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Effects of Planting Date and Gibberellic Acid on the Growth and Yield of Garlic (*Allium sativum* L.)

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Abstract: The effects of planting date and gibberellic acid (GA_3) on the growth and yield of a local cultivar of garlic were investigated during the growing period from November 2001 to April, 2002. The experiment was consisted of four planting dates (November 07, 22 and December 07, 22, 2001) and different concentrations of GA_3 (0, 100 and 200 ppm). The objective of the work was to find out the appropriate planting time and effective concentration of GA_3 on the growth and yield of garlic. Early planting favourably influenced plant height, number of leaves per plant, dry weights of leaves, bulbs and roots, total dry matter (TDM), leaf area index (LAI), crop growth rate (CGR), bulb diameter, individual bulb weight as well as yield. With the delay in planting time starting from November 07, the yield was chronologically reduced in later plantings. The highest bulb yield (2.67 t ha^{-1}) was recorded from November 07 planting and the minimum (0.92 t ha^{-1}) from December 22. There were deleterious effect of GA_3 concentrations used in this experiment. Control plants produced higher yield than the plants treated with different concentrations of GA_3. The interaction effect of planting dates and GA_3 concentrations indicated that early plantings grown without GA_3 showed better performance than the late plantings grown with or without GA_3.

Key words: Garlic (*Allium sativum* L.), gibberellic acid, growth, planting date, yield

INTRODUCTION

Garlic is one of the most important spice crops of Bangladesh. It is the most widely used cultivated *Allium* next to onion[1]. The crop is widely cultivated in Bangladesh during the winter season. Its per acre production in Bangladesh is 1187.5 kg which is much lower than that of world average[2]. So, Bangladesh has to import garlic every year to meet her domestic demand. Statistical data showed that this crop is cultivated in an area of about 32000 acres of land with the production of 38000 metric tons during the year 1998-99[2].

Farmers in Bangladesh plant garlic between mid-November and December because they can not adopt early planting due to climatic limitations. In late planting, plants are exposed to increasingly high temperatures before bulb initiation and during bulb development in the period from February to April. As a result, the bulb production is so poor. Bulbing of garlic is controlled by the day length and temperature to which the dormant cloves and growing plants are exposed before bulbing begins. Delay of a few weeks in the normal planting date (Mid-October) lead to severe losses in yield[3-5]. Siddique and Rabbani[6] also reported that growth, bulb size and yield reduce due to delayed planting. Rahim *et al.*[4] showed that 40% yield of garlic reduced when the planting was delayed by 40 days after October 31.

Plant growth regulator like gibberellic acid (GA_3) has been known to play a vital role in bulbing of garlic [5,7-11]. It has also been reported that foliar spray of GA_3 stimulates to form lateral bud and increases the number of cloves per bulb. Growth regulators have a potential use for the substitute of the cold requirement of flowering bulbs[12-15] and garlic[5]. Rahim[5] reported that lower concentrations of GA_3 significantly increased both leaf and root dry weight and total yield and higher concentrations of GA_3 showed deleterious effects and reduction in final bulb weight of garlic. It has been reported for onion that GA_3 (7.5-40 ppm) increased leaf number and weight which lead to higher yield and bulb size[16].

Like other crops the productivity of garlic depends on such growth attributes as leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR)[17]. In addition growth analysis is a useful technique in the study of plants, because it

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bridges between the empirical and the mechanistic approaches to modelling growth and development, a necessary prerequisite to the understanding of the whole behaviour of the plants[18].

Many studies have indicated that the application of growth regulators can affect the growth and development of bulb crops; but a little information is available for their effects on garlic[5]. Therefore, an attempt was made to evaluate the effectiveness of different planting time and application of different concentrations of GA_3 on the growth and yield of the local cultivar of garlic which might help for substantial contribution to the nation.

MATERIALS AND METHODS

The experiment was conducted at the experimental field laboratory of the Department of Crop Botany, Bangladesh Agricultural University (BAU), Mymensingh during the period from November 2001 to April 2002 using planting dates (November 07, 22 and December 07, 22, 2001) and growth regulator, GA_3 (0, 100 and 200 ppm) as experimental treatments. The experiment was laid out in the Randomized complete block design. The treatments were replicated 3 times. The whole plot was divided into three blocks each representing a replication. Each block was then divided into 12 unit plots of 2×2 m sizes. The blocks were separated from each other by 1 m and each plot within the same block was also separated from each other by 50 cm. The cloves were planted in rows with 20 cm spacing and 15 cm apart. The experimental plots were fertilized with cowdung, urea, triple super phosphate (TSP) and muriate of potash (MP) @ 14 t ha^{-1}, 90 kg ha^{-1}, 120 kg ha^{-1} and 180 kg ha^{-1}, respectively[4]. Total amount of cowdung and TSP were added to the soil at the time of final land preparation (7 days before planting) in order to well mix them with the soil. Urea and MP were top dressed in two equal splits at 30 and 60 days after planting (DAP) the cloves. Seed cloves of a local available cultivar of garlic, collected from capital seed store, Nutan Bazar, Mymensingh were used as the propagating materials in this experiment. The cloves of uniform size were selected for planting. The mean weight of the cultivar was 65 g 100^{-1} cloves.

