EFFECT OF TEMPERATURE STRESS REGARDING TO SOWING DATE ON THE YIELD OF LENTIL (*Lens culinaris*)

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EFFECTS OF TEMPERATURE STRESS ON THE QUALITY AND YIELD OF LENTIL

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CERTIFICATE

This is to certify that the thesis entitled **"Effects of temperature stress on the quality and yield of lentil"** submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science** in**Department of Agroforestry and Environmental Science**, embodies the result of a piece of *bonafide* research work carried out by**JASMIN AKTER**, Registration No. **10-04110**under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2017

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Dedicated To

My Beloved Parents

EFFECT OF RAISING TEMPERATURE ON LENTIL(*Lens culinaris*)

ABSTRACT

The elevated global temperatures, particularly in tropical and subtropical regions, are markedly affecting the growth and yield of various winter and summer season crops. So the experiment was carried out at Bangladesh Agricultural Research Institute, Gazipurduring the period from November2016 to April 2017 to study the effects of temperature stress on the quality and yield of lentil. The treatment consisted of 10 lentil genotypes viz., G_1 (LRIL-22-68), G_2 (LRIL-22-70), G_3 (LRIL-22-133), G_4 (BLX-O6004-12), G_5 (BARI Masur-3), G_6 (BLX-04005-9), G_7 (LRIL-21-109), G_8 (BARI Masur-8), G_9 (BARI Masur-5) and G_{10} (LRIL-22-205), and three sowing date, *viz*., S_1 (15 November, 2016), S_2 (5 December, 2016) and S_3 (20 December, 2016). The experiment was laid out in a randomized complete block design (RCBD) with three replications.Among the different genotypes, the highest number of viable pollen content/plant (90.72), pods/plant (24.67), number of filled pods/plant (22.78), 1000 seed weight (31.00 g), yield/plant (1.72g) and yield/ha (441.67 kg) were recorded from G_2 (LRIL-22-70). Among the studied three planting date, the highest days to1stemergence (10.30),days to 50% flowering (68.44),number of viable pollen content/plant (79.89), number of pods/plant (21.92), number of filled pods/plant (19.25), 1000 seed weight (28.01 g), yield/plant (1.64 g) and yield/ha (381.50 kg) at harvest was recorded from planting date of S_1 (15 November, 2016). Considering interaction effect of variety and sowing date, the number of viable pollen content/plant (93.50), highest number of pods/plant (34.00), number of filled pods/plant (34.00), 1000 seed weight (34 g), yield/plant (2.73 g) and yield/ha (682.50 kg) were achieved from the treatment combination of G_2S_1. In terms of PAR (photosynthetic active radiation), G4S1 exhibited the highest PAR (610 micro mole/metre^2).

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ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
e.g.	=	exempli gratia (L), for example
et al.	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
Kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Miligram
ml	=	MiliLitre
NaOH	=	Sodium hydroxide
No.	=	Number
^oC	=	Degree Celceous
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
USA	=	United States of America
var.	=	Variety
WHO	=	World Health Organization
µg	=	Microgram

CHAPTER I

INTRODUCTION

Agriculture is highly vulnerable to climate change. Higher temperature eventually reduces yields ofdesirable winter crops while encouraging weed and pestproliferation. Changes in temperature and rainfalletc. patterns increasethe likelihood of short-run crop failures and long runproduction declines. Although there will be gain in somecrops in some regions of the world, the overall impactsof climate change on agriculture are expected to benegative, threatening global food security. In developingcountries climate change will cause yield declines forthe most important crops and results in price increases(Dubey *et al.*, 2011)

Global temperatures would probably increase significantly by the end of the twenty-first century due to anthropogenic activities that will increase gases particularly carbon dioxide, methane, chlorofluorocarbons, and nitrous oxides (Sanchez *et al*., 2014). This will have devastating influence on the growth and development of plants, further reducing their potential yield and quality of food products (Delahunty *et al*., 2015). Moreover, local increases in temperature are higher than the global level, and more damaging to crops grown in these regions (Kaushal *et al*., 2013; Kaur *et al*., 2015). The elevated temperatures, particularly in tropical and subtropical regions, are markedly affecting the growth and yield of various winter and summerseason crops. These crops need to be examined as to how heat stress affects their vegetative and reproductive growth stages involving various morpho-physiological approaches. Various studies on legumes such as chickpea; Kaushal *et al*., 2013; Kumar *et al*., 2013, mung bean (*Vigna radiata* L.; Tzudir, 2014) and cowpea (*Vigna unguiculata* L.; Ahmed *et al*., 1992) have reported adverse effects of heat stress. Similar studies on lentil are limited

(Delahunty *et al*., 2015; Bhandari *et al*., 2016; Kumar *et al*., 2016), where susceptibility of vegetative growth and reproductive function to heat stress has been depicted. Hence, further investigation is needed involving a large number of genotypes grown under similar heat stress environment to understand the mechanism of heat tolerance in this crop.

Cultivated Lentil (*Lens culinaris*), an annual crop has been grown as an important food source for over 8,000 years. Lentils are grown in the cooler temperate zones of the world or in the winter season in countries such as India and Australia which have a warm winter and hot summer. Lentil is sown as a cool-season crop, and is highly susceptibleto rising temperatures. It needs low temperatures at the time ofvegetative growth, while maturity requires warm temperatures;the best temperature for its optimum growth has been found to be 18°–30°C (Sinsawat *et al*., 2004; Roy *et al*., 2012). Lentil isalso grown in relatively warmer regions in central and southernparts of India, where the crop is exposed to supra-optimaltemperatures that reduce its yield potential (Verma *et al*., 2014).Moreover, it has been observed that the chilling periods arebecoming shorter and the heat periods are becoming longer, further resulting in exposure of cool-season crops to heat stress, particularly in the reproductive stage (Hasanuzzaman *et al*., 2013).Temperatures above 32/20°C (max/min) during flowering andpod filling in lentil can drastically reduce seed yield and quality (Delahunty *et al*., 2015). In 2009, across southeastern Australia, a heat wave (35°C for 6 days) reduced the yield in lentil crops by 70% (Delahunty *et al*., 2015).

In Bangladesh different practices information about different cultivars along with optimum planting time to be used in lentil cultivation is scanty. But still today there is few research works available focusing on the effects of temperature stress regarding planting time on the quality and yield of different lentil genotypes in Bangladesh.

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

1. To investigate the growth and other traits of ten lentil genotypes at high temperature under field condition and

2. To study the effect of planting time on yield of different genotypes of lentil.

CHAPTER II

REVIEW OF LITERATURE

Temperature stress on yield of different lentil genotypes were studied under field condition. In this chapter, an attempt has been made to review the available information in home and abroad regarding temperature effect or sowing time on yield of different lentil genotypes.

2.1. Effect of variety

Dutta *et al*. (1998) evaluated lentil mutants; ML-432/8, ML-18, ML-20 and ML-22 and L-5 (parent variety) for nitrate reduction and photo harvest capacity in relation to growth potential and seed yield. The results demonstrated that seed yield did not depend on leaf area/plant, leaf area ratio or specific leaf weight. Although seed yield of mutant ML-18 was less than that of mutants with lower values of ML-432/8, ML-22 and ML-20.

Tomar *et al*. (2000) conducted an experiment with lentil cultivars Pant L 209, Pant L 639, Pant L 406 and T36 were evaluated for yield, protein yield and nutrient uptake under 2 sowing methods (20-cm row spacing with 60 kg seed rate and 30 cm row spacing with 45 kg seed rate). Pant L 639 gave the best performance for seedling emergence, flower number, pod number, crop yield, nutrient uptake and protein yield.

Solanki (2001) conducted in a field experiment with seventy-two genotypes of lentil, collected from 11 locations in India, to stability analysis of seed yield and its components. Seven genotypes (LH91-9, LH 84-8, L 9-12, LH 94-5, PL 81-17, LH 92-63 and LH 92-65) showed high yields and were stable over a wide range of environments; L 4603, IPL 71, LH 94-12, LH 92-78 and L 4146 were responsive to superior environments, and IPL 76 and LH 90-110 to inferior environments.

The stability of genotypes for grain yield in the superior or inferior environment was impaired by the stability of different yield-contributing traits.

Hamdi *et al*. (2003) studied on genetic variability, heritability and genetic advance for earliness and seed yield characters in 24 lentil genotypes. The environments (season and location) showed major effects on the performance of genotypes. High phenotypic variation was observed for number of pods and seeds per plant. Considering wide variability, heritability and genetic advance, progress could be expected from selection for number of seeds per plant and seed yield per plant. The early-maturing genotypes Sina 1, FLIP 87-21L and FLIP 92-54L could be recommended for planting in case the earliness in maturity is more important than seed yield. On the other hand, high-yielding genotypes FLIP 89-71L, FLIP 95-68L, 89503, FLIP 92-48L and FLIP 95-50L could be recommended for planting in case high yield potential is more important than earliness in maturity.

Solaiman *et al*. (2003) studied on the response of mungbean cultivars BARI mung-2, BARI mung-3, BARI mung-4, BARI mung-5, BINA moog-2 and BU mung-1 to Rhizobium sp. strains TAL 169 and TAL 441. Irrespective of Rhizobium inoculam, they found significant difference in yield and yield contributing characters and dry matter production due to variety.

According to Sarker*et al*. (2004) lentil yields at the farm level are far below the genetic potential of its cultivars. Unavailability of the tested sitespecific lentil cultivars and imbalanced use of fertilizers could be the contributing factors towards these lower yields.

Turk *et al*. (2004) carried out an experiment with the aim to (I) investigate the response of 3 lentil cultivars, i.e. FLIP 86-16 L (large seeds), FLIP 89-31 L (small seeds) and FLIP 95-3L (small seeds), to osmotic stress during germination and seedling growth; (ii) identify characters that can be used for screening genotypes; and (iii) determine the effects of cultivars on yield and yield components of rainfed lentil in arid (150 mm rainfall) and semiarid (364 mm) regions in Jordan. Large-seeded cultivars exhibited higher percentage of germination and germination speed under moisture stress than did the small-seeded cultivars. Germination speed was more sensitive to change in osmotic potential than percent germination. Root and shoot weights of all cultivars were reduced when osmotic potential was decreased, but the extent of reduction in root growth was less than that for shoots. Lentil plants at the semi-arid location (Houfa) had greater seed yield, 1000-seed weight and plant height than those grown at the arid location (JUST). Lentil plants from large-seeded cultivars had greater seed yield, 1000-seed weight and plant height than those from small-seeded cultivars.

Shrestha *et al*. (2005) carried out an experiment with nineteen diverse lentil genotypes, 8 originating from South Asia, 6 from West Asia, and 5 crossbreds using parents from South Asia and West Asia (or other Mediterranean environments), were evaluated for growth, phenology, yield, and yield components. Additionally, dry matter production, partitioning, root growth and water use of 8 selected genotypes from the 3 groups were measured at key phenological stages. The seed yield of the West Asian genotypes was only 330 kg/ha, whereas the South Asian genotypes produced a mean seed yield of 1270 kg/ha. The crossbreds had a significantly greater seed yield (1550 kg/ha) than the South Asian genotypes. The high seed yield of both the South Asian and crossbred genotypes was associated with rapid ground cover, early flowering and maturity, a long reproductive period, a greater number of seeds and pods, high total dry matter, greater harvest index.

Ezzat *et al*. (2005) conducted experiments to evaluate 30 exotic and Egyptian lentil genotypes for earliness, yield, yield components, seed protein content, hydration coefficient before and after cooking, total soluble solids and seed cook ability characters. Correlation and factor analysis procedures were used to determine the contributing characters in yield variation. Field experiments were conducted at Giza Research Station, Egypt during 2001/02 and 2002/03. Genotypes FLIP 88-42L, PKVL-1, FLIP 96-52L, FLIP 97-30L, FLIP 97-33L and Sinai 1 were the earliest in flowering and maturity. FLIP 88-34L had the highest number of pods and seeds per plant, and produced the highest seed yield/fed recording 4.10 ardab, surpassing Giza 9 by 35%.

Tickoo *et al*. (2006) studied mungbean cultivars Pusa 105 and Pusa Vishal, which were sown at 22.5 and 30 cm spacing and supplied with 36-46 and 58-46 kg NP ha^{-1} in a field experiment. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 ton ha^{-1} and 1.63 ton ha^{-1}, respectively) compared to cv. Pusa 105 irrespective of NP fertilizers and spacing.

Gupta *et al*. (2006) conducted an experiment with forty lentil genotypes for genotype × environment interaction and phenotypic stability under 8 diverse environments. Eleven different growth and yield characters were evaluated: days to 50% flowering, days to maturity, primary branch number per plant, secondary branch number per plant, pod number per plant, 100-seed weight, plant height, seed number per plant, biological yield/plant, harvest index and seed yield/plant. High yielding and stable genotypes included JLS-1, PL 639, PL 81-64, E 153, L3685, Sehore 74-3, PL 81-49, PL-81-67, L4605, L263, PL 4 and P 22127.

Vinay *et al*. (2006) evaluated with small-seeded (twenty-five) and bold-seeded (eighteen) genotypes of lentil were evaluated to understand and compare the contribution of various characters to yield. Seed yield was positively associated with pod length, plant height and maturity in both the lentil types. Plant height showed more of direct contribution towards yield than indirect contribution. A significant shift in the association between yields with pods/plant, flowering and maturity was observed. In small-seeded lentil all the characters were important with an emphasis on delayed maturity and tall plant habit, while in bold-seeded lentil, pod length, delayed maturity and tall plant type were important with more emphasis on tall plant type.

An improved variety is the first and foremost requirement for initiation and accelerated production program of any crop. Variety plays an important role in producing high yield of lentil because different varieties responded differently for their genotypic characters; BARI has developed some varieties of lentil (Zahan *et al*., 2009).

Zahan *et al*. (2009) conductedan experiment to study the effects of variety and potassium levels on the growth, yield and yield contributing characters of lentil. The experiment comprised of three varieties *viz*. BARImasur-4, BARImasur-5 and BARImasur-6. The results revealed that among the three varieties, BARImasur-6 produced the highest seed yield (2.24 t ha^{-1}) and BARImasur-4 produced the lowest seed yield (1.79 t ha^{-1}).

Zike *et al*., (2017) conducted a field experiment during the 2016 main croppingseason to evaluate the performance of lentil varieties and their response to phosphorus application. Four Lentil varieties (Gudo, Alemtena, Teshale and EL-142) were used. Varieties weresignificantly varied in days to 50% flowering and 95% maturity, number of nodules, plant height and biological yields.

2.2 Effect of sowing time or temperature

Global temperature has increased by 0.3–0.6°C since the late 19^{th}century and by 0.2–0.3°C over last 40 years. In the last 140 years, the 1990s was the warmest period (Jones and Briffa, 1992). The pattern of spatial and temporal changes in climatic variables due to global warming need more debate and studies are being conducted globally (Feddema, 1999). As a consequence of climatic changes, a significant impact on hydrological parameters, *viz*. runoff, Evapotranspiration, soil moisture, ground water etc. is expected (Bultot*et al*., 1988).

Failure of only one critical enzyme system can cause death of a plant. This fact may explain why most crop species survive sustained high temperatures up to a relatively narrow range, 40 to 45°C. The relationship between the thermal environment for an organism and the thermal dependence of enzymes has been well established (Senioniti *et al*., 1986). Heat stress may be an oxidative stress (Lee *et al*., 1983). Peroxidation of membrane lipids has been observed at high temperatures (Mishra and Singhal, 1992), which is a symptom of cellular injury. Enhanced synthesis of an anti-oxidant by plant tissues may increase cell tolerance to heat (Upadhyaya *et al*., 1990, 1991).

Productivity of some crop species falls markedly at high temperatures. Acute effects of high temperature are most striking when heat stress occurs during anthesis. In rice, heat stress at anthesis prevents anther dehiscence and pollen shed, to reduce pollination and grain numbers (Mackill *et al*., 1982).

High maximum and minimum temperatures in September (about 34/20°C), adversely affect seedling establishment of some crops like cereals and pulses, accelerate early vegetative development, reduce canopy cover and yield. Hence, sowing is typically delayed until after mid-October when seedbeds have cooled, though much of the residual soil moisture may be lost. High temperatures in the second half of February (25/10°C), March (30/13°C) and April (30/20°C) reduce the numbers of viable florets and the grain-filling duration. High temperature stress particularly reduces yield in December/January which is necessitated in some regions because of the multiple cropping system (Rasul *et al*., 2015).

