ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 49(4): 393-408, December 2024

EFFECT OF GA_3 AND GROWING CONDITION ON EMERGENCE AND SEEDLING GROWTH OF LETTUCE *(LACTUCA SATIVA* L.)

M. MONIRUZZAMAN[1] AND R. KHATOON[2]

Abstract

Two experiments were conducted in the research field of the Plant Physiology Section, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) from 05 to 30 December each of 2019 and 2020 to examine the influence of GA_3 and find suitable growing conditions for better seed germination of lettuce seeds. The experiment consisted of two levels of GA_3 *viz.* T_1 = 0.0 ppm (control) and T_2 = 10 ppm, and four growing conditions, G_1 = Seeding in polythene bag placed under diffused light; G_2 = Seeding in polythene bag placed under bright light, G_3 = Seeding in seedbed placed under diffused light and G_4 = Seeding in seedbed placed under bright light. Soaking of lettuce seeds in 10 ppm GA_3 gave higher seed emergence percent, seedling fresh weight, seedling dry weight, seedling length and seedling dry weight and seedling vigour index than that with control treatment and seed growing condition, G_1 treatment recorded the maximum seed emergence percent, seedling length and seedling vigour index. The treatment combination T_2 x G_1 or T_2 x G_3 showed the maximum seed emergence percent, seedling length and seedling vigour index. Treatment of lettuce seeds with 10 ppm GA_3 and grown under diffused light would be good for growing healthy seedlings.

Keywords: Lettuce, *Lactuca sativa*, field emergence, gibberellic acid, diffused light, vigour index.

Introduction

Lettuce (*Lactuca sativa* L.), an annual plant of Asteraceae family, is an important vegetable. It is normally consumed fresh as salads with tomato, carrot, cucumber or other salad vegetable and often served alone or with dressing. It is a good source of vitamins and is often prescribed to weight-conscious consumers because of its low kilojoules content (Maboko, 2007). The composition of lettuce leaves is approximately 94.3% water, 1.2% protein, 0.2% fat, 2.9% carbohydrate (CHO), 0.7% fiber, and 0.7% ash. It is rich in vitamin A, C, and E and minerals such as calcium, phosphorus, sodium, magnesium, and potassium.

BARI has released two varieties, namely BARI Lettuce-1 and BARI Lettuce-2, but seed germination of these two varieties is low (Quamruzzaman, 2019). Plant growth regulators have been reported to improve germination, seed yield and seed quality (Saimbhi, 1993). It is reported that soaking seeds with GA_3 solution could break the dormancy of lettuce seeds. The period of imbibitions is extremely

[1]Chief Scientific Officer, Planning and Evaluation Wing, Bangladesh Agricultural Research Institute (BARI), Gazipur, and [2]Senior Scientific Officer, Plant Physiology Section, HRC, BARI, Gazipur, Bangladesh.

sensitive to changes in the environment, and slight or sudden changes appear to profound effect on seedling emergence (Kahn and Goss, 1978). Lettuce seed is positively photoblastic and germinate only after they have been exposed to light. Gibberellins are known to replace the effect of light on seed germination at moderate temperature (Thomas *et al.*, 1977). GA_3 promotes germination, reduces many of the environmental requirements for germination and has a role in counteracting the inhibitory effects of ABA. Schuller and Colquhoun (2022) reported that the potential use of plant growth regulators such as gibberellic acid (GA) could enhance early emergence and growth rates. In response, a controlled environment study was conducted to investigate the effects of GA on cabbage, carrot, and onion. At 7 days after seeding carrot emergence was greater (14%) when carrot seeds were treated with 4 ppm GA compared with non-treated seeds and treatment of cabbage seeds with 2 to 4 ppm GA increased cabbage emergence rate compared with non-treated seeds (Schuler and Colquhaon, 2022). With the above facts in mind, the experiment was carried out to examine the influence of GA_3 and to find out suitable growing condition for better seed germination of lettuce seeds.