Preparation and application of GA_3: GA_3 at the concentrations of 100 and 200 ppm were applied as foliar spray at 30 DAP. A 200 ppm stock solution of GA_3 was prepared by dissolving 0.2 g of it in a small quantity of ethanol prior to dilution with distilled water in one litre volumetric flask. The stock solution was used to prepare the required treatment concentration. 500 mL of this stock solution was diluted with 500 mL distilled water to get 100 ppm. A control solution was also prepared only by adding a small quantity of ethanol with distilled water. An adhesive agent (Tween 20) was added to all solutions including the control one.

Intercultural operation: Weeding and mulching were done as and when required to keep the plot free from weeds and to pulverise the soil. Irrigation was provided after each fertilization by water can.

Collection of data: The experimental plots were observed frequently to record changes in plant characters at different physiological stages of growth. Five plants were harvested randomly at each time from each plot at 15 d interval. The first harvesting was done at 30 DAP for each date of planting. Before harvesting the number of leaves per plant was counted and the height of the individual plant was measured by a graduated scale placed ground level to top of the plants. At the time of each harvest the plants were uprooted carefully by a 'khurpi' in order to ensure maximum root extraction and brought to the laboratory keeping within polyethylene bags to prevent transpiration loss. After cleaning and removing the adherring water the leaves, roots and bulbs were separated and the weight of individual bulb was measured. The leaf area was measured with an automatic leaf area meter (Model LI-3000, Soil Moisture Equipment Corpn, Santa Barbara, California, USA). Bulb diameter at each harvest was measured by slide callipers. Then the components were oven dried for 48 h at 80°C and their corresponding dry weights were determined by a sensitive balance. Growth attributes like crop growth rate (CGR) and net assimilation rate (NAR) were made following the formulae rendered by Hunt[19]. Yield was estimated from the final harvest.

Data of the experiment were analyzed statistically and their mean differences were adjusted as per DMRT or LSD.

RESULTS AND DISCUSSION

Morphological parameters

Plant height: Plant heights as recorded from 30 DAP to 120 DAP are presented in Table 1-3. It was evident that plant height increased gradually with the advancement of seedling age. It differed significantly with the date of planting (Table 1). The cloves which were planted on November 07 had the highest plant height (41.74 cm). These plants received longer cool period and shorter day length which possibly enhanced meristematic elongation of plant and as a result maximum plant height was attained. Plant height was gradually decreased with the

Table 1: Effect of planting date on growth and yield of garlic

	Plant height (cm)				No. of leaves/plant				Bulb diameter (cm)		
Treatment	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP	60 DAP	90 DAP	120 DAP
Nov. 07	26.65a	33.90a	41.44a	41.74a	4.49a	5.52a	6.22a	6.62a	0.45a	1.77a	2.15a
Nov. 22	26.40ab	28.36b	34.72b	35.12b	4.21b	4.64b	5.22b	6.40a	0.44ab	1.75ab	1.83b
Dec. 07	25.32b	32.81a	34.17b	34.46b	3.91c	4.36c	4.64c	5.49b	0.41b	1.70b	1.78b
Dec. 22	22.72c	29.61b	31.28c	33.08b	3.38d	3.79d	4.21d	5.00c	0.31c	1.56c	1.62c
LSD (0.05)	1.09	1.30	0.87	2.04	0.24	0.18	0.31	0.25	0.03	0.03	0.10
	Weight of leaves/plant				Weight of bulb/plant				Weights roots/plant			
Treatment	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
Fresh weight (g)												
Nov. 07	1.22ab	2.06a	6.10a	4.26a	1.37a	1.63a	6.70a	7.58a	0.27a	0.59a	0.80a	1.19a
Nov. 22	1.30a	1.67b	5.31b	4.06b	1.26b	1.49b	5.76b	7.08a	0.23b	0.33b	0.73b	0.79a
Dec. 07	1.19bc	1.64b	5.20b	3.77c	0.95c	1.07c	5.13c	7.13a	0.17c	0.22d	0.63c	0.88a
Dec. 22	1.15c	1.31c	4.33c	3.26d	0.39d	0.83d	4.61d	6.15b	0.12d	0.27c	0.51d	0.62b
LSD (0.05)	0.05	0.11	0.15	0.13	0.03	0.06	0.28	0.58	0.01	0.03	0.04	0.13
Dry weight (g)												
Nov. 07	0.14b	0.22a	0.92c	1.76a	0.18a	0.27a	1.15b	2.92a	0.02b	0.10a	0.22a	0.27a
Nov.22	0.12c	0.24a	1.17a	1.66b	0.13b	0.25b	1.22a	2.14b	0.02b	0.07b	0.21b	0.25ab
Dec. 07	0.23a	0.22a	1.13b	1.67ab	0.10c	0.22c	0.68d	2.12b	0.05a	0.09a	0.19c	0.23bc
Dec.22	0.10d	0.19b	0.69d	1.58b	0.09c	0.14d	0.89c	1.43c	0.05a	0.08b	0.18c	0.20 c
LSD (0.05)	0.01	0.03	0.03	0.09	0.01	0.01	0.03	0.06	0.01	0.01	0.01	0.03