The arid areas of Pakistan where the evapotranspiration rate is already high and water table is shallow, an increase in air temperature may cause loss of water rapidly and consequently the aridity would increase. If the evapotranspiration rate continues to increase then the water reservoirs in the form of small dams, ponds and tobas etc. would dry more rapidly and water shortage may engrip humans along with plants. Due to global warming, variability of summer rainfall has considerably increased and glaciers have started melting at a much faster rate than observed before (Rasul, 2008).

Dhuppar *et al*., (2012) Climate change and agriculture are inter-related processes both of which takes place on global scale. The rate of warming has varied temporally and spatially. Temperature increases above 2.5ºC will generally have negative overall effects on world agriculture. Reproductive performance of Lentil is particularly affected because Lentil has poor tolerance for high temperatures, especially at flowering and pod set stage. Adaptive technologies include changing sowing dates, seasonality of crop production, efficient plant nutrient management etc.

Singh (2013) conducted an experiment to study the effect of different sowing dates and tillage systems on growth and yield of lentil (*Lens culinaris*Medik.). Sowing dates for lentil were 15th October, 30th October, 14th November and 30th November. Sowing on 30th October was found to increase growth parameters as seedling emergence (82.33%), dry matter production (6.89%, 17.72%, 33.81%), plant height (2.13%, 6.75%, 11.86%), branches/plant (6.20%, 25.46%, 64%) and yield(14.09%, 44.10%, 189.73%) on 15thOctober, 14thNovember and 30thNovember. Tillage also had significant influence on growth parameters and yield.

Moosavi *et al*. (2014) conducteda study to study the effects of sowing date and plant density onyield and yield components of lentil cv. Sistan. The factors included sowing date at four levels (November 21, December 5, December 19 and January 2) and plant density at four levels (18, 24, 36 and 71 plantsm^{-2}). The results of analysis of variance showed that sowing date significantly affected pod number per plant and per m^2, seed yield per unit area and per plant and harvest index, but its effect was not significant on seed number per pod, 100-seed weight and biologicalyield per unit area and per plant, while the change in plant density significantly affected all of them at 1% level. The interaction between sowing date and plant density did not significantly affect the measure traits. Means comparison showed that the delay in sowing from November 21 to January 2 decreased pod number per plant, pod number per m^2 and seed yield by 15.6, 14.7 and 10.3%, respectively.

Turk *et al*. (2003) reported that out of three sowing dates of December 30, January 14 and February 3, the highest yield (1786 kg ha^{-1}) was obtained at the earliest sowing date. Additionally, delayed sowing decreased seed yield per plant, 1000-seed weight and pod number per plant. Also, Varshnery (1992) mainly related the yield loss of lentil at delayed sowing to the decrease in pod number/plant, seed number/plant and 100-seed weight. The seed yield loss of lentil as affected by delayed sowing was reported by Mishra *et al*. (1996), too. Moreover, the decrease in biological yield of lentil at delayed sowing was confirmed by Turk *et al*. (2003) and Pezeshkpoor *et al*. (2005), too.

According to the report of Pezeshkpoor *et al*. (2005), delay in sowing of pea decreased its seed yield through shortening its growth period and the occurrence of drought and heat stress at the seed-filling stage. Also, delayed sowing of faba bean decreased yield and pod number per plant but did not significantly affect seed number per plant (Hashemabadi and Sedaghathoor, 2006). Also an increase in faba bean seed yield due to the production of more pods at earlier sowings was reported by Reference (Thalji and Shalaldeh, 2006), too.

2.3 Combined effect of variety and sowing dates

Roy *et al*. (2009) studied the response of promising lentil varieties *viz*. PL 639, B 77 (Asha), WBL 58 (Subrata) and WBL 77 (Moitree) to varying sowing dates *viz*. Oct. 20, Nov. 01, Nov. 10 and Nov. 20 during two consecutive rabi seasons of 2004-06. Among the varieties, Moitree (WBL 77) yielded the highest (1332.71 kg ha-1), exhibiting yield advantages to the tune of about 49-70% over the others and its superiority could be explained on the basis of higher podding potentiality (110.63 pods plant^{-1}). Irrespective of the varieties, sowing on November 01 and 10 were found to be advantageous and any advancement or delay in sowing caused yield reduction. As the higher yields were achieved with WBL 77 and B 77 in sowing on Nov. 01, and that too with WBL 58 and PL 639 in sowing on Nov. 10, the first week of November might be considered as the optimum time of sowing these varieties.

Sen *et al*. (2016) conducted a field experiment during rabi, 2012-13 to study the effect of three sowing dates (November 1, November 15 and November 30) on phenology, growth and yield of four varieties (HUL 57, Moitree, KLS 218 and Ranjan) of lentil. Delay in sowing of four lentil varieties from November 1 to 30 reduced the duration by 11.1 days (114.7 vs. 103.6 days). Mean cultivar days of lentil from sowing to emergence, flower initiation, pod initiation and maturity were 10.4, 54.2, 73.1 and 108.7 days, respectively. Lentil sown on November 15 produced the highest seed yield (908.6 kg ha-1), which was 2.72 and 16.09% higher over earlier (1 November) and later sowing (30 November) dates, respectively. Among four varieties, HUL 57 recorded the highest plant height (41.3 cm), number of nodules plant^{-1}, dry matter yield, number of pods plant^{-1} (105.7) and seed yield (887.8 kg ha^{-1}). Thus, a 15-day period (first fortnight of November) could be recommended as optimum sowing time for lentil, but sowing of HUL 57 during early November appeared as promising for better seed yield.

CHAPTER III

MATERIALS AND METHOD

The experiment was conducted at Bangladesh Agricultural Research Institute (BARI) during the period of November 2016 to April 2017. A brief description on the experimental site and season, soil, climate and weather, plant materials, experimental design and treatment combination, data collection, statistical analysis etc. are included here. The working procedures are given below:

3.1 Experimental site

The experiment was conducted in research field of Pulse Research Sub-Centre (PRC) and laboratory works were done in PRSS lab in Bangladesh Agricultural Research Institute (BARI), Gazipur. The experimental site is situated between $23^0 59^{\prime}$N latitude and $90^0 25^{\prime}$E longitude and at an elevation of 11 m from sea level. Experimental location is shown in Appendix I.

3.2 Soil

The experimental site belongs to Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soils. The soil was having a texture of sandy loam with p^H andCataion Exchange Capacity 5.5-5.6 and 2.64 meq 100g $soil^{-1}$, respectively. The morphological characteristics of the experimental site and physical and chemical properties of initial soil are given in Appendix III.

3.3 Climate

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period are collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix II.

3.4 Materials

The experiment consists of two factors:

Factor A:Three different sowing date

S_1 = 15 November, 2016

S_2 = 5 December, 2016

S_3 = 20 December, 2016

Factor B: Ten lentil genotypes are

G_1=LRIL-22-68,

G_2=LRIL-22-70,

G_3=LRIL-22-133,

G_4=BLX-O6004-12,

G_5=BARI Masur-3,

G_6=BLX-04005-9,

G_7=LRIL-21-109,

G_8=BARI Masur-8,

G_9=BARI Masur-5,

G_{10}=LRIL-22-205

3.5 Experimental design

Ten lentil genotypes are sown in field on three sowing dates with maintaining orientation of planting and distance of following the Randomized Complete Block Design (RCBD) with three replications. Each treatment combination of orientation and distance of planting was replicated 3 times.Three sowing date were used considering optimum sowing time and next two sowing time were used to expose the plant in high temperature at flowering stage. There were 90 unit plots altogether in the experiment. The size of the each unit plot was 2.0m × 2.0m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. Line to line and plant to plant distance was maintained as 40 cm and 10 cm respectively.

3.6Methods of Cultivation

3.6.1 Land preparation

The land was first opened with the tractor drawn disc plough at the 1st week of November 2016. Then the soil was ploughed and cross ploughed. Ploughed soil was then brought into desirable fine tilth by the operations of ploughing, harrowing followed by laddering. The stubble and weeds were removed from the land for easy germination of lentil seedlings. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before seed sowing and the basal dose of fertilizers was incorporated thoroughly with the soil.

3.6.2 Sowing of seeds

The seeds of lentil were hand sown in rows on 15 November 2016, 5 December 2016 and 20 December 2016. Seeds were placed at about 3-4 cm depth from the soil surface.

3.6.3 Fertilizer

Urea, triple super phosphate (TSP), Murate of potash (MP) and Gypsum were used as source of nitrogen phosphorus, potassium, sulphur and boron respectively. Total amount of Urea, TSP, MP and Gypsum were applied at basal doses during final land preparation. The doses of fertilizers were: Urea, TSP, MP and Gypsum 40, 80, 60 and 40 kg ha^{-1}respectively.

3.7 Intercultural operations

3.7.1 Thinning

Seeds were germinated four days after sowing (DAS). Thinning was done two times; first thinning was done at 20 DAS and second was done at 30 days after sowing maintaining 10 cm distance between plants and 40 cm distance between lines to obtain 100 plant population in each plot.

3.7.2 Irrigation and weeding

Irrigation was done at 20 and 30 DAS. The crop field was weeded twice; first weeding was done at 15 DAS and second at 30 DAS.

3.7.3 Protection against pest

At flowering stage few plants were affected by Aphid. Malathion 57EC was sprayed @ 25 L ha^{-1} at afternoon by using a sprayer.

3.8Harvesting and processing

At harvest firstly 10 random selected plants of a plot were uprooted and bundled and tagged carefully for recording necessary morphological and yield attributing parameters. This process was followed for all the plots individually. The harvested plants of each treatment brought to the cleaned threshing floor and separated pods from plants by hand threshing and allowed them for drying well under bright sunlight. Finally grain weight was taken an individual plot basis maintaining moisture content 12%.

3.9Sampling procedure

To study the growth characteristics a total five harvest were made and at final harvest data were collected on some morpho-physiological yield attributes and yield. The 1^{st} crop sampling was done at 50 DAS and continued at an interval of

15 and 10 days up to 95 DAS. From each plot five plants are uprooted for obtaining data of necessary parameters.

3.10Data collection

The following data were recorded:

3.10.1 Morpho-Physiological characters:

i) Days to emergence

ii) Number of branches

iii) Days to 50% flowering

iv) PAR (Photosynthetic Active Radiation

v) Percentage of Viable and Non-viable pollen content

3.10.2Yield and yield attributing character:

i) Dry weight/plant (g)

ii) Number of pods/plant

iii) Number of filled pods/plant

iv) Number of unfilled pods/plant

v) 1000 seed weight (g)

vi) Yield/plant (g)

vii) Yield/ha (kg)

3.11 Procedure of data collection

3.11.1 Days to emergence

Days to emergence were counted randomly selected plants from each plot and the mea number expressed on per plant basis.

3.11.2 Number of branches/plant

The branches were counted from selected plants at harvest. The total branches of 10 plants were averaged to have number of branches/plant.

3.11.3 Days to 50% flowering:

Days to 50% flowering were counted after maximum flowering of randomly selected plots.

3.11.4 Dry matter content/plant

Ten sample plants from each plot were uprooted at harvest. The uprooted plants were gently washed with tap water, thereafter soaked with paper towel. Then fresh weight was taken immediately after soaking. After taking fresh weight, the sample plants including root, stem, stem and pods were oven dried at 70°C for 72 hours. Then oven-dried samples were transferred into a desiccator and allowed to cool down to room temperature, thereafter dry weight was taken. The average weight of 10 plants was termed as dry matter/plant.

3.11.5 Pods per plant

Number of total pods of ten randomly selected plants from each plot were counted and the mean number expressed on per plant basis.

3.11.6 Number of filled pods/plant

Total pods collected from ten randomly selected plants from each plot and then filled pods were separated. The average filled pods was found as number of filled pods/plant.

3.11.7 Number of unfilled pods/plant

Total pods collected from ten randomly selected plants from each plot and then unfilled pods were separated. The average unfilled pods was found as number of unfilled pods/plant.

3.11.8Weight of 1000-seeds

One thousand cleaned dried seeds were counted randomly from the total seeds collected from the ten randomly selected plants and were weighed by a digital electronic balance. The weight was expressed in gram (g).

3.11.9 Seed yield/plant

The seeds collected from ten randomly selected plants from each plot and then weighed. The average weight of seeds was taken as seed yield/plant and was expressed in gram.

3.11.10PAR measurement:

Photosynthetic Active Radiation(PAR) was measured by SunfleckCeptometre(LP-80). It was express as µ mole /meter^2.

3.11.11Viable pollen determination

“About 200 pollen grains were tested for pollen viability with 0.5% acetocarmine/Alexander stain” (Kaushal*et al*., 2013). The pollen grains were collected from flowers, which opened on the same day. The pollen grains collected from flowers were pooled and tested for their viability (Alexander, 1969). To select viable pollen grains, section wasmade on the basis of size and shape (triangular or spherical) of the pollen, and the concentration of the stain taken up by the pollen (Kaushal*et al*., 2013).

3.11.12Pollen Tube Growth

"The pollen germination on the stigma and pollen tube growth through the style and in ovary was examined using Fluorescence microscope. The flowers were collected 1–3 days after anthesis and fixed in acetic alcohol (1:3) for 24 h and then transferred to 8N NaOH for 6 h at 60°C for clearing purposes. The complete gynoecium part was transferred to aniline blue (0.1%), which was kept overnight, followed by mounting on a slide in a 1:1 (aniline blue: 10% glycerin) solution" (Kaushal*et al.*, 2013). The stained gynoecium was observed under a fluorescence photomicrograph microscope (Nikon, Japan) (Dumas and Knox, 1983).

3.12 Statistical analyses

The data on different parameters as well as yield/plant of lentil were statistically analyzed to find out the significant differences among the effects of different genotypes, sowing dates and their interactions on these parameters. The mean values of all the characters were calculated and analyses of variance were performed by the 'F' (variance ratio) test by using MSTAT-C software. The significance of the differences was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the effect of cultivar and sowing date on the growth and yield of lentil. Data on yield contributing characters and yield were recorded to find out the suitable cultivar and optimum planting time. The analyses of variance (ANOVA) of the data on different yield contributing characters, yields are presented in Appendices IV-VIII. The results have been presented and discussed, and possible interpretations given under the following headings:

4.1 Growth characters

4.1.1 Days to 1st emergence

4.1.1.1 Effect of genotypes

Days to 1st emergence of lentil showed statistically significant variation due to different cultivars (Table 1 and Appendix IV). The highest days to 1stemergence(11.77) was recorded from G_1 (LRIL-22-68) which was statistically identical with G_4 (BLX-O6004-12) followed by G_3 (LRIL-22-133) and G_6 (BLX-04005-9) whereas the lowest days to 1st emergence (6.33) was found from G_2 (LRIL-22-70) which was statistically identical with G_9 (BARI Masur-5) and G_5 (BARI Masur-3). The result obtained from the present study was related to the findings of Tomar*et al*. (2000).

4.1.1.2 Effect of sowing date

Different sowing date of lentil had significant influence on days to1st emergence (Table 2 and Appendix IV). Results revealed that the highest days to1st emergence (10.30) was recorded from planting date of S_3 (20 December, 2016) followed by S_2 (5 December, 2016) where the lowest days to1st emergence (8.26) was recorded from planting date, S_1 (15 November, 2016). Singh (2013) also found similar resultwhich supports the present study.

4.1.1.3 Interaction effect of genotype and sowing date

Interaction of variety and sowing date had non-significant influence on days to 1st emergence (Table 3 and Appendix IV). But in was observed that the treatment combination of G_1S_3exhibited the highest days to1st emergence (12.33) where the lowest days to1st emergence (6.33) was found from the treatment combination of G_2S_2.Sen*et al*. (2016) also found similar result on days to 1st emergence under the varietiesand sowing date combination.

