DAS and in environment 3 (E 3) plants at 64 and 71 DAS. The lowest value was found in environment 1 (E1) plants at 57 and 64 DAS, in environment 2 (E 2) plants at 71 and 92 DAS and in environment 3 (E 3) plants at 50 and 78 DAS. All the genotypes and environments showed more, less or similar trends at different growth stages.

Experiment for 2010 – 2011

Mean squares from the analysis of variance for crop growth rate of lentil are shown in **Table 31**. The results show that the item genotype (G) was not significant at any

harvest. The item environment (E) was significant at 50, 64, 71 and 85 DAS, which indicated that the cultivars were affected by different soil moisture regimes. The item G×E interaction was significant only at 50 DAS.

Mean values on crop growth rate of all six lentil genotypes **(Table 33)** indicated that starting from a lower value, increased slowly at the early stages of growth and reached their highest value at the fifth harvest at 78 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fifth harvest (78 DAS) the highest crop growth rate was recorded in Barimasur 6 (G 6) and the lowest crop growth rate was recorded in Barimasur 3 (G 3). In all the genotypes, Barimasur 6 (G 6) showed the highest crop growth rate at most of growth harvests except at 64 and 92 DAS. Barimasur 1 (G 1) showed the lowest value at 71 and 85 DAS and Barimasur 3 (G 3) showed the lowest value of crop growth rate at 57 and 78 DAS. All the genotypes showed more, less or similar trends at different growth stages.

Mean values on crop growth rate of all four environments **(Table 33)** of lentil also indicated that starting from a lower value, increased slowly with the advancement of time and reached their highest value at the fifth harvest at 78 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fifth harvest (78 DAS) environment 2 (E 2) plants showed the highest value and environment 3 (E 3) plants showed the lowest value of crop growth rate. Among the environments, environment 1 (E1) plants showed the highest value at 57, 85 and 92 DAS and environment 4 (E 4) plants showed the highest value of crop growth rate at 50 and 71 DAS. Environment 2 (E 2) plants showed the lowest crop growth rate at 71, 85 and 92 DAS and environment 3 (E3) plants showed the lowest crop growth rate at 57 and 78 DAS. All the genotypes showed more, less or similar trends at different growth stages.

The mean effect between genotypes and environments on crop growth rate of lentil **(Table 33)** also starting from a lower value, increased slowly with the stages of growth and reached their highest value at the fifth harvest at 78 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. The mean effect between genotypes and environments, at the peak harvest (78 DAS) G5×E2 showed the maximum value and G3×E4 showed the minimum value. The highest value

was found in G4×E4 at 50 and 85 DAS and in G5×E2 at 57 and 78 DAS. The highest and the lowest value showed more, less or similar trends at different growth stages.

The overall interaction effects between genotypes and environments on crop growth rate of lentil at different stages of growth are graphically shown in **Fig 8B**. The graphical results show that all the genotypes and environments indicated that starting from a lower value, increased slowly at the early stages of growth and reached their highest value at the fifth harvest at 78 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fifth harvest (78 DAS) Barimasur 6 (G 6) showed the highest value and Barimasur 3 (G 3) showed the lowest value of crop growth rate. Among the genotypes, Barimasur 6 (G 6) showed the highest value at most of the growth stages except at 64 and 92 DAS. Barimasur 1 (G1) showed the lowest value at 71 and 85 DAS and Barimasur 3 (G 3) showed the lowest value of crop growth rate at 57 and 78 DAS. In all the environments, at the fifth harvest (78 DAS) environment 2 (E 2) plants were found to show the highest peak and environment 3 (E 3) plants were observed to show the lowest peak. Environment 1 (E1) plants showed the highest peak at 57, 85 and 92 DAS. Environment 2 (E 2) plants were found to show the lowest value at 71, 85 and 92 DAS. All the genotypes and environments showed more, less or similar trends at different growth stages.

Table 30: Mean squares (MS) from the analysis of variance for crop growth rate (gm^{-2} day^{-1}) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2009 - 2010.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS
Replication (R)	2	0.0001	0.043	0.007	0.028	0.015	0.056	0.065
Genotype (G)	5	0.0001	0.055	0.002	0.083	0.061	0.005	0.027
Error - 1	10	0.0001	0.028	0.003	0.030	0.021	0.003	0.008
Environment (E)	3	0.0021**	0.067	0.093*	0.335**	0.027	0.098*	0.044
G × E	15	0.0018**	0.031	0.001	0.024	0.014	0.001	0.015
Error - 2	36	0.0001	0.026	0.002	0.016	0.018	0.009	0.016

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 31 : Mean squares (MS) from the analysis of variance for crop growth rate (gm^{-2} day^{-1}) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2010 - 2011.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS
Replication (R)	2	0.0001	0.034	0.004	0.02	0.012	0.043	0.041
Genotype (G)	5	0.0001	0.043	0.002	0.072	0.048	0.007	0.023
Error - 1	10	0.0001	0.026	0.003	0.031	0.023	0.004	0.009
Environment (E)	3	0.0024**	0.062	0.081**	0.226**	0.016	0.086**	0.038
G × E	15	0.0011**	0.029	0.002	0.023	0.018	0.015	0.013
Error - 2	36	0.0001	0.026	0.002	0.015	0.019	0.008	0.015

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 32 : Mean values of crop growth rate of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2009 – 2010

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS
Barimasur 1 (G1)	0.0161	0.2023	0.3865	1.0480	1.3927	1.3923	1.3403
Barimasur 2 (G2)	0.0168	0.2031	0.3893	1.1016	1.3638	1.2752	1.2662
Barimasur 3 (G3)	0.0313	0.2130	0.3945	1.2568	1.3737	1.2642	1.2512
Barimasur 4 (G4)	0.0154	0.2001	0.3837	1.1356	1.4189	1.2315	1.2104
Barimasur 5 (G5)	0.0155	0.2165	0.4174	1.173	1.4082	1.3642	1.2811
Barimasur 6 (G6)	0.0192	0.2161	0.4123	1.1341	1.4187	1.2525	1.1312
LSD 5%	0.0201	0.152	0.591	0.954	1.313	1.224	1.265
Environment (E)							
Environment 1 (E1)	0.0166	0.1194	0.1665	1.0504	1.3861	1.3825	1.3242
Environment 2 (E2)	0.0269	0.1317	0.3943	0.9575	1.4469	1.2636	1.2236
Environment 3 (E3)	0.0137	0.1389	0.3937	1.1953	1.3451	1.2414	1.2452
Environment 4 (E4)	0.0191	0.1385	0.4326	1.3631	1.4062	1.2302	1.2285
LSD 5%	0.0072	0.1011	0.0372	0.0893	0.0947	0.0675	0.0882
(G×E)							
G1×E1	0.0153	0.1258	0.3240	0.9990	1.4244	1.3514	1.0545
G1×E2	0.0231	0.1210	0.3844	0.9329	1.4231	1.3386	1.1560
G1×E3	0.0100	0.1156	0.3982	1.1009	1.4381	1.4038	1.2845
G1×E4	0.0161	0.1291	0.4392	1.1588	1.3848	1.3645	1.2730
G2× E1	0.0197	0.1120	0.3596	0.9853	1.4061	1.3372	1.1332
G2×E2	0.0191	0.1223	0.3704	0.9490	1.4802	1.4097	1.1944
G2×E3	0.0125	0.1250	0.3937	1.2713	1.4718	1.3676	1.3447
G2×E4	0.0159	0.1333	0.4338	1.2038	1.3973	1.3652	1.3025
G3× E1	0.0209	0.1049	0.3889	0.9968	1.2640	1.2530	1.1849
G3×E2	0.0149	0.1468	0.3916	1.0177	1.4892	1.3164	1.2115
G3×E3	0.0126	0.1387	0.4005	1.1060	1.4397	1.3655	1.3334
G3×E4	0.0204	0.1361	0.3971	1.2868	1.4021	1.3640	1.3341
G4× E1	0.0178	0.1130	0.3575	1.1206	1.4162	1.2984	1.2970
G4×E2	0.0123	0.1300	0.3968	1.0470	1.5056	1.3616	1.1944
G4×E3	0.0132	0.1386	0.3695	1.1395	1.4188	1.3382	1.2288
G4×E4	0.0185	0.1379	0.4110	1.1686	1.4325	1.3500	1.2911
G5×E1	0.0105	0.1277	0.3821	1.0980	1.4451	1.3832	1.3848
G5×E2	0.0139	0.1388	0.4280	1.0994	1.4419	1.3817	1.1926
G5×E3	0.0182	0.1397	0.3829	1.2586	1.3829	1.3334	1.3116
G5×E4	0.0194	0.1473	0.4420	1.3259	1.4632	1.3718	1.3218
G6× E1	0.0157	0.1327	0.4007	1.1385	1.4611	1.4252	1.2456
G6×E2	0.0214	0.1315	0.3941	1.1020	1.4381	1.3929	1.1993
G6×E3	0.0157	0.1746	0.3820	1.1952	1.4186	1.3569	1.3581
G6×E4	0.0241	0.1472	0.4725	1.3039	1.4571	1.4031	1.3988
LSD 5%	0.0152	0.2834	0.1728	0.2113	0.2147	0.1574	0.2114

Table 33 : Mean values of crop growth rate of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2010 - 2011.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS
Barimasur 1 (G1)	0.0174	0.0996	0.5219	1.0365	1.3871	1.2932	1.2050
Barimasur 2 (G2)	0.0208	0.0909	0.5054	1.0420	1.4193	1.3210	1.2490
Barimasur 3 (G3)	0.0192	0.0869	0.5151	1.0497	1.3835	1.3053	1.2397
Barimasur 4 (G4)	0.0190	0.1287	0.5406	1.1335	1.4293	1.4186	1.1954
Barimasur 5 (G5)	0.0160	0.1428	0.5322	1.1482	1.4785	1.4164	1.2568
Barimasur 6 (G6)	0.0244	0.2362	0.5384	1.2014	1.4862	1.4413	1.2328
LSD 5%	0.0242	0.1253	0.5213	0.9904	1.4411	1.2620	1.2204
Environment (E)							
Environment 1 (E1)	0.0150	0.2183	0.4362	1.0586	1.4282	1.3782	1.2614
Environment 2 (E2)	0.0217	0.1178	0.5186	0.9949	1.5078	1.3526	1.2139
Environment 3 (E3)	0.0185	0.0869	0.5951	1.1526	1.3695	1.3767	1.2181
Environment 4 (E4)	0.0326	0.1110	0.5526	1.2016	1.4195	1.3563	1.2201
LSD 5%	0.0074	0.1094	0.0305	0.0837	0.0931	0.0608	0.0834
(G×E)							
G1×E1	0.0132	0.1276	0.4041	0.9755	1.3774	1.2700	1.1807
G1×E2	0.0264	0.0835	0.5388	0.9202	1.4815	1.2735	1.1743
G1×E3	0.0004	0.0873	0.5848	1.1021	1.3256	1.3267	1.2390
G1×E4	0.0254	0.0998	0.5598	1.1484	1.3639	1.2985	1.1927
G2× E1	0.0186	0.1041	0.4064	0.9854	1.5120	1.3001	1.2774
G2×E2	0.0230	0.0780	0.5358	0.9459	1.4624	1.3723	1.2610
G2×E3	0.0171	0.0859	0.5730	1.0974	1.3584	1.3306	1.2230
G2×E4	0.0245	0.0954	0.5058	1.1393	1.3443	1.2803	1.2346
G3× E1	0.0209	0.1291	0.3909	1.0017	1.4700	1.4004	1.2905
G3×E2	0.0118	0.0812	0.5199	0.9731	1.4695	1.2774	1.1659
G3×E3	0.0006	0.0514	0.5898	1.0945	1.3692	1.2642	1.2419
G3×E4	0.0373	0.0858	0.5600	1.1295	1.3254	1.2791	1.2607
G4× E1	0.0187	0.1640	0.4563	1.1209	1.4060	1.4052	1.2248
G4×E2	0.0088	0.1473	0.5116	1.0474	1.4579	1.3734	1.1695
G4×E3	0.0060	0.1000	0.6136	1.1022	1.4743	1.4385	1.1883
G4×E4	0.0427	0.1039	0.5806	1.2640	1.4680	1.4575	1.1989
G5×E1	0.0052	0.1557	0.4801	1.0989	1.4782	1.4472	1.3116
G5×E2	0.0197	0.1751	0.5177	1.0187	1.6172	1.3809	1.2593
G5×E3	0.0101	0.1041	0.5880	1.2394	1.3877	1.2530	1.2458
G5×E4	0.0289	0.1362	0.5428	1.2357	1.5307	1.3845	1.2104
G6× E1	0.0133	0.1654	0.4792	1.1691	1.5001	1.4457	1.2837
G6×E2	0.0407	0.1418	0.4866	1.0640	1.5585	1.4343	1.2537
G6×E3	0.0066	0.0926	0.6216	1.2797	1.4017	1.1947	1.1707
G6×E4	0.0368	0.1450	0.5665	1.2928	1.4844	1.4380	1.2234
LSD 5%	0.0174	0.2671	0.0743	0.2035	0.2280	0.1486	0.2032

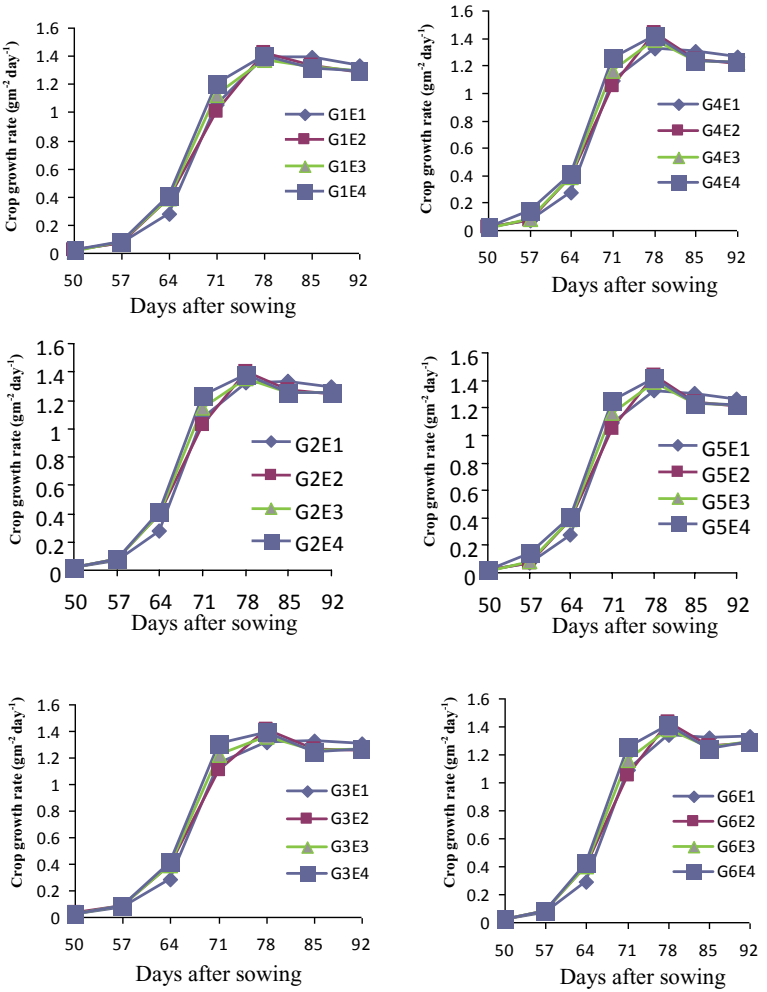


Figure 8A: Interaction between genotypes and environments on crop growth rate (CGR) of six lentil genotypes at different growth stages in 2009-2010 experiment.