Figures in a column followed by the same letter (s) are not significantly different at P = 0.05

Table 2: Effect of gibberellic acid on growth and yield of garlic

	Plant height (cm)				No. of leaves/plant				Bulb diameter (cm)		
Treatment	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP	60 DAP	90 DAP	120 DAP
0 ppm	27.34a	34.60a	37.79a	38.67a	4.14a	4.88a	5.32a	6.33a	0.42a	1.76a	1.93a
100 ppm	25.16b	31.05b	36.42b	35.75b	3.99ab	4.48b	5.10a	5.77b	0.41ab	1.70b	1.85ab
200 ppm	23.33c	27.86c	32.00c	33.12c	3.85b	4.37b	4.81b	5.53c	0.38b	1.64c	1.77b
LSD (0.05)	0.94	1.13	0.76	1.76	0.21	0.16	0.27	0.22	0.03	0.03	0.09
	Weight of leaves/plant				Weight of bulb/plant				Weight of roots/plant			
Treatment	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
Fresh weight (g)												
0 ppm	1.29a	1.77a	5.39a	4.35a	1.16a	1.41a	5.75a	7.26a	0.21a	0.38a	0.86a	0.79a
100 ppm	1.23b	1.75a	5.21b	3.90b	0.94b	1.28b	5.46b	7.11a	0.18b	0.37a	0.74b	0.85a
200 ppm	1.06c	1.49b	5.12b	3.27c	0.87c	1.09c	5.45b	6.59b	0.20a	0.31b	0.71b	0.67 b
LSD (0.05)	0.05	0.09	0.13	0.11	0.03	0.05	0.24	0.50	0.01	0.03	0.04	0.12
Dry weight (g)												
0 ppm	0.21a	0.24a	1.01a	1.78a	0.12	0.26a	1.02a	2.31a	0.05a	0.11a	0.19a	0.28a
100 ppm	0.12b	0.21b	0.99a	1.67b	0.13	0.21b	0.99b	2.18b	0.03b	0.09b	0.17b	0.23b
200 ppm	0.11b	0.20b	0.93b	1.55c	0.12	0.18c	0.96c	1.97c	0.03b	0.06c	0.15c	0.20c
LSD (0.05)	0.01	0.03	0.03	0.08	NS	0.01	0.03	0.06	0.01	NS	0.01	0.03

NS = Not significant. Figures in a column followed by the same letter (s) are not significantly different at P = 0.05

delay in planting date and the lowest plant height (33.08 cm) was obtained from planting on December 22. This result is similar to the findings of Rahim *et al.*[4] who reported that height of garlic plant was decreased as the planting was delayed. Plant height decreased significantly with the increase in concentration of GA_3 at each harvesting time. The highest plant height (38.67 cm) was obtained from the control plants. 200 ppm GA_3 produced the shortest plant (Table 2). Similar result was reported by Nasim Ara[20].

The interaction effects of planting date and GA_3 on plant height were significant. Maximum plant height (44.36 cm) was obtained from control plants those planted on November 07 (Table 3).

Number of leaves per plant: The plants which were planted on November 07 exhibited highest number of leaves (6.62) per plant (Table 1) and December 22 planted plants exhibited the minimum (5.00). This result is similar to the findings of many authors[3,4,21]. All of them observed that early planting produced higher number of leaves per plant and decreased gradually with the late planting. In our experiment, there were deleterious effects of GA_3 on the number of leaves per plant. The number of leaves decreased gradually with the higher concentration of GA_3. The highest number of leaves were obtained from control plants (Table 2). Here, the results of our experiment are quite contradictory to the findings of Takagi and Aoba [8] who reported that GA_3 enhanced rapid leaf proliferation by secondary lateral branching.