Materials and Methods

The experiment was carried out in the research field of Plant Physiology Section, Horticulture Research Center, BARI from 05 to 30 December 2019 and 03 to 28 December 2020. The treatment consisted of two levels of GA_3 (T_1 = 0.0 ppm GA_3, control as distilled water and T_2 = 10 ppm GA_3) and four growing conditions: G_1 = Seeding in poly bag placed under diffused light created by bamboo chatai with black polythene, G_2=Seeding in poly bag placed under bright light keeping open, G_3 = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene and G_4 = Seeding in seed bed placed under bright light keeping open. The experiment was laid out in Split-Plot design. Growth regulator treatments and growing condition treatments were allocated in main plot and subplot, respectively. The field was dived into 24 unit plots [1.0 m^2 (1 m x 1 m)]. Poly bags (7 cm x 6 cm) were kept in twelve unit plots. Thirty poly bags were taken for each unit plot. The medium of poly bag was prepared by mixing sandy loam soil and well rotten cowdung in 1:1 ratio. The rest of the 12 plots were prepared like seed bed. Only three kg well rotten cowdung was applied to each unit plot. Required amount of lettuce (BARI Lettuce -1) seeds were divided into two parts; one part was soaked in control (distilled water) for 12 hours and another part was soaked in 10 ppm GA_3 solution for 12 hours. After soaking, the seeds were air dried. Then air dried seeds were sown in unit plots on 5 December 2019 and 03 December 2020 maintaining spacing of 20 cm x 5 cm. Twenty seeds were sown in each line. After sowing, twelve plots were covered by bamboo-chatai and black polythene, and the rest 12 plots were kept open. Watering was done to poly bags and seed bed daily by water can with fine meshed nozzle until germination. The experiment was daily surveyed, and some traits were measured. Emergence started after 6 days of sowing. Data on emergence was recorded at 15 days after sowing (DAS). Data on shoot length, root length, shoot fresh weight, root fresh weight, SPAD value were recorded on 30 December 2019 and 28 December 2020. SPAD value was recorded by SPAD meter ((502 plus, Konika, Minolta, Japan) two days before taking growth related data. The root and shoot fresh sample were collected and were oven dried at 72ºC, for 72 hours. For root sampling, the desired plants were well watered and uprooted cautiously and collected roots were cleaned properly. The seedlings selected for calculating the seedling vigour index was oven dried at 72ºC for seven days. The oven dry weight of these seedlings was used as seedling dry matter. Seedling vigour index was determined by using the formula given by Abdul-Baki and Anderson (1973) as below:

Seedling Vigour index = Seedling length x germination percentage (%)

The collected data were subjected to analysis of variance using MSTAT-C. Mean separation was performed by LSD at 5% level of probability.

Results and Discussion

Emergence percentage

Application of GA_3 significantly influenced seed emergence percent in both the years 2019 and 2020 (Fig. 1 A). A higher emergence% was obtained from 10 ppm GA_3 (75.25% in 2019 and 73.61% in 2020) while lower from control (without GA_3) (60.53% in 2019 and 66.71% in 2020). Mohammed (2023) obtained the highest emergence percent (59.08%) of soybean seed using GA_3 while 48.75% emergence from control (without GA_3) in field condition. Abdullah *et al*. (2023) reported that GA_3 treed seeds of barley gave 97-98% germination while the control gave 93% germination in different varieties in field. Seed emergence was also significantly influenced by different growing conditions (Fig. 1 B). The maximum emergence% was recorded from G_1 (79.39% in 2019 and 85.28% in 2020) followed by G_3 (75.72% in 2019 and 82.21% in 2020) and the lowest from G_4 (55.28% in 2019 and 57.56% in 2020). The combination of GA_3 and growing condition had also a significant effect on emergence % (Fig. 2). The highest emergence % was obtained from T_2 x G_1 combination (86.11% in 2019 and 94.34% in 2020) followed by T_2 x G_3 combination (78.44% in 2019 and 88.90% in 2020) and its minimum value was recorded from T_1 x G_4 combination (44.44% in 2019 and 52.22% in 2020). Seed priming with GA_3 caused physiological and biochemical changes before germination that helps to increase germination percentage (Jaskani *et al.*, 2006). It is known that lettuce is a positive photoblastic seed, so poor germination is supposed to occur in the field underneath the soil. In this circumstance, GA_3 could meet the requirement of light. It is reported that the germination of photoblastic lettuce seeds is regulated by phytochrome, which is a red (R) and far-red (FR) light receptor in plants (Butler *et al*., 1959). Red light irradiation induces the germination of lettuce seeds, and FR irradiation given after R cancels the effect of R; hence, phytochrome-induced changes in seeds are reversibly modulated by different light frequencies. The regulation of lettuce seed germination by phytochrome is thought to be mediated by gibberellin (GA) (Sawada *et al*., 2008).