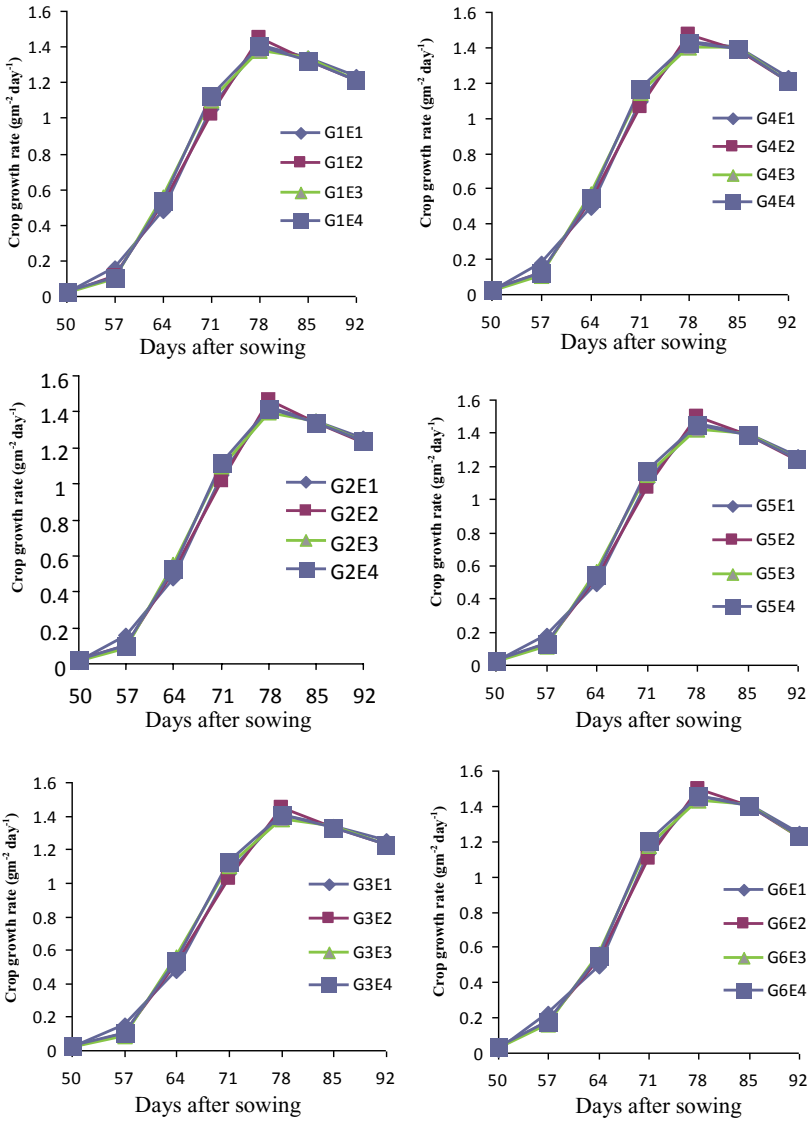


Figure 8B: Interaction between genotypes and environments on crop growth rate (CGR) of six lentil genotypes at different growth stages in 2010-2011 experiment.

4.9. Relative growth rate (RGR)

Experiment for 2009 – 2010

The results of analysis of variance for relative growth rate of lentil are shown in **Table 34.** The results show that the item genotype (G) was not significant at any harvest. The item environment (E) was significant at 50, 57, 71 and 85 DAS, which indicated that the cultivars were affected by different soil moisture conditions. The item G×E interaction was significant at only two harvests at 50 and 71 DAS.

Mean values on relative growth rate of all six lentil genotypes **(Table 36)** starting from a lower value, increased slowly at the early stages of growth and reached their highest value at the fourth harvest at 71 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fourth harvest (71 DAS) Barimasur 3 (G 3) was found to show the highest value and Barimasur 5 (G 5) showed the lowest value. Barimasur 6 (G 6) showed the highest value at 64 and 78 DAS. Barimasur 1 (G1) showed the lowest value at 85 and 92 DAS. The highest and the lowest relative growth rate showed more, less or similar trends at different growth stages.

Mean values on relative growth rate of all four environments **(Table 36)** of lentil indicated that starting from a lower value, increased with the advancement of time and reached their highest value at 71 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fourth harvest (71 DAS) the highest relative growth rate was recorded in environment 3 (E 3) plants and the lowest relative growth rate was recorded in environment 1 (E1) plants. Environment 4 (E 4) plants showed the highest value at most of the growth stages except at 71 and 85 DAS. Environmnt 1 (E1) plants showed the lowest relative growth rate at most of the growth stages except at 64, 85 and 92 DAS.

The mean effect between genotypes and environments on relative growth rate of lentil **(Table 36)** also starting from a lower value, increased slowly with the stages of growth and reached their highest value at the fourth harvest at 71 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. The mean effect between genotypes and environments, at the peak harvest (71 DAS) G1×E4 showed the highest value and G4×E1 showed the lowest value. The highest relative

growth rate was found in G1×E4 at 57 and 71 DAS, in G5×E4 at 50 and 92 DAS and in G6×E4 at 78 and 85 DAS. The lowest relative growth rate was found in G3×E2 at 50 and 64 DAS and in G5×E1 at 57 and 78 DAS. The highest and the lowest relative growth rate showed more, less or similar trends at different growth stages.

The overall interaction effects between genotypes and environments on relative growth rate of lentil at different stages of growth are graphically shown in **Fig 9A**. The graphical results show that all the genotypes and environments indicated that starting from a lower value, increased slowly with the age of plants and reached their highest value at the fourth harvest at 71 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fourth harvest (71 DAS) Barimasur 3 (G 3) was found to show the highest peak and Barimasur 5 (G 5) showed the lowest peak. Barimasur 6 (G 6) showed the highest value at 64 and 78 DAS. Barimasur 1 (G1) showed the lowest peak at 85 and 92 DAS. Of all the environments, at the fourth harvest (71 DAS) environment 3 (E 3) plants showed the highest peak and environment 1 (E1) plants showed the lowest peak. Environment 4 (E 4) plants showed the highest value at most of the growth phases except at 71 and 85 DAS. Environment 1 (E 1) plants was found to be the lowest value at most of the harvesting dates except at 64, 85 and 92 DAS. The highest and the lowest value showed more, less or similar trends at different growth stages.

Experiment for 2010 – 2011

Mean squares from the analysis of variance for relative growth rate of lentil are shown in **Table 35.** The results show that the item genotype (G) was not significant at any growth stage. The item environment (E) was significant at 57, 64, 71 and 85 DAS, which indicated that the cultivars were affected by different soil moisture regimes. The item G×E interaction was significant at only two harvest at 50 and 78 DAS.

Mean values on relative growth rate of all six genotypes **(Table 37)** of lentil starting from a lower value, increased slowly with the age of plants and reached their highest value at the fourth harvest at 71 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fourth harvest (71 DAS) the highest relative growth rate was recorded in Barimasur 3 (G 3) and the lowest

relative growth rate was recorded in Barimasur 6 (G 6). Barimasur 3 (G 3) showed the highest value at 64 and 71 DAS. The lowest relative growth rate was observed in Barimasur 2 (G 2) at 85 and 92 DAS, in Barimasur 4 (G 4) at 57 and 78 DAS and in Barimasur 6 (G 6) at 50, 64 and 71 DAS. The highest and the lowest relative growth rate showed more, less or similar trends at different growth stages.

Mean values on relative growth rate of all four environments **(Table 37)** of lentil indicated that starting from a lower value, increased slowly with the advancement of time and reached their highest value at 71 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. At the fourth harvest (71 DAS) the highest relative growth rate was recorded in environment 3 (E 3) plants and the lowest relative growth rate was recorded in environment 1 (E1) plants. Environment 3 (E 3) plants showed the highest value at 57, 64, 71 and 92 DAS and environment 4 (E 4) plants showed the highest relative growth rate at 50 and 78 DAS. Environmnt 1 (E1) plants showed the lowest relative growth rate at most of the growth stages except at 92 DAS.

The mean effect between genotypes and environments on relative growth rate of lentil **(Table 41)** also starting from a lower value, increased slowly at the early stages of growth and reached their highest value at the fourth harvest at 71 DAS and then the values decreased and reached towards the zero direction at the last harvest at 92 DAS. The mean effect between genotypes and environments, at the peak harvest (71 DAS) G3×E2 showed the highest value and G6×E2 showed the lowest value. The highest relative growth rate was observed in G3×E2 at 64 and 71 DAS and in G5×E4 at 50, 57 and 78 DAS. The lowest relative growth rate was observed in G5×E1 at 50 and 92 DAS and in G6×E2 at 71 and 85 DAS. The highest and the lowest relative growth rate showed more, less or similar trends at different growth stages.

The overall interaction effects between genotypes and environments on relative growth rate of lentil at different stages of growth are graphically shown in **Fig 9B**. The graphical results show that all the genotypes and environments indicated that starting from a lower value, increased slowly with the age of plants and reached their highest value at the fourth harvest at 71 DAS and then the values decreased and reached

towards the zero direction at the last harvest at 92 DAS. At the fourth harvest (71 DAS) the highest relative growth rate was found in Barimasur 3 (G 3) and the lowest relative growth rate was recorded in Barimasur 6 (G 6). Barimasur 3 (G 3) showed the highest value at 64 and 71 DAS. Barimasur 6 (G 6) showed the lowest value at 50, 64 and 71 DAS. In all the environments, at the fourth harvest (71 DAS) environment 3 (E 3) plants showed the highest peak and environment 1(E 1) plants showed the lowest peak. Environment 3 (E 3) plants showed the highest peak at 57, 64, 71 and 92 DAS and environment 4 (E 4) plants were found to show the highest value at 50 and 78 DAS. Environment 1 (E 1) plants were found to show the lowest value at most of the growth stages except at 92 DAS.

Table 34: Mean squares (MS) from the analysis of variance for relative growth rate (gg^{-1} day^{-1}) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2009 - 2010.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS
Replication (R)	2	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0045
Genotype (G)	5	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0030
Error - 1	10	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0030
Environment (E)	3	0.0008**	0.0009**	0.0001	0.0014**	0.0001	0.0011**	0.0030
G × E	15	0.0013**	0.0001	0.0001	0.0012**	0.0001	0.0001	0.0015
Error - 2	36	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0021

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 35 : Mean squares (MS) from the analysis of variance for relative growth rate (gg^{-1} day^{-1}) at different harvests of six lentil genotypes as influenced by soil moisture for experiment 2010 - 2011.

Sources of Variation	df.	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS
Replication (R)	2	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.005
Genotype (G)	5	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.002
Error - 1	10	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.003
Environment (E)	3	0.0001	0.0013**	0.0012**	0.0009**	0.0001	0.0008**	0.003
G × E	15	0.0011**	0.0001	0.0001	0.0001	0.0009**	0.0001	0.001
Error - 2	36	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.002

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 36 : Mean values of relative growth rate of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2009 - 2010.

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS
Barimasur 1 (G1)	0.0149	0.0286	0.0638	0.0813	0.0323	0.0238	0.0144
Barimasur 2 (G2)	0.0203	0.0226	0.0648	0.0794	0.0314	0.0264	0.0153
Barimasur 3 (G3)	0.0147	0.0246	0.0626	0.0826	0.0342	0.0266	0.0153
Barimasur 4 (G4)	0.0151	0.0203	0.0663	0.0791	0.0331	0.0269	0.0150
Barimasur 5 (G5)	0.0183	0.0211	0.0665	0.0780	0.0327	0.0253	0.0159
Barimasur 6 (G6)	0.0126	0.0255	0.0680	0.0790	0.0357	0.0253	0.0151
LSD 5%	0.0082	0.0094	0.0073	0.0096	0.0097	0.0085	0.0513
Environment (E)							
Environment 1 (E1)	0.0125	0.0187	0.0653	0.0753	0.0301	0.0238	0.0149
Environment 2 (E2)	0.0148	0.0197	0.0649	0.0780	0.0355	0.0153	0.0150
Environment 3 (E3)	0.0163	0.0279	0.0656	0.0836	0.0333	0.0306	0.0148
Environment 4 (E4)	0.0203	0.0286	0.0657	0.0826	0.0379	0.0291	0.0225
LSD 5%	0.0074	0.0065	0.0094	0.0069	0.0086	0.0085	0.0281
(G×E)							
G1×E1	0.0121	0.0287	0.0634	0.0724	0.0458	0.0195	0.0137
G1×E2	0.0202	0.0214	0.0631	0.0840	0.0296	0.0242	0.0140
G1×E3	0.0113	0.0302	0.0648	0.0835	0.0326	0.0246	0.0132
G1×E4	0.0159	0.0342	0.0640	0.0852	0.0349	0.0267	0.0165
G2× E1	0.0181	0.0232	0.0649	0.0711	0.0311	0.0179	0.0153
G2×E2	0.0216	0.0257	0.0658	0.0783	0.0344	0.0184	0.0160
G2×E3	0.0224	0.0279	0.0633	0.0846	0.0289	0.0209	0.0137
G2×E4	0.0192	0.0336	0.0650	0.0786	0.0311	0.0289	0.0150
G3× E1	0.0139	0.0179	0.0647	0.0752	0.0342	0.0248	0.0156
G3×E2	0.0010	0.0227	0.0607	0.0835	0.0337	0.0243	0.0159
G3×E3	0.0145	0.0247	0.0615	0.0829	0.0310	0.0291	0.0160
G3×E4	0.0208	0.0331	0.0634	0.0744	0.0380	0.0281	0.0138
G4× E1	0.0107	0.0139	0.0636	0.0715	0.0249	0.0224	0.0150
G4×E2	0.0061	0.0126	0.0646	0.0724	0.0323	0.0235	0.0143
G4×E3	0.0196	0.0230	0.0676	0.0844	0.0370	0.0317	0.0150
G4×E4	0.0242	0.0252	0.0693	0.0780	0.0383	0.0300	0.0157
G5×E1	0.0078	0.0115	0.0689	0.0755	0.0246	0.0232	0.0140
G5×E2	0.0173	0.0183	0.0640	0.0733	0.0373	0.0208	0.0159
G5×E3	0.0205	0.0295	0.0647	0.0813	0.0344	0.0287	0.0162
G5×E4	0.0256	0.0265	0.0684	0.0818	0.0346	0.0263	0.0176
G6× E1	0.0128	0.0179	0.0662	0.0761	0.0337	0.0228	0.0159
G6×E2	0.0120	0.0305	0.0711	0.0734	0.0363	0.0180	0.0141
G6×E3	0.0095	0.0275	0.0717	0.0850	0.0356	0.0261	0.0147
G6×E4	0.0162	0.0241	0.0632	0.0834	0.0463	0.0343	0.0155
LSD 5%	0.0186	0.0164	0.0177	0.0162	0.0185	0.0191	0.0783

Table 37: Mean values of relative growth rate of six lentil genotypes at different growth stages as influenced by soil moisture for experiment 2010 - 2011

