EFFECT OF SOWING DATE AND GIBBERELLIC ACID ON WATER RELATIONS AND YIELD OF LENTIL UNDER RESIDUAL SOIL MOISTURE CONDITION

BY

SUDIP SARKER

REG. NO. : 07-02416

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
AGRONOMY

SEMESTER: JANUARY-JUNE, 2014

APPROVED BY:

(Dr. Md. Shahidul Islam)
Professor
Department of Agronomy
Sher-e-Bangla Agricultural University

Supervisor

(Dr. Md. Hazrat Ali)
Professor
Department of Agronomy
Sher-e-Bangla Agricultural University

Co-Supervisor

(Prof. Dr. H.M.M. Tariq Hossain)
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/ Agronomy

CERTIFICATE

This is to certify that the thesis entitled **"Effect of Sowing Date and Gibberellic Acid on Water Relations and Yield of Lentil under Residual Soil Moisture Condition"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science (MS)** in **Agronomy**, embodies the result of a piece of bonafide research work carried out by **Sudip Sarker**, Registration number: **07-02416** 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 duly been acknowledged.

Dated: 31.05.2015
Dhaka, Bangladesh

(Prof. Dr. Md. Shahidul Islam)
Supervisor

DEDI CATED
TO
MY PARENTS & TEACHERS

ACKNOWLEDGEMENTS

All praises to Almightly and Kindfull trust on to "Omnipotent God" for His never-ending blessing, the author deems it a great pleasure to express his profound gratefulness to his respected parents, who entiled much hardship inspiring for prosecuting his studies, receiving proper education.

The author likes to express his deepest sense of gratitude to his respected Supervisor ***Dr. Md. Shahidul Islam****, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period and gratuitous labour in conducting and successfully completing the research work and in the preparation of the manuscript writing including data analysis.*

The author also expresses his gratefulness to his respected Co-Supervisor ***Dr. Md. Hazrat Ali****, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimable help, valuable suggestions throughout the research work and in preparation of the thesis.*

The author expresses his sincere gratitude towards the sincerity of the Chairman, ***Professor Dr. H.M.M. Tariq Hossain****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his valuable suggestions and cooperation during the study period. The author also expresses heartfelt thanks to all the teachers of the Department of Agronomy, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.*

The author expresses his sincere appreciation to his parents, brother, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

EFFECT OF SOWING DATE AND GIBBERELLIC ACID ON WATER RELATIONS AND YIELD OF LENTIL UNDER RESIDUAL SOIL MOISTURE CONDITION

ABSTRACT

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2012 to March 2013 to study the effect of gibberellic acid and sowing date on water relations and yield of lentil (variety: BARI Masur-6) under residual soil moisture condition. The experiment consists of two factors: Factor A: Sowing date (3) - S_1= 27 November, S_2= 7 December and S_3 = 17 December; Factor B: GA_3 application (just before flowering) (3 levels) - G_0 = 0 ppm (Control); G_{100} = 100 ppm and G_{200} = 200 ppm. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different water relations, yield and yield contributing characters were recorded and variation was observed. Highest exudation rate (ER) (11.22 mg hr^{-1}) and relative water content (RWC) (78.02%) was found from S_1 (sowing on 27 November), in contrary lowest ER (4.67 mg hr^{-1}) and RWC (70.42%) was found from S_3 (sowing on 17 December). Maximum days to first flowering (46 DAS), pod maturity (98.89 DAS), pods per plant (39.91), pod length (2.35 cm), seeds per pod (1.90), thousand seeds weight (18.58 gm), seed yield (0.98 t ha^{-1}) and stover yield (1.24 t ha^{-1}) was found from sowing on 27 November. Whereas, minimum days to first flowering (41 DAS), pod maturity (91.11 DAS), pods per plant (15.38), pod length (1.44 cm), seeds per pod (1.18), thousand seeds weight (15.55 gm), seed yield (0.54 t ha^{-1}) and stover yield (0.67 t ha^{-1}) was found from sowing on 17 December. Highest ER (10.89 mg hr^{-1}) and RWC (79.12%) was found from G_{200} (200 ppm GA_3), in contrary lowest ER (5.33 mg hr^{-1}) and RWC (70.28%) was found from G_0 (control). For 200 ppm GA_3 application days to first flower bud initiation was earlier (42.67 DAS) than 100 ppm GA_3 (43.33 DAS) and control (44.44 DAS). Highest pods per plant (32.08), thousand seeds weight (18.38 gm), seed yield (0.82 t ha^{-1}) and stover yield (1.13 t ha^{-1}) was found from G_{200} (200 ppm GA_3). Whereas, lowest pods per plant (22.04), thousand seeds weight (16.44 gm), seed yield (0.69 t ha^{-1}) and stover yield (0.80 t ha^{-1}) was found from G_0 (control). For sowing on 27 November seed yield was increased 17.65% and 29.41% due to 100 ppm and 200 ppm GA_3 application respectively over control. For sowing on 7 December seed yield was increased 14.49% and 18.84% due to 100 ppm and 200 ppm GA_3 application respectively over control. But, the effect of GA_3 application was insignificant on yield for sowing on 17 December. It was revealed that yield of BARI Masur-6 can be significantly increased by applying 200 ppm GA_3 and 100 ppm GA_3 for sowing on late November and early December respectively. But, for sowing on late December foliar application of GA_3 is useless under residual soil moisture condition as application of GA_3 did not increase yield significantly.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

Abbreviation	Full meaning
AEZ	Agroecological zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
CV	Coefficient of variation
DAS	Days after sowing
ER	Exudation rate
FAO	Food and Agricultural Organization
$mg\ hr^{-1}$	Milligram per hour
$mg\ L^{-1}$	Milligram per litre
ppm	Parts per million
RWC	Relative water content
SRDI	Soil Resources Development Institute
STY	Stover yield
SY	Seed yield
$t\ ha^{-1}$	Ton per hectare
TSW	Thousand seeds weight
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

Pulses are vital components in diversification of Bangladesh's predominantly rice-based cropping system. On an average 222,000 tons of pulses are produced in Bangladesh every year occupying 4% of total cropped area (BBS, 2008). Lentil (*Lens culinaris* Medik) is the second most important pulse crop in terms of area (82,970 ha) and production (80,442 t), but ranks the highest in consumer preference and total consumption (BBS, 2010). Bangladesh ranks tenth in the world in terms of area (89,840 ha) and production (93,000 t) of lentil. But production per unit area is very low (1035.2 kg ha^{-1}) as compared to other countries of the world (FAO, 2013). Greater Faridpur, Jessore, Kushtia, Pabna, and Rajshahi are the major lentil growing area in the country. The people of Bangladesh consume about 12.0 g of pulses per capita per day, far below the 45 g per day recommended by WHO (Islam and Ali, 2002). Lentil seed is a rich source of protein and several essential micronutrients such as K, P, Fe, Zn and beta-carotene (Bhatty, 1988; Sarker *et al*., 2007). Lentil stover is valued animal feed.

A number of agronomic practices have been found to influence the yield of pulse (Boztok, 1985). Sowing time had a remarkable effect on growth and development of crops (Mittel and Srivastava, 1964). Optimum sowing time provides more time for growth and development of plant which is favourable for higher yield whereas both early and late sowing hinder the growth and development with lowest yield potential (Gurung *et al.*, 1996). Sowing date significantly affect the growth, yield and yield contributing characters of lentil. Al-Hussien *et al.* (2002) reported that different sowing dates (early and late) significantly affected number of branches per plant of lentil. Delay sowing of lentil under residual soil moisture condition may create water scarcity in soil and plant.

Plant growth regulators are the chemicals which influence the plant growth when applied in very minute quantity. There are many reports which indicate that application of growth regulators enhanced plant growth and crop yield. The gibberellins are a large family of tetracyclic diterpenoid plant growth substances. The function of gibberellic acid (GA_3) as a hormone in regulating plant growth is known as early as 1950s (Brian and Hemming, 1955; Vlitos and Meudt, 1957). GA_3 is associated with various plant growth and development processes such as seed germination, stem and hypocotyl elongation, leaf expansion, floral initiation, floral organ development, fruit development (Matsuoko, 2003). The successful fertilization of the ovule is followed by cell division and cell expansion. GA_3 is known to influence both cell division and cell enlargement (Adams *et al.*, 1975; Kamijima, 1981). Lee *et al.* (1999) reported that GA_3 increased stem length and number of flower per plant. Kabar (1990) found that GA_3 accelerated bud development and stem elongation.

Water is absolutely necessary for the functioning of protoplasm of cell. Thus adequacy and inadequacy of water are the limiting factors for life both in land and water environments (Onwugbuta, 2004). The adequacy and inadequacy of water reflected on the status of plant water relations *viz.* leaf water potential, relative water content, exudation rate etc. of a plant (Omae *et al.*, 2007). It has been well documented that water stress reduces growth and yield of legumes to a great extant (Ohashi *et al.*, 2000).The yield reduction is mainly attributed due to low pod set and early pod abscission. However various morphological and physiological changes occur in plants due to water stress, which make the plants either tolerant or susceptible to that condition (Subbarao *et al.,* 1995). However, morphological and physiological modifications, either by reducing transpiration loss or by increasing water absorption capacity, make the plants adaptable to water stress.

Hormonal regulation of plant growth and metabolism is a complex process. Water stress affects many metabolic pathways, mineral uptake, membrane structure etc. Therefore, it is not surprising that phytohormone synthesis can also be changed by water stress. Plant hormones are the main signals in root to shoot communication and vice-versa (Davies and Zhang, 1991; Tardieu and Davies, 1993; Naqvi, 1994) and the change in hormonal balance might play a key role in the sequence of events induced by water stress (Itai, 1999).

Balanced levels of endogenous growth regulators greatly influence morphological and physiological characters of a plant. Water stress inhibits the synthesis or the movement of endogenous growth promoters like auxin, gibberellin and cytokinin. Contrary, it stimulates the synthesis or activity of endogenous growth retardants like abscisic acid (ABA), ethylene etc. (El Saeid *et al.*, 1994). Thus water stress causes imbalance in the levels of endogenous growth regulators. Water stress also significantly reduced internal water status of the plant such as relative water content (RWC), water potential, exudation rate (ER) etc. (Kumari and Bharti, 1988). Growth regulators modify the growth response of plants to water stress by changing their internal water status. Although drought generally causes a reduction in cytokinin, IAA, and GA_3 levels, there are few reports about increases in phytohormones during water stress (Nelson and Orcutt, 1996).

Yield of lentil increases with irrigation (Panwar and Paliwal, 1975), while other have reported small or negative responses to irrigation (Ojha *et al.*, 1977; Jermyn *et al.*, 1981). The variable response to irrigation reported in many experiments with grain legumes may be due to the lack of quantification of drought.

In Bangladesh lentil is grown in rabi season. But in some low lying areas where flood water takes time to go down, lentil is grown in late rabi season. In that time (late November to late December) the crop experiences severe drought condition.

It adversely affects the yield of lentil. So this experiment was done to find out the possibility of minimizing this effect.

Lentil is very popular among the people of third world countries like Bangladesh because the other protein sources like meat is very expensive in these countries. With the ever growing population of third world countries the demand of lentil increased, so it is the urgent need of the present age that the yield of this crop should be increased using different means. The use of growth regulators is becoming popular to enhance crop productivity and varieties of such substances are available in the market which is being utilized for crop production. There is little known about how, or whether, GA_3 affects development of lentils. The present work was undertaken to determine how water availability and GA_3 affect yield of lentil grown in different times.

Keeping in view the above factors the present experiment was conducted with the following objectives:

i. To find out the effect of GA_3 level on water relations of lentil under residual soil moisture condition.
ii. To investigate the effect of sowing date on water relations of lentil under residual soil moisture condition.
iii. To observe the combined effect of sowing time and GA_3 level on the yield and yield contributing characters of lentil.

CHAPTER 2

REVIEW OF LITERATURE

In Bangladesh and in many countries of the world lentil is an important pulse crop. The crop has conventional less attention by the researchers on various aspects because normally it grows without care or management practices. Based on this a very few research work related to effect of sowing date and gibberellic acid on water relations and yield of lentil have been carried out in our country. However, researches are going on in home and abroad to maximize the yield of lentil. Sowing date and gibberellic acid affect the yield of lentil significantly. But research works related to gibberellic acid on lentil are limited in Bangladesh context. However, some of the important and informative works and research findings related to the effect of sowing date and gibberellic acid so far been done at home and abroad have been reviewed in this chapter under the following headings:

2.2. Effect of sowing date

Sowing date significantly affect water content of plant and yield of different crops that were observed by different reseachers. These are summarized below:

Inderjit *et al.* (2005) conducted a field experiment on sandy-loam soil of Gurudaspur, Punjab, India, during the 1998-2000 winter season to study the effect of different sowing dates, row spacing and seed rates on the productivity of lentil (*Lens culinaris* cv. LG 308) and reported significant effect for emergence of seedling for different sowing date.

The optimum sowing time and seed rate for the growth and yield of large-seeded lentil cv. Diskiai and the small-seeded cv. Smelinukai were investigated by Kazemekas (2001) on light loamy soil in Lithunia from 1998 to 2000 and was reported that sowing time significantly influenced seedling germination due to different levels of available soil moisture condition. He also found that the earliest sowing date were optimum for the optimum flowering and maturity.

The effects of sowing date (1 January, 15 January and 2 February), plant density, phosphorus level and ethophone application were investigated in the semi-arid region in the north of Jordan by Turk *et al.* (2003) reported significant effect regarding seedling emergence for different sowing time and early sowing (1 January) ensured high plant density (120 plants m^{-2}) and high yields were obtained for early sowing (1 January).

Gurung *et al.* (1996) carried out a field experiment in 1991-94 at Dhankuta, Nepal to determine the appropriate sowing date for lentils and reported that October sowings were associated with early good crop vigour with highest percentage of seedling germination. They also reported that warmer air temperature during vegetative growth period and longer total growth period, seed yield from September sowing was low. This was mainly due to excess rainfall during early vegetative growth stage which had adverse effects on crop establishment.

Siddique *et al.* (1998) reported that sowing in late April or early May allowed a longer period for vegetative and reproductive growth, rapid canopy development, more water use, and, hence, greater dry matter production. Early sown lentils began flowering and filling seeds earlier in the growing season, at a time when vapour pressure deficits and air temperatures were lower. The values of water use efficiency for dry matter production and transpiration efficiency, for early sown lentil were comparable to those reported for cereal and other grain legume crops in similar environments.