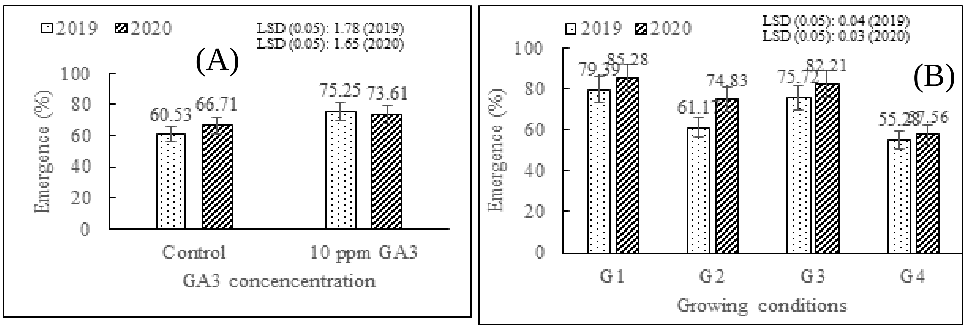


Fig. 1. Effect of GA_3 (A) and growing conditions (G) on emergence percent of lettuce seed.

T_1= 0.00 ppm GA_3 (distilled water), T_2 = 10 ppm GA_3, G_1 = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; G_2 = Seeding in polythene bag placed under bright light keeping open; G_3 = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; G_4 = Seeding in seed bed placed under bright light place keeping open; Y_1 = 2019, Y_2 = 2020.

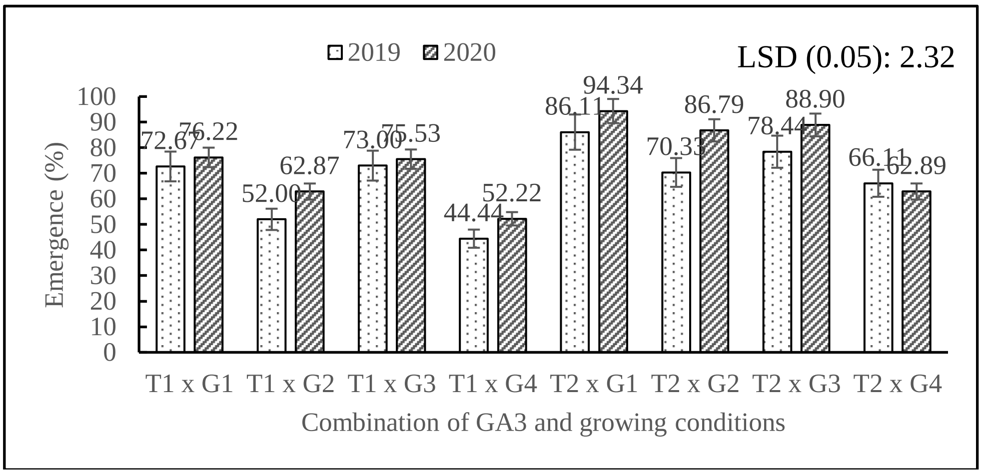


Fig. 2. Combined effect of GA_3 and growing conditions on emergence percent of lettuce seed.

T_1= 0.00 ppm GA_3 (distilled water), T_2 = 10 ppm GA_3, G_1 = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; G_2 = Seeding in polythene bag placed under bright light keeping open; G_3 = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; G_4 = Seeding in seed bed placed under bright light place keeping open; Y_1 = 2019, Y_2 = 2020.

Lewak and Khan (1977) reported that the seeds of lettuce (*Lactuca sativa* L. cv. Grand Rapids) germinate in darkness at 25^0 C when treated by gibberellic acid (GA_3) @ 10^{-3} M GA_3 for 1 hour following 2 hours of imbibition. Shade and dark condition created by bamboo chatai and black polythene influenced to synthesize less auxin hormone that also helped balance indigenous phytohormones within seeds and increase germination percentage (Korobova *et al*., 2023). Shaded condition also helped preserve soil moisture and seed germination was increased.