Genotype (G)	50 DAS	57 DAS	64 DAS	71 DAS	78 DAS	85 DAS	92 DAS
Barimasur 1 (G1)	0.0174	0.0316	0.0785	0.0813	0.0323	0.0247	0.0173
Barimasur 2 (G2)	0.0241	0.0255	0.0794	0.0831	0.0328	0.0243	0.0170
Barimasur 3 (G3)	0.0145	0.0247	0.0812	0.0836	0.0327	0.0255	0.0173
Barimasur 4 (G4)	0.0159	0.0204	0.0731	0.0768	0.0315	0.0259	0.0173
Barimasur 5 (G5)	0.0177	0.0211	0.0744	0.0772	0.0320	0.0254	0.0178
Barimasur 6 (G6)	0.0116	0.0265	0.0716	0.0766	0.0348	0.0244	0.0177
LSD 5%	0.0092	0.0094	0.0091	0.0096	0.0094	0.0091	0.0507
Environment (E)							
Environment 1 (E1)	0.0109	0.0157	0.0683	0.0746	0.0301	0.0228	0.0174
Environment 2 (E2)	0.0151	0.0204	0.0755	0.0802	0.0329	0.0310	0.0173
Environment 3 (E3)	0.0198	0.0339	0.0817	0.0834	0.0321	0.0276	0.0178
Environment 4 (E4)	0.0218	0.0297	0.0799	0.0826	0.0356	0.0288	0.0171
LSD 5%	0.0074	0.0076	0.0075	0.0078	0.0072	0.0079	0.0308
(G×E)							
G1×E1	0.0130	0.0324	0.0713	0.0767	0.0341	0.0225	0.0171
G1×E2	0.0156	0.0251	0.0785	0.0861	0.0329	0.0204	0.0171
G1×E3	0.0147	0.0369	0.0803	0.0834	0.0289	0.0264	0.0186
G1×E4	0.0164	0.0356	0.0806	0.0858	0.0331	0.0296	0.0162
G2× E1	0.0105	0.0204	0.0719	0.0762	0.0350	0.0221	0.0174
G2×E2	0.0192	0.0291	0.0826	0.0911	0.0347	0.0194	0.0168
G2×E3	0.0232	0.0409	0.0817	0.0848	0.0298	0.0267	0.0170
G2×E4	0.0203	0.0334	0.0813	0.0835	0.0317	0.0288	0.0168
G3× E1	0.0115	0.0174	0.0672	0.0744	0.0351	0.0228	0.0168
G3×E2	0.0102	0.0227	0.0854	0.0916	0.0304	0.0241	0.0172
G3×E3	0.0128	0.0287	0.0842	0.0905	0.0274	0.0255	0.0172
G3×E4	0.0202	0.0333	0.0671	0.0891	0.0377	0.0277	0.0170
G4× E1	0.0135	0.0157	0.0656	0.0776	0.0225	0.0212	0.0171
G4×E2	0.0042	0.0095	0.0656	0.0745	0.0304	0.0229	0.0173
G4×E3	0.0173	0.0382	0.0784	0.0862	0.0367	0.0304	0.0170
G4×E4	0.0251	0.0288	0.0773	0.0822	0.0365	0.0289	0.0179
G5×E1	0.0033	0.0124	0.0690	0.0772	0.0228	0.0205	0.0149
G5×E2	0.0183	0.0222	0.0712	0.0773	0.0308	0.0214	0.0172
G5×E3	0.0190	0.0295	0.0800	0.0834	0.0344	0.0268	0.0191
G5×E4	0.0304	0.0432	0.0773	0.0811	0.0380	0.0272	0.0171
G6× E1	0.0102	0.0218	0.0630	0.0723	0.0310	0.0219	0.0178
G6×E2	0.0128	0.0374	0.0633	0.0707	0.0363	0.0179	0.0171
G6×E3	0.0085	0.0293	0.0829	0.0866	0.0355	0.0276	0.0182
G6×E4	0.0149	0.0340	0.0770	0.0802	0.0363	0.0304	0.0166
LSD 5%	0.0171	0.0174	0.0172	0.0176	0.0175	0.0174	0.0749

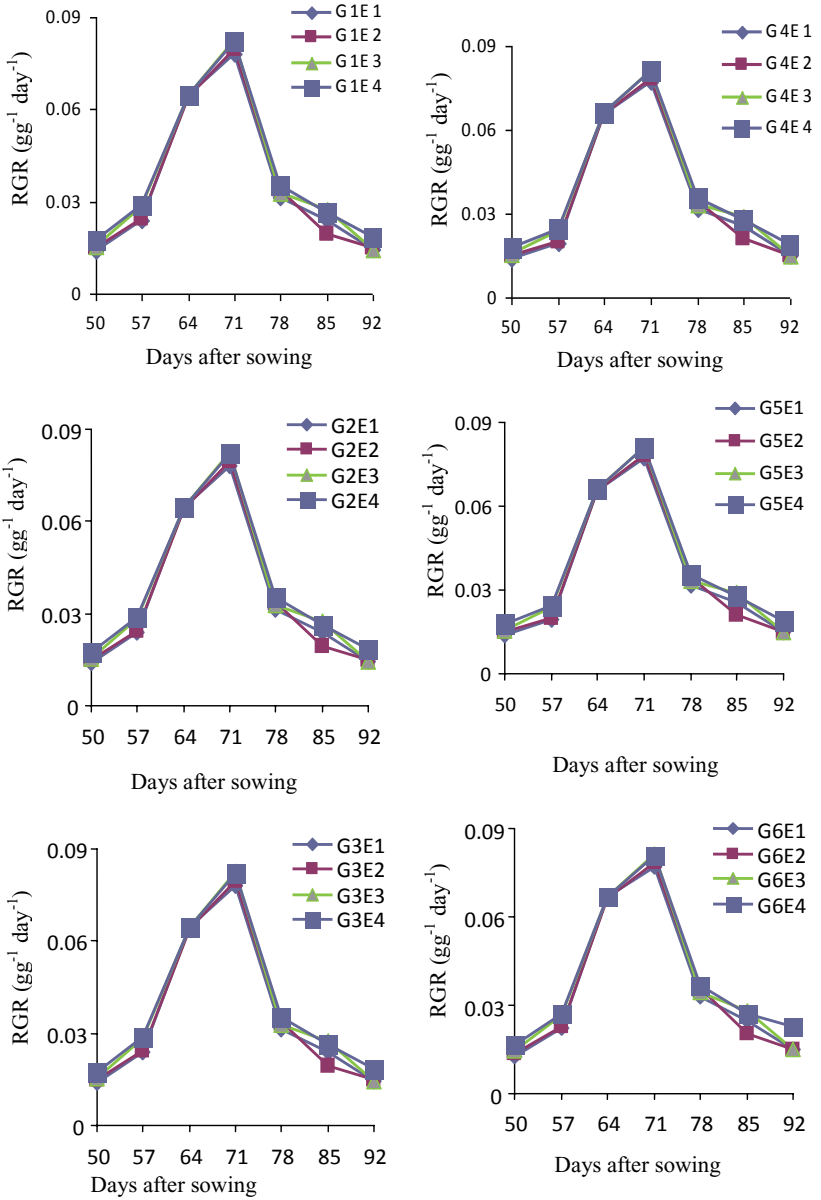


Figure 9A: Interaction between genotypes and environments on relative growth rate (RGR) of six lentil genotypes at different growth stages in 2009-2010 experiment.

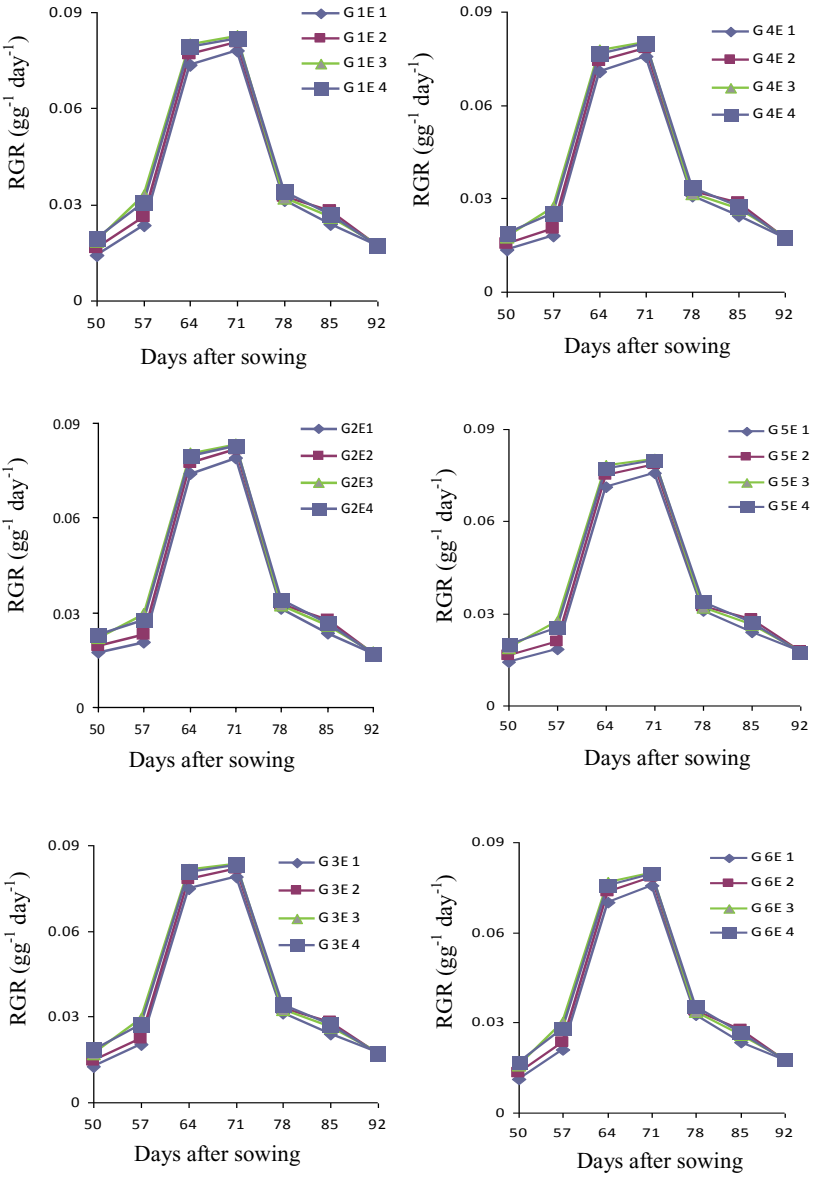


Figure 9B: Interaction between genotypes and environments on relative growth rate (RGR) of six lentil genotypes at different growth stages in 2010-2011 experiment.)

4.10. Yield and Yield Components

The grain yield in lentil is the final outcome of the contribution of different physio-morphological characters. As such ten different yield contributing characters were studied. Data on plant height, branch number per plant, plant area per plant, days to 50% flower, days to maturity, pod number per plant, seed number per plant, 1000 seed weight , total dry matter and grain yield per hectare of six lentil genotypes under different environments were collected at maturity. The results of different environments on these yield contributing characters are presented below.

Experiment for 2009-2010

1. Plant height (PH)

Mean squares from the analysis of variance for plant height are shown in **Table 38.** The results show that the items genotype (G), environment (E) and G×E interaction were significant.

Mean values of plant height in all the genotypes **(Table 40),** Barimasur 1 (G1) showed the highest value and Barimasur 6 (G 6) showed the lowest value. In all the environments, environment 4 (E 4) plants showed the highest value and environment 1 (E1) plants showed the lowest plant height. The mean effect between genotypes and environments, G1×E4 showed the highest plant height and G2×E1 showed the lowest plant height.

2. Branch number per plant (BNPP)

The results of analysis of variance for branch number per plant are shown in **Table 38**. The results show that the items genotype (G) and environment (E) were significant. But the item G×E interaction was not significant.

Mean values of branch number per plant in all the genotypes **(Table 40**), Barimasur 6 (G 6) showed the highest value and Barimasur 3 (G 3) showed the lowest value. In all the environments, environment 4 (E 4) plants showed the highest value and environment 1 (E1) plants showed the lowest branch number per plant. The mean effect between genotypes and environments, G5×E4 showed the highest value and G4×E1 showed the lowest branch number per plant.

3. Plant area per plant (PAPP)

Mean squares from the analysis of variance for plant area per plant are shown in **Table 38.** The results show that the items genotype (G), environment (E) and G×E interaction were significant.

Mean values of plant area per plant in all the genotypes (**Table 40),** Barimasur 6 (G 6) showed the highest value and Barimasur 1 (G1) showed the lowest value. In all the environments, environment 3 (E 3) plants showed the highest value and environment 1 (E1) plants showed the lowest plant area per plant. The mean effect between genotypes and environments, G6**×**E3 showed the highest value and G2**×**E1 showed the lowest value of plant area per plant.

4. Days to 50% flower (D 50% F)

The results of analysis of variance for days to 50% flower are shown in **Table 38**. The results show that the items genotype (G) and environment (E) were significant. But, the item G×E interaction was not significant.

Mean values of days to 50% flower of all the genotypes **(Table 40),** the highest days to 50% flower was found in Barimasur 5 (G 5) and the lowest value was observed in Barimasur 3 (G 3). In all the environments, environment 3 (E3) plants showed the highest value and environment 4(E4) plants showed the lowest value of days to 50% flower. The mean effect between genotypes and environments, G5**×**E3 showed the highest value and G6**×**E4 showed the lowest value of days to 50% flower.

5. Days to maturity (DM)

The results of analysis of variance for days to maturity are shown in **Table 38.** The results indicated that the items genotype (G) and environment (E) were significant. But, the item G×E interaction was not significant.

Mean values of days to maturity among the genotypes **(Table 40),** the highest days to maturity was observed in Barimasur 5 (G 5) and the lowest value was found in Barimasur 1 (G 1), Barimasur 2 (G 2) and Barimasur 6 (G 6). In all the environments, environment 3 (E 3) plants were found to show the highest value and environment 1 (E1) plants showed the lowest days to maturity. The mean effect between genotypes and environments, G4**×**E4,

G5×E3 and G5×E4 showed the same highest value and G1× E1, G2× E1, G2× E2, G6×E1 and G6×E2 showed the same lowest value of days to maturity.

6. Pod number per plant (PNPP)

Mean squares from the analysis of variance for pod number per plant are shown in **Table 38**. The results show that the item genotype (G) was significant. The items environment (E) and G×E interaction were not significant.

Mean values of pod number per plant in all the genotypes **(Table 40),** Barimasur 6 (G6) showed the highest value and Barimasur 1 (G1) had the lowest pod number per plant. In all the environments, environment 4 (E 4) plants showed the highest value and environment 1 (E1) plants showed the lowest value of pod number per plant. The mean effect between genotypes and environments, G4×E4 was found to show the maximum and G1×E1 was found to show the minimum pod number per plant.

7. Seed number per plant (SNPP)

The results of analysis of variance for seed number per plant are shown in **Table 38.** The results show that the item genotype (G) was significant. The items environment (E) and G×E interaction were not significant.