Bukhtiar *et al.* (1991) observed that the higher hervest index (HI) of 42.3% in AARIL344 and 41.4% in AARIL337 was obtained from 23 November sowing. The lower HI (25.1%) was recorded in AARIL355 sown on 26 September. The last week of October was found better with an optimum range from the end of

September to 2nd week of November. Yeild of lentil varied significantly for different sowing date.

Lal *et al.* (2006) found maximum disease intensity (51%) was recorded in 15 October-sown crop, while maximum seed yeild (730 kg ha^{-1}) was obtained in crop sown as 5 November. Higher seed yields were achieved through the contribution of higher total dry matter, more pods per plant and bigger seeds.

Hossain *et al.* (2006) reported that lentil aphid appeared in the field in the first week of January. The crop sown in November received less aphid infestation and cousequently produced higher yeild than the crop sown in December.

The perfomance of lentil cv. Giza 9 were investigated Allam (2002) under various sowing dates (1 November, 15 November and 1December) and reported that sowing on 1 November gave higher number of pods per plant, number of seeds per pod and seed yield per plant. Harvest index was higher when sowing was conducted in 1 to 15 November.

Mishra *et al.* (1996) reported that seed yield decreased with delay in sowing date after 23 October and the weed free control gave the highest yield.

A research was conducted by Soltani *et al.* (2015) in Qazvin Plain, Iran, during 2011-2012. In this research, supplemental irrigation and sowing dates, which are two effective factors on productivity of rainfed lentils were investigated. The treatments included two sowing dates and four irrigation levels. The sowing dates were April 4 and April 14, and the irrigation treatments were: no irrigation, single irrigation at seedling stage, single irrigation at pod filling stage, and double irrigation at both of these stages. The results showed that the effects of the two factors on grain yield and biomass were highly significant at the 1% level, both separately and simultaneously. The sowing date of April 4 led to a rise in yield components. Although the double irrigation treatment with 1,329.4 kg ha^{-1} had the most grain yield, the single irrigation treatment at seedling stage with the irrigation water productivity of 1.878 kg m^{-3} was the best approach when water productivity was considered. The results indicated that single irrigation at the seedling stage had better water productivity than the double irrigation treatment.

Silim *et al.* (1991) conducted a field experiment to determine the effect of advancing the sowing date from early February to November on the growth and seed and straw yields of three large seeded and three small seeded lines of lentil (*Lens culinaris*) under rainfed conditions in northern Syria between 1982 and 1985. The average seed and straw yields from early winter sowing were 838 and 2476 kg ha^{-1} compared with 679 and 1470 kg ha^{-1}, respectively, from a late sown crop.

A field experiment was conducted by Kayan (2010) where three different sowing dates (1^{st}, 15^{th} and 30^{th} October) were located into the main plots. Plant height, first pod height, biological yield per plant, number of pods per plant, number of seeds per plant, grain yield per plant, biological yield, grain yield and harvest index were recorded. Sowing date had a significant effect on yield and yield components. The most suitable period for winter lentil sowing date is between 1^{st} and 15^{th} of October.

Krishna and Pandey (1985) conducted a field experiment to determine the effects of different soil moisture regimes on lentils grown in different sowing dates in two seasons (1978-79 and 1979-80) in North India. Earlier sowing with irrigation increased both seed yields and straw yield.

McKenzie (1987) reported that sowing date caused the most marked effect on lentil yield. At populations of about 150 plants m^{-2}, autumn/winter sowings yielded from 2.4 to 3.3 t seed ha^{-1} and spring sowings yielded from 0.5 to 1.5 t seed ha^{-1}. Seed yields in the 1985-86 field experiment were much lower due to a severe outbreak of *Botrytis cinerea*. For the relatively disease free unirrigated plots, sowing date again had the major effect on seed yield. The unirrigated May sowing yielded 1. 5 t seed ha^{-1}, with the August sowing yielding about 0.8 t ha^{-1}.

In Sudan, El-Sanag and Nourai (1983), found that delaying sowing from 1 October until 21 October increased seed yield by 217 %, while sowing after the first week in November generally significantly reduced yield.

2.1. Effect of Gibberellic Acid (GA_3)

Gibberellic Acid (GA_3) significantly affect water content of plant and yield of different crops that were observed by different reseachers. These are summarized below:

Abdel and Al-Rawi (2012) conducted a field experiment in Iraq where Baraka, Adlib and Nineveh lentil cultivars were grown during 2010 growing season in order to discriminate the performance differences between these cultivars under rainfall incidences and supplementary irrigation whenever 25, 50, and 75% of soil water available capacity was depleted, and to find out the crucial growth stage for supplementary watering and the possibility of improving plant growth by the aid of GA_3 rates namely 0, 100, and 200 mg L^{-1}. They observed that application of GA_3 substantially improved most yield component traits, particularly that found in (200 mg L^{-1}) which exceeded that of untreated in seed yield per plant (7.85%) and harvest index (14.94%). Yield improvement brought about by gibberellins applications might be attributed to the role of gibberellins in growth, and flowering performances. Regression analysis revealed that lentil yield components were linearly responded to varying GA_3 rates accept that of biomass which manifested quadratic correlation.

Ahmed *et al.* (1989) found that retardation of proline accumulation may lead to the conclusion that each of the three phytohormones (IAA, GA_3 or kinetin) used could alleviate the adverse effects of water stress. If proline accumulation is considered as an indication of stress injury, thus it can be said that, the exogenously applied growth hormones seem either to protect the plant against water stress injury and consequently the synthesis of proline is retarded, and/or to play a specific role in proline transformations to other growth constituents.

Aktas *et al.* (2008) found that higher GA_3 and Zeatin content in acclimated seedlings corroborated with better maintained photochemical efficiency of PSII. This adaptive response reflected the increased surviving capacity of acclimated seedlings when exposed to drought stress in field conditions.

Sedghi *et al.* (2012) conducted two greenhouse experiments to evaluate the effect of phytohormones on the changes of antioxidant enzymes and carotenoids in petals of pot marigold (*Calendula officinalis* L.) under drought stress. Results showed that the activities of superoxide dismutase and catalase increased 47 and 73%, respectively, in petals under water deficit conditions compared with the control plants. Spraying with gibberellic acid (GA_3) and benzyl amino purine (BAP) alleviated drought effects, but application of abscisic acid (ABA), jasmonic acid (JA), salicylic acid (SA) and brassinolid (BR) induced the activity of these enzymes.

Keykha *et al.* (2014) conducted a field experiment at Islamic Azad University, Zahedan, Iran to evaluate the effect of salycylic acid and gibberellic acid on some characteristics in mungbean (*Vigna radiata*) and found that both salycylic acid and gibberellic acid affect the grain yield of mungbean significantly.

A field experiment was conducted by Naeem *et al.* (2004) in Faisalabad, Pakistan to investigate the effect of some growth hormones (GA_3, IAA and kinetin) on the morphology and early or delayed initiation of bud of lentil *(Lens culinaris* Medik*)*.

The hormones viz., 1.5 mM (500 mg L^{-1}) GA_3, 2.85 mM (500 mg L^{-1}) IAA and 0.14 mM (30 mg L^{-1}) kinetin were applied individually as well as in combination i.e., 1.5 mM GA_3 + 2.85 mM IAA, 1.5 mM GA_3 + 0.14 mM kinetin, 2.85 mM IAA + 0.14 mM kinetin and 1.5 mM GA_3 + 2.85 mM IAA + 0.14 mM kinetin. GA_3 showed a marked elongation in the length of shoot and increase in the number of internodes and compound leaves. Application of IAA showed a decrease in length of shoot and number of internodes. Kinetin showed inhibition in length and in the number of internodes. The combined dose of GA_3+IAA, GA_3+kinetin and GA_3+IAA+kinetin showed a significant increase in length and number of internodes as well as in the number of compound leaves. In GA_3 treated plants, early flowering with higher number of floral buds was recorded. Applied IAA caused late flowering and increased the number of floral buds, while kinetin showed no significant delay in flowering but number of floral buds was more as compared to control. The mixed doses of GA_3 with IAA and kinetin revealed early flowering along with insignificant increase in the number of flower buds. However, the dose of IAA+kinetin promoted late flowering with noticeable increase in number of floral buds. In GA_3 the first floral bud appeared on 42^{nd} day, which shows early flowering as compared to control (45^{th} day).

Milansei *et al.* (2008) conducted a field experiment to evaluate the rate and time of GA_3 application and irrigation on plant morphology and yield of lentil. The experiment was conducted in the experimental field of Rosario University (33°1′ S and 60°53′ W) in Argentina using cv. Silvina. A three-factor experiment including use of, or no, irrigation; gibberellic acid concentration (4); and application times (2) was arranged in a completely randomized design with three replications. Four concentrations of GA_3 (0, 10, 50, and 100 mg L^{-1}) were applied at 42 days post emergence and at flower initiation, which occurred at approximately 67 days. Concentration of GA_3 affected plant height, numbers of branches and pods, 100 seed weight, and yield. The 10 mg L^{-1} concentration of GA_3 resulted in increased yield and increased percentage of pods with two seeds. The 50 mg L^{-1} concentration of GA_3 produced more branches. Application of GA_3 at flowering increased yield by 60%. Irrigation produced the greatest number of pods and the highest yield. They concluded that lentil production can be increased by applying concentrations of GA_3 between 10 and 50 mg L^{-1} at flowering.

Bora and Sarma (2006) conducted a field experiment at Gauhati University, Assam, India to find out the effect of Gibberellic acid (GA_3) and Cycocel [(2-Chloroethyl) trimethyl ammonium chloride] singly on growth, yield and protein content of pea (cv. Aparna and Azad-P-1). The experiment was carried out in a randomized block design with three replications. Concentrations of PGRs used 10, 100, 250, 500 and 1000 µg mL^{-1}. Both the hormones significantly affected the yield characteristics. GA_3 at 250 µg mL^{-1} produced maximum number of pods per plant, seed yield, seed index and protein content in seeds in both the varieties. Cycocel at 100 and 250 μg^{-1} mL recorded maximum number of pods per plant and seed yield in cv. Azad-P-1 and cv. Aparna, respectively. Protein content in seeds was recorded highest at 500 µg mL^{-1} of cycocel. They concluded that judicious application of GA_3 and cycocel can increase yield and protein content in seeds of pea.

From the above review of literature, it is noticed that sowing date and gibberellic acid (GA_3) application exerted significant influence on growth, yield and yield contributing characters of pulse crops like lentil. Majority of the authors reported that lentil response differently to different sowing date and gibberellic acid levels.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted during the period from November 2012 to March 2013 to study the effect of sowing date and gibberellic acid (GA_3) on water relations and yield of lentil (*Lens culinaris*) under residual soil moisture condition. This chapter includes materials and methods that were used in conducting the experiment and presented below under the following headings:

3.1. Experimental site

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^0 74'$N latitude and $90^0 35'$E longitude (Anon., 1989).

3.2. Soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical properties. The analytical data of the soil sample collected from the experimental area were determined in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka and presented in Appendix I.

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 (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfalls during the period of the experiment was collected from the

Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar and presented in Appendix II.

3.4. Planting material

BARI Masur-6 was used as the test crop. The seeds were collected from the Pulse Seed Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701. It was developed by Pulse Research Center, Ishurdi, Pabna under the technical assistance by International Center for Agricultural Research in the Dry Areas (ICARDA) in 2006. It is a recommended variety by National Seed Board. Sowing time is mid October to mid November and harvesting time is mid February to mid March. It is resistant to rust and tolerant to foot rot, moderately resistant to aphid. Maximum seed yield 2.2-2.3 ton ha^{-1}. Seeds contain 27.12% protein and 59.40% carbohydrate (Anon., 2008).This variety has now highly been accepted by the farmers in the country.

3.5. Land preparation

The land was first opened with the tractor drawn disc plough. Then the soil was ploughed and cross ploughed. Ploughed soil was then brought into desirable fine tilth by the operations of ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 22 November and 25 November 2012, respectively. 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. Fertilizer application

Urea, Triple super phosphate (TSP) and Muriate of potash (MOP) were used as a source of nitrogen, phosphorous and potassium, respectively. Urea, TSP and MOP were applied at the rate of 45, 85 and 35 kg per hectare, respectively as basal dose at the time of final land preparation, following the Bangladesh Agricultural Research Institute (BARI) recommendation.

3.7. Treatments of the experiment

The experiment consists of two factors:

Factor A: Sowing date (3)

i) S_1 = Sowing on 27 November

ii) S_2 = Sowing on 7 December

iii) S_3 = Sowing on 17 December

Factor B: Gibberellic acid (GA_3) application (3 levels)

i) G_0 = 0 ppm (Control)

ii) G_{100} = 100 ppm

iii) G_{200} = 200 ppm

There were in total 9 (3×3) treatment combinations such as S_1G_0, S_1G_{100}, S_1G_{200}, S_2G_0, S_2G_{100}, S_2G_{200}, S_3G_0, S_3G_{100} and S_3G_{200}.

3.8. Experimental design and layout

The two-factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 30.4 m ×8 m was divided into three equal blocks. Each block was divided into 9 plots where 9 treatment combinations were allotted randomly. There were 27 unit plots altogether in the experiment. The size of the each unit plot was 3.0 m × 2.0 m. The space between two blocks and two plots were 0.5 m and 0.3 m, respectively. The layout of the experiment is shown in Figure 1.

3.9. Seed Sowing

The seeds of lentil were sown as per sowing date of treatment in solid rows in the furrows having a depth of 2-3 cm and line to line distance was 30 cm. Before sowing seeds were treated with Bavistin to control the seed borne disease.