Shoot fresh weight, root fresh weight and seedling fresh weight

Shoot fresh weight and seedling fresh weight were significantly influenced by single effect of GA_3 application (Table 1). Shoot fresh weight (19.11 g in 2019) and seedling fresh weight (20.82 g in 2019 and 24.02 g in 2020) were found maximum from 10 ppm GA_3 application. Shoot fresh weight, root fresh weight and seedling fresh weight were also significantly affected by single effect of different growing conditions (Table 1). Maximum shoot fresh weight was found from G_4 (23.79 g in 2019 and 25.83 g in 2020) followed by G_2 (16.87 g in 2019 and 18.58 g in 2020) and G_3 (17.32 g in 2019 and 21.11 g in 2020) and the lowest shoot fresh weight from G_1 (14.70 g in 2019 and 18.78 g in 2020). The highest root fresh weight was obtained from G_1 (1.80 g in 2019 and 2.55 g in 2020) closely followed by G_2 and G_4 only in 2019. The growing condition G_4 produced maximum seedling fresh weight (25.29 g in 2019 and 27.64 g in 2020) which was followed by G_3 treatment (18.82 g in 2019 and 23.13 g in 2020) and the treatment G_1 gave the lowest seedling fresh weight (16.50 g in 2019 and 21.33 g in 2020). The combination of GA_3 and growing conditions had significant effect on shoot fresh weight, root fresh weight and seedling fresh weight (Table 1). The highest shoot fresh weight was recorded from T_2 x G_4 combination (25.45 g in 2019 and 26.58 g in 2020) followed by T_1 x G_4 combination (22.14 g in 2019 and 25.08 g in 2020). The lowest shoot fresh weight was obtained from T_1 x G_1 combination (14.10 g in 2019 and 18.06 g in 2020). In 2019, the combination T_2 x G_1 gave the maximum root fresh weight (1.86 g), which was statistically similar to T_2 x G_2 combination (1.85 g) and the lowest root fresh weight was obtained from T_1 x G_4 combination. In 2020, the highest root fresh weight was recorded from T_2 x G_1 combination (2.63 g) and the lowest from T_1 x G_4 combination (1.75 g).

Higher seedling fresh weight was obtained from 10 ppm GA_3 (20.82 g in 2019 and 24.02 g in 2020) while lower from the control (18.79 g in 2019 and 22.39 g in 2020) (without GA_3) (Table 1). Maximum seedling fresh weight was recorded from G_4 (25.29 g in 2019 and 27.64 g in 2020) followed by G_3 treatment (18.82 g in 2019 and 23.13 g in 2020) and the lowest from G_1 treatment (16.50 g in 2019 and 21.33 g in 2020). GA_3 and growing condition in combination gave the maximum seedling fresh weight (27.06 g in 2019 and 28.45 g in 2020) followed by T_1 x G_4 combination (23.53 g in 2019 and 26.83 g in 2020). The combination T_1 x G_1 combination produced the lowest seedling fresh weight (15.84 g in 2019 and 20.54 g in 2020).

Table 1. Effect of GA_3 and growing condition on seed emergence percentage, shoot fresh weight, root fresh weight, seedling fresh weight and SPAD value of lettuce seed

Treatment	Shoot fresh weight (g)		Root fresh weight (g)		Seedling fresh weight (g)		SPAD value	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
GA_3 (T)								
T_1	17.23	20.33	1.56	2.06	18.79	22.39	30.59	30.89
T_2	19.11	21.82	1.71	2.20	20.82	24.02	30.42	30.72
LSD (0.05)	1.15	NS	NS	NS	0.08	0.09	NS	NS
G_1	14.70	18.78	1.80	2.55	16.50	21.33	28.36	28.64
G_2	16.87	18.58	1.74	2.13	18.61	20.71	31.42	31.73
G_3	17.32	21.11	1.49	2.02	18.82	23.13	28.08	28.36
G_4	23.79	25.83	1.50	1.81	25.29	27.64	34.16	34.50
LSD (0.05)	1.15	1.75	0.09	0.11	0.10	0.13	2.41	2.61
CV (%)	3.70	4.31	9.20	5.76	3.98	6.76	6.81	7.09
Combined effect (TxG)								
T_1 x G_1	14.10	18.06	1.74	2.48	15.84	20.54	27.83	28.11
T_1 x G_2	15.60	17.78	1.63	2.06	17.23	19.84	32.81	33.14
T_1 x G_3	17.10	20.40	1.46	1.94	18.56	22.34	29.51	29.80

Treatment	Shoot fresh weight (g)		Root fresh weight (g)		Seedling fresh weight (g)		SPAD value	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
T_1 x G_4	22.14	25.08	1.39	1.75	23.53	26.83	32.71	33.04
T_2 x G_1	15.30	19.50	1.86	2.63	17.16	22.13	29.89	30.19
T_2 x G_2	18.15	19.38	1.85	2.20	20.00	21.58	30.53	30.84
T_2 x G_3	17.55	21.82	1.52	2.10	19.07	23.92	26.65	26.92
T_2 x G_4	25.45	26.58	1.61a	1.87f	27.06	28.45	35.61	35.97
LSD (0.05)	2.09	2.31	0.11	0.13	0.54	1.17	3.09	3.09
CV (%)	3.70	4.31	9.20	5.76	6.12	6.76	6.81	7.05

T_1= 0.00 ppm GA_3 (distilled water), T_2 = 10 ppm GA_3, G_1 = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; G_2 = Seeding in polythene bag placed in bright light keeping open; G_3 = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; G_4 = Seeding in seed bed placed under bright light place keeping open; Y_1 = 2019, Y_2 = 2020.