Mean values of seed number per plant in all the genotypes **(Table 40),** Barimasur 6 (G 6) showed the highest value and Barimasur 1 (G1) showed the lowest value of seed number per plant. In all the environments, environment 4 (E 4) plants had the highest value and environment 1 (E1) plants had the lowest value of seed number per plant. The mean effect between genotypes and environments, G4×E4 was found to show the maximum value and G1×E1 was found to show the minimum value of seed number per plant.

8. Thousand (1000) seed weight (g)

The results of analysis of variance for 1000 seed weight are shown in **Table 38.** The results show that the item genotype (G) was significant. But, the items environment (E) and G×E interaction were not significant.

Mean values of 1000 seed weight in all the genotypes **(Table 40),** Barimasur 3 (G 3) showed the maximum value and Barimasur 2 (G 2) showed the minimum value of 1000

seed weight. Of all the environments, environment 4 (E 4) plants had the highest value and environment 3 (E 3) plants had the lowest value of 1000 seed weight. The mean effect between genotypes and environments, G3×E2 was found to show the maximum and G2×E4 was found to show the minimum 1000 seed weight.

9. Total dry matter (g)

Mean squares from the analysis of variance for total dry matter are shown in **Table 38.** The results indicated that the items genotype (G) and environment (E) were significant. But, the item G×E interaction was not significant.

Mean values of total dry matter in all the genotypes (**Table 40),** the maximum total dry matter was observed in Barimasur 5 (G 5) and the minimum in Barimasur 2 (G 2). In all the environments, environment 4 (E4) plants had the highest value of total dry matter than any other environments plants. The mean effect between genotypes and environments, G6×E4 showed the highest value and G2×E1 showed the lowest total dry matter.

10. Grain yield (kg/hac)

The results of analysis of variance for grain yield per hectare are shown in **Table 38**. The results show that the items genotype (G) and environment (E) were significant. But, the item G×E interaction was not significant.

Mean values of grain yield per hectare in all the genotypes **(Table 40),** Barimasur 6 (G 6) had the highest value and the lowest value of grain yield in Barimasur 1(G1). In all the environments, the highest grain yield per hectare was observed in environment 4 (E 4) plants than those of the other environments plants. The mean effect between genotypes and environments, G4×E4 was found to show the higher value and G1×E1 was found to show the lowest value of grain yield per hectare.

Experiment for 2010-2011

1. Plant height (PH)

The results of analysis of variance for plant height are shown in **Table 39.** The results show that the items genotype (G), environment (E) and G×E interaction were significant.

Mean values of plant height of all the genotypes (**Table 41),** Barimasur 1 (G1) was found to show the highest value and Barimasur 5 (G 5) showed the lowest value of plant height. In all the environments, environment 4 (E 4) plants showed the highest value and environment 1 (E1) plants showed the lowest value. The mean effect between genotypes and environments, G1×E4 showed the highest plant height and G2×E1 showed the lowest plant height.

2. Branch number per plant (BNPP)

Mean squares from the analysis of variance for branch number per plant are shown in **Table 39.** The items genotype (G) and environment (E) were significant. But, the item G×E interaction was not significant.

Mean values of branch number per plant in all the genotypes (**Table 41),** Barimasur 6 (G 6) showed the highest value and Barimasur 3 (G 3) showed the lowest value. In all the environments, environment 4 (E 4) plants showed the highest value and environment 1 (E1) plants showed the lowest value of branch number per plant. The mean effect between genotypes and environments, G6×E4 showed the highest value and G2×E1 showed the lowest value of branch number per plant.

3. Plant area per plant (PAPP)

The results of analysis of variance for plant area per plant are shown in **Table 39.** The results show that the items genotype (G), environment (E) and G×E interaction were significant.

Mean values of plant area per plant in all the genotypes **(Table 41),** Barimasur 4 (G 4) showed the highest value and Barimasur 1 (G1) showed the lowest value. In all the environments, environment 3 (E 3) plants showed the highest value and environment 1

(E 1) plants showed the lowest value of plant area per plant. The mean effect between genotypes and environments, G6×E3 showed the highest plant area per plant and G2×E1 showed the lowest plant area per plant.

4. Days to 50% flower (D 50% F)

Mean squares from the analysis of variance for days to 50% flower are shown in **Table 39**. The results show that the items genotype (G) and environment (E) were significant. But, the item G×E interaction was not significant.

Mean values of days to 50% flower of all the genotypes **(Table 41**), the highest days to 50% flower was found in Barimasur 4 (G 4) and the lowest value was found in Barimasur 1 (G 1). In all the environments, environment 1 (E 1) plants showed the highest value and environment 4 (E 4) plants showed the lowest value of days to 50% flower. The mean effect between genotypes and environments, G4×E1 showed the highest value and G1×E2 showed the lowest value of days to 50% flower.

5. Days to maturity (DM)

The results of analysis of variance for days to maturity are shown in (**Table 39)**. The results indicated that the items genotype (G) and environment (E) were significant. But, the item G×E interaction was not significant.

Mean values of days to maturity among the genotypes (**Table 41),** the highest days to maturity was observed in Barimasur 5 (G 5) and the same lowest value was observed in Barimasur 2 (G 2), Barimasur 3 (G 3) and Barimasur 4 (G 4). In all the environments, environment 4 (E 4) plants were found to show the highest value and environment 1 (E1) plants showed the lowest value of days to maturity. The mean effect between genotypes and environments, the same highest value was found to show in G5×E4, G5×E3 and G4×E4 and the lowest value of days to maturity was found in G1× E1 and G2×E2.

6. Pod number per plant (PNPP)

Mean squares from the analysis of variance for pod number per plant are shown in **Table 39**. The results show that the items genotype (G) and environment (E) were significant. The item G×E interaction was not significant.

Mean values of pod number per plant of all the genotypes (**Table 41),** Barimasur 6 (G 6) showed the highest value and Barimasur 2 (G 2) showed the lowest pod number per plant. In all the environments, environment 4 (E 4) plants showed the highest value and environment 1 (E 1) plants showed the lowest value of pod number per plant. The mean effect between genotypes and environments, G4×E4 was found to show the maximum value and G1×E1 was found to show the minimum pod number per plant.

7. Seed number per plant (SNPP)

The results of analysis of variance for seed number per plant are shown in **Table 39.** The results show that the items genotype (G) and environment (E) were significant. The item G×E interaction was not significant.

Mean values of seed number per plant in all the genotypes (**Table 41),** Barimasur 6 (G 6) showed the highest value and Barimasur 1 (G1) showed the lowest value of seed number per plant. Of all the environments, environment 4 (E 4) plants had the highest value and environment 1 (E 1) plants had the lowest value of seed number per plant. The mean effects between genotypes and environments, G4×E4 was found to show the maximum value and G1×E1 was found to show the minimum value of seed number per plant.

8. Thousand (1000) seed weight (g)

Mean squares from the analysis of variance for 1000 seed weight are shown in **Table 39**. The results show that the item genotype (G) was significant. But,the items environment (E) and G×E interaction were non significant.

Mean values of 1000 seed weight in all the genotypes **(Table 41),** Barimasur 3 (G 3) showed the maximum value and Barimasur 2 (G 2) showed the minimum value of 1000 seed weight. Of all the environments, environment 4 (E 4) plants had the highest value and environment 3 (E 3) plants had the lowest value of 1000 seed weight. The mean effect between genotypes and environments, G3×E2 was found to show the maximum value and G2×E4 was found to show the minimum value of 1000 seed weight.

9. Total dry matter (g)

The results of analysis of variance for total dry matter are shown in **Table 39.** The results indicated that the items environment (E) was significant. But, the items genotype (G) and G×E interaction were non significant.

Mean values of total dry matter in all the genotypes (**Table 41),** Barimasur 6 (G 6) showed the maximum value and Barimasur 1 (G 1) showed the minimum value of total dry matter. Of all the environments, environment 4 (E 4) plants had the highest value and environment 1 (E 1) plants had the lowest value of total dry matter. The mean effect between genotypes and environments, G5×E4 showed the highest value and G2×E1 showed the lowest value of total dry matter.

10. Grain yield (kg/hac)

Mean squares from the analysis of variance for grain yield per hectare are shown in **Table 39**. The results show that the items genotype (G) and environment (E) were significant. But, the item G×E interaction was not significant.

Mean values of grain yield per hectare in all the genotypes (**Table 41),** Barimasur 4 (G 4) showed the highest value and Barimasur 1 (G 1) showed the lowest value of grain yield per hectare. In all the environments, the highest grain yield per hectare was observed in environment 4 (E 4) plants and the lowest value of grain yield per hectare was found in environment 1 (E1) plants. The mean effects between genotypes and environments, G4×E4 was found to show the highest value and G1×E1 was found to show the lowest value of grain yield per hectare.

Table 38 : Mean squares (MS) from the analysis of variance for grain yield and its components of six lentil genotypes as influenced by soil moisture for experiment 2009 – 2010.

Sources of Variation	df.	PH (cm)	BNPP	PAPP (cm)	Days to 50% F	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/hac
Replication (R)	2	9.65	0.792	15012.7	0.681	0.181	72.681	3351.764	0.504	0.421	5021.056
Genotype (G)	5	69.804**	70.97**	56023.5**	29.022**	72.856**	3273.947	12353.86**	176.94**	2.304**	557189.2**
Error - 1	10	4.028	0.451	9309.5	0.997	0.347	1465.964	4308.431	0.148	0.583	581.189
Environment(E)	3	153.639**	15.69**	72125.5**	29.87**	10.259**	13505.79**	57704.17**	0.094	8.039**	43962.13**
G × E	15	16.422**	0.251	31092.9**	0.17	0.27	1338.281	5860.056	0.148	0.225	1652.19
Error - 2	36	4.156	0.925	7102.31	1.426	0.338	2177.991	6594.449	0.121	0.363	1843.22

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 39 : Mean squares (MS) from the analysis of variance for grain yield and its components of six lentil genotypes as influenced by soil moisture for experiment 2010 – 2011.

Sources of Variation	df.	PH (cm)	BNPP	PAPP (cm)	Days to 50% F	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/hac
Replication (R)	2	0.248	0.452	14802.5	0.542	0.292	151.125	6733.847	0.541	0.164	5460.292
Genotype (G)	5	63.282**	51.47**	53982.9**	23.667**	66.658**	1992.66**	12072.51**	176.64**	0.626	567069.8**
Error - 1	10	0.431	0.764	8962.2	2.108	0.325	798.208	3390.281	0.152	0.771	1045.092
Environment (E)	3	215.202**	14.04**	76245.9**	30.704**	10.273**	9788.755**	46660.46**	0.086	10.246**	40390.94**
G × E	15	8.843**	0.752	30988.7**	1.348	0.429	849.155	7415.736	0.137	0.182	1035.595
Error - 2	36	1.178	0.884	7085.48	1.644	0.375	1893.713	5993.301	0.124	0.43	2456.069

* = significant at 5% level, and ** = significant at 1% level, respectively.

Table 40: Mean values of yield and its components of six lentil genotypes at final harvest as influenced by soil moisture for experiment 2009 – 2010.

Genotype (G)	PH (cm)	BNPP	PAPP (cm)	Days to 50% F	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/ha^{-1}
Barimasur 1 (G1)	44.14	77.50	486.87	65.25	107.00	261.67	491.25	15.56	33.83	1885.17
Barimasur 2 (G2)	39.97	76.92	515.12	65.01	107.00	264.33	502.33	12.64	33.74	1980.50
Barimasur 3 (G3)	39.08	74.58	498.25	65.00	107.08	275.83	525.17	23.59	33.76	1986.00
Barimasur 4 (G4)	39.98	78.42	658.26	67.75	111.75	278.33	537.92	20.25	34.16	2069.83
Barimasur 5 (G5)	38.68	84.00	622.32	68.17	111.83	295.17	554.58	19.19	34.69	2176.42
Barimasur 6 (G6)	38.07	84.67	636.89	64.67	107.00	303.08	576.92	19.66	34.64	2265.83
LSD 5%	1.83	3.78	60.96	0.91	0.54	34.83	59.71	0.35	0.69	21.93
Environment (E)										
Environment 1 (E1)	35.42	64.61	401.98	67.06	107.78	245.17	456.94	18.48	33.37	1983.77
Environment 2(E2)	39.48	73.33	598.68	65.00	108.17	274.17	522.94	18.53	33.89	2085.00
Environment 3 (E3)	40.04	81.83	656.64	67.11	109.28	289.33	555.78	18.38	34.37	2091.17
Environment 4 (E4)	42.46	97.61	621.54	64.72	109.22	310.28	589.78	18.54	34.93	2182.56
LSD 5%	1.38	6.87	560.86	0.81	0.39	31.55	54.90	0.24	0.41	29.02
(G×E)										
G1×E1	38.43	67.00	389.83	66.67	106.33	178.67	314.00	15.62	33.22	1722.33
G1×E2	46.07	67.67	415.87	64.00	106.67	253.67	482.33	15.64	33.53	1812.67
G1×E3	43.07	82.67	564.91	66.33	107.67	304.33	578.67	15.46	34.10	1803.00
G1×E4	49.00	92.67	971.72	64.00	107.33	310.00	590.00	15.51	34.47	1804.33
G2× E1	34.33	58.00	366.58	66.00	106.33	222.67	423.33	12.69	32.54	1810.00
G2×E2	40.93	77.00	540.57	64.00	106.33	260.67	495.67	12.67	33.85	1880.67
G2×E3	39.57	76.67	556.71	66.00	107.67	265.33	504.00	12.63	34.02	1877.00
G2×E4	41.03	96.00	598.42	64.00	107.67	308.67	586.33	12.57	34.56	1874.33
G3× E1	34.83	64.00	379.72	66.00	106.67	258.33	492.33	23.55	33.18	1904.67
G3×E2	34.34	68.35	477.62	64.00	106.67	265.00	504.00	23.67	33.40	1994.33
G3×E3	39.77	74.67	539.28	66.00	107.67	275.00	524.67	23.48	33.95	2000.00
G3×E4	46.60	91.33	595.73	64.00	107.33	305.00	579.67	23.65	34.50	2005.00
G4× E1	34.67	56.33	448.63	68.67	110.33	251.67	478.67	19.91	33.63	2233.00
G4×E2	39.67	70.00	696.52	67.00	111.67	263.33	502.67	20.08	33.39	2298.33
G4×E3	40.20	87.33	744.15	69.00	112.33	283.00	571.00	20.58	34.54	2302.00
G4×E4	39.80	100.00	741.67	66.33	112.67	315.33	599.33	20.43	35.09	2326.00
G5×E1	35.13	69.67	406.12	69.00	110.67	266.00	475.33	19.18	33.58	2058.00
G5×E2	39.80	82.67	725.08	67.33	111.33	311.67	597.00	19.22	34.80	2216.33
G5×E3	38.63	80.33	749.23	69.33	112.67	295.00	560.67	19.00	34.94	2249.00
G5×E4	38.73	103.33	608.95	67.00	112.67	308.00	585.33	19.36	35.45	2182.33
G6× E1	35.13	72.67	418.01	66.00	106.33	293.67	558.00	19.94	34.04	2176.33
G6×E2	36.10	74.33	736.41	63.67	106.33	290.67	556.00	19.90	34.36	2307.67
G6×E3	39.03	89.33	788.13	66.00	107.67	313.33	595.67	19.12	34.66	2316.00
G6×E4	39.60	102.33	604.71	63.00	107.67	314.67	598.00	19.67	35.51	2303.33
LSD 5%	3.38	2.67	590.23	1.98	0.96	77.28	134.47	0.58	1.00	71.09

Table 41: Mean values of yield and its components of six lentil genotypes at final harvest as influenced by soil moisture for experiment 2010 – 2011.