Table 1. Effect of different genotypes on first emergence for lentil genotypes

Treatments	Days to1st emergence
G_1	11.77 a
G_2	6.33 f
G_3	10.66b
G_4	11.33 a
G_5	8.22 de
G_6	10.33 b
G_7	8.33 d
G_8	8.66 d
G_9	7.66 e
G_{10}	9.66 c
CV	7.39
Significance	**

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

Table 2. Effect of different sowing dates on first emergence for lentil genotypes

Treatments	Days to1st emergence
S_1	8.26 c
S_2	9.33 b
S_3	10.30 a
CV	7.39
Significance	**

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

Table 3. Combined effect of different genotypes and sowing dates on first emergence for lentil genotype

Treatments	Days to1st emergence
G_1S_1	11.33
G_1S_2	11.66
G_1S_3	12.33
G_2S_1	5.33
G_2S_2	6.33
G_2S_3	7.33
G_3S_1	9.00
G_3S_2	11.00
G_3S_3	12.00
G_4S_1	10.33
G_4S_2	11.33
G_4S_3	12.33
G_5S_1	7.33
G_5S_2	8.33
G_5S_3	9.00
G_6S_1	9.33
G_6S_2	10.33
G_6S_3	11.33
G_7S_1	7.33
G_7S_2	8.33
G_7S_3	9.33
G_8S_1	7.66
G_8S_2	8.66
G_8S_3	9.66
G_9S_1	7.00
G_9S_2	7.33
G_9S_3	8.66
$G_{10}S_1$	8.00
$G_{10}S_2$	10.00
$G_{10}S_3$	11.00
CV	7.39
Significance	NS

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.1.2 Number of branch/plant

4.1.2.1Effect of genotypes

Number of branch/plant of lentil showed statistically significant variation due to different cultivars at harvest (Fig.1 and Appendix IV).The highest number of branch/plant (8.33) was recorded from G_9 (BARI Masur-5) followed by G_2 (LRIL-22-70) and G_8 (BARI Masur-8) whereas the lowest number of branch/plant (4.55) at harvest was found from G_5 (BARI Masur-3) which was statistically identical with G_4 (BLX-O6004-12) and G_{10} (LRIL-22-205). Gupta *et al*. (2006) also observed similar results and found that different genotypes had significant influence on number of branch/plant of lentil which supported the present study.

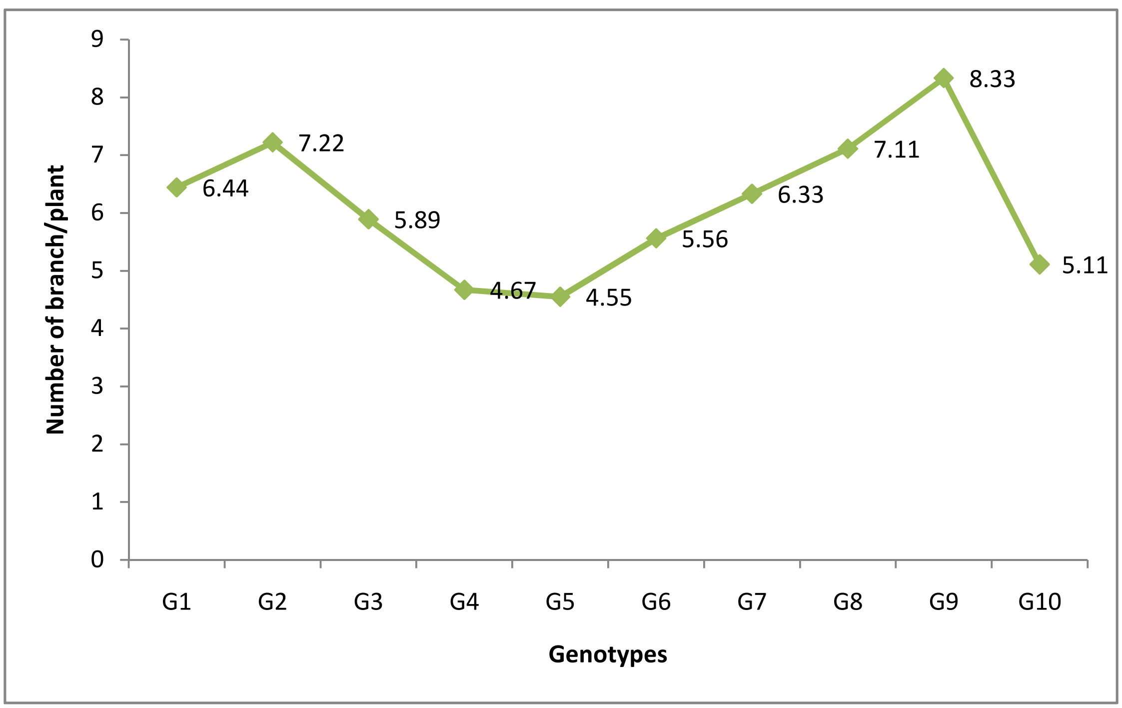

Fig. 1. Effect of different genotypes on number of branch/plantof lentil

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

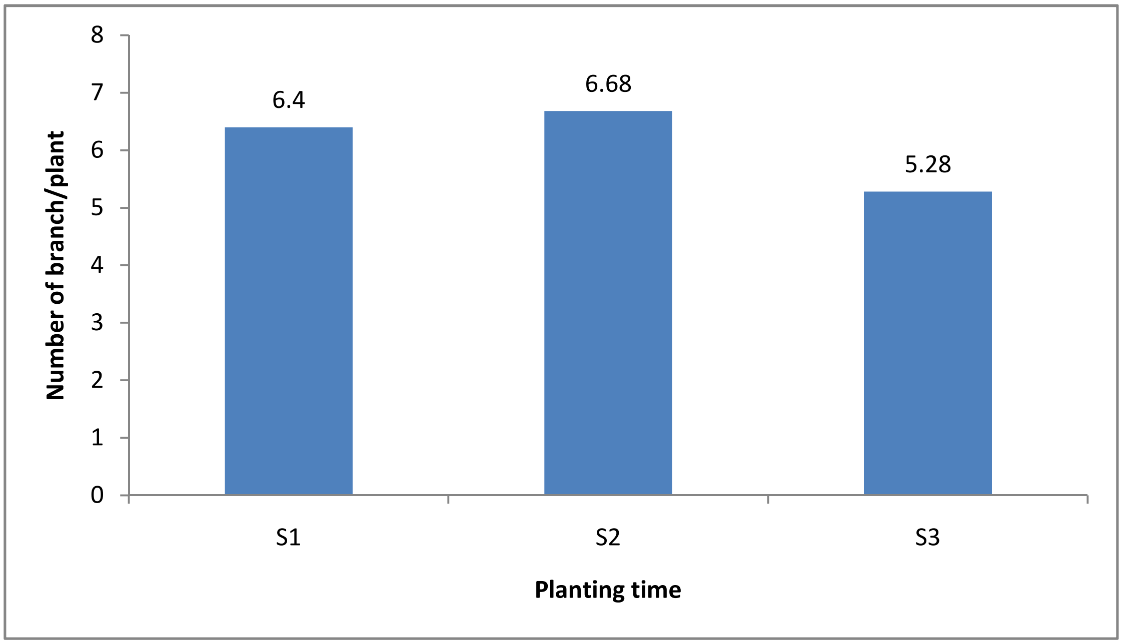

Fig. 2. Effect of different planting time on number of branch/plantof lentil

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.1.2.2 Effect of sowing date

Different sowing date of lentil had significant influence on number of branch/plant (Fig. 2 and Appendix IV). Results revealed that the highest number of branch/plant (6.68) at harvest was recorded from planting date of S_2 (5 December, 2016) which was statistically identical with planting date, S_1 (15 November, 2016) where the lowest number of branch/plant (5.28) at harvest was recorded from planting date, S_3 (20 December, 2016). Similar result was also observed by Singh (2013) and observed that different sowing date influenced number of branch/plant significantly.

4.1.2.3 Interaction effect of genotype and sowing date

Interaction of variety and sowing date had a significant influence on number of branch/plant (Table 4 and Appendix IV). Results exposed that the treatment combination of G_9S_2 exhibited the highest number of branch/plant (13.3) followed by G_1S_3. The lowest number of branch/plant (3.00) was found from the treatment combination of G_4S_1 which was statistically similar with G_5S_1 followed by $G_{10}S_1$ and G_1S_3.

4.1.3Dry weight/plant

4.1.3.1 Effect of genotypes

Dry weight/plant of lentil affected by different genotypes showed statistically significant variation at harvest (Fig. 3 and Appendix IV). It was found that the highest dry weight/plant (107.33 g) was recorded from G_3 (LRIL-22-133) followed by G_2 (LRIL-22-70) and G_8 (BARI Masur-8) where the lowest dry weight/plant (97.33 g) at harvest was found from G_4 (BLX-O6004-12) followed by G_1(LRIL-22-68) and statistically similar with G_{10} (LRIL-22-205). The result on dry weight/plant under the present study was similar with the findings of Solaiman*et al*. (2003) and Shrestha*et al*. (2005).

4.1.3.2 Effect of sowing date

Significant influence was observed for dry weight/plant at harvest affected by different sowing date of lentil (Fig. 4 and Appendix IV). Results revealed that the highest dry weight/plant (111.0 g) at harvest was recorded from planting date of S_3 (20 December, 2016)where the lowest dry weight/plant (95.00 g) at harvest was recorded from planting date, S_1 (15 November, 2016) followed by the planting date ofS_2 (5 December, 2016). Different sowing dated influenced dry weight/plant significantly was also observed by Singh (2013) and Sen*et al*. (2016) which similar with the present investigation.

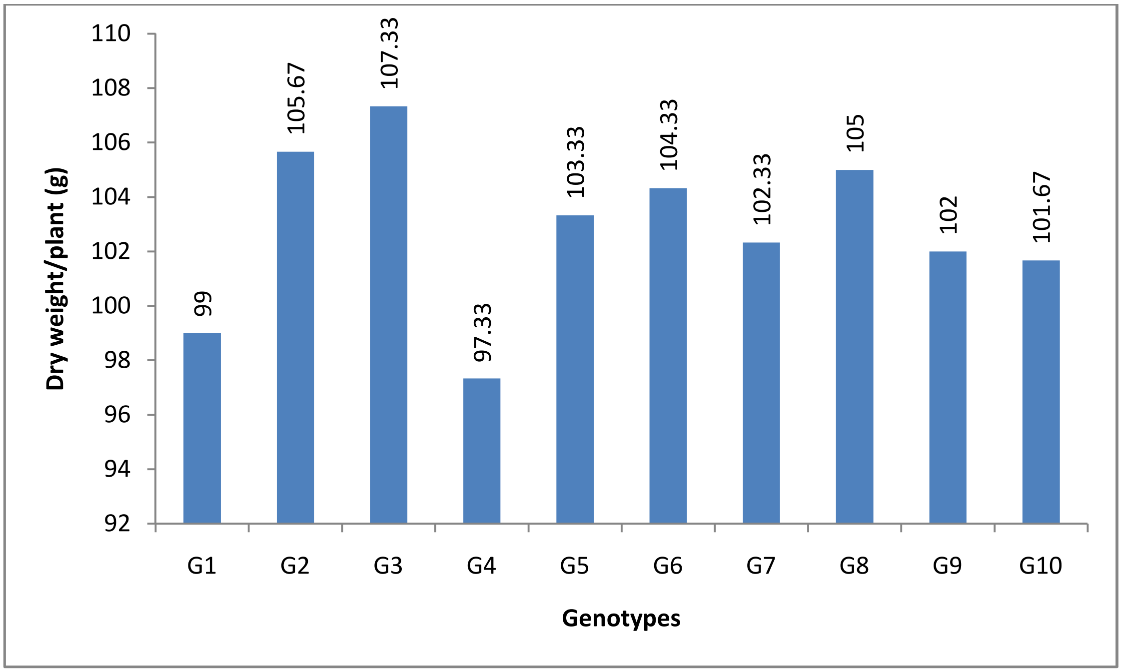

Fig. 3. Effect of different genotypes on dry weight/plant of lentil

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

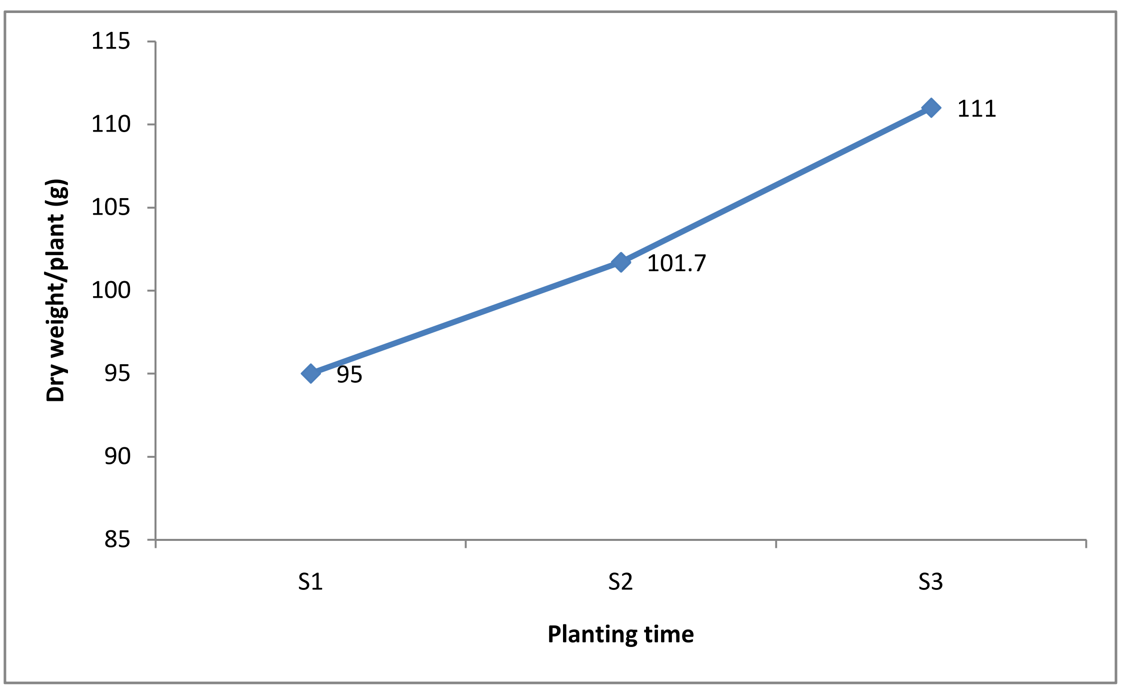

Fig. 4. Effect of different planting time on dry weight/plant of lentil

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.1.3.3 Interaction effect of genotype and sowing date

Dry weight/plant of lentil at harvest was significantly varied due to interaction of variety and sowing date (Table 4 and Appendix IV). Results demonstrated that the treatment combination of G_3S_3exhibited the highest dry weight/plant (115.0 g) which was statistically identical G_6S_3 with and $G_{10}S_3$ followed by G_2S_3 G_5S_3 and G_8S_3 . The lowest dry weight/plant (91.90 g) was found from the treatment combination of G_4S_1 which was statistically identical with the treatment combination of G_4S_2, G_5S_1, G_6S_1, G_7S_1 and $G_{10}S_1$.

4.1.4 PAR (photosynthetic active radiation) measurement

4.1.4.1 Effect of genotypes

PAR (photosynthetic active radiation) of lentil affected by different genotypes showed statistically significant variation (Fig. 5 and Appendix IV). It was found that the highest PAR (479.33) was recorded from G_1 (LRIL-22-68) which was statistically different from all other genotypes where the lowest PAR (276.00) was found from G_3 (LRIL-22-133)which was also statisticallydifferent from all other test genotypes.

4.1.4.2 Effect of sowing date

Significant influence was observed for PAR (photosynthetic active radiation) affected by different sowing date of lentil (Fig. 6 and Appendix IV). Results revealed that the highest PAR (373.60) was recorded from planting date of S_1 (15 November, 2016) which was statistically different from the rest. The lowest PAR(342.50) was recorded from planting date, S_3 (20 December, 2016) followed by the planting date of S_2 (5 December, 2016).

4.1.4.3 Interaction effect of genotype and sowing date

PAR (photosynthetic active radiation) of lentil was significantly varied due to interaction of genotypes and sowing dates (Table 4 and Appendix IV). Results showed that the treatment combination of G_4S_1exhibited the highest PAR (610) which was statistically identical G_1S_2 and G_1S_3. The lowest PAR (170) was found from the treatment combination of G_9S_1which was statistically identical with the treatment combination of $G_5S_3$and $G_{10}S_2$.