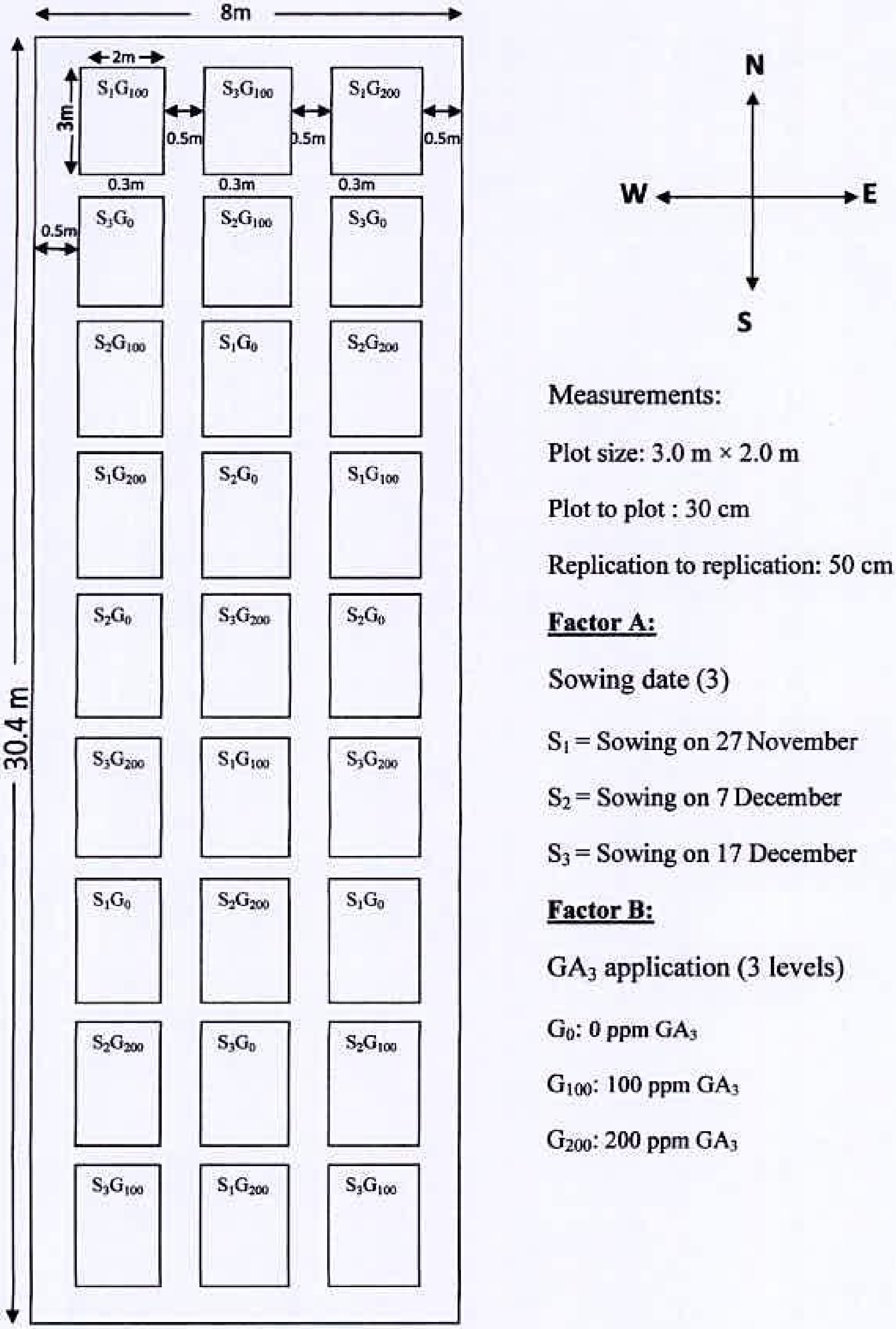

Figure 1. Field layout of two-factorial experiment in the Randomized Complete Block Design (RCBD)

3.10. Intercultural operations

3.10.1. Thinning

Thinning was done two times; first at 10 days after sowing and second at 17 days after sowing maintaining 10 cm distance between plants to obtain proper plant population in each plot.

3.10.2. Irrigation

The plants were irrigated with water at the appearance of first wilting symptom by using water can. Amount of water was 10 L $plot^{-1}$.

3.10.3. Weeding

Weeding was done as per requirements.

3.10.4. Preparation and application of GA_3

GA_3 solution was prepared three different times for three different sowing dates. Spraying was done just before first flowering. Each time, a concentration of 200 ppm of GA_3 was prepared by dissolving 1 gm of GA_3 in a small quantiy of ethanol prior to dilution with distilled water. The distilled water was added to make the volume 5 litre to get 200 ppm solution. After spraying 3 litre 200 ppm GA_3 solution in 3 plots (1 litre for each plot), 2 litre distilled water was added with rest of the 2 litre 200 ppm GA_3 solution to make 100 ppm solution. Then this 100 ppm solution was sprayed in 3 plots (1 litre for each plot). Spraying was done at noon using a hand sprayer.

3.10.5. Protection against pest

At later stage of growth, aphid attacked the plant of 17 December sowing. Malathion 57EC was sprayed at the rate of 1.12 L ha^{-1}.

3.11. Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown to golden brown in color.Before harvesting ten sample plants from each plot was marked and harvested for recording the data on different yield contributing characters. The matured plants were collected by hand picking from a pre demarcated three linear areas at the center of each plot and seeds were separated which was converted to t ha^{-1}.

3.12. Data Collection

The recorded data on the following parameters were recorded

i. Exudation rate (ER)
ii. Relative water content (RWC)
iii. Days to first flowering
iv. Days to 80% pod maturity
v. Number of pods per plant
vi. Pod length
vii. Number of seeds per pod
viii. Weight of 1000 seeds
ix. Seed yield per hectare
x. Stover yield per hectare

3.13. Procedure of data collection

3.13.1. Exudation rate (ER)

Exudation rate was measured from the stem at about 5 cm above from the ground. At first, dry cotton including celophane paper piece was weighed. A slanting cut on the stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface and was covered with the celophane paper piece. The exudation of the sap was collected from the stem for one hour at normal temperature. The final weight of the cotton with sap including celophane paper was taken. The exudation rate was calculated by deducting cotton weight including celophane paper from the sap containing cotton weight including celophane paper and was expressed as miligram per hour basis after three days of GA_3 application as follows:

$$\text{ER (mg hr}^{-1}) = \frac{\text{(Weight of cotton including celophane paper+sap)} - \text{(Weight of cotton including celophane paper)}}{\text{Time}}$$

3.14.2. Relative water content (RWC)

Relative water content (RWC) was measured from first fully expanded leaf of lentil plants in different treatments. The leaf samples were cut with a sharp knife with petiole and were put in a polythene bag treatment wise. The bags were kept on a tray and wrapped with a moist towel to avoid light and desiccation. Then the samples were brought in the laboratory and their fresh weights were recorded immediately. The leaf samples were then dipped in water for 24 hours and their turgid weights were recorded after soaking the leaf surface water gently by tissue paper. The samples were then oven dried to constant weight. The relative water content (RWC) was measured after three days of GA_3 application using the following formula:

$$\text{RWC} = \frac{\text{(Fresh weight} - \text{Dry weight)}}{\text{(Turgid weight} - \text{Dry weight)}} \times 100\%$$

3.13.3.Days to first flowering

Days to first flowering were recorded by counting the number of days required after sowing to start flower initiation in each plot.

3.13.4. Days to 80% pod maturity

Days to 80% pod maturity were measured by counting the number of days required after sowing to attain maturity of 80% pods. Maturity was measured on the basis of brown colour of leaves and stem and dark grey colour of pods.

3.13.5.Number of pods per plant

Numbers of total pods of ten randomly selected plants from each plot were counted and the mean numbers were expressed as per plant basis. The ten plants were selected at random from the inner rows of each plot.

3.13.6. Pod length

Pod length was measured from randomly selected ten pods and the mean length was expressed as per pod basis.

3.13.7. Number of seeds per pod

The number of seeds per pod was recorded from randomlyselected ten pods at harvest. Data were recorded as the average of 10 pods selected at random from each plot.

3.13.8. Weight of 1000 seeds

One thousand cleaned, dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (gm).

3.13.9. Seed yield

The seeds collected from $6m^2$ (3 m ×2 m) of each plot were sun dried properly. The weight of seeds was taken and converted the yield in t ha^{-1}.

3.13.10. Stover yield

The stover collected from 6 m^2 (3 m ×2 m) of each plot was sun dried properly. The weight of stover was taken and converted the yield in t ha^{-1}.

3.14. Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference due to different doses of GA_3 and sowing date on water relations, yield contributing characters and yield of lentil. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the LSD (Least Significant Difference) Test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to study the effect of sowing date and GA_3 on water relations and yield of lentil (variety: BARI Masur-6) under residual soil moisture condition. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix III-V. The results have been presented with the help of table and graphs and possible interpretations given under the following headings:

4.1. Exudation Rate (ER)

Exudation rate is known as the flow of sap per unit time from cut end of stem against the gravitational force. Exudation rate can be used as an indicator to measure the severity of water stress. Effect of sowing date on ER was statistically significant (Appendix III). The highest ER (11.22 mg hr^{-1}) was found from S_1 (sowing on 27 November) which was greater than the ER (7.56 mg hr^{-1}) found from S_2 (sowing on 7 December) (Table 1). The lowest ER (4.67 mg hr^{-1}) was found from S_3 (sowing on 17 December). Availability of water in the soil might be decreases as much as the sowing late. Water stress might be drastically reduced the exudation rate. Thus, later sowing decreased ER.

Exudation rate varied significantly due to different levels of GA_3 application under residual soil moisture condition (Appendix III). The highest exudation rate (10.89 mg hr^{-1}) was found in G_{200} (200 ppm GA_3 application), which was greater than the ER (7.22 mg hr^{-1}) found from G_{100} (100 ppm GA_3 application) (Table 2). The lowest ER (5.33 mg hr^{-1}) was found in G_0 (0 ppm GA_3 application).

Table 1. Effect of sowing date on exudation rate (ER), relative water content (RWC), days to first flowering and days to pod maturity of lentil under residual soil moisture condition

Treatment	Exudation rate ($mg\ hr^{-1}$)	RWC (%)	Days to first flowering (DAS)	Days to pod maturity (DAS)
S_1	11.22 a	78.02 a	46.00 a	98.89 a
S_2	7.56 b	74.84 ab	43.44 b	93.22 b
S_3	4.67 c	70.42 b	41.00 c	91.11 c
$LSD_{(0.05)}$	0.95	5.58	0.42	0.42
CV(%)	12.13	7.51	0.96	0.44

Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05); DAS = Days after sowing
S_1 = Sowing on 27 November; S_2 = Sowing on 7 December and S_3 = Sowing on 17 December

Table 2. Effect of GA_3 on exudation rate (ER), relative water content (RWC), days to first flowering and days to pod maturity of lentil under residual soil moisture condition

Treatment	Exudation rate ($mg\ hr^{-1}$)	RWC (%)	Days to first flowering (DAS)	Days to pod maturity (DAS)
G_0	5.33 c	70.28 b	44.44 a	93.44 c
G_{100}	7.22 b	73.88 ab	43.33 b	94.11 b
G_{200}	10.89 a	79.12 a	42.67 c	95.67 a
$LSD_{(0.05)}$	0.95	5.58	0.42	0.42
CV(%)	12.13	7.51	0.96	0.44

Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05); DAS = Days after sowing
G_0 = 0 ppm GA_3; G_{100} = 100 ppm GA_3 and G_{200} = 200 ppm GA_3

Interaction effect of sowing date and GA_3 on ER was statistically significant (Appendix III). The highest ER (15.00 mg hr^{-1}) was found in S_1G_{200} (sowing on 27 November with 200 ppm GA_3 application) and the lowest ER (3.00 mg hr^{-1}) was found from S_3G_0 (sowing on 17 December with 0 ppm GA_3 application) (Table 3).

Table 3. Interaction effect of sowing date and GA_3 on exudation rate (ER), relative water content (RWC), days to first flowering and days to pod maturity of lentil under residual soil moisture condition

Treatment	Exudation rate (mg hr^{-1})	RWC (%)	Days to first flowering (DAS)	Days to pod maturity (DAS)
S_1G_0	8.00 c	74.90 ab	47.00 a	98.00 b
S_1G_{100}	10.67 b	78.03 a	45.67 b	98.67 b
S_1G_{200}	15.00 a	81.12 a	45.33 b	100.00 a
S_2G_0	5.00 d	71.24 ab	44.33 c	92.33 d
S_2G_{100}	7.00 c	73.38 ab	43.33 d	93.00 d
S_2G_{200}	10.67 b	79.90 a	42.67 de	94.33 c
S_3G_0	3.00 e	64.69 b	42.00 e	90.00 e
S_3G_{100}	4.00 de	70.23 ab	41.00 f	90.67 e
S_3G_{200}	7.00 c	76.34 a	40.00 g	92.67 d
$LSD_{(0.05)}$	1.64	9.67	0.73	0.73
CV(%)	12.13	7.51	0.96	0.44

Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05); DAS = Days after sowing

S_1 = Sowing on 27 November; S_2 = Sowing on 7 December and S_3 = Sowing on 17 December

G_0 = 0 ppm GA_3; G_{100} = 100 ppm GA_3 and G_{200} = 200 ppm GA_3

4.2. Relative Water Content (RWC)

Relative Water content (RWC) signifies the water content of plants. Sowing date significantly influenced the RWC of the plant (Appendix III). The highest RWC (78.02%) was found in S_1 (sowing on 27 November), which was statistically similar in that found in S_2 (74.84%; sowing on 7 December). The lowest RWC (70.42%) was found in S_3 (sowing on 17 December), which was statistically similar to that found in S_2 (Table 1). Water stress reduces water availability in soil for plant and consequently reduces RWC. Baque *et al.* (2002) also observed that RWC decreases in water stress condition in his study with wheat.

There was a significant effect of GA_3 application on RWC of lentil (Appendix III). Highest RWC (79.12%) was found in treatment of G_{200} (200 ppm GA_3 application), which was statistically similar to the RWC (73.88%) found in treatment of G_{100} (100 ppm GA_3 application). The lowest RWC (70.28%) was found in treatment of G_0 (0 ppm GA_3 application) and was statistically similar to that of G_{100} and significantly different from that of G_{200} (Table 2).

Interaction effect of sowing date and GA_3 application on RWC was statistically significant (Appendix III). The highest RWC (81.12%) was found from S_1G_{200} (sowing on 27 November with 200 ppm GA_3 application), which was statistically similar to S_1G_{100}, S_2G_{200} and S_3G_{200} (78.03%, 79.90% and 76.34%, respectively). The lowest RWC (64.69%) was found from S_3G_0 (sowing on 17 December with 0 ppm GA_3 application) (Table 3).