Genotype (G)	PH (cm)	BNPP	PAPP (cm)	Days 50% F	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/hac
Barimasur 1 (G1)	44.47	78.17	497.87	64.83	107.08	272.92	494.08	15.55	33.89	1795.33
Barimasur 2 (G2)	39.81	77.50	525.12	65.58	107.00	266.83	508.25	12.64	33.67	1960.33
Barimasur 3 (G3)	40.96	75.25	506.33	65.25	107.00	278.42	511.67	23.57	34.06	1975.92
Barimasur 4 (G4)	40.53	80.67	668.71	68.17	111.50	274.25	539.75	20.26	34.04	2088.42
Barimasur 5 (G5)	38.53	83.25	629.32	67.92	111.67	293.42	553.50	19.20	34.11	2182.67
Barimasur 6 (G6)	38.59	84.75	656.89	66.25	107.00	299.92	577.83	19.64	34.36	2276.08
LSD 5%	0.60	5.26	61.02	1.32	0.52	25.70	52.96	0.35	0.80	29.41
Environment (E)										
Environment 1 (E1)	35.60	65.89	408.98	67.56	107.83	252.39	464.94	18.49	32.96	1990.61
Environment 2(E2)	41.18	74.06	508.62	65.50	107.94	277.61	528.61	18.52	34.10	2083.83
Environment 3 (E3)	40.66	82.78	667.64	67.33	109.17	284.78	541.39	18.38	34.29	2090.00
Environment 4 (E4)	43.89	97.00	629.54	64.94	109.22	309.06	588.44	18.53	34.73	2181.39
LSD 5%	0.73	2.46	606.45	0.87	0.41	29.42	52.34	0.24	0.44	33.50
(G×E)										
G1×E1	38.67	67.66	396.07	66.33	106.33	214.33	319.33	15.62	32.64	1722.33
G1×E2	46.30	67.67	421.53	63.00	106.67	260.33	488.67	15.61	33.86	1813.33
G1×E3	43.57	84.00	582.68	66.00	107.67	307.67	575.67	15.48	34.46	1801.33
G1×E4	49.33	93.33	581.72	64.00	107.67	309.33	592.67	15.50	34.62	1804.33
G2× E1	34.57	58.33	372.15	67.33	106.67	231.33	435.00	12.71	32.63	1812.67
G2×E2	41.10	77.67	551.29	65.00	106.33	265.33	507.00	12.66	33.77	1880.00
G2×E3	40.20	80.00	567.42	66.33	107.67	267.33	497.33	12.64	33.81	1875.67
G2×E4	41.37	94.00	600.27	63.67	107.33	303.33	593.67	12.56	34.48	1873.00
G3× E1	35.07	64.33	386.11	66.33	106.34	262.00	503.33	23.55	33.31	1908.00
G3×E2	41.03	71.33	486.18	64.67	106.67	268.67	520.67	23.66	33.85	1992.67
G3×E3	40.83	75.00	547.47	65.67	107.33	275.00	453.00	23.45	34.67	1999.33
G3×E4	46.90	90.33	599.86	64.33	107.67	308.00	569.67	23.63	34.41	2003.67
G4× E1	34.97	65.00	458.93	69.67	110.67	257.00	483.33	19.96	32.96	2231.00
G4×E2	39.80	70.33	708.71	68.00	110.33	269.33	501.00	20.09	34.16	2298.00
G4×E3	40.67	88.00	753.12	68.67	112.33	256.33	579.00	20.55	34.15	2301.00
G4×E4	46.70	99.33	761.71	66.33	112.67	314.33	595.67	20.43	34.91	2323.67
G5×E1	35.23	69.33	409.92	69.00	110.33	263.67	483.67	19.20	32.80	2092.00
G5×E2	39.43	80.66	733.37	67.33	111.00	309.33	588.33	19.21	34.35	2211.33
G5×E3	39.20	80.67	753.12	68.67	112.67	293.00	557.67	19.02	34.29	2246.67
G5×E4	39.07	102.33	617.36	66.67	112.67	307.67	584.33	19.37	35.00	2180.67
G6× E1	35.10	70.67	427.42	66.67	106.67	286.00	565.00	19.93	33.44	2177.67
G6×E2	39.40	76.67	765.82	65.00	106.67	292.67	566.00	19.88	34.64	2307.67
G6×E3	39.50	89.00	795.65	68.67	107.33	309.33	585.67	19.11	34.37	2316.00
G6×E4	39.97	102.67	616.86	64.67	107.33	311.67	594.67	19.65	34.99	2303.00
LSD 5%	1.80	4.092	539.67	2.12	1.01	72.06	128.20	0.58	1.09	82.071

4.11. Correlation Coefficients between Grain Yield and Yield Components

The results of simple correlation coefficients between grain yield and its components of six lentil genotypes in both the experimental seasons are shown in **Tables 42** to **47.**

4.11.1. Correlation coefficient between grain yield and its components in the environment 1 (E 1) plants.

Plant height showed **(Table 42)** significant correlation with branch number per plant, plant area per plant and yield per hectare in both the experimental years and negatively significant correlation with 1000 seed weight and total dry matter in the first year and negative significant correlation with days to 50% flower in the second season. Branch number per plant was significantly correlated with plant area per plant, days to maturity, seed number per plant, total dry matter and yield per hectare in both the years. Plant area per plant had positively significant correlation with days to 50% flower, days to maturity and yield per hectare over two growing seasons.

Days to 50% flower was found to be significantly correlated with days to maturity and yield per hectare in both the years. Days to maturity had significant correlation with yield per hectare in both the experimental seasons. Pod number per plant had significant correlation with seed number per plant over two growing seasons.

Seed number per plant was significantly correlated with 1000 seed weight, total dry matter and yield per hectare in both the years. Thousand seed weight was significantly correlated with total dry matter and yield per hectare in both the seasons. Total dry matter showed non significant correlation with yield per hectare in both the years.

4.11.2. Correlation coefficient between grain yield and its components in the environment 2 (E 2) plants.

Plant height showed **(Table 43)** significant correlation with branch number per plant, plant area per plant and yield per hectare in both the years and negatively significant correlation with days to 50% flower in both the seasons and negative significant correlation with days to maturity in the second year. Branch number per plant was significantly correlated with plant area per plant, days to 50% flower, days to maturity, seed number per plant, total dry matter and yield per hectare in both the years. Plant

area per plant had positively significant correlation with days to 50% flower, days to maturity and yield per hectare in both the experimental seasons.

Days to 50% flower was found to be significantly correlated with days to maturity and yield per hectare in both the years. Days to maturity had significant correlation with yield per hectare in both the experimental seasons. Pod number per plant had significant correlation with seed number per plant over two growing seasons.

Seed number per plant was significantly correlated with 1000 seed weight, total dry matter and yield per hectare in both the years. Thousand seed weight had significant correlation with total dry matter and yield per hectare and total dry matter showed non significant correlation with yield per hectare in both the years.

Table 42: Simple correlation coefficient between grain yield and yield components of six lentil genotypes as influenced by environment 1 (E1) (Upper diagonal shows values in 2010-2011 and lower diagonal shows values in 2009-2010 experiment).

Characters	PH (cm)	BNPP	PAPP (cm)	Days to 50% F	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/hac
PH (cm)	-	0.219**	0.507**	-0.458*	-0.257	-0.148	-0.131	-0.249	-0.231	0.505**
BNPP	0.325**	-	0.622**	-0.172	0.401**	0.507	0.616*	-0.265	0.301*	0.601**
PAPP	0.355**	0.520**	-	0.371**	0.517**	0.626	0.887	0.281	0.339	0.612**
D 50% F.	-0.237	-0.151	0.106**	-	0.106**	0.135	0.184	0.055	-0.143	0.558*
DM	-0.201	0.337**	0.492**	0.325**	-	0.463	0.570	0.187	-0.199	0.650*
PNPP	-0.193	0.445	0.784	0.351	0.369	-	0.873**	0.384	0.376	0.616
SNPP	-0.184	0.581*	0.803	0.573	0.608	0.627**	-	0.453*	0.499*	0.656*
1000 SW	-0.427*	-0.119	0.487	0.106	0.211	0.408	0.509*	-	0.474*	0.507*
TDM(g)	-0.502*	0.103*	0.505	-0.194	-0.117	0.421	0.526*	0.101*	-	0.187
Yield kg/h	0.422**	722**	0.801**	0.533*	0.707*	0.755	0.803*	0.256*	0.305	-

Table 43: Simple correlation coefficient between grain yield and yield components of six lentil genotypes as influenced by environment 2 (E 2) (Upper diagonal shows values in 2010-2011 and lower diagonal shows values in 2009-2010 experiment).

Characters	PH (cm)	BNPP	PAPP (cm)	Days to 50% F	DM	PNPP	SNPP	1000 S.W. g	TDM (g)	Yield kg/hac
PH (cm)	-	0.198**	0.227**	-0.596**	-0.407*	-0.170	-0.104	-0.389	-0.342	0.736**
BNPP	0.312**	-	0.554**	0.257*	0.285**	0.297	0.641*	-0.322	0.266*	0.589**
PAPP(cm)	0.364**	0.773**	-	0.471**	0.496**	0.527	0.784	0.307	0.358	0.885**
D 50% F.	-0.415**	0.207*	0.519**	-	0.720**	0.141	0.515	0.251	0.173	0.577*
DM	-0.189	0.263**	0.672**	0.401**	-	0.276	0.639	0.250	0.241	0.574*
PNPP	-0.135	0.701	0.907	0.432	0.509	-	0.879**	0.133	0.329	0.663
SNPP	-0.132	0.725**	0.895	0.454	0.527	0.784**	-	0.162*	0.346*	0.763*
1000 S.W	-0.311	-0.385	0.433	0.325	0.355	0.407	0.421*	-	0.213*	0.533*
TDM (g)	-0.307	0.432**	0.490	0.387	0.409	0.451	0.475*	0.358*	-	0.536
Yield kg/h	0.488**	0.661**	0.901**	0.492*	0.517*	0.726	0.835*	0.452*	0.466	-

4.11.3. Correlation coefficient between grain yield and its components in the environment 3 (E 3) plants.

Plant height showed **(Table 44)** positively significant correlation with plant area per plant, seed number per plant and yield per hectare and negatively significant correlation with days 50% flower in both the seasons and with pod number per plant in the first year and negatively significant correlation with days to maturity in the second year. Branch number per plant had significant correlation with plant area per plant, days to 50% flower, days to maturity, seed number per plant, 1000 seed weight and yield per hectare over two growing seasons. Plant area per plant had positively significant correlation with days to 50% flower, days to maturity and yield per hectare in both the experimental years.

Days to 50% flower was found to be significantly correlated with days to maturity and yield per hectare in both the years. Days to maturity had significant correlation with yield per hectare in both the experimental seasons. Pod number per plant was significantly correlated with seed number per plant in both the years.

Seed number per plant was significantly correlated with yield per hectare in both the years and negatively significant correlation with total dry matter in the second year. Thousand seed weight was significantly correlated with total dry matter and yield per hectare and total dry matter showed non significant correlation with yield per hectare in both the years.

4.11.4. Correlation coefficient between grain yield and its components in the environment 4 (E 4) plants.

Plant height showed **(Table 45)** significant correlation with branch number per plant, plant area per plant, pod number per plant, seed number per plant and yield per hectare in both the seasons. Branch number per plant was positively significant correlated with plant area per plant, days to 50% flower, days to maturity, seed number per plant, 1000 seed weight, total dry matter and yield per hectare in both the experimental years. Plant area per plant had positively significant correlation with days to 50% flower, days to maturity and yield per hectare in both the seasons.

Days to 50% flower was found to be significantly correlated with days to maturity and yield per hectare over two growing seasons. Days to maturity had significant correlation with yield per hectare in both the experimental years. Pod number per plant was significantly correlated with seed number per plant in both the years.

Seed number per plant was significantly correlated with total dry matter and yield per hectare in both the years. Thousand seed weight was significantly correlated with yield per hectare in both the experimental years and with total dry matter in the first year. Total dry matter showed non significant correlation with yield per hectare in both the years.

Table 44: Simple correlation coefficient between grain yield and yield components of six lentil genotypes as influenced by environment 3 (E 3) (Upper diagonal shows values in 2010-2011 and lower diagonal shows values in 2009-2010 experiment).

Characters	PH (cm)	BNPP	PAPP (cm)	Days to 50% F	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/hac
PH (cm)	-	0.108**	0.351**	-0.480*	-0.288**	0.068	0.136**	-0.178	0.069	0.577**
BNPP	0.077	-	0.322**	0.215*	0.271**	0.298	0.337*	0.125*	-0.194	0.601**
PAPP(cm)	0.206**	0.550**	-	0.474**	0.525**	0.582	0.645	0.274	0.312	0.636**
D 50% F.	-0.254*	0.357*	0.209**	-	0.599**	0.154	0.223	0.137	-0.081	0.584*
DM	-0.129	0.492**	0.232**	0.351**	-	0.138	0.286	0.223	-0.093	0.566*
PNPP	0.109*	0.517	0.554	0.492	0.504	-	0.621**	-0.084	-0.239	0.621
SNPP	0.177**	0.562*	0.602	0.534	0.557	0.564**	-	-0.116	-0.379*	0.695*
1000 SW	-0.169	0.249*	0.194	0.224	0.236	-0.129	-0.101	-	0.278*	0.529*
TDM (g)	0.172	-0.124	0.201	-0.234	-0.197	-0.114	-0.098	0.317*	-	0.555
Yield kg/h	0.412**	0.604**	0.672**	0.501*	0.552*	0.641	0.703*	0.324*	0.369	-

Table 45: Simple correlation coefficient between grain yield and yield components of six lentil genotypes as influenced by environment 4 (E 4) (Upper diagonal shows values in 2010-2011 and lower diagonal shows values in 2009-2010 experiment).

Characters	PH (cm)	BNPP	PAPP (cm)	Days to 50% F.	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/hac
PH (cm)	-	0.103**	0.227**	-0.210	-0.147	0.139*	0.160**	0.121	-0.080	0.396**
BNPP	0.196**	-	0.517**	0.431*	0.452**	0.464	0.525*	0.197*	0.301*	0.601**
PAPP(cm)	0.414**	0.673**	-	0.622**	0.599**	0.761	0.853	0.407	0.415	0.884**
D 50% F.	-0.207	0.117*	0.314**	-	0.733**	0.160	0.231	0.275	0.067	0.589*
DM	-0.111	0.223**	0.452**	0.425**	-	0.208	0.297	0.295	0.147	0.565*
PNPP	0.354*	0.609	0.626	0.532	0.588	-	0.786**	0.164	0.234	0.624
SNPP	0.397**	0.654*	0.796	0.568	0.597	0.757**	-	-0.217	0.321*	0.766*
1000 SW	0.102	0.104*	0.219	0.081	0.098	0.215	-0.212	-	0.023	0.562*
TDM (g)	-0.237	0.114*	0.301	0.096	0.109	0.245	0.254*	0.122*	-	0.313
Yield kg/h	0.559**	0.714**	0.907**	0.604*	0.659*	0.792	0.825*	0.474*	0.526	-

4.11.5. Association between grain yield and its components under all irrigated conditions.

Plant height was found to be **(Table 46)** positively significant correlation with plant area per plant and yield per hectare in both the years and negative significant correlation with days to 50% flower in both the seasons. Branch number per plant had significant correlation with plant area per plant, days to 50% flower, days to maturity, pod number per plant and 1000 seed weight in both the experimental years and with seed number per plant and yield per hectare in the first year. Plant area per plant had positively significant correlation with days to 50% flower, days to maturity and yield per hectare in both the years and with pod number per plant in the first year.