Table 3: Interaction effect of planting date and gibberellic acid on growth and yield of garlic

		Plant height (cm)				No. of leaves/plant				Bulb diameter (cm)		
Treatment		30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP	60 DAP	90 DAP	120 DAP
Nov. 07	0 ppm	30.00	36.67a	43.67a	44.36a	4.65	6.00	6.67	7.24	0.46	1.86	2.20
	100 ppm	26.21	33.41bc	43.00a	42.46ab	4.54	5.29	6.33	6.32	0.45	1.76	2.12
	200 ppm	23.73	31.63bcd	37.67b	38.40cd	4.27	5.27	5.67	6.29	0.44	1.71	2.03
Nov. 22	0 ppm	28.91	36.37a	39.00b	39.28bc	4.23	4.80	5.33	7.01	0.46	1.84	1.96
	100 ppm	25.97	27.05e	35.50c	32.62ef	4.08	4.63	5.33	6.25	0.43	1.77	1.79
	200 ppm	24.33	21.67f	28.00f	28.45g	4.30	4.50	5.00	5.94	0.43	1.65	1.75
Dec. 07	0 ppm	26.60	34.02b	35.67c	36.11df	4.13	4.67	4.87	5.82	0.43	1.75	1.88
	100 ppm	25.47	32.93bcd	35.00cd	35.40ef	3.97	4.23	4.50	5.42	0.43	1.71	1.78
	200 ppm	23.91	31.47cd	33.50de	33.86ef	3.63	4.17	4.57	5.23	0.38	1.66	1.89
Dec. 22	0 ppm	23.83	31.35cd	32.83e	34.91def	3.55	4.03	4.40	5.27	0.34	1.60	1.67
	100 ppm	23.00	30.82d	32.17e	32.53ef	3.40	3.78	4.23	5.08	0.32	1.57	1.60
	200 ppm	21.33	26.67e	28.83f	31.78fg	3.20	3.57	4.00	4.65	0.28	1.53	1.58
LSD (0.05)		NS	2.26	1.51	3.53	NS	NS	NS	0.43	NS	NS	NS

		Weight of leaves/plant				Weight of bulb/plant				Weight of roots/plant			
Treatment		30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
Fresh weight (g)													
Nov. 07	0 ppm	1.37a	2.65a	6.28	5.05a	1.42a	1.71a	7.33a	8.28	0.24b	0.64a	1.47a	0.98a
	100 ppm	1.32ab	2.17b	6.02	4.19cd	1.37ab	1.63ab	6.44b	7.94	0.22cd	0.61a	1.06b	0.94a
	200 ppm	0.97g	1.36c	6.00	3.55e	1.32bc	1.55bc	6.33bc	6.52	0.34a	0.52b	1.03b	0.85ab
Nov. 22	0 ppm	1.31ab	1.75cd	5.52	4.60b	1.32bc	1.64ab	5.74d	7.28	0.24bc	0.37c	0.75c	0.92a
	100 ppm	1.24bcd	1.60d	5.25	4.28e	1.27c	1.49c	5.67d	7.18	0.22d	0.34c	0.73cd	0.82ab
	200 ppm	1.23bcd	1.65d	5.17	3.30f	1.20d	1.35d	5.88cd	6.78	0.27b	0.30cd	0.72cd	0.73ab
Dec. 07	0 ppm	1.27abc	1.35e	5.23	4.06cd	1.01e	1.18e	5.18e	7.20	0.20e	0.28de	0.65de	0.85ab
	100 ppm	1.18cdef	1.88c	5.22	4.01d	1.00e	1.11e	5.13e	7.16	0.18e	0.20fg	0.63ef	0.78ab
	200 ppm	1.12ef	1.69cd	5.17	3.23fg	0.84g	0.93f	5.10cf	7.03	0.12g	0.19g	0.61ef	0.73ab
Dec. 22	0 ppm	1.20cdf	1.33e	4.53	3.68e	0.91f	1.10e	4.73efg	6.27	0.15f	0.25def	0.55fg	0.74ab
	100 ppm	1.16def	1.33e	4.33	3.10fg	0.13h	0.89f	4.60fg	6.15	0.11g	0.34c	0.52gh	0.71ab
	200 ppm	1.10f	1.27e	4.13	3.01g	0.14h	0.52g	4.50g	6.03	0.11g	0.23efg	0.46h	0.40c
LSD (0.05)		0.09	0.19	NS	0.23	0.05	0.11	0.48	NS	0.02	0.05	0.08	0.23
Dry weight (g)													
Nov. 07	0 ppm	0.15b	0.25a	0.94c	1.92a	0.18a	0.31a	1.20	3.11a	0.03cde	0.13a	0.24	0.32
	100 ppm	0.14b	0.19bc	0.91c	1.72bc	0.17a	0.27b	1.13	3.04a	0.02ef	0.13ab	0.22	0.27
	200ppm	0.13bcd	0.23ab	0.90c	1.64c	0.19a	0.23cd	1.23	2.59b	0.02def	0.03g	0.20	0.24
Nov. 22	0 ppm	0.14bc	0.24ab	1.23a	1.84ab	0.14b	0.27b	1.14	2.25c	0.04cd	0.10cd	0.23	0.28
	100 ppm	0.12cde	0.24ab	1.20a	1.72bc	0.12c	0.25c	1.22	2.12d	0.01f	0.07e	0.22	0.27
	200 ppm	0.11e	0.23ab	1.09b	1.41d	0.17b	0.23cd	1.21	2.04d	0.02ef	0.05f	0.17	0.22
Dec.07	0 ppm	0.12a	0.24ab	1.15b	1.72bc	0.11c	0.24cd	0.71	2.25d	0.07a	0.11bc	0.15	0.25
	100 ppm	0.12de	0.22ab	1.14b	1.66c	0.10cd	0.23cd	0.72	2.08d	0.05bc	0.08de	0.13	0.23
	200 ppm	0.11e	0.21ab	1.11b	1.63c	0.08gf	0.18e	0.62	2.02d	0.04bc	0.08de	0.12	0.22
Dec. 22	0 ppm	0.11e	0.22ab	0.74d	1.63c	0.11c	0.23d	0.92	1.61e	0.08a	0.10cd	0.14	0.24
	100 ppm	0.11ef	0.19abc	0.71d	1.58c	0.09df	0.11e	0.89	1.45f	0.06ab	0.07ef	0.12	0.20
	200 ppm	0.09f	0.15c	0.61e	1.54cd	0.07f	0.10f	0.87	1.22g	0.02def	0.07ef	0.12	0.17
LSD(0.05)		0.02	0.05	0.05	0.02	0.02	0.02	NS	0.12	0.02	0.02	NS	NS