4.3. Days to first flowering

Sowing date statistically influenced days to first flowering (Appendix III). Early flowering (41 DAS) was recorded in S_3 (sowing on 17 December) and late flowering (46 DAS) was in S_1 (sowing on 27 November) (Table 1). Days required for flowering varied significantly from each other due to sowing.

Effect of GA_3 on days to first flowering was statistically significant (Appendix III). Early flowering (42.67 DAS) was recorded for G_{200} (200 ppm GA_3) and late flowering (44.44 DAS) was recorded for G_0 (0 ppm GA_3) and were statistically different (Table 2). Foliar application of GA_3 in soybean increased stem diameter, promoted stem elongation and leaf formation, accelerates flowering, and increased flower stalk length and numbers of flowers (Eldabh *et al.*, 1978). Awan *et al.*, (1999) reported that exogenous application of GA_3showed early flowering in rice.

Interaction effect of sowing date and GA_3 on days to first flowering was varied significantly (Appendix III). Early flowering (40 DAS) was recorded in S_3G_{200} (sowing on 17 December with 200 ppm GA_3) and late flowering (47 DAS) was recorded in S_1G_0 (sowing on 27 November with 0 ppm GA_3) (Table 3). A pre-anthesis application of GA_3 results early flowering in indian mustard (*Brassica juncea* L.) and it was reported by Mobin *et al.* (2007).

4.4. Days to 80% pod maturity

Sowing date significantly influenced days to 80% pod maturity (Appendix III). Early pod maturity (91.11 DAS) was recorded in S_3 (sowing on 17 December) and late pod maturity (98.89 DAS) was recorded in S_1 (sowing on 27 November) (Table 1).

Effect of GA_3 on days to 80% pod maturity was statistically significant (Appendix III). Early pod maturity (93.44 DAS) was recorded in G_0 (0 ppm GA_3) and late maturity (95.67DAS) was recorded in G_{200} (200 ppm GA_3) (Table 2).

Interaction effect of sowing date and GA_3 on days to 80% pod maturity was also significant (Appendix III). Early pod maturity (90 DAS) was found from S_3G_0 (sowing on 17 December with 0 ppm GA_3) and late 80% pod maturity (100 DAS) was recorded in S_1G_{200} (sowing on 27 November with 200 ppm GA_3) (Table 3).

4.5. Pod length

Effect of sowing date on pod length was significant (Appendix IV). Highest pod length (2.35 cm) was recorded in S_1 (sowing on 27 November), which was statistically similar to S_2 (sowing on 7 December) and lowest pod length (1.44 cm) was recorded in S_3 (sowing on 17 December) (Table 4).

Effect of GA_3 on pod length was statistically insignificant (Appendix IV). Highest pod length (2.08 cm) was recorded in G_{200} (200 ppm GA_3) which was statistically similar to G_0 and G_{100} (1.99 cm and 2.02 cm respectively) (Table 5).

Table 4. Effect of sowing date on pod length, pods per plant and seeds per pod of lentil under residual soil moisture condition

Treatment	Pod length (cm)	Pods per plant (no.)	Seeds per pod (no.)
S_1	2.35 a	39.91 a	1.90 a
S_2	2.30 a	23.99 b	1.46 b
S_3	1.44 b	15.38 c	1.18 c
$LSD_{(0.05)}$	0.11	1.37	0.08
CV(%)	5.64	5.18	5.68

Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05)
S_1 = Sowing on 27 November; S_2 = Sowing on 7 December and S_3 = Sowing on 17 December

Table 5. Effect of GA_3 on pod length, pods per plant and seeds per pod of lentil under residual soil moisture condition

Treatment	Pod length (cm)	Pods per plant (no.)	Seeds per pod (no.)
G_0	1.99 a	22.04 c	1.49 a
G_{100}	2.02 a	25.16 b	1.53 a
G_{200}	2.08 a	32.08 a	1.51 a
$LSD_{(0.05)}$	0.11	1.37	0.08
CV(%)	5.64	5.18	5.68

Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05)
G_0 = 0 ppm GA_3; G_{100} = 100 ppm GA_3 and G_{200} = 200 ppm GA_3

Interaction effect of GA_3 and sowing date was also significant for pod length (Appendix IV). Highest pod length (2.46 cm) was recorded in S_1G_{200} (sowing on 27 November with 200 ppm GA_3) and lowest pod length (1.40 cm) was recorded in S_3G_{200} (sowing on 17 December with 200 ppm GA_3) which was statistically similar to that in S_3G_0 and S_3G_{100} (1.51 cm and 1.41 cm, respectively) (Table 6).

Table 6. Interaction effect of sowing date and GA_3 on pod length, pods per plant and seeds per pod of lentil under residual soil moisture condition

Treatment	Pod length (cm)	Pods per plant (no.)	Seeds per pod (no.)
S_1G_0	2.27 ab	32.87 c	1.83 a
S_1G_{100}	2.33 ab	37.43 b	1.93 a
S_1G_{200}	2.46 a	49.43 a	1.93 a
S_2G_0	2.21 b	21.27 ef	1.47 b
S_2G_{100}	2.32 ab	23.57 e	1.50 b
S_2G_{200}	2.38 ab	27.13 d	1.40 b
S_3G_0	1.51 c	12.00 h	1.17 c
S_3G_{100}	1.41 c	14.47 g	1.17 c
S_3G_{200}	1.40 c	19.67 f	1.20 c
$LSD_{(0.05)}$	0.197	2.370	0.144
CV(%)	5.64	5.18	5.68

Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05)
S_1 = Sowing on 27 November; S_2 = Sowing on 7 December and S_3 = Sowing on 17 December
G_0 = 0 ppm GA_3; G_{100} = 100 ppm GA_3 and G_{200} = 200 ppm GA_3

4.6. Pods per plant

Effect of sowing date on pods per plant was significant (Appendix IV). Highest pods per plant (39.91) was counted forS_1 (sowing on 27 November) and lowest (15.38) forS_3 (sowing on 17 December) (Table 4). Allam (2002) reported that lentil sowing on 1 November gave higher number of pods per plant than that sowing on 15 November and 1 December.

Effect of GA_3 on pods per plant was statistically significant (Appendix IV). Highest pods per plant (32.08) was counted for G_{200} (200 ppm GA_3) and lowest pods per plant (22.04) was observed from G_0 (0 ppm GA_3) (Table 5). Khan *et al.* (1998) reported that application of GA_3 in *Brassica juncea* increased number of siliquae per plant. Similar result was also found in grass peas by Rahman *et al.* (1989).

Interaction effect of sowing date and GA_3 also significantly influenced pods per plant (Appendix IV). Highest pods per plant (49.43) was recorded in S_1G_{200} (sowing on 27 November with 200 ppm GA_3) and lowest (12.00) in S_3G_0 (sowing on 17 December with 0 ppm GA_3 (Table 6).

4.7. Seeds per pod

Effect of sowing date on seeds per pod was statistically significant (Appendix IV). Highest seeds per pod (1.90) was counted for S_1 (sowing on 27 November) and lowest (1.18) for S_3 (sowing on 17 December) (Table 4).

Effect of GA_3 on seeds per pod was statistically insignificant (Appendix IV). Highest seeds per pod (1.53) was counted for G_{100} (100 ppm GA_3), which was statistically similar to G_0 and G_{200} (1.49 and 1.51, respectively) (Table 5).

Statistically significant variation was recorded due to interaction effect of sowing date and GA_3 (Appendix IV). Highest number of seeds per pod (1.93) was counted for S_1G_{100} and S_1G_{200}, which was statistically similar to that in S_1G_0 (1.83). On the contrary, lowest number of seeds per pod (1.17) was recorded for S_3G_0 and S_3G_{100}, which was statistically similar to S_3G_{200} (1.20) (Table 6).

4.8. Thousand seeds weight

Statistically significant variation was recorded for weight of thousand seeds due to different sowing dates (Appendix V). The highest weight of thousand seed (18.58 gm) was recorded from S_1 (sowing on 27 November) which was statistically identical (18.23 gm) to S_2 (sowing on 7 December), whereas the lowest weight (15.55 gm) from S_3 (sowing on 17 December) (Table 7).

Weight of thousand seeds of lentil differed significantly due to different doses of GA_3 application (Appendix V). The highest weight of thousand seeds (18.38 gm) was recorded from G_{200} (200 ppm GA_3) followed by G_{100} (17.54 gm), while the lowest was obtained from G_0 (16.44 gm) (Table 8). Thousand seeds weight was increased by applying foliar spray with GA_3 in grass pea (Rahman *et al.*, 1989), in sesame (Sontakey *et al.*, 1991).

Thousand seeds weight showed significant differences due to the interaction effect of sowing date and GA_3 (Appendix V). The highest weight of thousand seeds (19.43 gm) was recorded from S_1G_{200}, which was statistically similar with S_1G_{100} and S_2G_{200} (18.68 gm and 18.67 gm respectively). The lowest weight of thousand seeds (14.20 gm) was from S_3G_0 (Table 9).

4.9. Seed Yield

Seed yield per hectare showed significant variation for different sowing dates (Appendix V). Highest yield (0.98 t ha^{-1}) was obtained from S_1 (sowing on 27 November) and lowest yield (0.54 t ha^{-1}) was obtained from S_3 (sowing on 17 December) (Table 7). Inderjit *et al.* (2005) reported that there was a significant reduction in seed yield with delay in sowing from 10 November to 10 December. Lentil sown on 10 November out yielded (14.6 q ha^{-1}) the crop sown on 25 November and 10 December by a margin of 12.8 and 90.1%, respectively. Muhammad *et al.* (2002) reported that sowing in November significantly enhanced seed yield by 113.2% in 1993-94 and 102.1% in 1994-95 compared to sowing in December. The highest seed yield in S_1 (sowing on 27 November) was attributed mainly due to maximum number of pods per plant and the highest thousand seeds weight.

Table 7. Effect of sowing date on thousand seeds weight (TSW), seed yield and stover yield of lentil under residual soil moisture condition

Treatment	TGW (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
S_1	18.58 a	0.98 a	1.24 a
S_2	18.23 a	0.77 b	1.02 b
S_3	15.55 b	0.54 c	0.67 c
$LSD_{(0.05)}$	0.553	0.0316	0.044
CV(%)	3.17	4.15	4.58

Means under a parameter, having a common letter separated by LSD test, do not differ significantly ($p=0.05$)
S_1 = Sowing on 27 November; S_2 = Sowing on 7 December and S_3 = Sowing on 17 December

Table 8. Effect of GA_3 on thousand seeds weight (TSW), seed yield and stover yield of lentil under residual soil moisture condition

Treatment	TSW (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
G_0	16.44 c	0.69 c	0.80 c
G_{100}	17.54 b	0.78 b	0.99 b
G_{200}	18.38 a	0.82 a	1.13 a
$LSD_{(0.05)}$	0.553	0.0316	0.044
CV(%)	3.17	4.15	4.58

Means under a parameter, having a common letter separated by LSD test, do not differ significantly ($p=0.05$)
G_0 = 0 ppm GA_3; G_{100} = 100 ppm GA_3 and G_{200} = 200 ppm GA_3

Table 9. Interaction effect of sowing date and GA_3 on thousand seeds weight (TSW), seed yield and stover yield of lentil under residual soil moisture condition

Treatment	TGW (gm)	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
S_1G_0	17.62 bc	0.85 c	0.96 c
S_1G_{100}	18.68 a	1.00 b (17.65%)	1.27 b
S_1G_{200}	19.43 a	1.10 a (29.41%)	1.48 a
S_2G_0	17.51 c	0.69 e	0.82 d
S_2G_{100}	18.52 ab	0.79 d (14.49%)	1.02 c
S_2G_{200}	18.67 a	0.82 cd (18.84%)	1.23 b
S_3G_0	14.20 e	0.52 f	0.63 e
S_3G_{100}	15.43 d	0.54 f (3.85%)	0.68 e
S_3G_{200}	17.03 c	0.55 f (5.77%)	0.69 e
$LSD_{(0.05)}$	0.957	0.054	0.077
CV(%)	3.17	4.15	4.58

Means under a parameter, having a common letter separated by LSD test, do not differ significantly (p=0.05); Figures in the parentheses indicate yield increase by GA_3 over control under respective sowing dates

S_1 = Sowing on 27 November; S_2 = Sowing on 7 December and S_3 = Sowing on 17 December

G_0 = 0 ppm GA_3; G_{100} = 100 ppm GA_3 and G_{200} = 200 ppm GA_3

Effect of GA_3 on seed yield was statistically significant (Appendix V). The highest seed yield (0.82 t ha^{-1}) was recorded from G_{200} (200 ppm GA_3), whereas the lowest seed yield (0.69 t ha^{-1}) was recorded from G_0 (0 ppm GA_3) (Table 8). Abdel and Al-Rawi (2012) reported that 100 and 200 mg L^{-1} GA_3 application highly improved seed yield per plant (15.55 and 24.44%, respectively) and harvest index (8.11 and 46.1%, respectively) in lentil grown under supplemental irrigation.

Foliar application of GA_3 in soybean increased total yield (Atal and Sethil, 1961; Maske *et al.*, 1998). Increasing the concentration of GA_3 in alfalfa and brome grass increased the growth and total yield (Bidlack and Buxton, 1995).

Interaction effect of sowing date and GA_3 on seed yield was significant (Appendix V). Highest seed yield (1.1 t ha^{-1}) was obtained from S_1G_{200}, which was statistically different from S_1G_{100} (1.0 t ha^{-1}), whereas lowest seed yield was recorded from S_3G_0 (0.52 t ha^{-1}), which was statistically identical with S_3G_{100} and S_3G_{200} (0.54 t ha^{-1} and 0.55 t ha^{-1} respectively) (Table 9).

4.10. Stover Yield

Different sowing dates showed significant difference in terms of stover yield per hectare (Appendix V). Highest stover yield (1.24 t ha^{-1}) was found from S_1 (sowing on 27 November) and lowest stover yield (0.67 t ha^{-1}) was found from S_3 (sowing on 17 December) (Table 7).

Statistically significant variation was recorded for stover yield per hectare due to different doses of GA_3 application (Appendix V). Highest stover yield (1.13 t ha^{-1}) was obtained from G_{200} (200 ppm GA_3), in contrary lowest stover yield (0.80t ha^{-1}) was obtained from G_0 (0 ppm GA_3) (Table 8).