Days to 50% flower showed significant correlation with days to maturity and yield per hectare in both the seasons. Days to maturity had significant correlation with seed number per plant, 1000 seed weight and yield per hectare over two growing seasons. Pod number per plant was significantly correlated with seed number per plant in both the years.

Seed number per plant had positively significant correlation with yield per hectare in first the year. Thousand seed weight was significantly correlated with yield per hectare in both the experimental seasons. Total dry matter showed significant correlation with yield per hectare in the second year.

4.11.6. Association between grain yield and its components under all environments.

Plant height showed **(Table 47)** positively significant correlation with branch number per plant, plant area per plant, pod number per plant, seed number per plant and total dry matter and negatively significant correlation with days to 50% flower in both the experimental seasons. Branch number per plant had positively significant correlation with plant area per plant, days to maturity, pod number per plant, seed number per plant, total dry matter and yield per hectare over two growing seasons. Plant area per plant had positively significant correlation with days to maturity, pod number per plant, seed number per plant, total dry matter and yield per hectare in both the years.

Days to 50% flower was found to be positively significant correlation with days to maturity and yield per hectare in both the seasons and negatively significant correlation with total dry matter in the second year. Days to maturity had significant correlation with seed number per plant,1000 seed weight and yield per hectare in both the experimental seasons and with total dry matter in the first year. Pod number per plant had significant correlation with seed number per plant, total dry matter and yield per hectare in both the years.

Seed number per plant showed significant correlation with total dry matter and yield per hectare in both the years. Thousand seed weight was significantly correlated with yield per hectare in both the experimental years. Total dry matter showed significant correlation with yield per hectare over two experimental periods.

Table 46: Simple correlation coefficient between grain yield and yield components of six lentil genotypes under irrigated conditions (Upper diagonal shows values in 2010-2011 and lower diagonal shows values in 2009-2010 experiment).

Characters	PH (cm)	BNPP	PAPP (cm)	Days to 50 % F	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/hac
PH (cm)	-	-0.237	0.294*	-0.464**	-0.162	0.119	0.275	-0.078	0.061	0.464**
BNPP	-0.151	-	0.329**	0.354**	0.518**	0.232*	0.315	0.242*	0.180	0.470
PAPP(cm)	0.364*	0.401**	-	0.354**	0.411**	0.506	0.831	0.301	0.314	0.701**
D 50% F.	-0.395**	0.368**	0.449**	-	0.590**	0.073	0.122	0.204	-0.046	0.537**
DM	-0.143	0.501**	0.564**	0.305**	-	0.123	0.257*	0.246*	-0.046	0.550**
PNPP	0.108	0.322*	0.856*	0.398	0.517	-	0.825**	0.259	0.138	0.612
SNPP	0.175	0.355*	0.901	0.437	0.546**	0.754**	-	0.269	0.239	0.626
1000 SW	-0.106	0.192*	0.361	0.245	0.288*	0.315	0.354	-	0.156	0.541**
TDM(g)	0.182	0.211	0.407	-0.259	-0.101	0.327	0.396	0.201	-	0.471*
Yield kg/h	0.385**	0.570**	0.916**	0.422**	0.514**	0.774	0.802*	0.311*	0.409	-

Table 47: Simple correlation coefficient between grain yield and yield components of six lentil genotypes under all environments (Upper diagonal shows values in 2010-2011 and lower diagonal shows values in 2009-2010 experiment).

Characters	PH (cm)	BNPP	PAPP (cm)	Days to 50% F	DM	PNPP	SNPP	1000 S.W. g	TDM (g)	Yield kg/hac
PH (cm)	-	0.241*	0.315*	-0.545**	-0.001	0.286*	0.291*	-0.073	0.474**	0.388
BNPP	0.181*	-	0.491**	0.150	0.509**	0.411**	0.484**	0.192	0.216**	0.614**
PAPP(cm)	0.251*	0.555**	-	0.258	0.521**	0.558**	0.923**	0.315	0.412**	0.822**
D 50% F.	-0.259*	0.124	0.503	-	0.506**	-0.152	-0.089	0.143	-0.270*	0.431**
DM	-0.042	0.292**	0.612**	0.593**	-	0.338	0.389*	0.158*	0.176	0.559**
PNPP	0.205*	0.391**	0.809**	-0.076	0.234	-	0.865**	0.125	0.338**	0.730**
SNPP	0.215*	0.472**	0.933**	-0.128	0.252*	0.920**	-	0.127	0.389**	0.737**
1000 SW	-0.218	0.178	0.334	0.133	0.239*	0.161	0.182	-	0.158	0.522**
TDM(g)	0.208**	0.241**	0.425**	-0.028	0.378*	0.360**	0.364**	0.118	-	0.459*
Yield kg/h	0.435	0.626**	0.945**	0.493**	0.515**	0.771**	0.931**	0.336**	0.413*	-

4.12. Path Coefficient Analysis

The correlation coefficients between grain yield and other yield components were partitioned into direct and indirect effects through path coefficient analysis in order to find out more realistic figure of relationship. Direct and indirect effects of the component characters on grain yield are presented in **Tables 48** to **49** and **Figures 10** to **11**.

4.12.1. Path coefficient analysis in 2009-2010

The results of path coefficients analysis are shown in **Table 48**. This table shows that the highest positive direct effect was contributed by plant area per plant (0.961) on grain yield and it was followed by seed number per plant (0.957) and pod number per plant (0.721).

Thousand seed weight (0.015) and days to 50% flower (0.169) showed the lowest positive direct effect. Branch number per plant (-0.181) and days to maturity (-0.252) showed the negative direct effect on grain yield. Seed number per plant (0.941) and pod number per plant (0.930) showed the large positive indirect effects on grain yield through plant area per plant. On the other hand, days to maturity (-0.731) and days to 50% flower (-0.657) had the large negative indirect effects on grain yield through plant area per plant.

Plant height showed negative indirect effect through branch number per plant, days to maturity, pod number per plant and seed number per plant on grain yield. It had positive indirect effects through plant area per plant (0.177), days to 50% flower (0.076), 1000 seed weight (0.063) and total dry matter (0.261) on grain yield. The character plant area per plant showed negative indirect effect through days to 50% flower, days to maturity, 1000 seed weight and total dry matter. It had positive indirect effect through plant height (0.147), branch number per plant (0.462), pod number per plant (0.656) and seed number per plant (0.662) on grain yield.

Days to 50% flower showed negative indirect effect through branch number per plant, plant area per plant, days to maturity and total dry matter on grain yield. It had positive indirect effect through plant height (0.174), pod number per plant (0.014), seed number

per plant (0.016) and 1000 seed weight (0.147) on grain yield. The character days to maturity showed negative indirect effect through plant height, plant area per plant, days to 50% flower and total dry matter. It had positive indirect effect through branch number per plant (0.219), pod number per plant (0.063), seed number per plant (0.074) and 1000 seed weight (0.060) on grain yield.

Total dry matter showed the negative indirect effect through branch number per plant (-0.193), plant area per plant (-0.504), days to 50% flower (-0.0018), days to maturity (-0.0138), pod number per plant (-0.417) and seed number per plant (-0.571) on grain yield. It had positive indirect effects through plant height (0.131) and 1000 seed weight (0.174).

The considerable amount of residual effect (0.14064) indicated that some other characters which have not been included in this study have also effect on grain yield in this crop.

Table 48: Path coefficient analysis of direct and indirect effects of grain yield components on yield of six lentil genotypes in 2009-2010 experiment.

Characters	PH (cm)	BNPP	PAPP (cm)	Days to 50% F	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/hac
PH (cm)	**0.293**	-0.044	0.147	0.174	-0.051	-0.121	-0.097	0.003	0.131	0.435
BNPP	-0.055	**-0.181**	0.462	-0.252	0.219	0.251	0.274	0.101	-0.193	0.626
PAPP (cm)	0.177	0.394	**0.961**	-0.657	-0.731	0.930	0.941	-0.566	-0.504	0.945
D 50% F	0.076	-0.033	-0.272	**0.169**	-0.049	0.280	0.320	0.020	-0.018	0.493
DM	-0.012	0.294	-0.406	-0.097	**-0.252**	0.401	0.494	0.231	-0.138	0.515
PNPP	-0.572	0.113	0.656	0.014	0.063	**0.721**	0.571	-0.378	-0.417	0.771
SNPP	-0.585	0.126	0.662	0.016	0.074	0.677	**0.957**	-0.425	-0.571	0.931
1000 SW	0.063	0.252	-0.306	0.147	0.060	-0.061	-0.008	**0.015**	0.174	0.336
TDM (g)	0.261	-0.088	-0.108	-0.019	-0.095	-0.156	-0.115	0.102	**0.631**	0.413

Bold and diagonal figures indicate the direct effect, Residual effect (R) = 0.14064

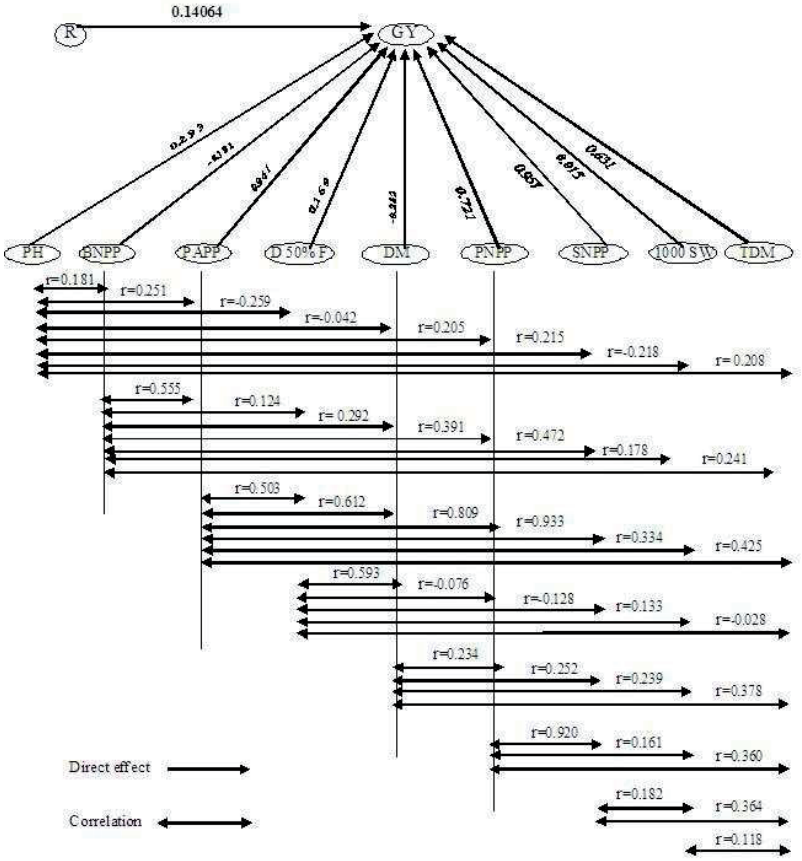


Figure 10: Path diagram of different grain yield contributing characters on yield (2009- 2010)

4.12.2. Path coefficient analysis in 2010-2011.

The results of path coefficient analysis in 2010-2011 are presented in **Table 49**. This table shows that the highest positive direct effect was contributed by plant area per plant (0.927) on grain yield and it was followed by seed number per plant (0.902) and pod number per plant (0.792).

Plant height (0.173) and days to maturity (0.224) showed the lowest positive direct effect. Days to 50% flower (-0.198) and 1000 seed weight (-0.676) showed the negative direct effect on grain yield. Seed number per plant (0.821) and pod number per plant (0.802) showed the large positive indirect effect on grain yield through plant area per plant. On the other hand, 1000 seed weight (-0.658) and total dry matter (-0.601) had the large negative indirect effect on grain yield through plant area per plant and pod number per plant.

Branch number per plant showed negative indirect effect through plant height, plant area per plant, pod number per plant, seed number per plant and 1000 seed weight on grain yield. It had positive indirect effect through days to 50% flower (0.157), days to maturity (0.363) and total dry matter (0.052) on grain yield. The character days to 50% flower showed negative indirect effect through plant area per plant, days to maturity, 1000 seed weight and total dry matter. It had positive indirect effect through plant height (0.169), branch number per plant (0.192), pod number per plant (0.029) and seed number per plant (0.035) on grain yield.

Days to maturity showed negative indirect effect through plant height, plant area per plant, days to 50% flower, pod number per plant and total dry matter on grain yield. It had positive indirect effect through branch number per plant (0.233), seed number per plant (0.202) and 1000 seed weight (0.377) on grain yield. The character 1000 seed weight showed negative indirect effects through branch number per plant, plant area per plant, days to 50% flower and seed number per plant. It had positive indirect effect through plant height (0.151), days to maturity (0.244), pod number per plant (0.085) and total dry matter (0.107) on grain yield.

Total dry matter showed the negative indirect effect through plant height (-0.182), days to 50% flower (-0.161), days to maturity (-0.105), pod number per plant (-0.601) and seed number per plant (-0.543) on grain yield. It had positive indirect effect through branch number per plant (0.376), plant area per plant (0.294) and 1000 seed weight (0.363) on grain yield.

The considerable amount of residual effect (0.21897) indicated that some other characters which have not been included in this study have also effect on grain yield in lentil crop.

It may be concluded from the results of the presents study that plant height, branch number per plant, plant area per plant, pod number per plant, seed number per plant, total dry matter, 1000 seed weight and grain yield per hectare are the major components of grain yield in lentil and hence maximum stress should be given on these characters while selection is done for maximum grain yield.

Table 49: Path coefficient analysis of direct and indirect effects of grain yield components on yield of six lentil genotypes in 2010-2011 experiment.