NS = Not significant. Figures in a column followed by the same letter (s) are not significantly different at P = 0.05

Table 4: Effect of planting date on TDM (g/plant) and LAI of garlic

	TDM				LAI		
Treatment	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP
Nov. 07	0.34a	0.60a	2.60a	4.90a	0.13a	0.48a	0.82a
Nov. 22	0.27b	0.56b	2.29a	4.06b	0.11b	0.45b	0.79b
Dec. 07	0.27b	0.54b	1.95c	4.04b	0.07c	0.41c	0.76c
Dec. 22	0.24b	0.41c	1.71d	3.22c	0.05d	0.36d	0.71d
LSD (0.05)	0.03	0.03	0.05	0.13	0.01	0.01	0.03

Figures in a column followed by the same letter (s) are not significantly different

Table 5: Effect of gibberellic acid on TDM (g/plant) and LAI of garlic

	TDM				LAI		
Treatment	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP
0 ppm	0.31a	0.61a	2.22a	4.36a	0.13a	0.47a	0.82a
100 ppm	0.28b	0.52b	2.15b	4.08b	0.09b	0.42b	0.77b
200 ppm	0.25b	0.45c	2.04c	3.72c	0.05c	0.38c	0.73c
LSD (0.05)	0.03	0.03	0.05	0.11	0.01	0.01	0.03

Figures in a column followed by the same letter (s) are not significantly different

Table 6: Interaction effect of planting date and gibberellic acid on TDM (g/plant) and LAI of garlic

		TDM				LAI		
Treatment		30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP
Nov. 07	0 ppm	0.36a	0.68a	2.38b	5.31a	0.18a	0.53a	0.87
	100 ppm	0.35ab	0.58bcd	2.27c	4.98b	0.12c	0.48c	0.82
	200 ppm	0.31abc	0.53def	2.23c	4.41c	0.08e	0.44d	0.78
Nov. 22	0 ppm	0.29cde	0.61b	2.70a	4.41c	0.16b	0.50b	0.84
	100 ppm	0.25de	0.56bcd	2.63a	4.11de	0.10d	0.44d	0.78
	200 ppm	0.28cde	0.50ef	2.47b	3.67fg	0.06fg	0.40e	0.75
Dec. 07	0 ppm	0.30abcd	0.60bc	2.01d	4.24cd	0.11cd	0.45d	0.80
	100 ppm	0.27cde	0.54cde	1.99d	3.40e	0.07ef	0.41e	0.75
	200 ppm	0.24ef	0.47f	1.84e	3.87ef	0.04hi	0.38f	0.72
Dec. 22	0 ppm	0.30bcde	0.54de	1.80ef	3.48g	0.08e	0.40e	0.76
	100ppm	0.25cde	0.39g	1.72f	3.24h	0.05gh	0.36g	0.71
	200 ppm	0.18f	0.31h	1.60g	2.93i	0.03i	0.31h	0.65
LSD (0.05)		0.05	0.05	0.09	0.23	0.016	0.017	NS

NS = Not significant. Figures in a column followed by the same letter (s) are not significantly different

Table 7: Effect of planting date on CGR (g m^{-2} d^{-1}) and NAR (g m^{-2} d^{-1}) of garlic