Statistically significant variation was found due to the interaction effect of sowing date and GA_3 (Appendix V). Highest stover yield (1.48 t ha^{-1}) was obtained from S_1G_{200}, which was statistically different from S_1G_{100} (1.27 t ha^{-1}), whereas lowest stover yield was recorded from S_3G_0 (0.63 t ha^{-1}), which was statistically identical with S_3G_{100} and S_3G_{200} (0.68 t ha^{-1} and 0.69 t ha^{-1} respectively) (Table 9).

4.11. Relationship between relative water content and yield contributing characters

Analyses of functional relationship revealed that a significant positive relationship exhibited between exudation rate (ER) and pods per plant (Figure 2). The equation y = 2.799x + 4.550 gave a good fit to the data and the value of coefficient of determination ($R^2 = 0.828$) showed that the fitted regression line had a significant regression coefficient. It also indicated that 82.8% pods per plant was attributed due to ER.

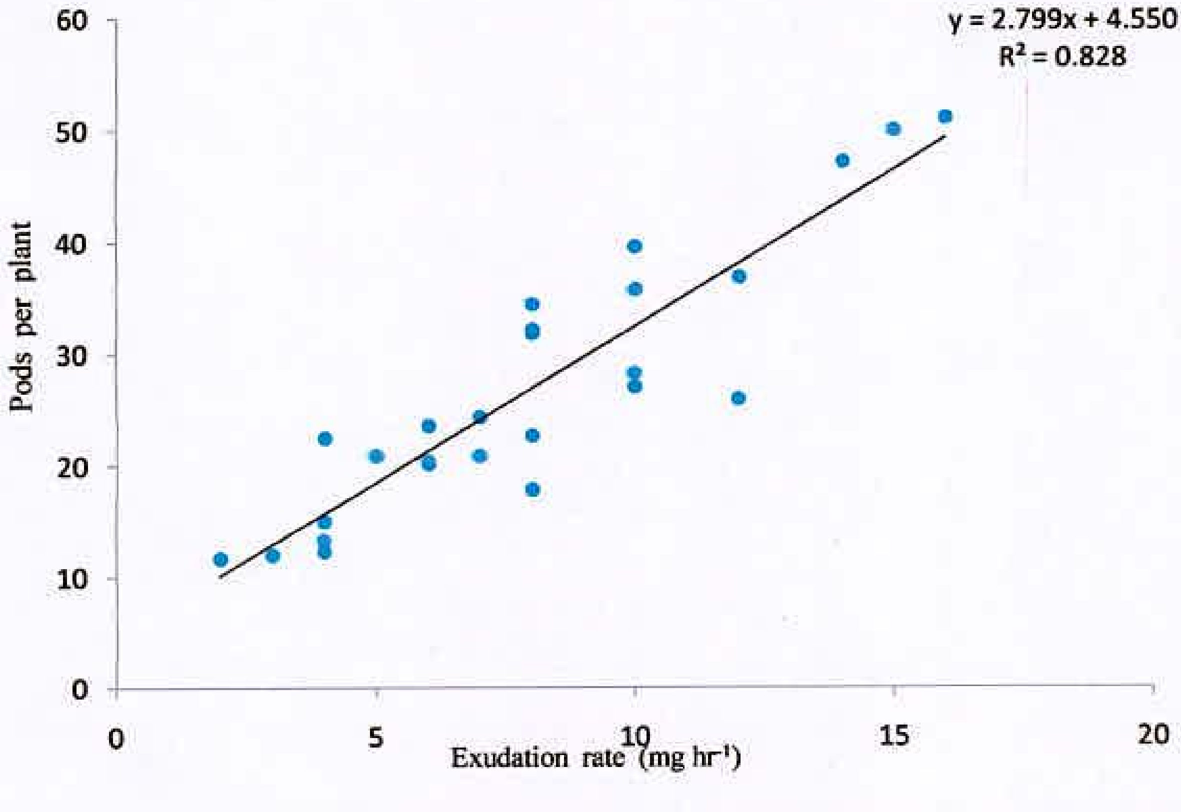

Figure 2. Functional relationship between exudation rate and pods per plant under residual soil moisture condition

A significant positive relationship was found between ER and seeds per pod (Figure 3). The equation y = 0.061x + 1.028 gave a good fit to the data and the value of coefficient of determination ($R^2 = 0.540$) showed that the fitted regression line had a significant regression coefficient. It also indicated that 54.0% seeds per pod was attributed due to ER.

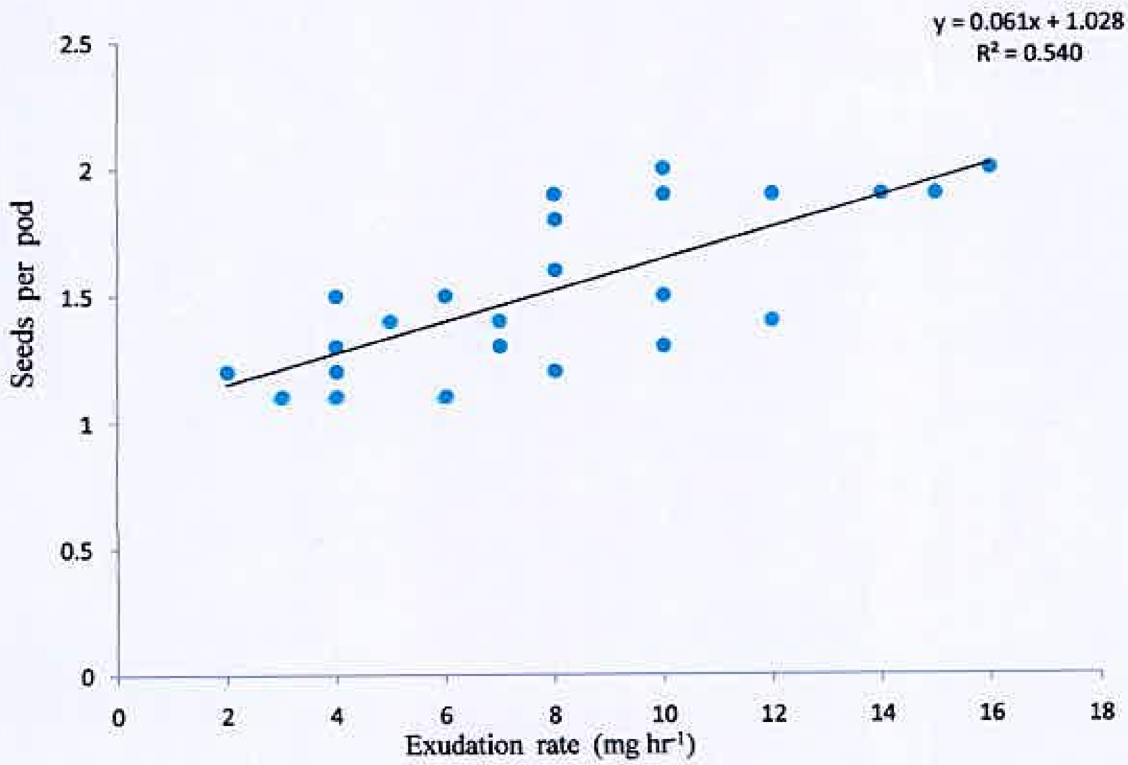

Figure 3. Functional relationship between exudation rate and seeds per pod under residual soil moisture condition

A significant positive relationship was found between ER and thousand seeds weight (TSW) (Figure 4). The equation y = 0.370x + 14.55 gave a good fit to the data and the value of coefficient of determination (R^2 = 0.671) showed that the fitted regression line had a significant regression coefficient. It also indicated that 67.1% TSW was attributed due to ER.

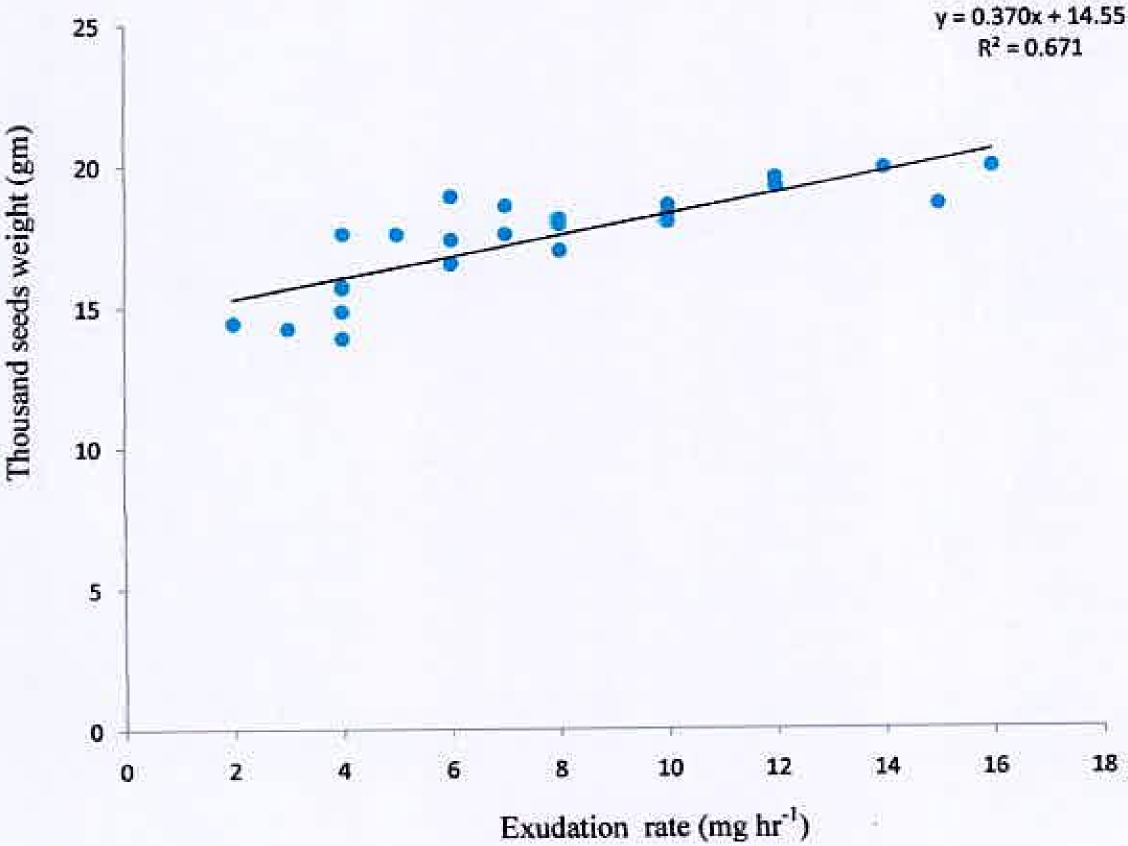

Figure 4. Functional relationship between exudation rate and thousand seeds weight under residual soil moisture condition

A significant positive relationship was found between ER and seed yield (SY) (Figure 5). The equation y = 0.047x + 0.393 gave a good fit to the data and the value of coefficient of determination ($R^2 = 0.766$) showed that the fitted regression line had a significant regression coefficient. It also indicated that 76.6% SY was attributed due to ER.

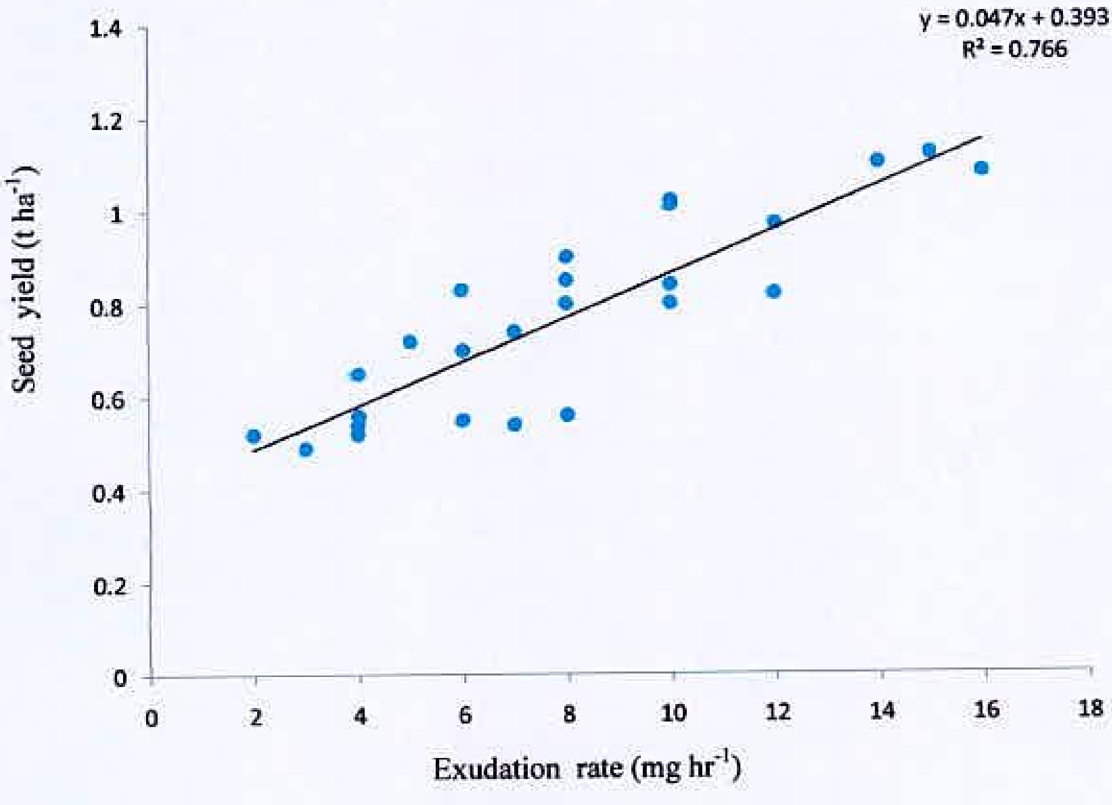

Figure 5. Functional relationship between exudation rate and seed yield under residual soil moisture condition

A significant positive relationship was found between ER and stover yield (STY) (Figure 6). The equation y = 0.071x + 0.414 gave a good fit to the data and the value of coefficient of determination ($R^2 = 0.845$) showed that the fitted regression line had a significant regression coefficient. It also indicated that 84.5% STY was attributed due to ER.