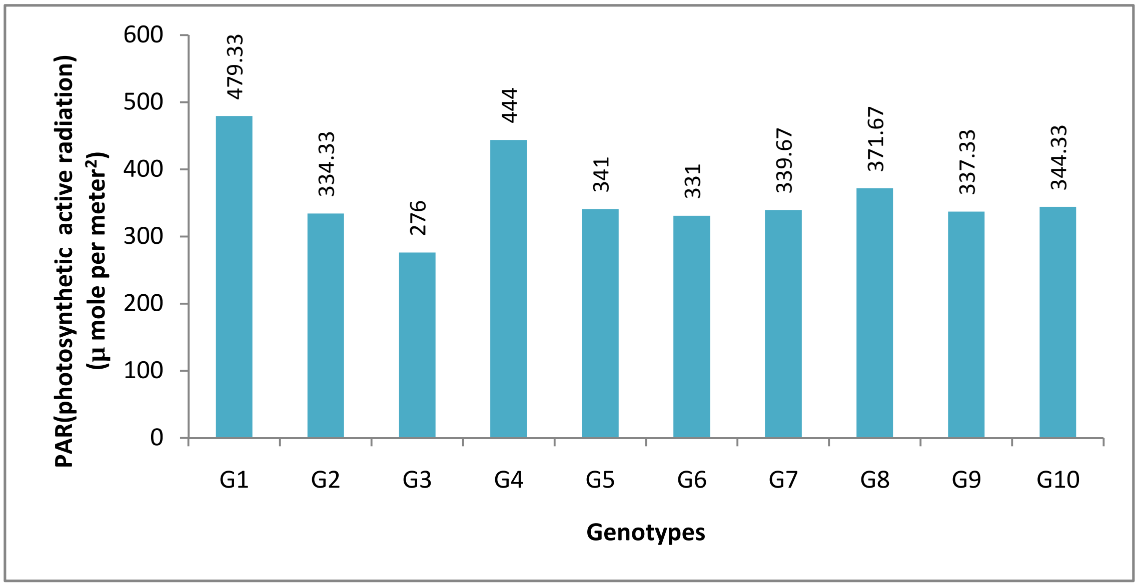

Fig. 5. Effect of different genotypes on PAR (photosynthetic active radiation)

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

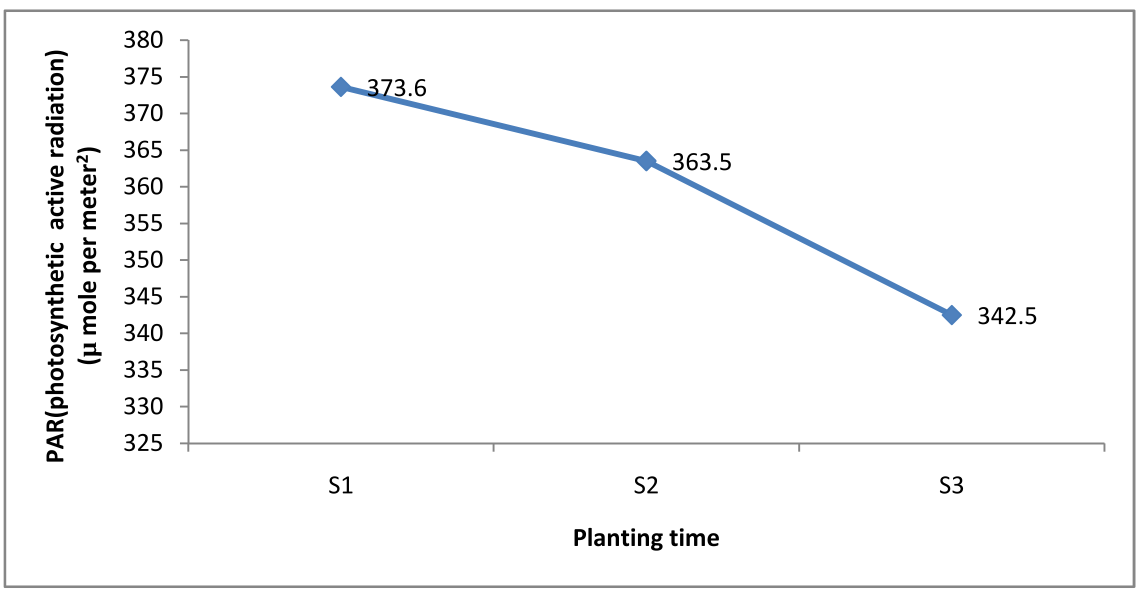

Fig. 6. Effect of different planting time on PAR (photosynthetic active radiation)

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

Table 4. Combined effect of different genotypes and sowing date on growth parameters of lentil

Treatment combinations	Growth parameters		
	Number of branch/plant	Dry weight/plant (g)	PAR(photosynthetic active radiation)(μ mole per meter^2)
G_1S_1	7.33 e	96.00 j	244 l
G_1S_2	7.67 de	95.00 j	600 a
G_1S_3	4.33 kl	106.0 e	594 a
G_2S_1	11.7 b	100.0 h	456 d
G_2S_2	4.67 jk	105.0 ef	220 m
G_2S_3	5.33 hi	112.0 b	327 i
G_3S_1	5.67 gh	102.0 g	332 i
G_3S_2	7.50 de	105.0 f	248 l
G_3S_3	4.50 j-l	115.0 a	248 l
G_4S_1	3.00 o	91.90 k	610 a
G_4S_2	5.33 hi	92.00 k	350 h
G_4S_3	5.67 gh	108.0 d	372 g
G_5S_1	3.33 no	93.00 k	418 f
G_5S_2	5.00 ij	105.0 ef	425 f
G_5S_3	5.33 hi	112.0 b	180 n
G_6S_1	6.00 g	93.00 k	441 e
G_6S_2	4.00 lm	105.0 ef	220 m
G_6S_3	6.67 f	114.9 a	332 i
G_7S_1	8.00 d	92.00 k	312 j
G_7S_2	6.00 g	105.0 ef	335 i
G_7S_3	5.00 ij	110.0 c	372 g
G_8S_1	8.67 c	101.0 g	238 l
G_8S_2	6.67 f	102.0 g	502 c
G_8S_3	6.00 g	112.0 b	375 g
G_9S_1	6.67 f	96.00 j	170 n
G_9S_2	13.3 a	105.0 ef	555 b
G_9S_3	5.00 ij	105.0 ef	287 k
$G_{10}S_1$	3.67 mn	92.00 k	515 c
$G_{10}S_2$	6.67 f	98.00 i	180 n
CV (%)	6.278	11.279	8.389
Significance	**	*	**

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.1.5percentage of Viable and non-Viable Pollen content

4.1.5.1 Effect of genotypes

Pollen content of lentil affected by different genotypes showed statistically significant variation at harvest (Table 5 and Appendix IV). It was found that the highest viable pollen content/plant (90.72) was recorded from G_2 (LRIL-22-70) where highest non-viable pollen content(37.47) was recorded from G_4(BLX-O6004-12). Again, the lowest viable pollen content/plant (62.59) was achieved from G_4 (BLX-O6004-12) and lowest non-viable pollen content (9.28) was recorded from G_2(LRIL-22-70).

4.1.5.2 Effect of sowing date

Significant influence was observed for pollen content of lentil affected by different sowing date of lentil (Table6 and Appendix IV). Results revealed that the highest viable pollen content/plant (79.89) was recorded from planting date of S_1 (15 November, 2016)where the highest non-viable pollen content (27.88) was obtained from S_3 (20 December, 2016). Again, the lowest viable pollen content/plant (72.12) was recorded from planting date, S_3 (20 December, 2016) and lowest non-viable pollen content (20.11) was recorded from S_1 (15 November, 2016).

4.1.5.3 Interaction effect of genotype and sowing date

Pollen content of lentil was significantly varied due to interaction of variety and sowing date (Table 7 and Appendix IV). Results demonstrated that the treatment combination of G_2S_1exhibited the highest viable pollen content/plant (93.50) where the highest non-viable pollen content (42.44) was found from G_4S_3. Again, the lowest viable pollen content/plant (57.56) was found from the treatment combination of $G_4S_3$and lowestnon-viable pollen content (6.50) was found from the treatment combination of G_2S_1.

Table 5.Effect of different genotypes on percentage of viable and non viable pollen of lentil

Treatment/genotypes	Number of pollen(%)	
	Viable	Non-viable
G_1	73.74 cd	26.26 de
G_2	90.72 a	9.280 g
G_3	65.74 fg	34.26 ab
G_4	62.59 g	37.47 a
G_5	81.39 b	18.61 f
G_6	75.01 c	24.99 e
G_7	70.48 de	29.66 cd
G_8	80.03 b	19.97 f
G_9	68.03 ef	31.97 bc
G_{10}	65.22 fg	34.78 ab
CV (%)	9.389	7.524
Significance	*	**

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

Table 6.Effect of different sowing date on percentage of viable and non viablepollen of lentil

Treatment/genotypes	Number of pollen	
	Viable	Non-viable
S_1	79.89 a	20.11 c
S_2	76.13 b	23.87 b
S_3	72.12 c	27.88 a
CV (%)	9.389	7.524
Significance	*	**

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

Table 7.Combined effect of different genotypes and sowing date on percentage of viable and non viable pollen of lentil

Treatment/genotypes	Number of pollen(%)	
	Viable	Non-viable
G_1S_1	77.66 cd	22.34 ij
G_1S_2	74.45 def	25.55 hi
G_1S_3	68.65 gh	31.46 ef
G_2S_1	93.50 a	6.500 m
G_2S_2	90.25 ab	9.750 l
G_2S_3	88.09 b	11.91 l
G_3S_1	68.33 ghi	31.67 ef
G_3S_2	66.28 hij	33.72 de
G_3S_3	62.40 kl	37.60 bc
G_4S_1	66.32 hij	33.68 de
G_4S_2	63.05 jkl	36.95 bc
G_4S_3	57.56 m	42.44 a
G_5S_1	88.32 b	11.68 l
G_5S_2	80.92 c	19.08 k
G_5S_3	74.70 def	25.30 hi
G_6S_1	78.85 c	21.15 jk
G_6S_2	74.58 def	25.42 hi
G_6S_3	71.35 fg	28.65 fg
G_7S_1	75.21 de	24.79 i
G_7S_2	68.09 ghi	31.91 ef
G_7S_3	66.67 hij	33.33 de
G_8S_1	78.92 c	21.08 jk
G_8S_2	80.37 c	19.63 jk
G_8S_3	81.06 c	18.94 k
G_9S_1	71.80 efg	28.20 gh
G_9S_2	68.75 gh	31.25 efg
G_9S_3	63.11 jkl	36.89 bc
$G_{10}S_1$	70.59 g	29.41 fg
$G_{10}S_2$	64.71 ijk	35.29 cd
$G_{10}S_3$	60.09 lm	39.83 ab
CV (%)	9.389	7.524
Significance	**	**

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.1.6 Days to 50% flowering

4.1.6.1 Effect of genotypes

Days to 50% flowering of lentil showed statistically significant variation due to different cultivars (Table 8 and Appendix IV). The highest days to 50% flowering (78.00) was recorded from G_7 (LRIL-21-109) which was statistically different from others followed by G_8 (BARI Masur-8) whereas the lowest days to 50% flowering (52.66) was found from G_2 (LRIL-22-70) which was also significantly different from all other variety. Similar results were also observed by Shrestha*et al*. (2005) and Ezzat*et al*. (2005).

4.1.6.2 Effect of sowing date

Different sowing date of lentil showed significant variation on days to 50% flowering (Table 9 and Appendix IV). Results revealed that the highest days to 50% flowering (68.44) was recorded from planting date of S_3 (20 December, 2016) followed by S_2 (5 December, 2016) where the lowest days to 50% flowering (63.56) was recorded from planting date, S_1 (15 November, 2016). The result obtained from the present study was similar with the findings of Dhuppar*et al*., (2012).

4.1.6.3 Interaction effect of genotype and sowing date

Interaction of variety and sowing date had non-significant influence on days to 50% flowering (Table 10 and Appendix IV). But in was observed that the treatment combination of G_7S_3exhibited the highest days to 50% flowering (80.00) where the lowest days to 50% flowering (55.66) was found from the treatment combination of G_2S_3.Sen*et al*. (2016) also found similar result with the present study.

Table 8. Effect of different genotypes on 50% flowering for lentil genotype

Treatments	Days to 50% flowering
G_1	58.55 f
G_2	52.66 g
G_3	63.33 d
G_4	71.11 c
G_5	70.44 c
G_6	61.00 e
G_7	78.00 a
G_8	73.11 b
G_9	62.33 d
G_{10}	70.88 c
CV	1.73
Significance	**

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

Table 9. Effect of different sowing dates on 50% flowering for lentil genotype

Treatments	Days to 50% flowering
S_1	63.56 c
S_2	66.43 b
S_3	68.44 a
CV	1.73
Significance	**

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

Table 10. Combined effect of different genotypes and sowing dates on 50% flowering for lentil genotype

Treatments	Days to 50% flowering
G_1S_1	56.33
G_1S_2	58.66
G_1S_3	60.66
G_2S_1	50.00
G_2S_2	52.33
G_2S_3	55.66
G_3S_1	60.66
G_3S_2	64.66
G_3S_3	64.66
G_4S_1	69.00
G_4S_2	71.66
G_4S_3	72.66
G_5S_1	66.66
G_5S_2	71.33
G_5S_3	73.33
G_6S_1	59.33
G_6S_2	60.66
G_6S_3	63.00
G_7S_1	76.00
G_7S_2	78.00
G_7S_3	80.00
G_8S_1	70.00
G_8S_2	73.33
G_8S_3	76.00
G_9S_1	60.00
G_9S_2	62.00
G_9S_3	65.00
$G_{10}S_1$	67.66
$G_{10}S_2$	71.66
$G_{10}S_3$	73.33
CV	1.73
Significance	NS

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.2 Yield and yield attributes

4.2.1 Number of pods/plant

4.2.1.1 Effect of genotypes

Statistically significant variation was observed for number of pods/plant of lentil at harvest influenced by different cultivars (Fig. 7 and Appendix V). Results revealed that at the time of harvest, the highest number of pods/plant (24.67) was recorded from G_2 (LRIL-22-70)which was significantly different from all other studied varieties followed by G_1 (LRIL-22-68), G_5 (BARI Masur-3), G_6 (BLX-04005-9), G_9 (BARI Masur-5) and G_{10} (LRIL-22-205). Again, the genotype, G_8 (BARI Masur-8) gave the lowest number of pods/plant (14.72) at harvest which was statistically identical with G_3 (LRIL-22-133) and G_7 (LRIL-21-109). Vinay*et al*. (2006), Gupta *et al*. (2006) and Shrestha*et al*. (2005) also observed similar results and found that different genotypes had significant influence on number of pods/plan which supported the present study.

4.2.1.2 Effect of sowing date

Different sowing date of lentil had significant effect on number of pod/plant (Fig. 8 and Appendix V). Results signified that the highest number of pods/plant (21.92) at harvest was recorded from planting date of S_1 (15 November, 2016) followed by the planting date, S_2 (5 December, 2016) where the lowest number of pods/plant (16.98) at harvest was recorded from planting date, S_3 (20 December, 2016). Similar result was also observed by Dhuppar*et al*., (2012), Moosavi*et al*. (2014) and Turk *et al*. (2003) and they observed that different sowing date influenced number of pods/plant significantly.