	CGR			NAR		
Treatment	30-45 DAP	45-60 DAP	60-75 DAP	30-45 DAP	45-60 DAP	60-75 DAP
Nov. 07	0.22b	0.24b	1.51b	3.65d	2.05c	9.08b
Nov.22	0.24a	0.26a	1.81a	4.57b	2.39b	11.42a
Dec. 07	0.23a	0.24b	1.25c	5.66a	2.41a	8.46c
Dec. 22	0.14c	0.16c	1.15d	4.10c	1.86d	8.87bc
LSD (0.05)	0.01	0.01	0.04	0.06	0.04	0.46

Figures in a column followed by the same letter (s) are not significantly different

Table 8: Effect of gibberellic acid on CGR (g m^{-2} d^{-1}) and NAR (g m^{-2} d^{-1}) of garlic

	CGR			NAR		
Treatment	30-45 DAP	45-60 DAP	60-75 DAP	30-45 DAP	45-60 DAP	60-75 DAP
0 ppm	0.25a	0.27a	1.42	4.11c	2.35a	8.61c
100 ppm	0.21b	0.22b	1.45	4.41b	2.11b	9.57b
200 ppm	0.17c	0.18c	1.42	4.96a	2.11b	10.19a
LSD (0.05)	0.01	0.01	NS	0.05	0.04	0.40

NS = Not significant. Figures in a column followed by the same letter (s) are not significantly different

Table 9: Interaction effect of planting date and gibberellic acid on CGR (g m^{-2} d^{-1}) and NAR (g m^{-2} d^{-1}) of garlic

		CGR			NAR		
Treatment		30-45 DAP	45-60 DAP	60-75 DAP	30-45 DAP	45-60 DAP	60-75 DAP
Nov. 07	0 ppm	0.29a	0.29a	1.51	3.74ij	2.20c	8.23cd
	100ppm	0.20e	0.21cd	1.49	3.28k	1.84e	8.93bc
	200 ppm	0.18f	0.21d	1.52	3.94h	2.11d	10.08b
Nov. 22	0ppm	0.28ab	0.29a	1.84	3.85hi	2.33b	11.52b
	100 ppm	0.27b	0.28a	1.84	5.08c	2.57a	11.71a
	200 ppm	0.18f	0.21cd	1.75	4.77d	2.27bc	12.04a
Dec. 07	0 ppm	0.24c	0.28a	1.25	4.37f	2.54a	7.86d
	100 ppm	0.24c	0.25b	1.28	5.57b	2.55a	8.76c
	200 ppm	0.22d	0.20d	1.20	7.03a	2.30b	8.75c
Dec. 22	0 ppm	0.20e	0.22c	1.13	4.49e	2.33b	7.80d
	100 ppm	0.12g	0.12e	1.17	3.72j	1.49g	8.90c
	200 ppm	0.10h	0.12e	1.15	4.08g	1.75f	9.91b
LSD (0.05)		0.17	0.17	NS	0.11	0.08	0.80

NS = Not significant. Figures in a column followed by the same letter (s) are not significantly different

There was no significant variation in the number of leaves per plant due to the interaction of planting time and GA_3 concentration. However, interaction effects showed that the highest number of leaves (7.24) was obtained from control plants those planted on November 07 (Table 3) and the December 22 plants grown with 200 ppm GA_3 produced the lowest number of leaves (4.65) per plant.

Growth parameters

Weight of leaves, bulbs and roots: Weight of leaves, bulb and roots per plant were remarkably influenced by planting date and GA_3. Early planted plants (on November 07) gave the higher dry weight of leaves (1.76 g) and bulbs (2.92 g) while delayed planted plants gave lower amount of them (Table 1). Dry weight of root was maximum with November 07 planted plants (0.27 g)

followed by November 22 (0.25 g). December 22 plants produced the minimum dry weight of root (0.20 g). Higher amount of leaves (1.78 g), bulb (2.31 g) and roots (0.28 g) dry weights were obtained from the plants grown without application of GA_3. Higher concentration of GA_3 showed deleterious effect on leaves, bulbs and roots dry weight (Table 2). Interaction effect showed that the plants which were planted on November 07 without growth regulator had the highest dry weight (Table 3).

Plant leaves are the main organs where photosynthates are produced. So the amount of leaf dry matter increases with the increasing of leaf area and the number of leaves with the time course. As bulbing began after 60 d of growth, the photosynthetic efficiency of the leaves increased to meet their own as well as the growing bulbs. In this experiment, GA_3 showed deleterious effect and reduction in bulb weight. This is in agreement with the findings of Rahim[5].