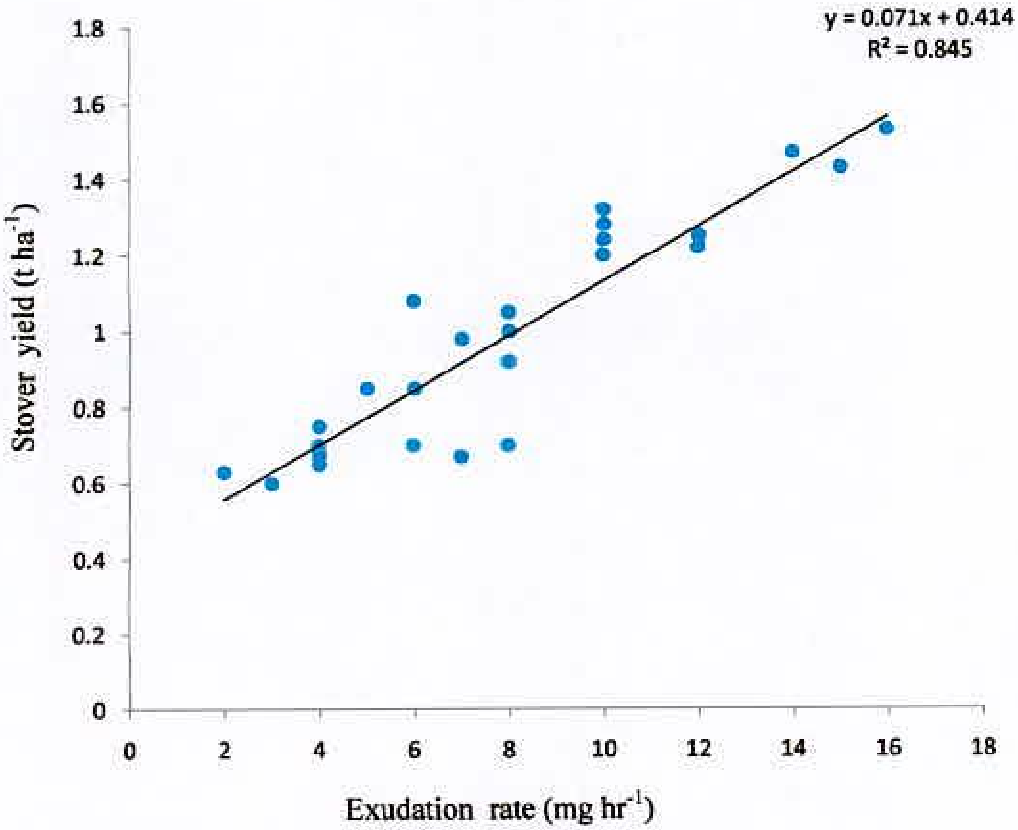

Figure 6. Functional relationship between exudation rate and stover yield under residual soil moisture condition

Analyses of functional relationship revealed that a significant positive relationship exhibited between relative water content (RWC) and pods per plant (Figure 7). The equation $y = 1.165e^{0.040x}$ gave a good fit to the data and the value of coefficient of determination ($R^2 = 0.39$) showed that the fitted regression line had a significant regression coefficient. It also indicated that 39% pods per plant was attributed due to RWC.

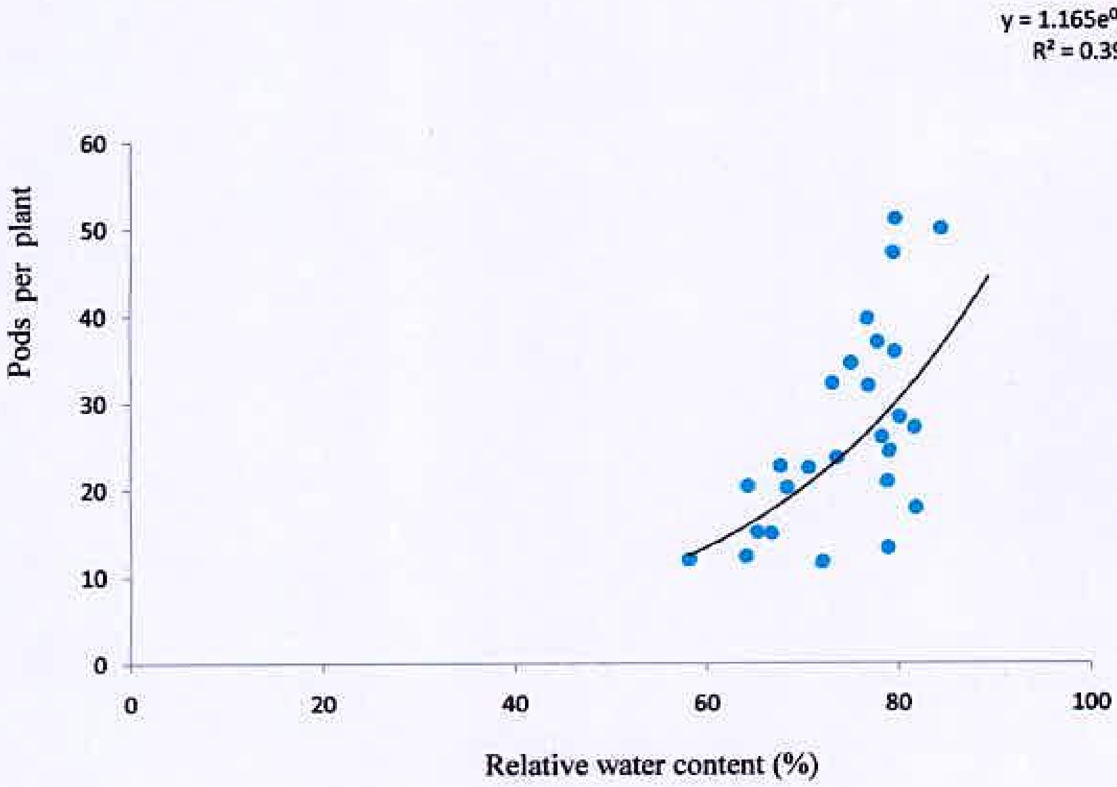

Figure 7. Functional relationship between relative water content and pods per plant under residual soil moisture condition

A significant positive relationship was found between RWC and seeds per pod (SPP) (Figure 8). The equation y = 0.020x + 0.016 gave a good fit to the data and the value of coefficient of determination (R^2 = 0.183) showed that the fitted regression line had a significant regression coefficient. It also indicated that 18.3% SPP was attributed due to RWC.

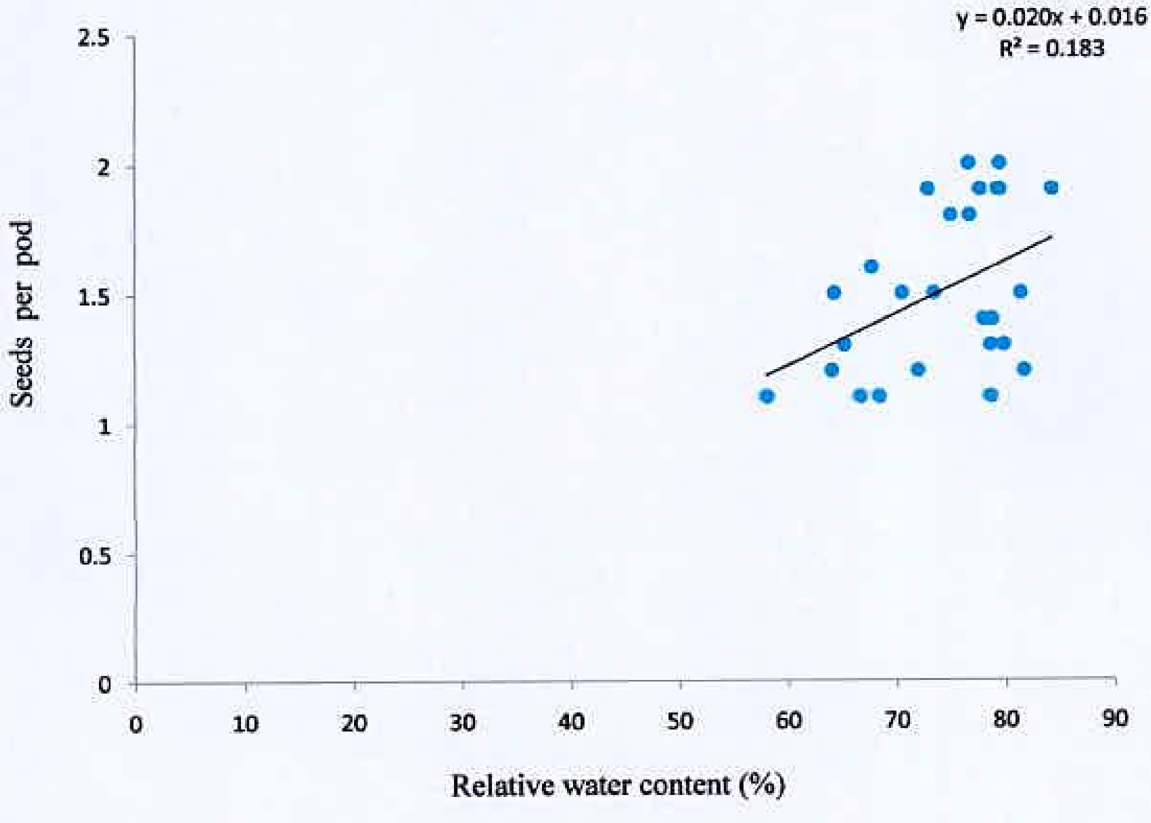

Figure 8. Functional relationship between relative water content and seeds per pod under residual soil moisture condition

A significant positive relationship was found between RWC and thousand seeds weight (TSW) (Figure 9). The equation y = 0.161x + 5.421 gave a good fit to the data and the value of coefficient of determination (R^2 = 0.411) showed that the fitted regression line had a significant regression coefficient. It also indicated that 41.1% TSW was attributed due to RWC.

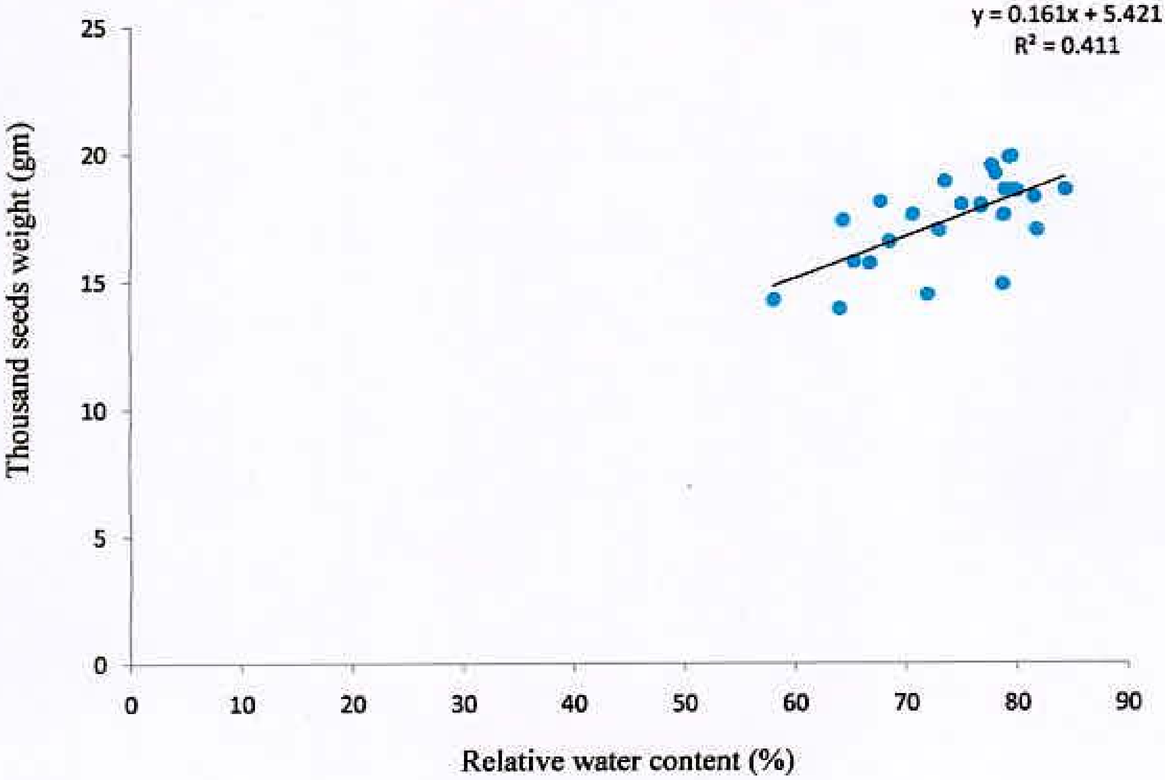

Figure 9. Functional relationship between relative water content and thousand seeds weight under residual soil moisture condition

A significant positive relationship was found between RWC and seed yield (SY) (Figure 10). The equation $y = 0.134e^{0.022x}$ gave a good fit to the data and the value of coefficient of determination ($R^2 = 0.329$) showed that the fitted regression line had a significant regression coefficient. It also indicated that 32.9% SY was attributed due to RWC.