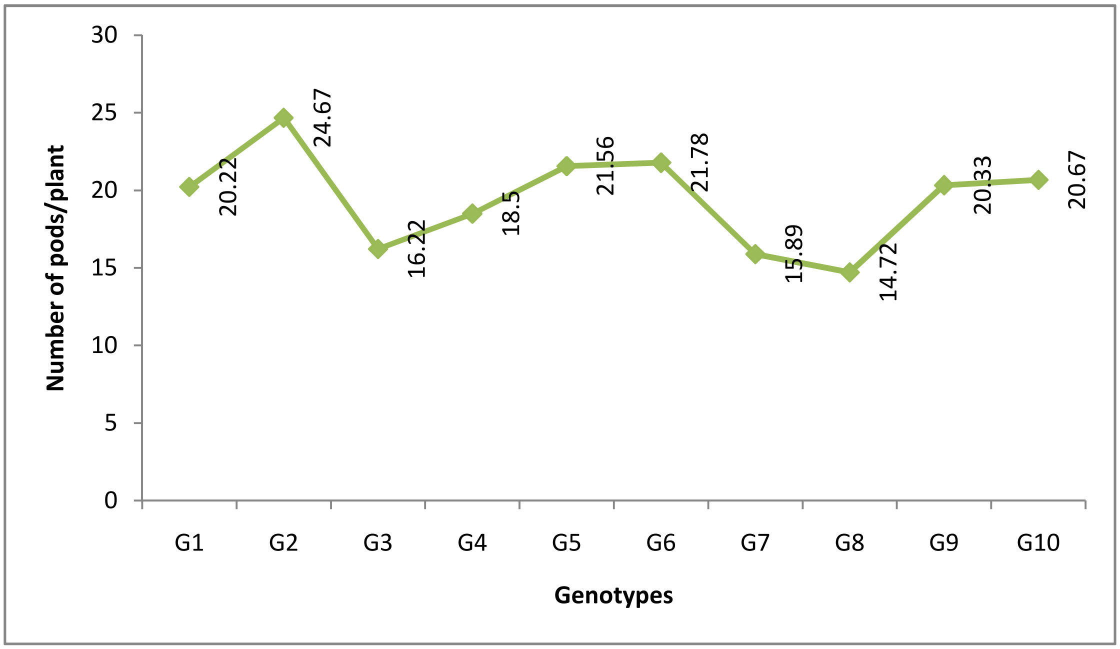

Fig. 7. Effect of different genotypes on number of pods/plant of lentil

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

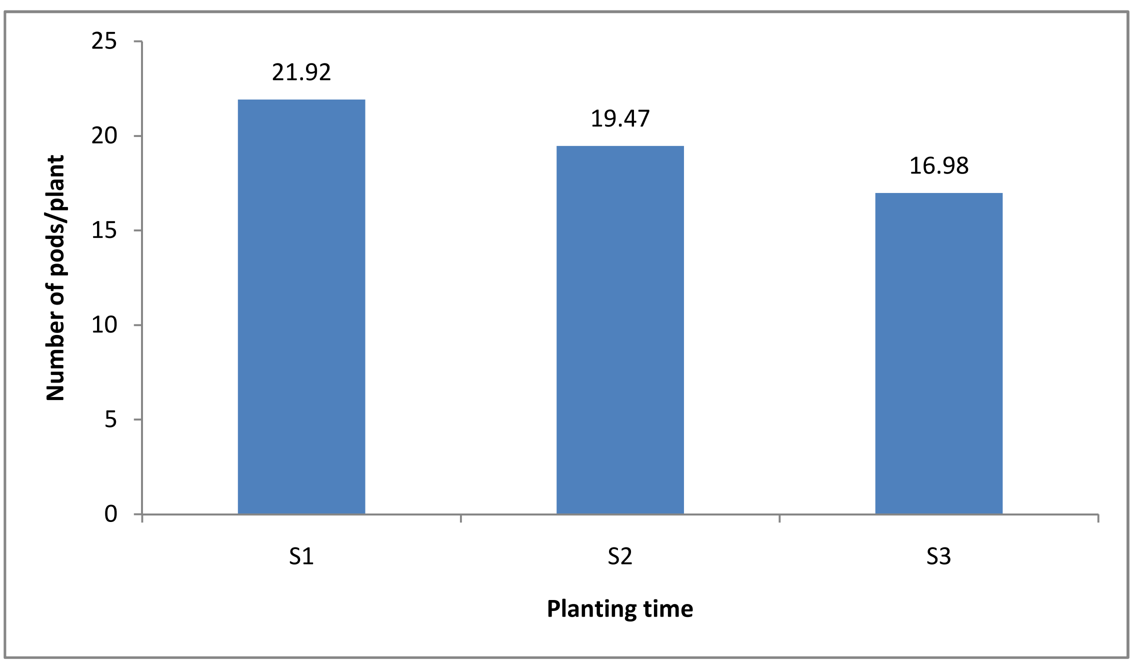

Fig. 8. Effect of different planting time on number of pods/plant of lentil

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.2.1.3 Interaction effect of variety and sowing date

Number of pods/plant of lentil at harvest was significantly varied by interaction of variety and sowing date (Table 11 and Appendix V). Results exhibited that the highest number of pods/plant (34.00) was achieved from the treatment combination of G_2S_1followed byG_6S_1. The results obtained from the treatment combination of G_1S_1, G_5S_2, G_6S_2, G_6S_3 and $G_{10}S_2$ also showed promising effect on number of pods/plant but significantly differed with G_2S_1.The lowest number of pods/plant (11.33) was found from the treatment combination of G_8S_3 which was statistically similar with G_7S_2.Significantly lower number of pods/plant was also obtained from the treatment combination of G_1S_3, G_3S_1, G_3S_2, G_4S_1 and G_7S_3 but statistically different from G_8S_3.

4.2.2 Number of filled pods/plant

4.2.2.1 Effect of genotypes

Significant variation was found for number of filled pods/plant of lentil at harvest influenced by different genotypes (Fig. 9 and Appendix V). Results indicated that the highest number of filled pods/plant (22.78) was recorded from G_2 (LRIL-22-70) which was statistically identical with G_5 (BARI Masur-3) which was statistically identical with G_5 (BARI Masur-3) followed by G_6 (BLX-04005-9). Again, the lowest number of filled pods/plant (13.50) at harvest was found from G_8 (BARI Masur-8) which was statistically identical with G_7 (LRIL-21-109) and statistically similar with G_3 (LRIL-22-133).

4.2.2.2 Effect of sowing date

Different sowing date of lentil had significant effect on number of filled pods/plant (Fig. 10 and Appendix V). It was observed that the highest number of filled pods/plant (19.25) at harvest was recorded from planting date of S_1 (15 November, 2016) which was statistically identical with S_2 (5 December, 2016) wherethelowest number of filled pods/plant (14.97) at harvest was recorded from planting date, S_3 (20 December, 2016).

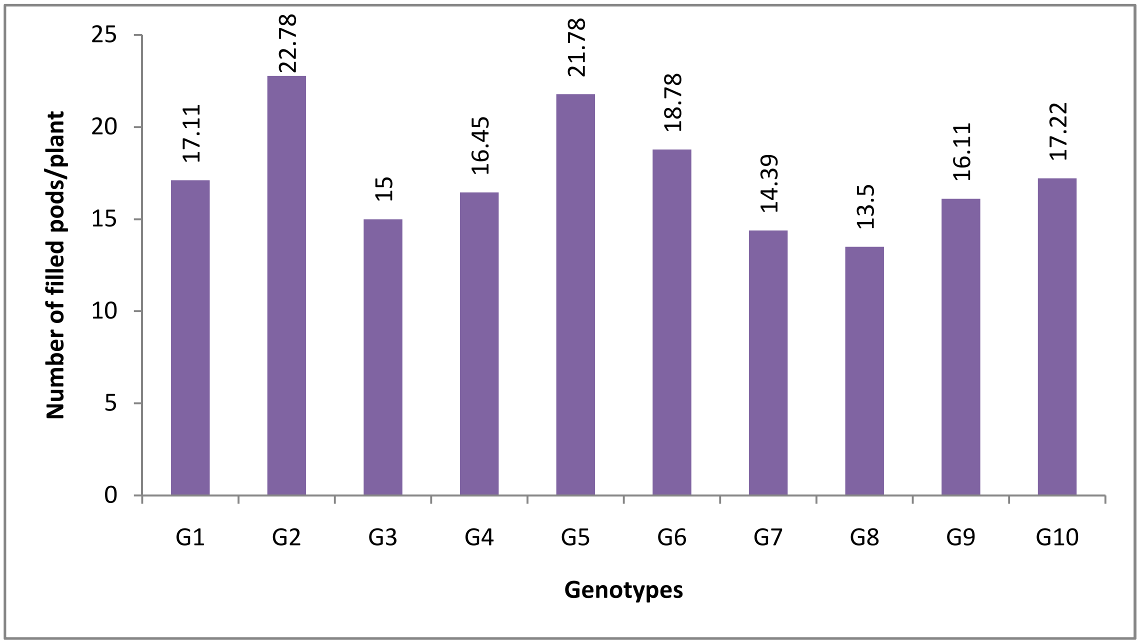

Fig. 9. Effect of different genotypes on number of filled pods/plant of lentil

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

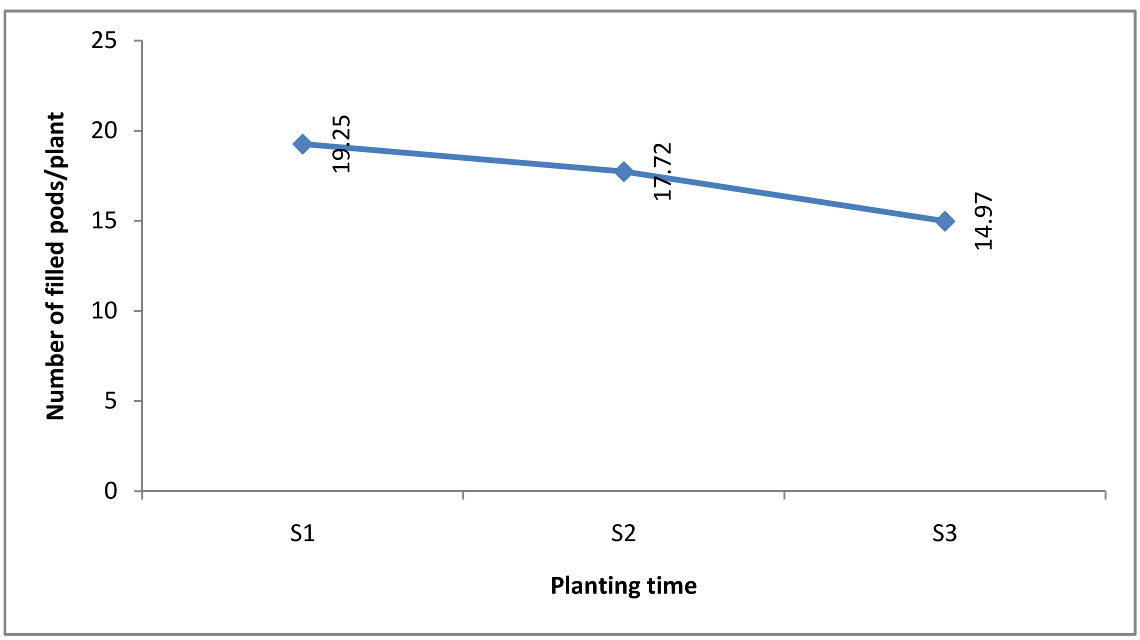

Fig. 10. Effect of different planting time on number of filled pods/plant of lentil

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.2.2.3 Interaction effect of variety and sowing date

Interaction effect of variety and sowing date had significant influence on number of filled pods/plant of lentil at harvest (Table 11 and Appendix V). It was examined that the highest number of filled pods/plant (34.00) was achieved from the treatment combination of G_2S_1followed by G_5S_2. Again, the lowest number of filled pods/plant (9.00) was found from the treatment combination of G_8S_3followed by G_3S_2, G_7S_2 and G_7S_3.

4.2.3 Number of unfilled pods/plant

4.2.3.1 Effect of genotypes

Significant effect was observed in terms of unfilled pods/plant of lentil by number affected by different genotypes (Fig. 11 and Appendix V). Results showed that the highest number of unfilled pods/plant (3.45) was recorded from G_1 (LRIL-22-68)which was statistically similar with G_2 (LRIL-22-70) and G_{10} (LRIL-22-205) where the lowest number of unfilled pods/plant (1.66) at harvest was found from G_3 (LRIL-22-133) which was statistically similar with G_5 (BARI Masur-3).

4.2.3.2 Effect of sowing date

Number of unfilled pods/plant was significantly varied due to different sowing date of lentil at harvest (Fig. 12 and Appendix V). Data represented that the highest number of unfilled pods/plant (2.98) at harvest was recorded from planting date of S_1 (15 November, 2016) where the lowest number of unfilled pods/plant (2.02) at harvest was recorded from planting date, S_2 (5 December, 2016) which was statistically identical with S_3 (20 December, 2016).

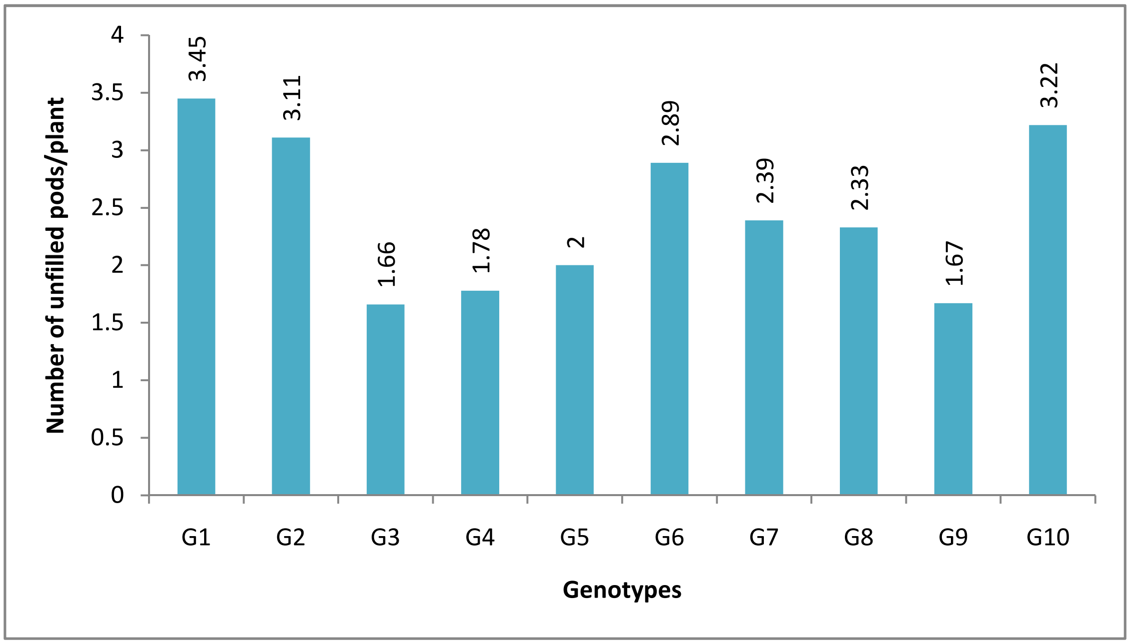

Fig. 11. Effect of different genotypes on number of unfilled pods/plant of lentil

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

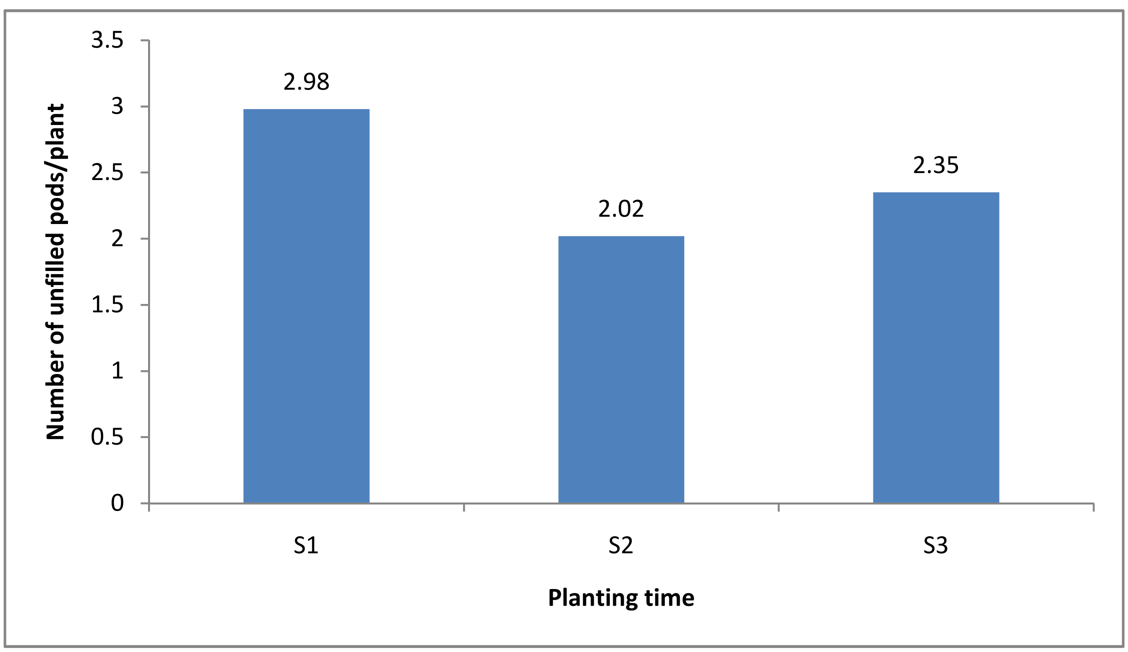

Fig. 12. Effect of different planting time on number of unfilled pods/plant of lentil

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.2.3.3 Interaction effect of variety and sowing date

Number of unfilled pods/plant affect by interaction of variety and sowing date was significant at the time of harvest of lentil (Table 11 and Appendix V). Results showed that the highest number of unfilled pods/plant (5.33) was achieved from the treatment combination of G_1S_1 followed by G_6S_1 and $G_{10}S_3$. But the lowest number of unfilled pods/plant (1.00) was found from the treatment combination of G_3S_2 which was statistically identical with G_3S_1 and G_5S_2.