Total dry matter (TDM): The cumulative dry matter accumulation in different planting dates and different concentrations of GA_3 was recorded from 30 DAP to 120 DAP and are presented in Tables 4 and 5, respectively. Rate of DM accumulation was slow upto 60 DAP. Then an accelerated rate of dry matter accumulation was observed. The highest TDM (4.90 g) was obtained from the planting date of November 07 (Table 4). Control plants (0 ppm GA_3) accumulated the highest dry matter (4.36 g) at maturity stage. Higher concentration of GA_3 reduced the TDM i.e. 100 ppm gave 4.08 g and 200 ppm gave 3.72 g TDM at maturity stage (Table 5). Interaction effect of early planting (November 07) and control (0 ppm) showed the highest TDM (5.31 g $plant^{-1}$) and accumulation decreased with later planting and higher concentrations of GA_3 (Table 6).

TDM weight is the cumulative dry weight of roots, leaves and bulbs. Production of higher dry matter in roots, leaves and bulbs from early planting resulted in higher TDM production. On the other hand, higher concentration of GA_3 reduced dry matter production in roots, leaves and bulbs resulted in lower production of TDM.

Leaf area index (LAI): LAI, a measure of the total assimilatory surface subtended by unit land area. Variation of LAI for different planting date and concentrations of GA_3 are presented in Tables 4 and 5, respectively. The initial slow rate of development of LAI was for poor vegetative growth and low temperature[22]. With the progression of time LAI increased steadily in all the individuals. Highest LAIs were obtained from control plants grown without GA_3 at all stages of growth. Application of GA_3 significantly reduced the LAIs. However, the magnitude was higher in 200 ppm than 100 ppm (Table 5).

The linear increase in LAIs with time was due to increased number of leaves and vigorous growth[23]. The subsequent reduction of LAI after attaining the maximum was due to the senescence of older leaves. Higher productivity of a crop depends on the persistence of high LAI[24]. A higher LAI was found with early planted (November 07) control plants at all stages of growth (Table 6).

Crop growth rate (CGR): Variations of CGR with different planting dates and concentrations of GA_3 were calculated from 30 DAP till 75 DAP and are presented in Tables 7, 8 and 9. CGR was lower at the initial stage of growth (30-45 DAP) and was almost similar to the growth stages of 45-60 DAP. CGR was rapidly increased at the growth stages of 60-75 DAP. November 22 plantings produced significantly higher CGR and December 22 the lowest at all stages of growth. CGR was the highest in the control plants and it gradually decreased with the increase in concentration of GA_3. Interaction effect between planting date and the concentration of GA_3 showed that early planted plants grown without GA_3 produced the highest CGR and December 22 plantings grown with 200 ppm GA_3 the lowest at all stages of growth. CGR is positively correlated with LA[24]. Thus CGR increased along with the increase in LAI. At the initial stages of growth CGR was lower with lower LAI. Similar result was reported in chickpea[17].

Net assimilation rate (NAR): Variations of NAR with different planting dates and concentrations of GA_3 and their interactions are presented in Tables 7, 8 and 9, respectively. The NAR at 30-45 DAP was higher than that of 45-60 DAP. However, the highest NAR was obtained during 60-75 DAP. Similar results were obtained in all treatments.

NAR is the measure of gaining in dry matter per unit leaf area per unit time and it is an important index of mean photosynthetic efficiency of a crop[17]. The higher values of NAR at 60-75 DAP both in date of planting and GA_3 might be related to the rapidly developing sinks i.e., bulbs[17].

Yield parameters

Bulb diameter: The diameter of bulb differed significantly by the different planting dates. The average diameter of the bulb was 1.85 cm. Plants which were planted on November 07 produced largest bulb diameter (2.15 cm) followed by 1.83 and 1.78 cm of November 22 and December 07 plantation, respectively. The minimum bulb diameter (1.62 cm) was obtained form the plants which were planted on December 22 (Table 1). These results are

similar to the report of many authors[3,4,6,25] who reported that early planted plants produced larger bulbs than the late planted plants. The plants that produced smaller bulb may be explained by the fact that the plants did not receive a long cool growing period, which was essential for proper development of bulbs[21,26,27,5,11].

100 and 200 ppm of GA_3 treated plants produced bulbs of 1.85 and 1.77 cm, respectively (Table 2). On the other hand, the control plants produced bulbs of 1.93 cm in diameter. Bulb size decreased at higher concentrations. Takagi and Aoba[8] reported that foliar spray of higher concentrations of GA_3 caused reduction in bulb growth of garlic. Suppression of bulb growth of onion due to GA_3 application was reported by Knypl[28,29].

There was no significant variation in bulb diameter due to the interaction of planting time and GA_3 concentration (Table 3). However, interaction effects showed that control plants that were planted on November 07 gave the largest bulb (2.20 cm) and the December 22 planted plants grown with 200 ppm GA_3 produced the smallest bulb (1.58 cm).

Individual bulb weight: Early planted plants produced higher individual bulb weight (7.58 g) and December 22 planted plants significantly reduced it in compared to early planted plants (Table 1). Higher weight of bulb in early planted crop was possibly due to longer period of photosynthesis that led to more deposition of photosynthates during the vegetative growth of plants. The highest bulb weight (7.26 g) was obtained from control plant and it was decreased with the increase in concentration of GA_3 (Table 2).