Characters	PH (cm)	BNPP	PAPP (cm)	Days 50% F	DM	PNPP	SNPP	1000 S.W.g	TDM (g)	Yield kg/hac
PH (cm)	**0.173**	-0.001	0.320	0.169	-0.004	-0.126	-0.112	0.151	-0.182	0.388
BNPP	-0.018	**0.283**	-0.084	0.192	0.233	-0.151	-0.101	-0.116	0.376	0.614
PAPP(cm)	0.116	-0.472	**0.927**	-0.484	-0.524	0.802	0.821	-0.658	0.294	0.822
D 50% F	0.040	0.157	-0.331	**-0.198**	-0.114	0.502	0.639	-0.103	-0.161	0.431
DM	-0.001	0.363	-0.271	-0.101	**0.224**	-0.149	0.355	0.244	-0.105	0.559
PNPP	-0.221	-0.488	0.794	0.029	-0.442	**0.792**	0.782	0.085	-0.601	0.730
SNPP	-0.272	-0.481	0.717	0.035	0.202	0.714	**0.902**	-0.537	-0.543	0.737
1000 SW	0.327	-0.101	-0.113	-0.064	0.377	0.421	-0.012	**-0.676**	0.363	0.522
TDM (g)	-0.035	0.052	0.248	-0.054	-0.040	-0.268	-0.146	0.107	**0.595**	0.459

Bold and diagonal figures indicate the direct effect, Residual effect (R) = 0.21897

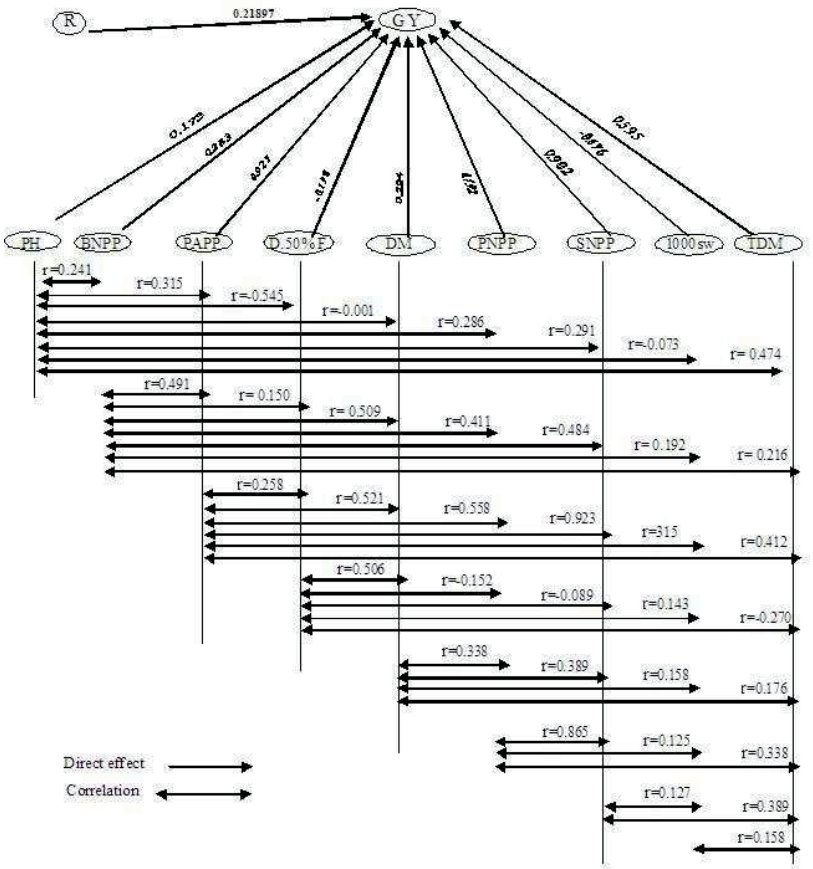


Figure 11. Path diagram of different grain yield contributing characters on yield (2010 -2011).

4.13. Genotype - Environment Interaction and Stability Parameters

The phenotypic stability of each genotype was expressed by two parameters : the slope of regression line and sum of squares of deviation from regression. A stable genotype was defined as "one with unit regression (b_i = 1.00) and low deviation from linearity ($\bar{S}^2_{di}$)". Analysis of variance showed that the mean sum of squares due to genotype (G) and environment (E) difference tested against the G×E interaction were significant for all the traits studied, indicating the presence of wide variability among the genotypes and environments. The significant estimates of G×E interaction indicated that the characters were unstable and showed considerable fluctuation with change in environments. The G×E (linear) interaction was significant against pooled deviation suggesting the possibility of variation for all the characters (**Table 50**).

The distribution of six bi values was found to be heterogeneous in most of the characters and hence all these genotypes had different response to different environments. Grand mean ($\bar{X}$), regression coefficients (b_i), standard error of bi (Sb_i) and stability ($\bar{S}^2_{di}$) values for different yield and its component characters are shown in **Table 51.**

In case of plant height three genotypes viz., Barimasur 1, Barimasur 3 and Barimasur 4 showed above average responses (b_i >1) at the maturity stage. The grand mean ranged from 38.38 to 44.31 and the maximum grand mean was shown by Barimasur 1 and Barimasur 6 showed the minimum value of grand mean. The regression coefficients ranged from 0.532 to 1.423. The highest grand mean was shown by Barimasur 1 and the maximum regression value was found in Barimasur 3. On the other hand, the lowest grand mean was shown by Barimasur 6 and the lowest regression value was observed in Barimasur 5. The stability ($\bar{S}^2_{di}$) values ranged from 0.010 to 0.154. The genotype, Barimasur 1 had higher mean performance (44.31), regression value nearly one (b_i = 1.362) and stability value nearly zero ($\bar{S}^2_{di}$ = 0.053). All the stability ($\bar{S}^2_{di}$) values were found to be highly significant in plant height at the maturity.

In case of branch number per plant three genotypes viz., Barimasur 2, Barimasur 4 and Barimasur 6 showed above average responses (b_i >1) at the maturity stage. The grand mean ranged from 74.92 to 84.71 and the maximum grand mean was shown by Barimasur 6 and Barimasur 3 showed the minimum value of grand mean. The regression coefficients ranged from 0.831 to 1.314. Barimasur 6 showed the highest grand mean and also the maximum value of regression. On the other hand, Barimasur 3 was found to show the lowest grand mean and also the lowest regression value. The stability ($\overline{S}^2_{di}$) values ranged from 0.015 to 0.057. All the stability valuaes were found to show highly significant values in branch number per plant at the maturity. The genotype, Barimasur 6 had higher mean performance (84.71), regression value nearly one (b_i = 1.314) and stability nearly zero ($\overline{S}^2_{di}$ = 0.015), indicating its stability for favorable environments.

For plant area per plant three genotypes viz., Barimasur 4, Barimasur 5 and Barimasur 6 showed above average responses (b_i >1) at the maturity stage. The grand mean ranged from 492.37 to 663.29 and the maximum grand mean was shown by Barimasur 4 and Barimasur 1 showed the minimum value of grand mean. The regression coefficients ranged from 0.693 to 1.150. Barimasur 4 showed the highest grand mean and also the maximum regression value. On the other hand, the lowest grand mean was shown by Barimasur 1 and the lowest regression value was observed in Barimasur 3. The stability ($\overline{S}^2_{di}$) values ranged from - 0.632 to 1.914. The genotype, Barimasur 4 had higher mean performance (663.29), regression value nearly one (b_i = 1.150) and stability value nearly zero ($\overline{S}^2_{di}$ = 0.223). All the regression coefficient (b_i) values were found to be highly significant in plant area per plant at the maturity.

In case of pod number per plant three genotypes viz., Barimasur 1, Barimasur 2 and Barimasur 6 showed above average responses (b_i >1) at the maturity stage. The grand mean ranged from 265.58 to 301.25 and the maximum grand mean was shown by Barimasur 6 and Barimasur 2 showed the minimum value of grand mean. The regression coefficients ranged from 0.652 to 1.969. Barimasur 6 showed the highest grand mean and Barimasur 1 showed the maximum value of regression. On the other hand, Barimasur 2 was found to show the lowest grand mean and Barimasur 5 was

observed to show the lowest regression value. The stability ($\overline{S}^2_{di}$) values ranged from 0.012 to 0.096. All the genotypes were found to show highly significant stability ($\overline{S}^2_{di}$) values in pod number per plant at the maturity. The genotype, Barimasur 6 had higher mean performance (301.25), regression value nearly one (b_i = 1.127) and stability value nearly zero ($\overline{S}^2_{di}$ = 0.012), showed wider stability sites across the environments.

In case of seed number per plant three genotypes viz., Barimasur 1, Barimasur 2 and Barimasur 6 showed above average responses (b_i >1) at the maturity stage. The grand mean ranged from 492.67 to 577.38 and the maximum grand mean was shown by Barimasur 6 and Barimasur 1 showed the minimum value of grand mean. The regression coefficients ranged from 0.480 to 2.270. All the regression values were found to be highly significant in seed number per plant at the maturity except Barimasur 3. The highest grand mean was shown by Barimasur 6 and the maximum regression value was found in Barimasur 1. On the other hand, the lowest grand mean was shown by Barimasur 1 and the lowest regression value was observed in Barimasur 3. The stability ($\overline{S}^2_{di}$) values ranged from 0.321 to 2.482. The genotype, Barimasur 6 had higher mean performance (577.38), regression value nearly one (b_i = 1.093) and stability value nearly zero ($\overline{S}^2_{di}$ = 0.321), indicating its stability for favorable environments.

In case of 1000 seed weight five genotypes viz., Barimasur 1, Barimasur 3, Barimasur 4, Barimasur 5 and Barimasur 6 showed above average response (b_i>1) at the maturity stage. The grand mean ranged from 12.64 to 23.58 and Barimasur 3 showed the highest value and Barimasur 2 showed the lowest value. The regression coefficients ranged from 0.833 to 1.766. The highest grand mean was shown by Barimasur 3 and the maximum regression value was found in Barimasur 6. On the other hand, the lowest grand mean and the lowest regression value was observed in Barimasur 2. The stability ($\overline{S}^2_{di}$) values ranged from -0.043 to 0.043. All the regression coefficient (b_i) values were found to show highly significant in 1000 seed weight at the maturity.

In case of grain yield per hectare two genotypes viz., Barimasur 5 and Barimasur 6 showed above average response (b_i>1) at the maturity stage. The grand mean ranged

from 1840.36 to 2275.96 and the highest value was found in Barimasur 6 and the lowest value was observed in Barimasur 1. The regression coefficients ranged from 0.554 to 1.321. The highest grand mean was shown by Barimasur 6 and the maximum regression value was found in Barimasur 5. On the other hand, the lowest grand mean was shown by Barimasur 1 and the lowest regression value was observed in Barimasur 2. The stability ($\overline{S}_{di}^2$) values ranged from 0.455 to 3.498. The genotype, Barimasur 6 had higher mean performance (2275.96), regression value nearly one (b_i = 1.035) and stability value nearly zero ($\overline{S}_{di}^2$ =0.455). This genotype (G 6) had been regarded stable and widely adapted.

Table 50. Pooled analysis of variance for grain yield and its components in lentil over four environments (Eberhart and Rusell's model, 1966).

Source of variation	df	Plant height		Branch number per plant		Plant area per plant	
		SS	MS	SS	MS	SS	MS
Genotype (G)	5	323.75	64.75**	298.11	59.62**	270623.01	54124.62**
Environment (E)	3	538.32	179.44**	40.62	13.54**	221526.91	73842.31**
G×E	15	169.21	11.28**	13.05	0.871	461320.52	30754.70**
Pooled Error	36		2.141		0.914		7056.82

Source of variation	df	Pod number per plant		Seed number per plant	
		SS	MS	SS	MS
Genotype (G)	5	12948.51	2589.72**	24697.94	4939.59**
Environment (E)	3	34504.82	11501.63**	68107.71	22702.73**
G×E	15	14976.01	998.45	29443.26	1962.88
Pooled Error	36		1982.13		3075.42

Source of variation	df	1000 seed weight		Grain yield kg/hac.	
		SS	MS	SS	MS
Genotype (G)	5	841.35	168.27**	2807425.12	561485.01**
Environment (E)	3	3.036	1.012**	125682.61	41894.24**
G×E	15	7.905	0.527**	19584.93	1305.66
Pooled Error	36		0.123		2057.4

Table 51: Estimates of stability parameters [Grand mean ($\bar{X}$), regression value (b_i) and stability ($\bar{S}^2_{di}$)] for plant height, branch number per plant, plant area per plant, pod number per plant, seed number per plant, 1000 seed weight and grain yield.

Characters	Stability parameters	Genotypes					
		G 1	G 2	G 3	G 4	G 5	G 6
Plant height	$\bar{X}$	44.31	39.89	40.02	40.26	38.61	38.38
	b_i	1.362**	0.921*	1.423**	1.094**	0.532*	0.614*
	Sb_i	0.262	0.154	0.147	0.261	0.153	0.142
	$\bar{S}^2_{di}$	0.053	0.043	0.154	0.010	0.036	0.018
Branch number per plant	$\bar{X}$	77.84	77.21	74.92	79.55	83.63	84.71
	b_i	0.882*	1.053**	0.831*	1.256**	0.973**	1.314**
	Sb_i	0.426	0.441	0.506	0.512	0.414	0.514
	$\bar{S}^2_{di}$	0.039	0.057	0.017	0.029	0.050	0.015
Plant area per plant	$\bar{X}$	492.37	520.12	502.29	663.29	625.82	646.89
	b_i	0.980*	0.819*	0.693*	1.150**	1.116**	1.137**
	Sb_i	0.371	0.394	0.231	0.382	0.401	0.425
	$\bar{S}^2_{di}$	1.121	-0.632	0.432	0.223	1.914	1.641
Pod number per plant	$\bar{X}$	267.30	265.58	277.13	276.29	294.30	301.25
	b_i	1.969**	1.259**	0.743*	0.949*	0.652*	1.127**
	Sb_i	0.372	0.401	0.423	0.379	0.427	0.452
	$\bar{S}^2_{di}$	0.096	0.083	0.020	0.038	0.050	0.012
Seed number per plant	$\bar{X}$	492.67	505.29	518.42	538.84	554.04	577.38
	b_i	2.270**	1.191**	0.480*	0.961*	0.804*	1.093**
	Sb_i	0.419	0.523	0.534	0.637	0.501	0.612
	$\bar{S}^2_{di}$	1.758	0.856	2.193	1.553	2.482	0.321
1000 seed weight	$\bar{X}$	15.56	12.64	23.58	20.26	19.20	19.65
	b_i	1.108**	0.833**	1.693**	1.123**	1.469**	1.766**
	Sb_i	0.099	0.131	0.201	0.146	0.192	0.138
	$\bar{S}^2_{di}$	-0.018	0.010	0.043	-0.017	0.032	-0.043
Grain yield kg/hac	$\bar{X}$	1840.36	1970.42	1986.96	2079.13	2179.55	2275.96
	b_i	0.745*	0.554*	0.823*	0.626*	1.321**	1.035**
	Sb_i	0.387	0.292	0.386	0.379	0.401	0.482
	$\bar{S}^2_{di}$	2.126	2.308	2.603	3.498	3.168	0.455

Chapter 5

DISCUSSION

The modern world means a great mysterious island of science and technology. Twenty first century is a period of life science specially of genetical science. From the beginning of life science many investigators worked for its advancement and many papers have already been published in various crops. Genetics and breeding is one of the major parts of life science. The improvement of any crops depended on quantitative and meaningful breeding programmes. For this reason, analysis is very necessary for fertile country like Bangladesh.

Crop yield is a production character depending upon a large number of environmental, morphological and physiological characters. Environment plays an important role in respect of growth and development as well as yield of lentil. Yield is a complex character and it is the final product of action and interaction of various physiological and morphological characters and it is highly influenced by the genetic as well as environmental fluctuations. The yield of lentil is very low in Bangladesh as compared to other lentil growing countries of the World. Lack of knowledge for proper environment and irrigation management are the main reasons for low yield of lentil in Bangladesh.

If it is maintained properly, better growth development of the crop occur which is ultimately reflected to the yield. Like any other crop, growth and yield of lentil is under control of many environmental factors. Soil moisture is one of these factors. In the present study, yield and yield components were significantly affected by different soil moisture levels.