4.2.4 Weight of1000 seeds

4.2.4.1 Effect of genotypes

There was a significant effect was observed in case of 1000 seed weight of lentil at harvest distressed by different genotypes (Fig. 13 and Appendix V). It was tested that the highest 1000 seed weight (31.00 g) was recorded from G_2 (LRIL-22-70) which was statistically different from all other test genotypes followed by G_1 (LRIL-22-68) where the lowest 1000 seed weight (20.13 g) at harvest was found from G_4 (BLX-O6004-12) which was statistically similar with G_6 (BLX-04005-9) and G_9 (BARI Masur-5). The result obtained from the present study was conformity with findings of Turk *et al*. (2004) and Gupta *et al*. (2006). Turk *et al*. (2004) and Gupta *et al*. (2006) also observed that 1000 seed weight varied significantly due to varietal difference.

4.2.4.2 Effect of sowing date

Different sowing date of lentil had significant influence on 1000 seed weight (Fig. 14 and Appendix V). Results indicated that the highest 1000 seed weight (28.01 g) at harvest was recorded from planting date of S_1 (15 November, 2016) followed by S_2 (5 December, 2016) where the lowest 1000 seed weight (21.75 g) at harvest was recorded from planting date, S_3 (20 December, 2016). Significant effect on 1000 seed weight due to different planting date was also observed by Turk *et al*. (2003) and Moosavi*et al*. (2014) which also supported the present study.

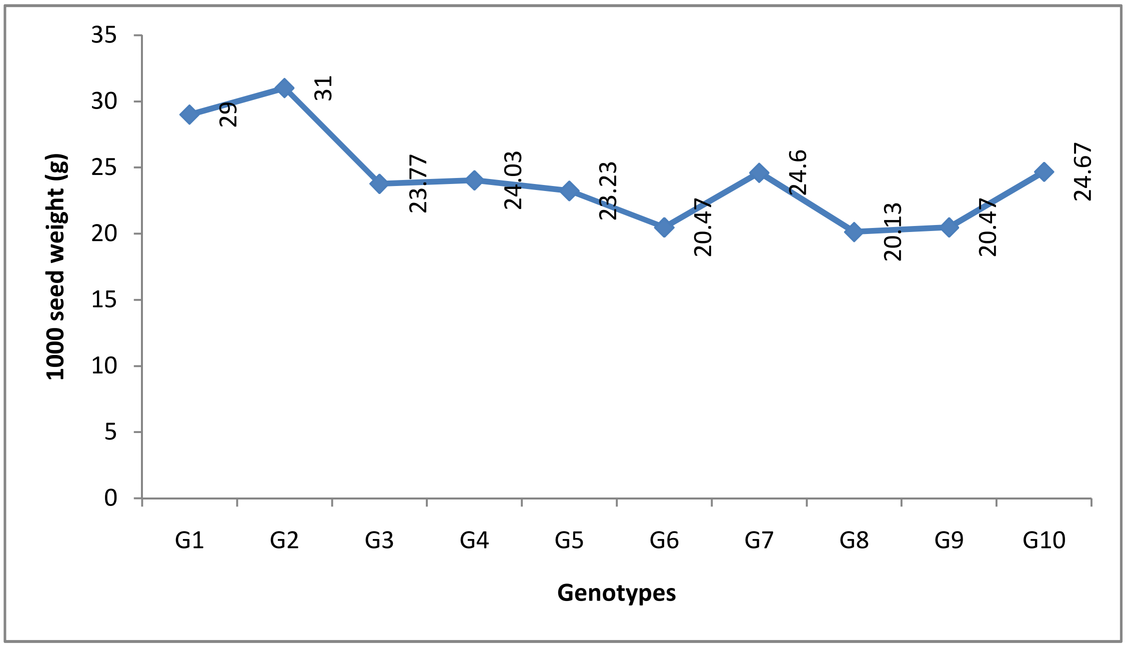

Fig. 13. Effect of different genotypes on 1000 seed weight (g) of lentil

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

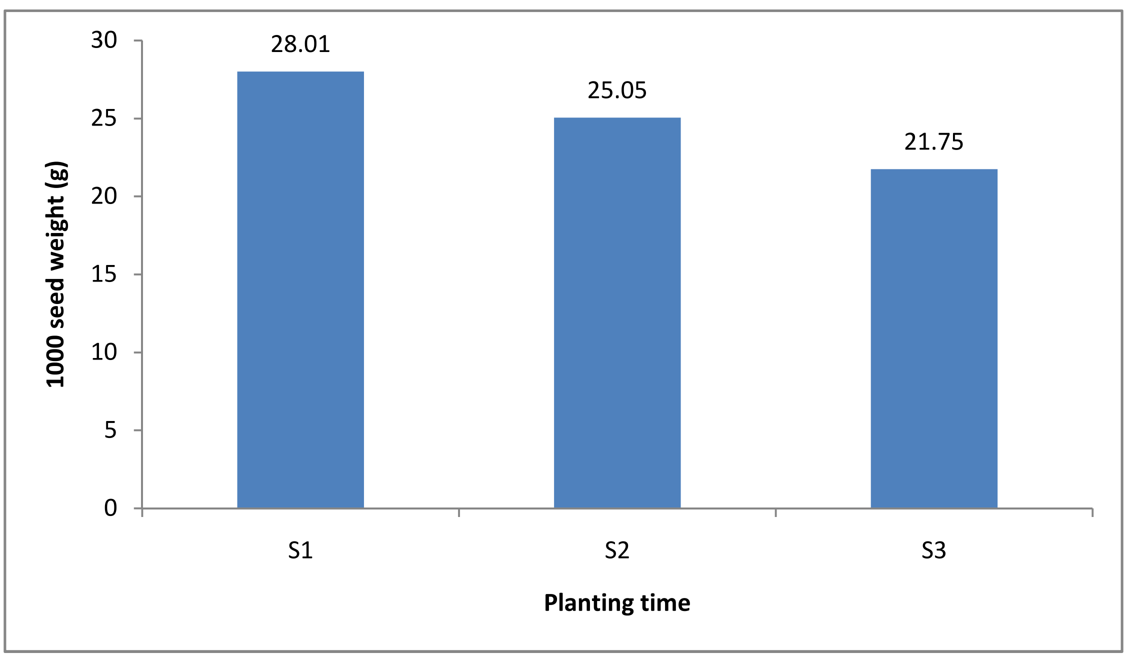

Fig. 14. Effect of different planting time on 1000 seed weight (g) of lentil

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.2.4.3 Interaction effect of variety and sowing date

Different interaction of variety and sowing date under the present study showed significant variation on 1000 seed weight of lentil (Table 11 Appendix V). It was observed that the highest 1000 seed weight (34.00g) was achieved from the treatment combination of G_2S_1followed byG_1S_1, G_1S_2 and G_7S_2. On the other hand, the lowest 1000 seed weight (13.00 g) was found from the treatment combination of G_8S_3which was immediate lower than G_6S_3 and G_9S_2.

4.2.5 Yield/plant

4.2.5.1 Effect of genotypes

Different genotypes of lentil gave statistically significant difference on yield/plant of lentil (Fig. 15 and Appendix V). Results revealed that the highest yield/plant (1.72g) was recorded from G_2 (LRIL-22-70) which was statistically different from all other test genotypes followed by G_1 (LRIL-22-68) where the lowest yield/plant (1.26 g) was found from G_8 (BARI Masur-8) which was statistically identical with G_4 (BLX-O6004-12) and G_7 (LRIL-21-109) and statistically similar with G_3 (LRIL-22-133) and G_9 (BARI Masur-5). The highest yield/plant from G_2 (LRIL-22-70) was probably due to cause of higher achievement of number of pods/plant, number of filled pods/plant and 1000 seed weight from this genotype. Similar result was also observed by Dutta*et al*. (1998), Hamdi*et al*. (2003), Gupta *et al*. (2006), Zahan *et al*. (2009) and Zike *et al*., (2017). Gupta *et al*. (2006) also found that different characters like seed yield/plant was significantly varied with varietal difference.

4.2.5.2 Effect of sowing date

Significant variation was obtained on yield/plant of lentil influenced by different sowing date (Fig. 16 and Appendix V). It was examined that the highest yield/plant (1.64 g) at harvest was recorded from planting date of S_1 (15 November, 2016) followed by S_2 (5 December, 2016) where the lowest yield/plant

(1.27 g) at harvest was recorded from planting date, S_3 (20 December, 2016). The planting date of S_1 (15 November, 2016) also gave higher number of pods/plant, number of filled pods/plant and 1000 seed weight and these also might be cause of highest yield/plant. The result on yield/plant was similar with the findings of Dhuppar*et al*., (2012), Singh (2013) and Moosavi*et al*. (2014) which supported the present study.

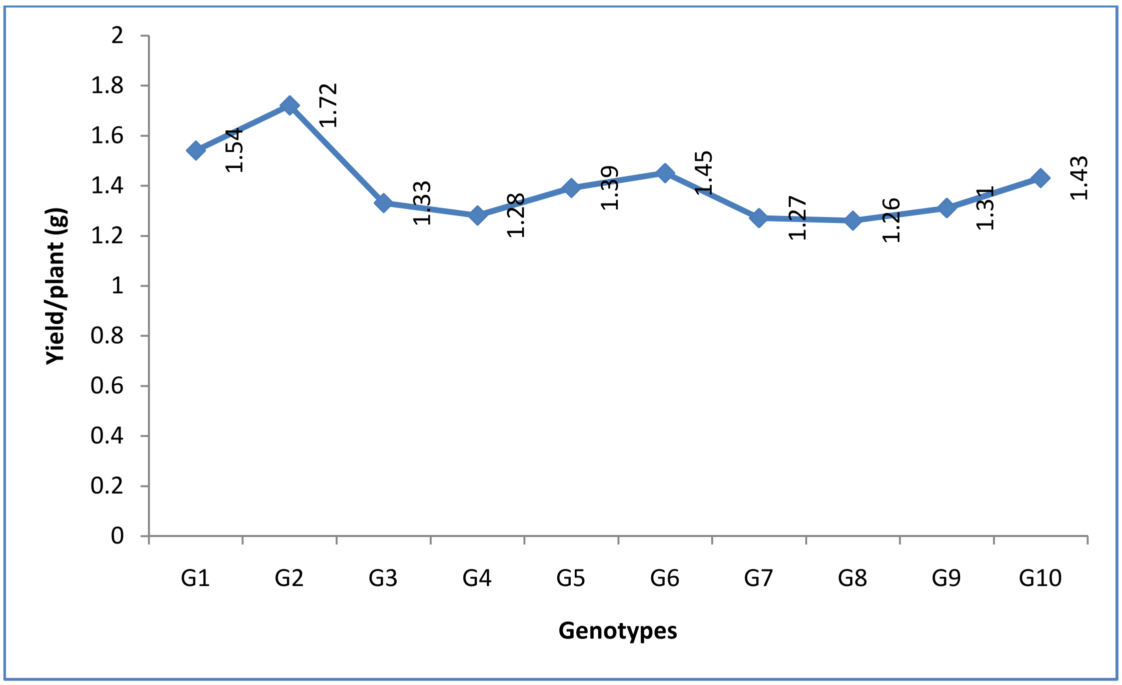

Fig. 15. Effect of different genotypes on yield/plant (g) of lentil

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

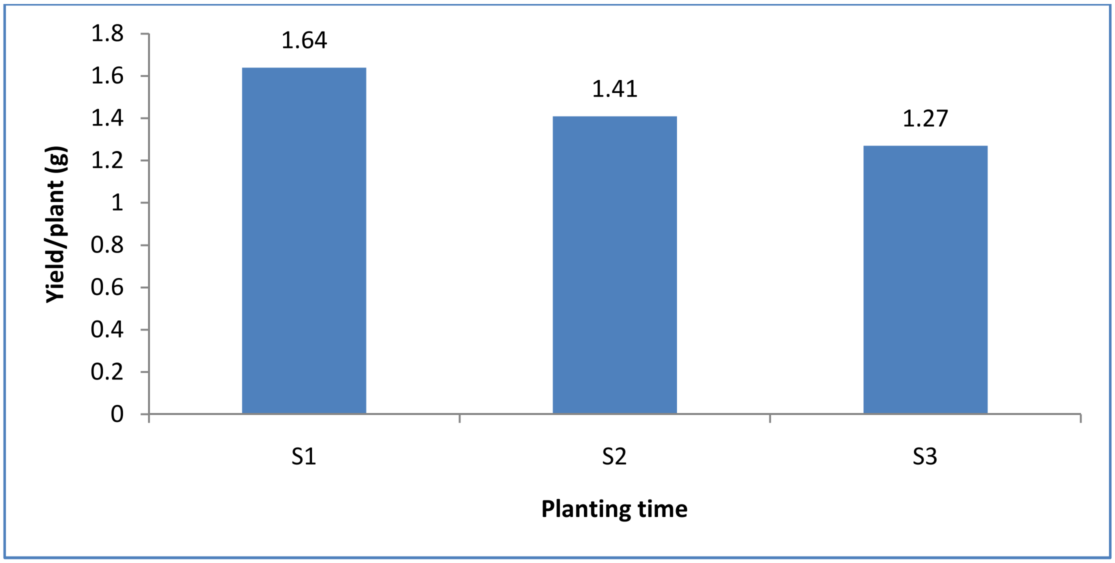

Fig. 16. Effect of different planting time on yield/plant (g) of lentil

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.2.5.3 Interaction effect of variety and sowing date

Yield/plant of lentil was significantly varied due to interaction effect of variety and sowing date (Table 11 and Appendix V). Results indicated that the highest yield/plant (2.73g) was achieved from the treatment combination of G_2S_1followed by G_1S_1. On the contrary, the lowest yield/plant (1.10g) was found from the treatment combination of G_8S_3which was immediate lower than G_3S_1, G_3S_2 and G_9S_3. The highest yield/plant from the treatment combination of G_2S_1 might be due to cause of higher number of pods/plant, number of filled pods/plant and 1000 seed weight from this treatment combination.