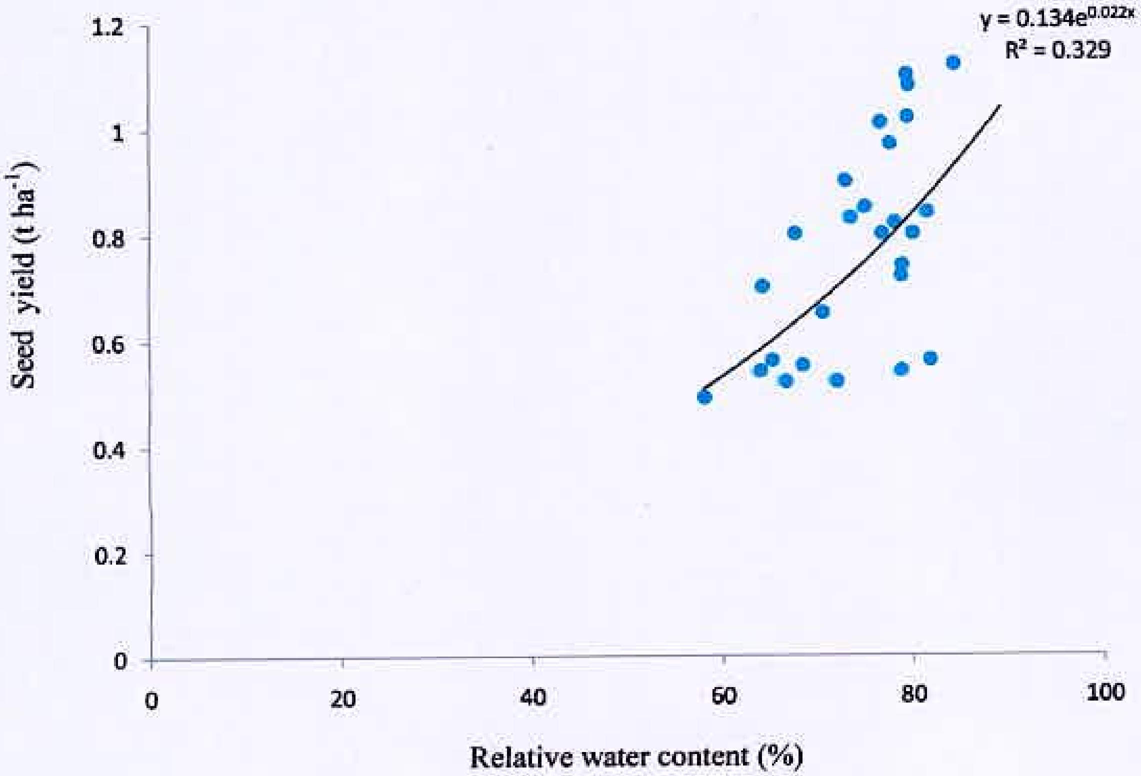

Figure 10. Functional relationship between relative water content and seed yield under residual soil moisture condition

A significant positive relationship was found between RWC and stover yield (STY) (Figure 11). The equation $y = 0.120e^{0.027x}$ gave a good fit to the data and the value of coefficient of determination ($R^2 = 0.379$) showed that the fitted regression line had a significant regression coefficient. It also indicated that 37.9% STY was attributed due to RWC.

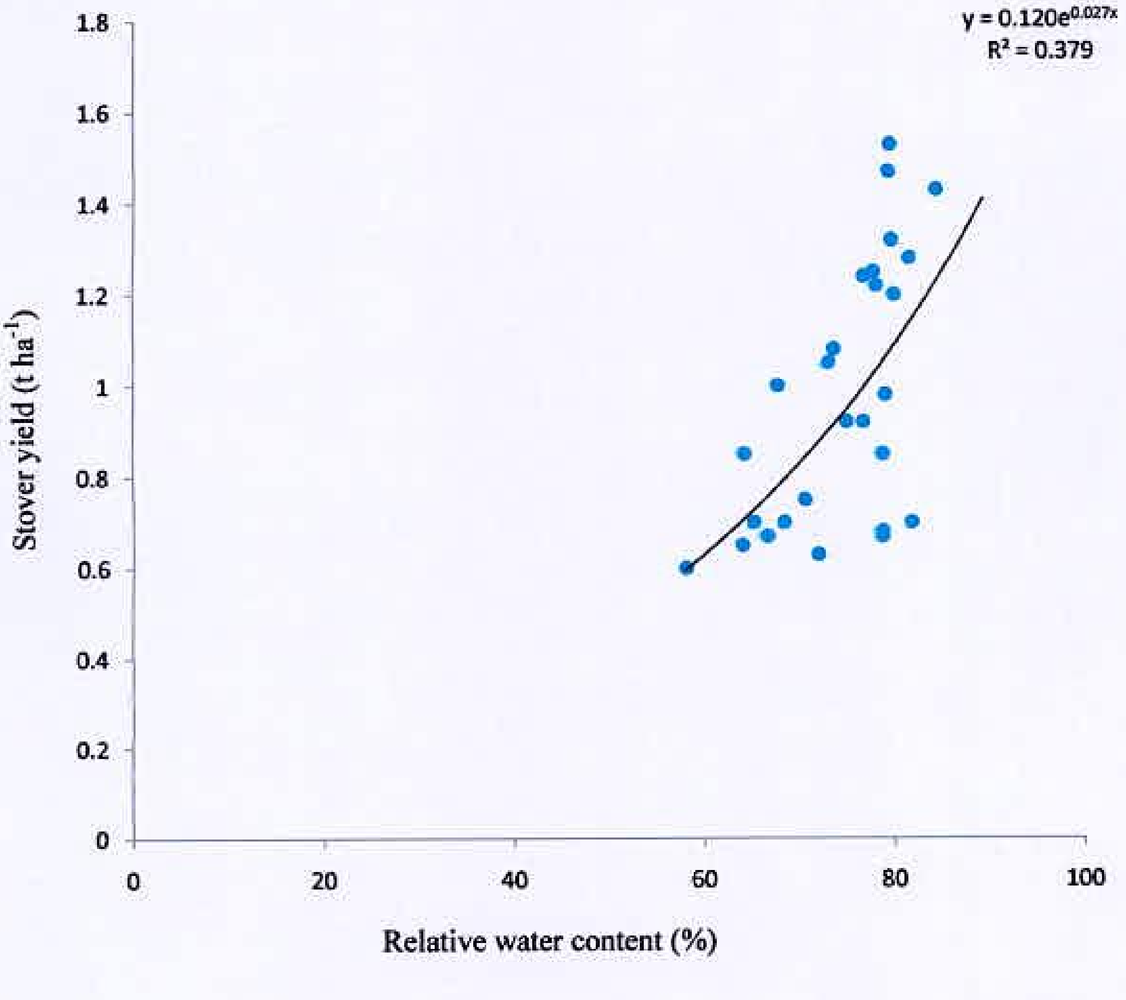

Figure 11. Functional relationship between relative water content and stover yield under residual soil moisture condition

4.12. Correlation between relative water content and yield contributing characters

The correlation between exudation rate (ER) and yield contributing characters was highly significant. A close correlation was also observed between relative water content (RWC) and yield contributing characters (Table 10).

Table 10.Correlation of ER and RWC with the yield contributing characters

Yield contributing character	ER	RWC
Pods per plant	0.9101**	0.5927**
Seeds per pod	0.7349**	0.4281*
Thousand seeds weight (TSW)	0.8191**	0.6411**
Seed yield	0.8756**	0.5693**
Stover yield	0.9193**	0.6112**

*Significant with $p \leq 0.05$ and ** Significant with $p \leq 0.01$

CHAPTER 5

SUMMARY AND CONCLUSION

Lentil is one of the oldest and most popular food legumes in Bangladesh. Because of its short duration, lentil fits well in the existing cropping pattern in Bangladesh. The adaptability and productivity of lentil is limited by major abiotic stresses, including drought, heat, frost, chilling, water logging, salinity, and mineral toxicities. The severity of these stresses is unpredictable. As lentil is grown mostly under rainfed condition, in late rabi season it experiences severe water stress condition. Water stress plays a vital role for various morpho-physiological changes. Again, exogenous application of different plant growth regulators helps to increase the yield. The present study was planned to evaluate the effect of gibberellic acid on water stress imposed by withholding irrigation and also due to different sowing dates.

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from November 2012 to March 2013 to study the effect of gibberellic acid and sowing date on water relations and yield of lentil (variety: BARI Masur-6) under residual soil moisture condition. The experiment consists of two factors: Factor A: Sowing date (3) - S_1= 27 November, S_2= 7 December and S_3 = 17 December; Factor B: GA_3 application (just before flowering) (3 levels) - G_0=0 ppm (control); G_{100}=100 ppm and G_{200}=200 ppm. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different water relations (exudation rate and relative water content), days to first flowering, days to pod maturity, yield contributing characters (pods per plant, pod length, seeds per pod, thousand seeds weight) and seed and stover yield were recorded and variation was observed.

Effect of sowing date on water relations, yield and yield contributing characters was highly significant. Highest exudation rate (ER) (11.22 mg hr^{-1}) and relative water content (RWC) (78.02%) was found from S_1 (sowing on 27 November), in contrary lowest ER (4.67 mg hr^{-1}) and RWC (70.42%) was found from S_3 (sowing on 17 December). Maximum days to first flowering (46 DAS), pod maturity (98.89 DAS), pods per plant (39.91), pod length (2.35 cm), seeds per pod (1.90), thousand seeds weight (18.58 gm) and stover yield (1.24 t ha^{-1}) was found from S_1treatment (sowing on 27 November), which ultimately gave highest seed yield (0.98 t ha^{-1}). Whereas, minimum days to first flowering (41 DAS),pod maturity (91.11 DAS), pods per plant (15.38), pod length (1.44 cm), seeds per pod (1.18), thousand seeds weight (15.55 gm) and stover yield (0.67 t ha^{-1}) was found from S_3 treatment (sowing on 17 December), which ultimately gave lowest seed yield (0.54 t ha^{-1}).

Effect of GA_3 on water relations, yield and yield contributing characters was significant. Highest ER (10.89 mg hr^{-1}) and RWC (79.12%) was found from G_{200} (200 ppm GA_3), in the contrary lowest ER (5.33 mg hr^{-1}) and RWC (70.28%) was found from G_0 (control). Foliar application of GA_3 helped to minimize the days to first flowering. For 200 ppm GA_3 application days to first flower bud initiation was earlier (42.67 DAS) than 100 ppm GA_3 (43.33 DAS) and control (44.44 DAS). Highest pods per plant (32.08), thousand seeds weight (18.38 gm),seed yield (0.82 t ha^{-1})and stover yield (1.13 t ha^{-1}) was found from G_{200} (200 ppm GA_3). Whereas, lowest pods per plant (22.04), thousand seeds weight (16.44 gm), seed yield (0.69 t ha^{-1}) and stover yield (0.80 t ha^{-1}) was found from G_0 (control).

Interaction effect of sowing date and GA_3 was significant. Highest ER (15.00 mg hr^{-1}) and RWC (81.12%) was found from S_1G_{200} (sowing on 27 November with 200 ppm GA_3), in the contrary lowest ER (3.00 mg hr^{-1}) and RWC (64.69%) was found from S_3G_0 (sowing on 17 December without any GA_3). Maximum number of pods per plant (49.43), pod length (2.46 cm) was recorded from S_1G_{200} (sowing on 27 November with 200 ppm GA_3), whereas minimum number of pods per plant (12.00) was recorded from S_3G_0 (sowing on 17 December without any GA_3). For sowing on 27 November seed yield was increased 17.65% and 29.41% due to 100 ppm and 200 ppm GA_3 application respectively over control. For sowing on 7 December seed yield was increased 14.49% and 18.84% due to 100 ppm and 200 ppm GA_3 application respectively over control. But, there was no significant effect of GA_3 application on yield for sowing on 17 December.

So, it can be said that activity of GA_3 may be affected by the water content of plant. Because availability of soil moisture decreases as the sowing date delays.

From the above findings, it was revealed that yield of BARI Masur-6 can be significantly increased by applying 200 ppm GA_3 and 100 ppm GA_3 for sowing on late November and early December respectively. But, for sowing on late December foliar application of GA_3 is useless under residual soil moisture condition as application of GA_3 did not increase yield significantly.

Recommendations

Considering the situation of the present experiment, further studies in the following areas may be suggested:

- Such study needs to be conducted under different levels of soil moisture condition.
- Other plant growth regulators may be included individually or combindly.
- Other concentrations of GA_3 needs to be tested.
- Such study can be conducted on other varieties of lentil.

REFERENCES

Abdel, C.G., and Al-Rawi, I.M.T. (2012). The influence of varying gibberellic acid on growth and yield of three lentil (*Lens culinaris* medik sub species *culinaris*) cultivars grown under supplementary irrigation. *Int. J. Environ. and Water*. **1**(2): 137-153.

Adams, P.A., Montague, M.J., Tepfer, M., Rayle, D.L., Ikuma, H. and Kaufman, P.B. (1975). Effect of gibberellic acid on the plasticity and elasticity of *Avena* stem segments. *Pl. Physiol.* **56**(9): 757-760.

Ahmed, A.M., Radi, A.F., Shaddad, M.A. and El-Tayeb, M.A. (1989). Effects of phytohormones on carbohydrate and nitrogen metabolism of some drought stressed crop plants. *J. Islamic Academy of Sci*. **2**(2): 93-99.

Aktas, Y., Akca, H., Altun, N. and Battal, P. (2008). Phytohormone levels of drought acclimated laurel seedlings in semiarid conditions. *Gen. Appl. Plant Physiol*. **34**(3): 203-214.

Al-Hussien, N., Bayaa, B. and Erskine, W. (2002). Integrated management of lentil broomrape, Sowing date and chemical treatments. *Arab J. Pl. Protec*. **20**(2): 84-92.

Allam, A.Y. (2002). Effect of sowing dates, seeding rates and nitrogen sources on yield, yield components and quality of lentil. *Assiut J. Agril. Sci.* **33**(5): 131-144.

Anonymous. (1989). Annual Report 1987-88. Bangladesh Agricultural Research Institute. Joydebpur, Gazipur. p. 133.

Anonymous. (2008). MasurerUnnotoJath. Strengthening Pulses and Oilseeds Res. project of Bangladesh. Bangladesh Agril. Res. Institute. Joydebpur, Gazipur. pub. no. 20 & 21.

Atal, C.K. and Sethil, J.K. (1961). Increase fibre content in *Cannaris sativa* and *Crotolariajuncea*by application of gibberellines. *Curr. Sci.* **30**(05): 177–179.

Awan, I.U., Baloch, M.S., Sadozai, N.S. and Sulemani, M.Z.(1999). Stimulatory effect of GA_3 and IAA on ripening process, kernel development and quality of rice. *Pak. J. Biol. Sci.* **2**(2): 410-412.

Baque, M.A., Karim, M.A. and Hamid, A. (2002). Role of potassium on water relation behaviour of *Triticum aestivum* L. under water stress conditions. *Progress Agric.* **13**(1 & 2): 71-75.

BBS. (Bangladesh. Bangladesh Bureau of Statistics) (2008). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh. Dhaka. Bangladesh.

BBS. (Bangladesh. Bangladesh Bureau of Statistics) (2010). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh. Dhaka. Bangladesh. pp. 76.

Bhatty, R.S. (1988). Composition and quality of lentil (*Lens culinaris* Medik.): A review. *Canadian Institute of Food Science and Technology J.* **21**(2): 144 - 160.