The present investigation was carried out to study on the effect of twelve economically important characters viz., primary branch height (PBH), secondary branch height, plant height (PH), plant area per plant (PAPP), branch number per plant (BNPP), days to 50% flower (D 50% F), days to maturity (DM), pod number per plant (PNPP), seed number per plant (SNPP), 1000 seed weight, total dry matter(TDM) and yield per hectare/ kg on four soil moisture conditions.

In the analysis all the characters showed a wide and pronounced range of variation indicating that they are under polygenic control and hence quantitative in nature. The wide range of variation showed that these lentil (*Lens culinaris* Medic.) lines are good breeding materials. Similar results were obtained in lentil by Malhotra *et al.* (1973), Rasul (1988) and Azad (1991), in chickpea by Haque (1989), Begum (1995), Hasan (2001) and Deb (2002), in green gram by Bhargava *et al.* (1966), in mustard by Paul *et al.* (1976), Chowdhuri and Prashad (1968) and Joarder and Eunus (1968), in sugarcane by Nahar (1997) and in chilli by Husain (1997).

In the present study, primary branch height of lentil started from a lower valve, increased with the advancement of growth periods and then reached their highest position. Environment 4 plants showed the highest primary branch height and environment 1 plants were found to show the lowest value. Among the six genotypes, Barimansur 2 showed the highest value and Barimansur 4 showed the lowest value for primary branch height at all the growth stages. Primary branch height of lentil showed higher value in the irrigated conditions than the rainfed conditions. This result was supported by Rasul (1988), Islam *et al.* (2002) and Afzal *et al.* (2003) in lentil.

Secondary branch height is an important morphological character directly linked with the production potential of plant in terms of grain yield. In the present investigation, genotype and environment items were significant. But interaction item was not significant for secondary branch height in both the years. Barimasur 2 showed the highest value and Barimasur 4 showed the lowest value of secondary branch at all the growth stages. In both the years, the plants grown under irrigation conditions produced higher secondary branch height than these grown under non-irrigation conditions. This result was supported by Rasul (1988), Islam *et al.* (2002) and Afzal *et al.* (2003) in lentil.

Plant height is a common morphological character, which plays an important role of grain yield. Plant height was found to show the highest in environment 4 plants and it was followed by other environments. In all the six genotypes, Barimasur 1 showed the highest plant height at all the growth stages. Plant height showed higher value in the irrigated conditions and less in rainfed conditions. Similar result was found in lentil by Afzal *et al.* (2003), Azad (1991), Babar Ali (1988), Islam *et al.* (2002), Khatun (1997)

and Rasul (1988) and in wheat by Khan and Paul (1993), Jat *et al.* (1990), Mohiuddin (2010) and Sarker and Paul (1988).

Plant area per plant is the greatest important morphological character, which plays an important role on grain yield in lentil. In the present investigation, varietal, environmental and interaction items were highly significant for plant area per plant in both the years. Among the six genotypes, Barimasur 6 showed the highest value and Barimasur 1 showed the lowest value of plant area per plant over two growing seasons. Lentil plant showed higher plant area in the irrigated conditions than the conditions of non irrigated. The similar results were also obtained in chickpea by Singh *et al.* (1973), in black gram by Majid *et al.* (1982) and in lentil by Malhotra *et al.* (1973), Azad (1991), Babar Ali (1988), Islam *et al.* (2002) and Khatun (1997).

The present investigation shows that total dry matter increased slowly at the early vegetative stages but increased rapidly with the advancement of time. On average of two experimental years the highest values for total dry matter production was found in Barimasur 6 and it was followed by Barimasur 4 and Barimasur 5. But Barimasur 1 showed the lowest total dry matter in both the years. In all the genotypes, total dry matter production was significantly greater in the irrigated conditions over two growing seasons. Similar results were found in barley by Kirby (1969), Anisuzzaman (2003) and Mollah and Paul (2008), in groundnut by Srinivasan *et al.* (1987), in *sorghum* by Sivakumar *et al.* (1979) and Wright *et al.* (1983), in wheat by Singh *et al.* (1987), Sarker and Paul (1997), Nahar and Paul (1998), Rahman (2001) and Mohiuddin (2010), in lentil by Azad (1991), Babar Ali (1988), Islam *et al.* (2002) and Khatun (1997) and in mustard by Mondal *et al.* (1986), Haque *et al.* (1987), Begum and Paul (1993) and Mondal and Paul (1995).

In the present study, total dry matter started from a lower value at the early stages of growth and increased with the advancement of time. Similar result was found in lentil by Azad (1991), Babar Ali (1988), Islam *et al.* (2002) and Khatun (1997), in barley by Sonmez (2000) and Anisuzzaman (2003), in wheat by Talukder (1987) and Mohiuddin (2010), in chickpea by Haque (1989), Begum (1995), Hasan (2001) and Deb (2002), in green gram by Bhargava *et al.* (1966), in mustard by Paul *et al.* (1976), Chowdhuri and Prashad (1968) and Joarder and Eunus (1968) and in chilli by Husain (1997).

In both the years, leaf weight ratio showed increasing tendency within very short time and there after gradually declined with the age of plants. The declining pattern was downward drift through out the growth period. The decrease of LWR was caused by increased plant dry weight. Saha and Paul (1995) studied LWR in wheat and reported that the sharp decrease in LWR at the later stages might be due to sharp increase of TDM. This result was also supported in barley by Anisuzzaman (2003), in wheat by Sarker and Paul (1997), Nahar and Paul (1998), Haider and Paul (2003) and Mohiuddin (2010).

Crop growth rate is regarded as the most meaningful growth function, since it represents the net results of photosynthesis, respiration and canopy area. As noted by Williams *et al.* (1965), crop growth rate was also representive of the most common agronomic measurement such as yield of dry matter per unit land area. Crop growth rate increased gradually with high fluctuations with increasing the age of plants of all the genotypes in both the years. Significantly higher crop growth rate was found in plants grown under non irrigated conditions than those grown under irrigated conditions at almost all the stages of growth in the present investigation. Similar result was found in wheat by Mohiuddin (2010) and in barley by Anisuzzaman (2003) and Ghosh (2005)

In the present investigation, relative growth rate of all the genotypes increased with the age of plants, reached the highest value and then the values decreased and reached towards the zero direction. Similar results were reported for RGR in wheat by Sarker and Paul (1988) and Mohiuddin (2010) and in barley by Alam *et al.* (2006) and Anisuzzaman (2003).

Crop yield is a complex character depending upon a large number of morphological and physiological characters . In the present study, primary branch height, secondary branch height, plant height, plant area per plant, branch number per plant, total dry matter, relative growth rate, pod number per plant, seed number per plant, 1000 seed weight and yield per hectare were significantly higher for environment 4. But, leaf weight ratio and crop growth rate were found higher in the environment 1.

The plants under irrigated conditions produced significantly better performance in all these characters than those of the rainfed plants except leaf weight ratio and crop growth rate. Branch number per plant, pod number per plant, seed number per plant, total dry

matter and yield per hectare were more produced by Barimasur 6 in both the years and the lowest values were shown by Barimasur 1. Therefore, the grain yield depended on the branch number per plant, pod number per plant and seed number per plant.

In the present investigation, it was observed that grain yield of lentil was significantly higher in the irrigated conditions than the rainfed conditions. Similar results were reported in wheat by Robins and Domingo (1962), Sairam *et al.* (1990), Paul and Nahar (2000), Rahman *et al.* (2001) and Mohiuddin (2010) and in lentil by Azad (1991), Rasul (1988), Khatun (1997) and Afzal *et al.* (2003).

Correlation study of lentil on plant height, branch number per plant, plant area per plant, days to 50% flower and days to maturity were the most important yield components in the present investigation. These components were significantly correlated with all other yield components in both the years.

In the present study, the correlation coefficients showed that branch number per plant, plant area per plant, days to 50% flower, days to maturity and seed number per plant had positive correlation with grain yield. Significant and positive correlations were also obtained by several workers such as Ramanujam and Rai (1963), Chowdhuri (1967), Singh and Malhotra (1970), Gupta (1972), Rammana Rao *et al.* (1974), Joarder *et al.* (1978), Alam *et al.* (1978), Kumar *et al.*(1984), Husain (1997), Deb (2002), Haider (2006), Ghosh (2005), Anisuzzaman (2003) and Mohiuddin (2010) in different crops.

In the present investigation, plant height showed negative significant correlation with days to 50% flower, days to maturity, 1000 seed weight and total dry matter. Similar result of negative significant correlation was found in barley by Anisuzzaman (2003).

In the present investigation path coefficient analysis was done. The highest positive direct effect was contributed by plant area per plant and it was followed by pod number per plant and seed number per plant. The lowest positive direct effect was found in 1000 seed weight. The highest positive indirect effect was recorded for seed number per plant and it was followed by pod number per plant and plant area per plant. These results are in the close agreement with those of Ghafoor *at al.* (1990), Singh *et al.* (2008), Amiruzzaman *et al.*

(2003), Razzaque *et al.* (1984), Ali Hayder (2006), Ariyo (1974), Dayal *et al.* (1987), Johnson *et al.* (1955) and Dangi and Poroda (1974) in different crops.

In the present study, branch number per plant and days to maturity showed the negative direct effect on grain yield. Deb (2002) observed negative direct effect on yield in chickpea. The negative direct effect was found in potato by Ali Hayder (2006).

In the present investigation, correlation analysis suggest that during selection more emphasis should be given on branch number per plant, plant area per plant, days to 50% flower and days to maturity. Path coefficient analysis suggested that more emphasis should be given on plant area per plant, pod number per plant and seed number per plant, since these characters had high correlation and high direct effect on grain yield.

In the present investigation phenotypic regression coefficients (b_i) and stability parameters ($\overline{S}_{di}^2$) were calculated to evaluate highly stable genotype over a wide range of environments. Regression coefficients were found to be highly significant in most cases indicating that the genotypes were highly responsive with the environmental variations. Phenotypic expression of a particular genotype in a specific environment depends on three properties: a mean expression, a linear response to environment and residual deviations from regression. Of the two sensitivity measures the linear sensitivity coefficient is of particular interest since it provides a convenient measure of a genotype's sensitivity and allows prediction across environments to be readily made (Breese, 1969; Jinks and Perkins, 1970; Samuel *et al.* 1970). The importance of the genotype in determining mean expression has long been recognized. A number of studies (Anisuzzaman *et al.* 2007; Islam *et al.* 2003; Alam *et al.* 2002; Bucio Alanis and Hill, 1966; Jinks and Perkins, 1970; Paroda and Hayes, 1971; Westerman, 1971; Fripp, 1972) have shown that the determination of the sensitivity aspects of phenotype also involves genetical components.

According to Eberhart and Russell (1966) model, a stable genotype is characterized by a slope not different from unity ($b_i = 1$) and deviation from regression close to zero ($\overline{S}_{di}^2 = 0$). Analysis of variance showed that the mean sum of squares due to genotypes (G) and environments (E) difference tested against the G×E interactions were significant for all

the traits studied, indicating the presence of wide variability among the genotypes and environments. The significant estimates of G×E interaction indicated that the characters were unstable and may considerably fluctuate with change in environments. The G×E (linear) interaction was significant against pooled deviation suggesting the possibility of the variation for all the characters. These findings are in close agreement with those Afiash *et al*. (1999), Saker (2002) and Mohamadi *et al*. (2005).

The linear regression (b_i) is considered to be definite and measurable response to the environment. Genotypes that have relatively the same amount of performance over a wide range of environments would b_i values less then unity and would be least responsive to change in the environments. The standard error of regression coefficients is a measure of Ôstability of response' exhibited by each population. Since the linear regression represents very definite and measurable response to the environment, it is no longer profitable to consider this component of genotype-environment interaction as a measure of stability in the way proposed by Finlay and Wilkinson (1963). The term stability should now rather be reserved to describe measurements of unpredictable irregularities in the response to environment as provided by the deviations from regression. Lerner (1958) has proposed this deviation.

A stable variety should be one with high mean performance, one with unit regression slope (b_i =1.00) and the deviation from regression as small as possible. Thus for a particular character the genotype with higher mean performance and average regression coefficient together with a considerable low $\overline{S}_{di}^2$ value will be suitable for favorable environments. However, even if the genotypes though have high deviation around their regression lines yet they deserve inclusion in suitable environments. These varieties are very sensitive to environmental changes and hence as the environment improves their performance will increase at a rate well above the average of the group. Under the most favorable condition they will be able to express themselves as very high yielding varieties suggesting their exploitation in favorable environments. On the other hand, these genotypes with comparatively low b_i and $\overline{S}_{di}^2$ values together with moderate high mean yield are specially adapted to low yielding environments. These varieties are so insensitive that they are unable to exploit in high yielding environments. Lastly, the

genotypes that have low b_i and $\overline{S}^2_{di}$ values and also low mean performance indicate that they are consistently lower yielder in all environments.

The phenomenon of genotype-environment interaction in high yielding varieties of lentil under Bangladesh condition was studied by Azad (1991), Babar Ali (1988), Islam *et al.* (2002) and Khatun (1997) in lentil, Islam (1978), Islam *et al*. (1981, 1987) in wheat, Alam *et al*. (1999) in soybean, Sarker (2002) in rice, Anisuzzaman (2003) in barley and Islam *et al*.(2003) in chickpea. In the present investigation, the varieties of lentil showed different combination of performances in different characters and therefore, it is difficult to draw conclusion regarding their stability over a wide range of environments. However, Barimasur 6 with high mean, one with unit regression slope and low $\overline{S}^2_{di}$ values for branch number per plant, pod number per plant, seed number per plant and grain yield, indicating its stability to varying environments. Barimasur 5 and Barimasur 4 gave moderate and Barimasur 1 gave the lowest grain yield significantly in all the environments. Nanak Chand *et al.* (2008) reported similar results for 1000 grain weight, only one genotype RD 2634 had average mean associated with $b_i = 1$ and $\overline{S}^2_{di} = 0$, identified for wider adaptation and stability over all sites across environments. These results are in conformity with the findings of Yadav and Rao (1985), Hadjichristodoulon (1992), Shahmohamadi *et al*. (2005), Verma (2007), Ali Hayder (2006), Deb (2002), Islam (2002) and Mohiuddin (2010).

The overall results of the present investigation revealed that the irrigated plants showed better performance than the rainfed plants. The results farther indicated that the maximum grain yield was obtained in environment 4 plants and it was followed by environment 2 and environment 3 plants. Among the six lentil genotypes, yield and yield components were also found to be higher in Barimasur 6 in both the years. Less production in yield was found in Barimasur 1 although it had higher plant height due to its greater vegetative growth. In all the genotypes studied, Barimasur 6 was comparatively the highest susceptible genotype. The performances of the remaining five genotypes Barimasur 1 and Barimasur 2 were not satisfactory. Phenotypic regression analysis also showed that Barimasur 6 had unit regression slope with low stability value for branch number per plant, pod number per plant, seed number per plant and grain

yield kg/ hac, which indicating its stability to varying soil moisture conditions and this genotype (G 6) had been regarded as stable and widely adapted. So, Barimasur 6 gave satisfactory results in both the experimental years.

Therefore, to get higher yield, Barimasur 6 may be recommended with optimum soil moisture regimes in the northern region of Bangladesh.

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