Table 11. Combined effect of different genotypes and sowing date on yield attributes and yield of lentil

Treatment combinations	Yield attributes and yield				
	Number of pods/plant	Number of filled pods/plant	Number of unfilled pods/plant	1000 seed weight (g)	Yield/plant (g)
G_1S_1	26.00 bc	21.00 efg	5.33 a	32.30 b	1.74 b
G_1S_2	23.33 de	20.33 fg	3.00 d	31.00 b	1.67 bc
G_1S_3	13.50 kl	10.00 mn	1.33 h	23.70 gh	1.20 k
G_2S_1	34.00 a	34.00 a	4.00 c	34.00 a	2.73 a
G_2S_2	14.67 k	12.33 kl	2.33 ef	24.70 efg	1.27 jk
G_2S_3	16.67 ij	13.67 jk	3.00 d	22.30 i	1.30 ij
G_3S_1	13.67 kl	13.00 jkl	1.03 i	20.30 k	1.20 k
G_3S_2	12.50 lm	11.50 lm	1.00 i	22.50 hi	1.20 k
G_3S_3	22.50 ef	20.50 fg	2.00 fg	28.50 c	1.40 gh
G_4S_1	13.50 kl	12.50 kl	2.00 fg	24.50 efg	1.25 jk
G_4S_2	14.33 k	13.00 jkl	1.33 h	25.30 ef	1.27 jk
G_4S_3	16.33 j	17.67 h	2.00 fg	22.30 hi	1.33 hij
G_5S_1	17.00 ij	15.00 ij	2.33 ef	24.30 efg	1.30 ij
G_5S_2	25.67 c	30.33 b	1.03 i	24.70 efg	1.53 ef
G_5S_3	22.00 fg	19.33 gh	2.67 de	20.70 jk	1.33 hij
G_6S_1	27.00 b	22.00 def	5.00 b	19.70 k	1.47 fg
G_6S_2	25.67 c	24.00 c	1.67 g	25.70 de	1.60 cde
G_6S_3	21.33 g	19.33 gh	2.00 g	16.00 l	1.27 jk
G_7S_1	22.67 ef	20.00 fg	2.67 e	20.30 k	1.33 hij
G_7S_2	11.50 mn	11.00 lm	2.50 e	31.50 b	1.25 jk
G_7S_3	13.50 kl	11.50 lm	2.00 fg	22.00 ij	1.20 k
G_8S_1	24.33 d	22.67 cde	2.50 e	26.70 d	1.57 de
G_8S_2	17.67 hi	15.67 i	2.00 fg	21.70 ij	1.33 hij
G_8S_3	11.33 n	9.000 n	2.50 e	13.00 m	1.10 *l*
G_9S_1	23.67 de	21.33 efg	2.33 ef	19.70 k	1.37 hi
G_9S_2	23.33 de	14.00 ijk	1.67 g	16.70 l	1.37 hi
G_9S_3	14.00 k	13.00 jkl	2.00 g	24.00 fg	1.20 k
$G_{10}S_1$	17.33 ij	14.67 ij	2.67 e	22.30 i	1.30 ij
$G_{10}S_2$	26.00 bc	23.33 cd	2.67 e	26.70 d	1.63 cd
$G_{10}S_3$	18.67 h	13.67 ijk	5.00 b	25.00 efg	1.37 hi
CV (%)	8.224	6.839	4.173	7.226	3.017
Significance	**	*	**	*	**

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

4.2.6 Yield/ha (kg)

4.2.6.1 Effect of genotypes

Different genotypes of lentil gave statistically significant difference on yield/ha of lentil (Fig. 15 and Appendix V). Results revealed that the highest yield/ha (441.67kg) was recorded from G_2 (LRIL-22-70) which was statistically different from all other test genotypes followed by G_1 (LRIL-22-68) where the lowest yield/ha (315 kg) was found from G_8 (BARI Masur-8) which was statistically identical with G_4 (BLX-O6004-12) and G_7 (LRIL-21-109) and statistically similar with G_3 (LRIL-22-133) and G_9 (BARI Masur-5). Similar result was also observed by Gupta *et al*. (2006), Zahan *et al*. (2009) and Zike *et al*., (2017). Gupta *et al*. (2006) also found that different characters like seed yield/hawere significantly varied with varietal difference.

4.2.6.2 Effect of sowing date

Significant variation was obtained on yield/ha of lentil influenced by different sowing date (Fig. 16 and Appendix V). It was examined that the highest yield/ha (381.50kg) was recorded from planting date of S_1 (15 November, 2016) followed by S_2 (5 December, 2016) where the lowest yield/ha (317.50kg) was recorded from planting date, S_3 (20 December, 2016). The planting date of S_1 (15 November, 2016) also gave higher number of pods/plant, number of filled pods/plant and 1000 seed weight and these also might be cause of highest yield/ha. The result on yield/ha was similar with the findings of Dhuppar*et al*., (2012), Singh (2013) and Moosavi*et al*. (2014) which supported the present study.

4.2.6.3 Interaction effect of variety and sowing date

Yield/ha of lentil was significantly varied due to interaction effect of variety and sowing date (Table 5 and Appendix V). Results indicated that the highest yield/ha (682.50 kg) was achieved from the treatment combination of G_2S_1followed by G_1S_1. On the contrary, the lowest yield/ha (275kg) was found from the treatment combination of G_8S_3which was immediate lower than G_1S_3, G_3S_1, G_3S_2, G_7S_3 and G_9S_3. The highest yield/ha from the treatment combination of G_2S_1 might be due to cause of higher number of pods/plant, number of filled pods/plant and 1000 seed weight from this treatment combination.

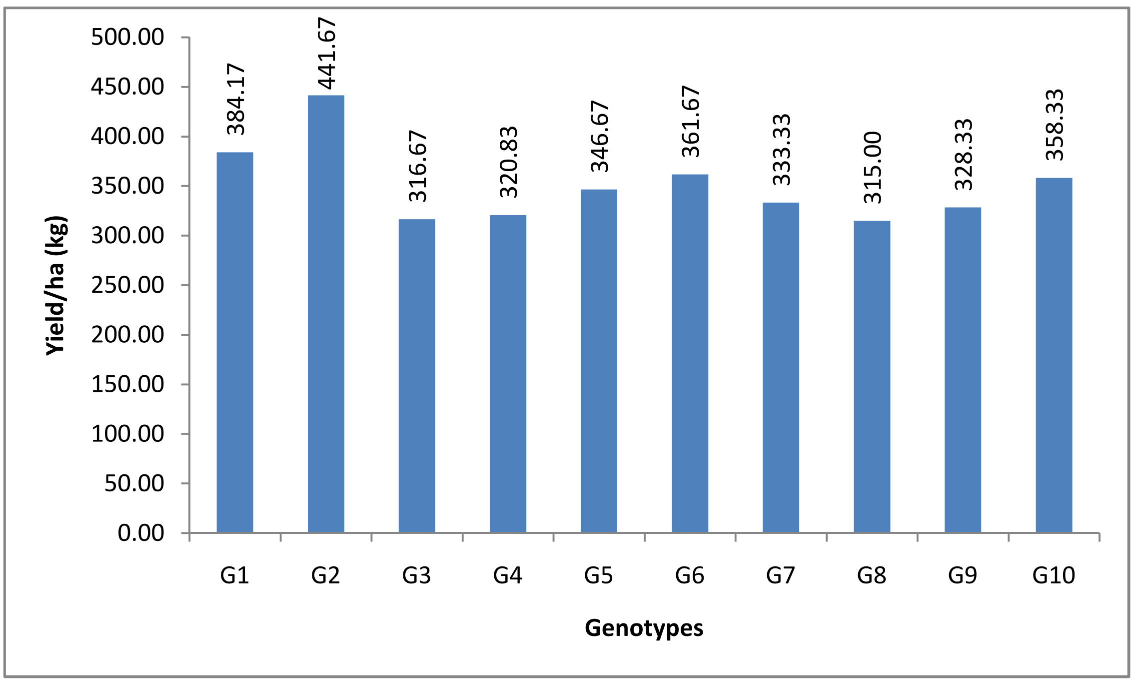

Fig. 17. Effect of different genotypes on yield/ha (kg) of lentil

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

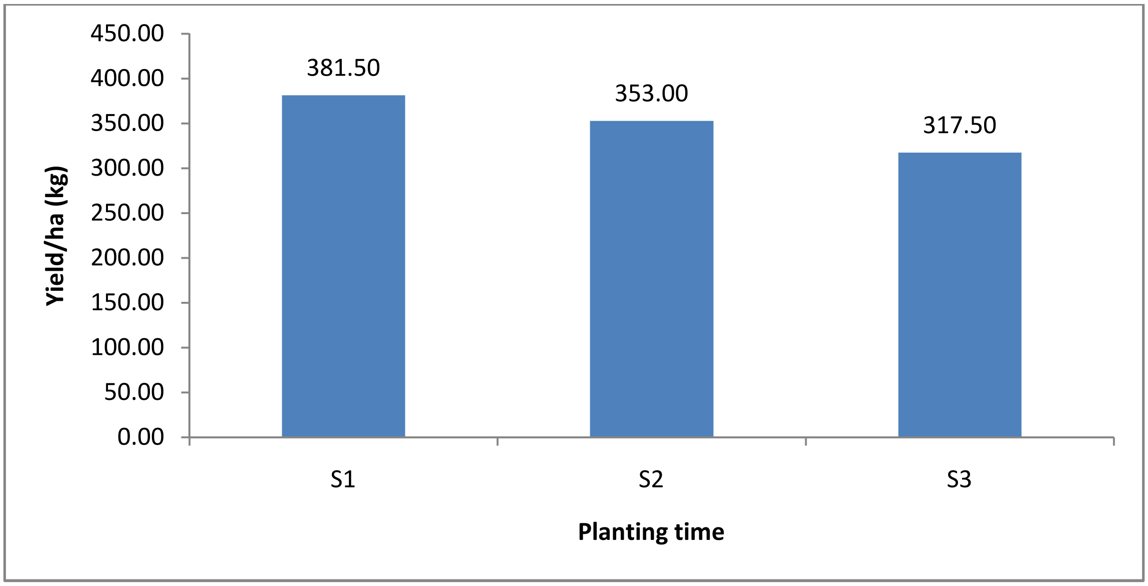

Fig. 18. Effect of different planting time on yield/ha (kg) of lentil

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

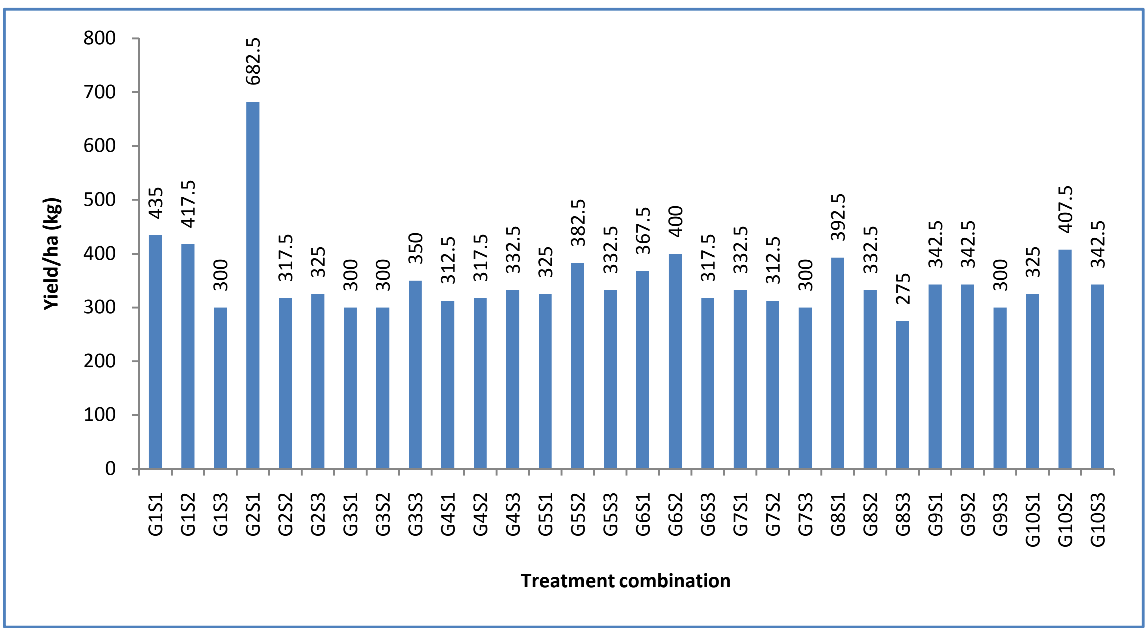

Fig. 19. Combined effect of different genotypes and sowing date on yield/ha (kg) of lentil

G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5, G_{10}=LRIL-22-205

S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

The experiment was conducted at Bangladesh Agricultural Research Institute (BARI)during November 2016 to April 2017 to study the effects of raising temperature on lentil. In the experiment, the treatment consisted of 10 genotypes*viz*., G_1=LRIL-22-68, G_2=LRIL-22-70, G_3=LRIL-22-133, G_4=BLX-O6004-12, G_5=BARI Masur-3, G_6=BLX-04005-9, G_7=LRIL-21-109, G_8=BARI Masur-8, G_9=BARI Masur-5 and G_{10}=LRIL-22-205, and three different date of sowing, *viz*. S_1 = 15 November, 2016, S_2 = 5 December, 2016, S_3 = 20 December, 2016 and also their combinations.The experiment was laid out in a two factors Randomized Complete Block Design (RCBD) with three replications. The collected data were statistically analyzed for evaluation of the treatment effect. All the studied parameters were affected significantly due to different genotypes and planting date and also their interaction.

In terms of genotypic performance, the highest days to 1stemergence (11.77) was recorded from G_1 (LRIL-22-68) andthe lowest days to 1stemergence (6.33) was found from G_2 (LRIL-22-70).The highest days to 50% flowering (78.00) was recorded from G_7 (LRIL-21-109) and the lowest days to 50% flowering (52.66) was found from G_2 (LRIL-22-70). The highest number of branch/plant (8.33) was recorded from G_9 (BARI Masur-5) where the highest dry weight/plant (107.33 g) was recorded from G_3 (LRIL-22-133). But the highest viable pollen content/plant (90.72), number of pods/plant (24.67), number of filled pods/plant (22.78), 1000 seed weight (31.00 g), yield/plant (1.72g) and yield/ha (441.67 kg) were recorded from G_2 (LRIL-22-70). Again, the lowest number of branch/plant (4.55) and dry weight/plant (97.33 g) was found from the genotype, G_5 (BARI Masur-3) and

G_4(BLX-O6004-12) respectively. The lowest number of viable pollen content/plant (62.59) was also obtained from G_4 (BLX-O6004-12).But the lowest number of pods/plant (14.72), number of filled pods/plant (13.50), 1000 seed weight (20.13 g), yield/plant (1.26g) and yield/ha (315 kg) were found from the genotype, G_8 (BARI Masur-8). The highest and lowest number of unfilled pods/plant (3.45 and 1.66 respectively) were recorded from G_1 (LRIL-22-68) and G_3 (LRIL-22-133) respectively. The highest PAR (479.33) was recorded from G_1 (LRIL-22-68) where the lowest PAR (276.00) was found from G_3 (LRIL-22-133).

In case of planting date,the highest days to 1stemergence (10.30) was recorded from planting date of S_3 (20 December, 2016) followed by S_2 (5 December, 2016) where the lowest days to1stemergence (8.26) was recorded from planting date, S_1 (15 November, 2016). The highest days to 50% flowering (68.44) was recorded from planting date of S_3 (20 December, 2016) followed by S_2 (5 December, 2016) where the lowest days to 50% flowering (63.56) was recorded from planting date, S_1 (15 November, 2016).The highest number of branch/plant (6.68) at harvest was recorded from planting date of S_2 (5 December, 2016) where the highest dry weight/plant (111.0 g) at harvest was recorded from planting date of S_3 (20 December, 2016).Again, the highest number ofviable pollen content/plant (79.89), number of pods/plant (21.92), number of filled pods/plant (19.25), 1000 seed weight (28.01 g), yield/plant (1.64 g) and yield/ha (381.50 kg) at harvest was recorded from planting date of S_1 (15 November, 2016).On the other hand, the lowest number of viable pollen content/plant (72.12) anddry weight/plant (95.00 g) at harvest was recorded from planting date, S_1 (15 November, 2016).But the lowest number of branch/plant (5.28), number of pods/plant (16.98), lowest number of filled pods/plant (14.97), lowest 1000 seed weight (21.75 g), lowest yield/plant (1.27 g) and lowest yield/ha (317.50 kg) at harvest were recorded from planting date, S_3 (20 December, 2016).The highest and lowest number of unfilled pods/plant (2.98 and 2.02 respectively) was achieved from S_1 (15 November,

2016) and S_2 (5 December, 2016).Again, the highest PAR (373.60) was recorded from planting date of S_1 (15 November, 2016) where the lowest PAR(342.50) was recorded from planting date, S_3 (20 December, 2016)

Considering interaction effect of variety and sowing date, the treatment combination of G_7S_3 exhibited the highest days to 50% flowering (80.00) where the lowest days to1stemergence (55.66) was found from the treatment combination of G_2S_3,the highest number of branch/plant (13.3) and dry weight/plant (115.0 g) were recorded from the treatment interaction of G_9S_2 and G_3S_3 respectively.Again, the highest number ofviable pollen content/plant (93.50), number of pods/plant (34.00), number of filled pods/plant (34.00), 1000 seed weight (34.00g), yield/plant (2.73g) and yield/ha (682.50 kg) were achieved from the treatment combination of G_2S_1.The lowest number of branch/plant (3.00) and dry weight/plant (91.90 g) were found from the treatment combination of G_4S_1. But the lowest number ofviable pollen content/plant (57.56), number of pods/plant (11.33), number of filled pods/plant (9.00), 1000 seed weight (13.00 g), yield/plant (1.10 g) and yield/ha (275 kg) were found from the treatment combination of G_8S_3. The highest and lowest number of unfilled pods/plant (5.33 and 1.00 respectively) was achieved from the treatment combination of G_1S_1 and G_3S_2 respectively.Again, it was found that G_4S_1exhibited the highest PAR (610) where the lowest PAR (170) was found from the treatment combination of G_9S_1.