Bidlack, J.E. and Buxton, D.R. (1995).Chemical regulation of growth, yield and digestibility of alfalfa and smooth brome grass. *J. Pl. Growth Regul.* **14**: 1-7.

Bora, R.K. and Sarma, C.M. (2006).Effect of gibberellic acid and cycocel on growth, yield and protein content of pea. *Asian J. of Pl. Sci.* **5**: 324-330.

Boztok, S. (1985).Investigation on the effect of sowing date and verbalisation on seed production in early cauliflower cv. Ege. *Univ. Zirrat fakultesi Dergis.* **22**:89-99.

Brian, P.W. and Hemming, H.G. (1955). The effects of gibberellic acid on shoot growth of pea seedlings. *Physiologia Plantarum*, **8**: 669-681.

Bukhtiar, B.A., Naseem, B.A. and Tufail, M. (1991). Sowing time effect on seed yield and yield components of lentil varieties. *J. Agril. Res. Lahore*. **29**(3): 347-356.

Davies, W. J. and Zhang, J. (1991). Root signals and the regulation of growth and development of plants in drying soil. Annual Rev. *Pl. Physiol. Mol. Biol.* 42: 55-76.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People's Republic of Bangladesh. p. 118.

El Saeid, H.M., AbouHadid, A.F. and Singer, S.M. (1984).Effect of Water stress upon endogenous hormones and yield in cowpea plants. *Egyptn. J. Hort.* **21**(1): 133-142.

Eldabh, R.S., Aboudahab, A.M. and Elbagoury.H. (1978).Effect of gibberellic acid on growth and flowering of *Cliviamaniata*. Regel Research Bulletin, Faculty Agricultural Ain Shams Univ. p. 964.

El-Sanag, G. and Nourai, A.H. (1983).A review of research on lentils (Lens culinaris) in the Sudan. *Lens Newsl*. **10**(1): 1-12.

FAO (Food and Agricultural Organization of the United Nations). (2013). Production of Lentils by Countries.Basic Data Unit. Statistics Division, FAO. Rome, Italy.

Gomez, K.A. and Gomez, A.A. (1984).Statistical procedures for Agricultural Research. Jhon Wiley and Sons, New York.

Gurung, G.B., Rijal, D.K. and Gurung, B.D. (1996). Effect of sowing time on grain yield of lentil under rainfed condition at Pakhribas Agril. Centre. *PAC Technical Paper Pakhribas Agril. Centre*. **172**: 22.

Hossain, M.A., Jannatul, F. and Salim, M.M.R. (2006). Relative abundance and yield loss assessment of lentil aphid, *Aphis craccivora* Koch in relation to different sowing dates. *J. Agril. and Rural Dev., Gazipur*. **4**(1/2): 101-106.

Inderjit, S., Virender, S. and Sekhon, H. S. (2005). Influence of row spacing and seed rate on seed yield of lentil (*Lens culinaris*) under different sowing dates. *Indian J. Agron.* **50**(4): 308-310.

Islam, Q.M.S. and Ali, M.O. (2002). Research Report on Pulses Socio-economics. A report of Pulses Research Center, BARI, Ishurdi, Pabna, Bangladesh. pp. 1-15

Itai, C. (1999). Role of phytohormones in plant responses to stresses. In: Plant Responses to Environmental Stress. From Phytohormone to Genome Reorganization. H.R. Lerner, (ed.). Marcel Dekkar, New York. pp. 287-301.

Jermyn, W.A., Goulden, D.S., Lancaster, I.M. and Banfield, R.A. (1981).Lentil evaluation in New Zealand. Proceedings of the Agronomy Society of New Zealand, 2011, New Zealand. pp. 77-81.

Kabar, K. (1990). Comparison of kinetin and gibberellic acid effects on seed germination under saline conditions. *Phyton.* **30**(2): 291-298.

Kamijima, O. (1981). Consideration on the mechanism of expression of dwarf genes in rice plants. *Jap. J. Breed.* **31**: 302-315.

Kayan, N. (2010). Response of lentil (*Lens culinaris* Medik.) to sowing date and timing of nitrogen application. *J. Food Agric. Environ.* **8**(2): 422–426.

Kazemekas, O. (2001). Seed yield of lentils in relation to sowing time and seed rate. *Zemdirbyste, MoksloDarbai*, **74**: 128-134.

Keykha, M., Ganjali, H.R. and Mobasser, H.R. (2014). Effect of salicylic acid and gibberellic acid on some characteristics in mungbean (*Vigna radiata*). *Inter. J. Biosci.* **5**(11): 70-75.

Khan, N.A., Ansari, H.R. and Saniullah.(1998). Effect of gibberellic acid spray during ontogeny of mustard on growth, nutrient uptake and yield characteristics. *J. Agron. and Crop Sci.* **181**(1): 61-63.

Krishna, M. and Pandey, S. I. (1985).Influence of soil moisture regimes, straw mulching, and kaolin spray on yield-attributing characters, and correlation between yield and yield attributes in lentils. *Lens Newsl.* **12**(1): 18-20.

Kumar, S. and Bharti, S. (1988). Effects of CCC and FAP on water status and yield of sunflower under simulated drought conditions. *Indian J. Pl. Physiol.* **31**(4): 381-387.

Lal, H.C., Upadhyay, J.P., Jha, A.K. and Atul, K. (2006). Effect of spacing and date of sowing on rust severity and yield of lentil. *J. Res. Birsa Agril. Univ.* **18**(1): 89-91.

Lee, J., K. T. Joung, K. H. Hayain and L. S. Hee.(1999). Effect of chilling and growth regulators in seedling stage on flowering of *Lilium formolongi*. *Hangut Wanye Hakcheochi*. **40**(2): 248-252.

Maske, V.G., Deotale, R.D., Sorte, N.V., Goramnagar, H.G. and Chore, C.N. (1998). Influence of GA_3 and NAA on growth and yield contributing parameters of soybean. *J. Soils Crops.* **8**:20–21.

Matsuoko, M. (2003). Gibberellins signaling: How do plant cells respond to GA signals. *J. Plant Growth Regul.* **22**: 123-125.

McKenzie, B.A. (1987). The growth, development and water use of lentils (*Lens culinaris* Medik.). Ph.D. Thesis, University of Canterbury, New Zealand.

Milanesi, L. A., Espósito, M. A., Martín, E. A., López-Anido, F. S., García, S. M. and Cointry, E. L. (2008). Rate and time of GA_3 application and irrigation on plant morphology and yield of lentil. *Int. J. Veg. Sci.* **14**(2): 139 —147.

Mishra, J.S., Singh, V.P. and Bhan, V.M. (1996). Response of lentil to date of sowing and weed control in Jabalpur, India. *Lens Newsl.* **23**(1/2): 18-23.

Mittel, S.P. and Srivastava, G. (1964). Seed yield in relation to bulb size and seed stalks in onion. *Indian J. Hort.* **21**: 264-269.

Mobin, M., Ansari, H.R. and Khan, N.A. (2007). Timing of GA3 application in Indian mustard (*Brassica juncea* L.): Dry matter distribution, growth analysis and nutrient uptake. *J. Agron.* **6**: 53–60.

Muhammad, A., Abid, H. and Wajid, S.A. (2002). Effect of sowing date, irrigation and plant population on seed yield and components of yield in lentil. *Pakistan J. Agril. Sci.* **39**(2): 119-122.

Naeem, M., Bhatti, I., Ahmad, R.H. and Ashraf, M.Y. (2004). Effect of some growth hormones (GA_3, IAA and Kinetin) on the morphology and early or delayed initiation of bud of lentil (*Lens culinaris* Medik). *Pak. J. Bot.* **36**(4): 801-809.

Naqvi, S.S.M. (1994). Plant hormone and stress phenomena. **In**: Handbook of Plant and Crop Strss. M. Pessarakli, (ed.). Marcel Dekkar, New York. pp. 383-400.

Nelsen, E.T. and Orcutt, D.M. (1996).Water limitation.**In**: Physiology of Plants under Stress. Abiotic Factors. E. T. Nilsen and D. M. Orcutt, (ed.). John Wiley and Sons, New York, USA. pp. 322-361.

Ohashi, Y., Saneoka, H. and Fujita, K. (2000).Effect of water stress on growth, photosynthesis and photoassimilate translocation in soyabean and tropical pasture legume siratro. *Soil Sci. Pl. Nutr.* **46**(2): 417-425.

Ojha, S.N. Jha, J.N. and Roy, R.K. (1977). A study of critical stages of irrigation for lentil under late sown conditions. *Indian J. Agron.* **22**(1): 54-55.

Omae, H., Kumar, A., Kshiwaba, K. and Shono, M. (2007). Assessing drought tolerance of snap bean (*Phaseolus vulgaris*) from genotypic differences in leaf water relations, shoot growth and photosynthetic parameters. *Pl. Prod. Sci.* **10**(1): 28-35.

Onwugbuta – Enyi, J. (2004). Water balance and proximate composition in cowpea (*Vigna unguiculata* (I) Walps) seedlings exposed to drought and flooding stress. *J. Appl. Sci. Environ. Mgt.* **8**(2): 55-57.

Panwar, K.S. and Paliwal, H.S. (1975). Critical stages of irrigation for lentil under late sown upland conditions. *Indian J. Agron.* **20**(2): 194-195.

Rahman, M.M., Islam, M.A. and Mondol, M.R.K. (1989). Effect of wave length of light and some phytohormones on the growth and yield of grass pea. *Bangladesh J. Agril. Res.* **14**(1): 19-23.

Sarker, A., Furman, B. and Erskine.W. (2007). Gene mining and use in improving yield resistance to stresses and quality in lentil. 18th Eucarpia Genetic Resources Section Meeting, 23–26 May 2007, Piestany, Slovak Republic.

Sedghi, M., Sharifi, R.S., Pirzad, A.R. and Amanpour-Balaneji, B. (2012). Phytohormonal regulation of antioxidant systems in petals of drought stressed pot marigold (*Calendula officinalis* L.). *J. Agr. Sci. Tech.* **14**: 869-878.

Siddique, K.H.M., Loss, S.P., Pritchard, D.L., Regan, K.L., Tennant, D., Jettner, R.L. and Wilkinson, D. (1998). Adaption of lentil (*Lens culinaris*) to Mediterranean-type environments: effect of time of sowing on growth, yield and water use. *Australian J. Agril. Res.* **49**(4): 613-626.

Silim, S. N., Saxena, M. C. , and Erskine, W. (1991). Effect of sowing date on the growth and yield of lentil in a rain-fed Mediterranean environment. *Exp. Agric.* 27(2): 145–154.

Soltani, M., Liaghat, A., Sotoodehnia, A., Heidari, A., and Kamali, B. (2015). Conjunctive Effects of Supplemental Irrigation and Planting Date on Rainfed Lentil in Qazvin Plain, Iran. *J. Irrig. Drain Eng.* **10**: 106-112.

Sontakey, P.Y., Belsore, W.V., Deotale, R.D., Takzure, S.C. and Wankhede, S.Z. (1991). Relative influence of growth hormones on growth and yield performance of sesamum (*Sesamum indicum* L.). *New Agriculturist.* **1**: 207-208.

Subbarao, G.V., Johansen, C., Slinkard, A.E., Nageswara, R.C., Saxena, N.P. and Chauhan, Y.S. (1995). Strategies for improving drought resistance in grain legumes. *Crit. Rev. Pl. Sci.* 14: 469-523.

Tardieu, F. and Davies, W.J. (1993). Root- shoot communication and whole- plant regulation of water flux. **In**: Water Deficits: Plant Responses from Cell to Cell Community. J.A.C. Smith, H. Griffiths, (ed.). Bios Scientific Publishers, Oxford. pp. 147-162.

Turk, M.A., Tawaha, A.M. and El-Shatnawi, M.K.J. (2003). Response of lentil (*Lens culinaris*) to plant density, sowing date, phosphorus fertilization and ethephon application in the absence of moisture stress. *J. Agron. and Crop Sci.* **189**(1): 1-6.

Vlitos, A.J. and Meudt, W. (1957). Relationship between shoot apex and effect of gibberellic acid on elongation of pea stem. *Nature*. **180**(4580): 284.

APPENDICES

Appendix I. Characteristics of the soil of experimental field analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Expeimental Field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI, 2012

Appendix II. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from November 2012 to March 2013

Month	*Air temperature (^{0}C)		*Relative humidity (%)	Rainfall (mm) (total)
	Maximum	Minimum		
November, 2012	24.82	16.64	78	26
December, 2012	21.4	13.25	71	00
January, 2013	25.5	12.48	66	00
February, 2013	27.81	16.17	64	08
March, 2013	30.14	19.6	56	24

* Monthly average

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1207

Appendix III. Analysis of variance of the data on exudation rate (ER), relative water content (RWC), days to first flowering and days to pod maturity of lentil under residual soil moisture condition

Source of variation	Degrees of freedom	Mean Square			
		ER	RWC	Days to first flowering	Days to pod maturity
Replication	2	0.481	5.933	0.259	0.259
Factor A (sowing date)	2	97.148**	131.073**	56.259**	145.593**
Factor B (GA_3 application)	2	71.815**	178.016**	7.259**	11.704**
AB	4	1.704	7.012	0.093	0.148
Error	16	0.898	31.213	0.176	0.176

** Significant at 0.01 level of significance; * Significant at 0.05 level of significance

Appendix IV. Analysis of variance of the data on pod length, pods per plant and seeds per pod of lentil under residual soil moisture condition

Source of variation	Degrees of freedom	Mean Square		
		Pod length	Pods per plant	Seeds per pod
Replication	2	0.005	1.717	0.001
Factor A (sowing date)	2	2.358**	1394.329**	1.194**
Factor B (GA_3 application)	2	0.016	237.396**	0.004
AB	4	0.023	27.212**	0.007
Error	16	0.013	1.875	0.007

** Significant at 0.01 level of significance; * Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on thousand seeds weight (TSW), seed yield and stover yield of lentil under residual soil moisture condition

Source of variation	Degrees of freedom	Mean Square		
		TSW	Seed yield	Stover yield
Replication	2	0.009	0.00015	0.002
Factor A (sowing date)	2	24.653**	0.4513**	0.746**
Factor B (GA_3 application)	2	8.454**	0.0441**	0.248**
AB	4	0.621	0.0089**	0.043**
Error	16	0.306	0.001	0.002

** Significant at 0.01 level of significance; * Significant at 0.05 level of significance