Interaction effect showed that early planted plants grown without GA_3 gave the highest weight of bulbs (8.28 g) per plant (Table 3). These weights were decreased gradually with late planting and higher concentrations of GA_3.

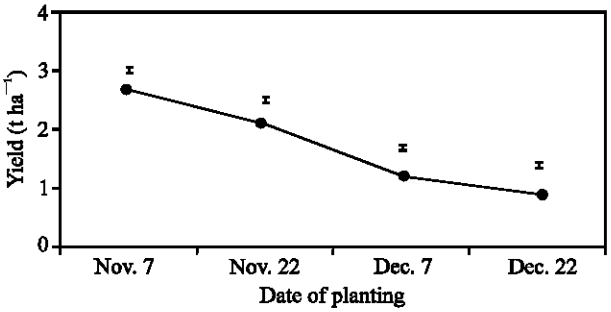

Fig. 1: Effects of planting date on the yield of garlic. The vertical bars indicate LSD at 5% level of significance

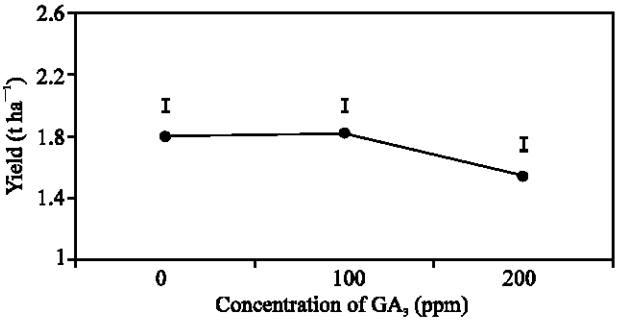

Fig. 2: Effects of GA3 on the yield of garlic. The vertical bars indicate LSD at 5% level of significance

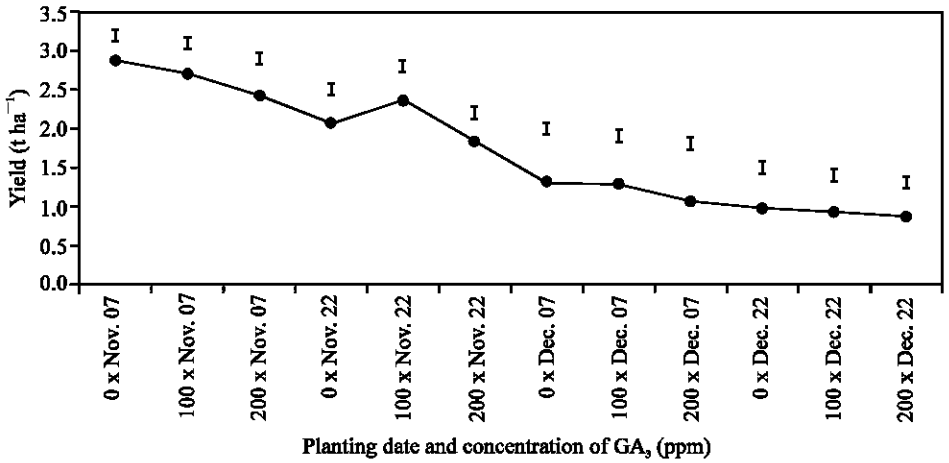

Fig. 3: Interaction effects of planting date and GA3 on the yield of garlic. The vertical bars indicate LSD at 5% level of significance

Yield: Per plot yield of garlic was converted into per hectare and was expressed in ton. Per hectare yield differed significantly due to different planting date and concentrations of GA_3. The yield decreased gradually with the lateness of planting. The highest yield (2.67 t ha^{-1}) was obtained from November 07 planting and the lowest (0.92 t ha^{-1}) was from December 22 planting (Fig. 1). These results agree with the findings of many authors[4,5,30-32]. The largest bulb size from the early planting contributed the highest yield. Smaller bulbs and lower yield was obtained from late planting which did not receive a long cool growing period which was essential for proper development of vegetative growth for garlic[3,26,27]. Bulb yield per hectare was higher in control plants than those of GA_3 treated plants (Fig. 2). Thus 100 ppm and 200 ppm of GA_3 showed deleterious effect on the growth and yield of garlic.

The combined effect of planting date and different concentrations of GA_3 showed that the highest yield (2.87 t ha^{-1}) was obtained from November 07 planting without application of GA_3. The yield of garlic gradually decreased with late planting and with the increase in concentrations of GA_3 (Fig. 3).

The main objective of the experiment was to observe the economic yield of garlic by planting in different planting dates and applying different concentrations of GA_3. Early planting can influence higher yield without application of growth regulators. Further investigation in this respect may provide information regarding the optimum date of planting and effective concentration of growth regulator to have better yield.

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