5.2 Conclusion:

Among the different genotypes, the highest number of pods/plant (24.67), number of filled pods/plant (22.78),viable pollen content/plant (90.72), 1000 seed weight (31.00 g), yield/plant (1.72 g) and yield/ha (441.67 kg) were recorded from G_2 (LRIL-22-70).

Among the three studied planting date, highest days to1stemergence (10.30), the highest days to 50% flowering (68.44), the highest viable pollen content/plant

(79.89), number of pods/plant (21.92), number of filled pods/plant (19.25), 1000 seed weight (28.01 g), yield/plant (1.64 g) and yield/ha (381.50 kg) were recorded from planting date of S_1 (15 November, 2016).

Considering interaction effect of variety and sowing date, the highest number of pods/plant (34.00), viable pollen content/plant (93.50), number of filled pods/plant (34.00), 1000 seed weight (34 g), yield/plant (2.73 g) and yield/ha (682.50 kg) were achieved from the treatment combination of G_2S_1. In terms of PAR (photosynthetic active radiation), G_4S_1 exhibited the highest PAR (610).

Consider the stated summary, it may be concluded that the genotype, G_2 (LRIL-22-70) planted on 15 November, 2016 (S_1) would be beneficial for the farmers throughout the entire period of the study.

5.3 Recommendation:

- In this experiment performance of only ten genotypes were observed only at three sowing dates. So, the response of many other related genotypes to different planting dates should be studied in order to make a clear recommendation on the subject.
- The experiment should be studied in different location or another AEZ of Bangladesh.
- The experiment should be studied with the genotype of another crop or tree or any agroforestry system

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

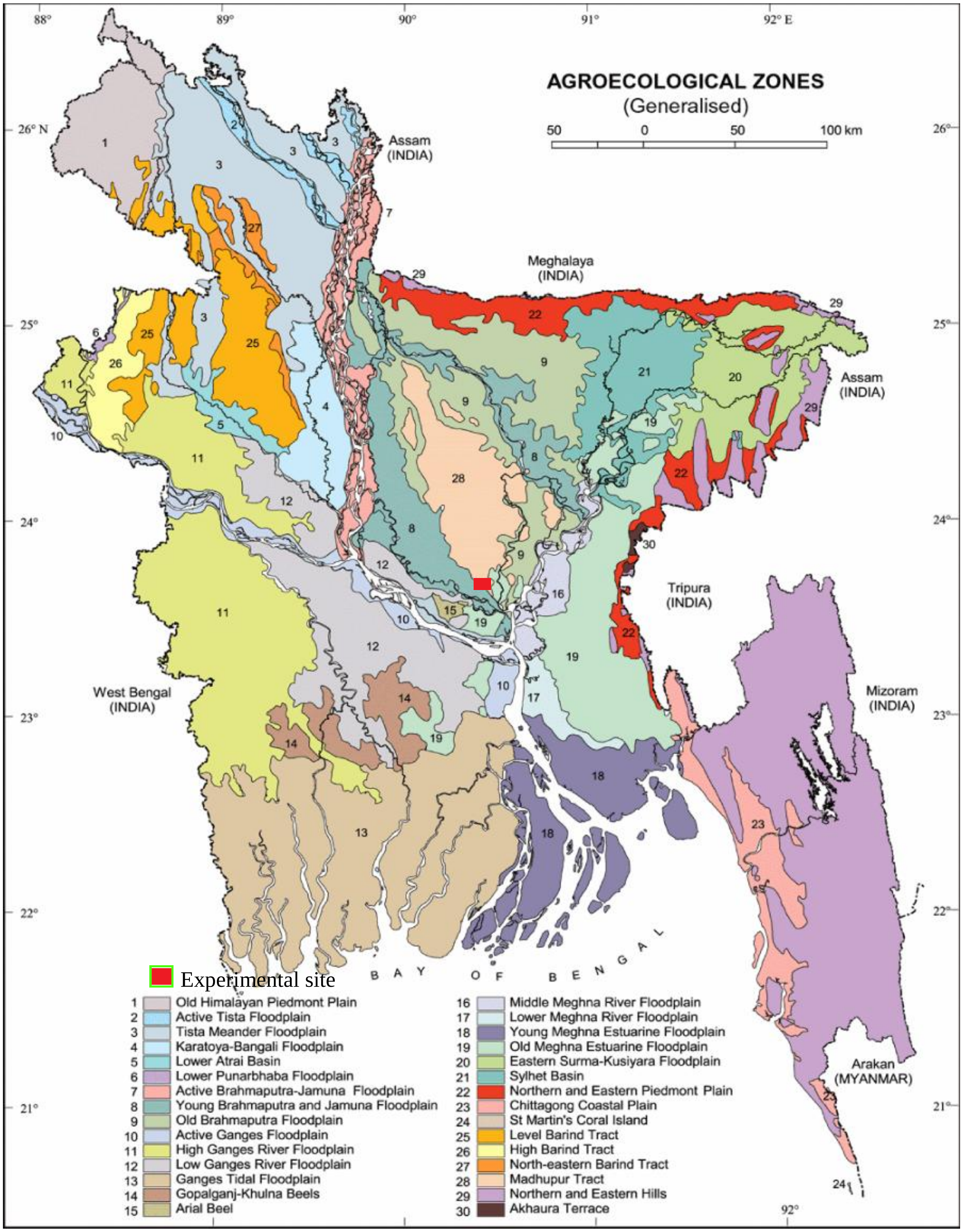

Fig. 20. Experimental site

Appendix II. Monthly records of air temperature (°C), relative humidity and rainfall during the period from November 2016 to April 2017

Appendix II(a). Monthly records of air temperature (°C), during the period from November 2016 to April 2017

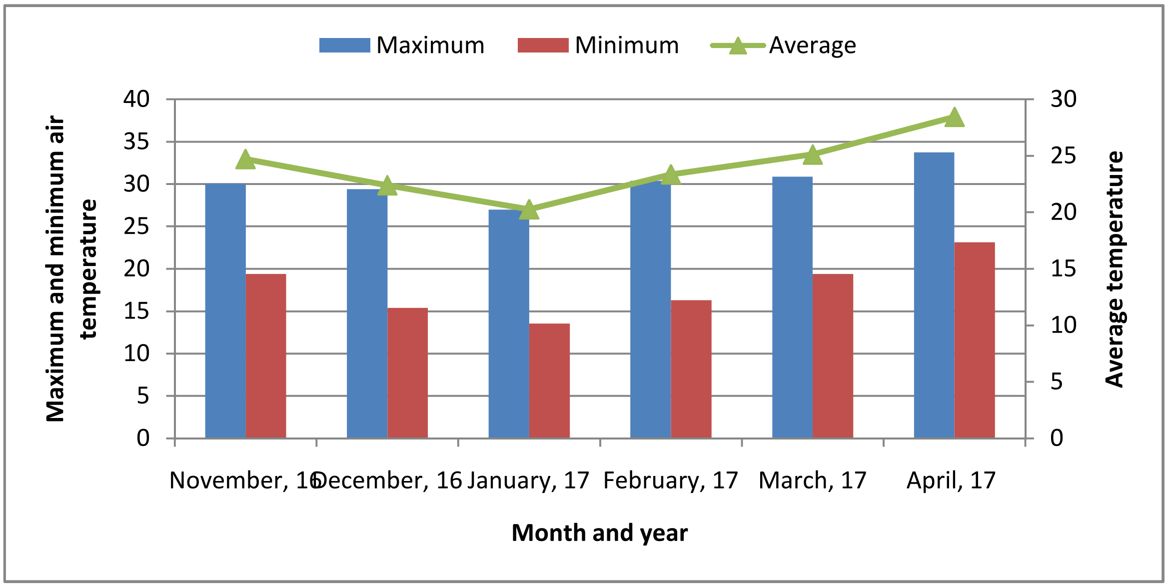

Fig. 21. Monthly records of air temperature (°C)

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix II(b). Monthly records of relative humidity (%),during the period from November 2016 to April 2017

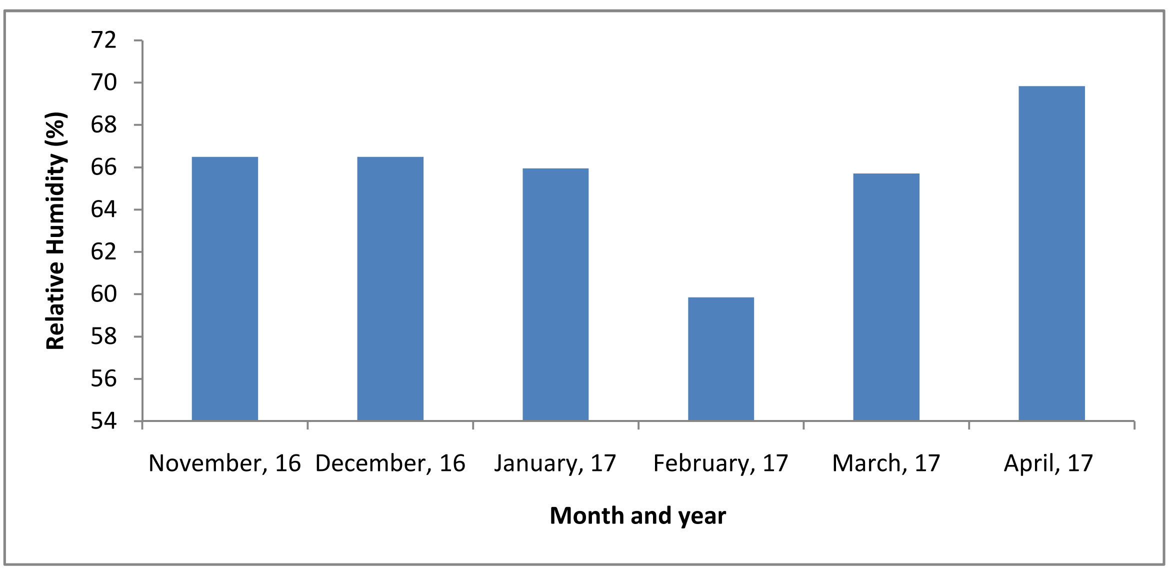

Fig. 22. Monthly records of relative humidity (%)

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix II(c). Monthly records of air temperature (°C), relative humidity, rainfall and sunshine during the period from November 2016 to April 2017

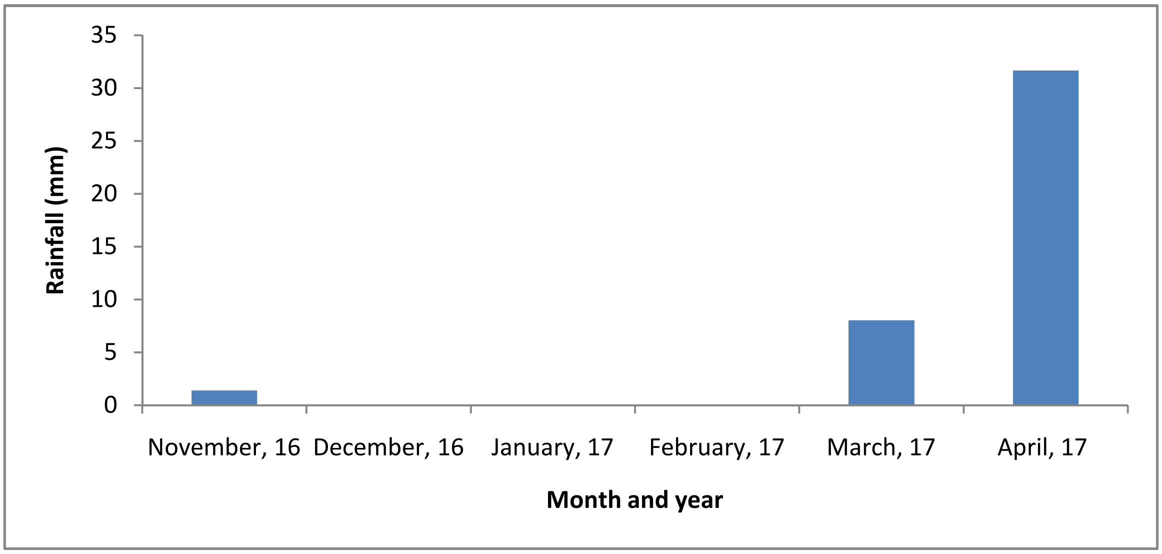

Fig. 23. Monthly records of rainfall (mm)

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
P^H	:	5.45-5.61
Total N (%)	:	0.07
Available P (μ gm/gm)	:	18.49
Exchangeable K (μ gm/gm)	:	0.07
Available S (μ gm/gm)	:	20.82
Available Fe (μ gm/gm)	:	229
Available Zn (μ gm/gm)	:	4.48
Available Mg (μ gm/gm)	:	0.825
Available Na (μ gm/gm)	:	0.32
Available B (μ gm/gm)	:	0.94
Organic matter (%)	:	0.83

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Appendix IV. Effect of different genotypes on growth parameters of lentil

Sources of variation	Degrees of freedom	Mean square of growth parameters						
		Days to 1st emer-gence	No. of branch/ plant	Dry weight/ plant	PAR	Viable pollen	Non-viable pollen	Days to 50% flowering
Replication	2	1.052	0.214	2.305	4.712	3.614	0.287	0.562
Factor A	9	12.37**	6.31**	32.08*	36.31**	42.28*	8.26**	10.26**
Factor B	2	10.26**	4.36*	12.36*	18.52*	16.37*	5.31**	4.88**
AB	18	14.22^{NS}	7.82**	24.53*	48.28**	38.54**	10.24**	12.52^{NS}
Error	58	1.172	0.256	5.329	6.278	2.366	0.512	1.024

Table V. Effect of different genotypes on yield attributes and yield of lentil

Sources of variation	Degrees of freedom	Mean square of yield attributes and yield					
		No. of pods/ plant	No. of filled pods/ plant	No. of unfilled pods plant	1000 seed weight	Yield/ plant	Yield/ ha
Replication	2	3.216	4.483	0.138	2.129	1.304	5.216
Factor A	9	28.114*	26.118*	8.058**	16.52*	9.24**	72.54*
Factor B	2	22.14*	18.91**	3.43**	7.35**	4.81*	33.71*
AB	18	36.71**	31.26*	10.34**	28.136*	13.25**	84.93*
Error	58	5.312	7.014	0.326	4.407	0.137	6.114

Appendix VI. Pictorial view of data collecting by Sunfleck Ceptometer

Fig. 24. Data collecting by Sunfleck Ceptometer

Appendix VI. Pictorial view of the experimental field

Fig. 25. Experimental Field

Appendix VI. Pictorial presentation of microscopic view of viable pollen

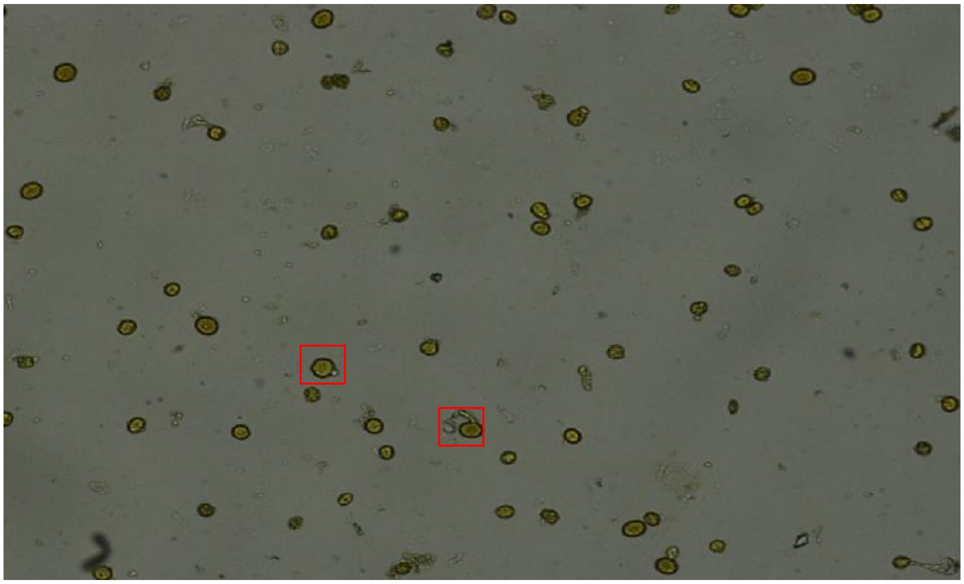

Fig. 26. Microscopic view of viable pollen