GA_3 application @ 10 ppm helped increase vegetative growth that is why maximum fresh weight was recorded from this treatment. Numerically root fresh weight was increased due to GA_3 application. As a result of increased shoot and fresh weight, seedling fresh weight was increased owing to GA_3 application. Under G_4 (Seeding in seed bed and placed in bright light place) treatment emergence percent was low that decreased the number of seedlings in unit area and hence the seedling got opportunity to have enough natural resources (light, nutrient, moisture, air etc.) and this treatment was able to give maximum shoot fresh weight. Conversely G_1 (shaded by bamboo chatai with black polythene) treatment helped increase root fresh weight because under this treatment, dark was created that increased root fresh weight. Ultimately seedling fresh weight was increased due to maximum shoot fresh weight that might be happened for higher chlorophyll synthesis and photosynthates.

SPAD value

GA_3 application singly did not influence SPAD value, but growing condition independently significantly influenced SPAD value (Table 1). Maximum SPAD value was recorded from G_4 (31.16 in 2019 and 34.50 in 2020) closely followed by G_2 (31.42 in 2019 and 31.73 in 2020) and its minimum value obtained from G_1 treatment (28.36 in 2019 and 28.64 in 2020). GA_3 and growing condition in combination had significant effect on SPAD value (Table 1). The highest SPAD value was obtained from T_2 x G_4 combination (35.61 in 2019 and 35.97 in 2020) closely followed by T_1 x G_4 (32.71 in 2019 and 33.04 in 2020), T_1 x G_2 (32.81 in 2019 and 33.14 in 2020) and T_2 x G_3 combination gave the lowest SPAD value (26.65 in 2019 and 26.92 in 2020) which was identical with T_2 x G_1, T_1 x G_3 and T_1 x G_1 combinations. Light helps in chlorophyll formation. Fan *et al*. (2023) reported that the concentration of photosynthetic pigments and chlorophyll biosynthesis precursors were higher under red and blue light, and this light condition was beneficial to pigment accumulation. For this reason, the seedlings grown in open condition had higher level of SPAD value than those grown in bamboo-chatai and black polythene covered condition that reduces light to create dark condition.

Shoot length and root length

Application of GA_3 irrespective of growing conditions had significant effect on shoot and root length of lettuce seedling (Table 2). GA_3 @ 10 ppm produced higher shoot length (7.86 cm in 2019 and 5.58 cm in 2020) and root length (8.82 cm in 2019 and 11.89 cm in 2020) than control treatment. Abdullah *et al*. (2023) reported that GA_3 treated seeds of barley gave higher shoot length than without GA_3. Growing condition singly influenced shoot and root length significantly (Table 2). Maximum shoot length was recorded from G_4 (8.56 g in 2019 and 5.70 g in 2020) followed by G_1 (7.53 cm in 2019), G_3 (7.43 cm in 2019) and G_2 (5.36 cm in 2020). In 2019, the highest root length was obtained from G_1 (9.65 cm) which was statistically similar to G_2 (9.54 cm) and growing condition G_3 and G_4 produced identical root length. In 2020, G_1 treatment produced maximum root length (14.48 cm) followed by G_2 (13.00 cm). GA_3 and growing condition in combination had significant effect on shoot and root length (Table 2). Maximum shoot length was recorded from T_2 x G_4 combination (9.38 cm in 2019 and 6.00 cm in 2020) followed by T_2 x G_3 combination (7.95 cm in 2019 and 5.28 cm in 2020). In 2020, there was no significant difference among T_1 x G_4, T_2 x G_1, T_2 x G_2 and T_2 x G_3 combinations. In the first year, the highest root length was obtained from T_2 x G_2 combination (10.78 cm) followed by T_1 x G_1 (9.70 cm) and T_2 x G_1 (9.60 cm) combination and the lowest from T_2 x G_4 combination. In 2020, the combination T_2 x G_2 combination gave the highest root length (14.95 cm) which was followed by T_1 x G_1 and T_1 x G_1 combinations and the lowest from T_1 x G_3 combination. GA_3 acts as a growth promoter and hence shoot length was increased (Noor *et al*., 2017) who obtained higher plant height than control treatment. Under bright light place (open condition), chlorophyll was synthesized more and greater photo-assimilates was produced (Fan *et al*., 2023) that helped increase shoot. Dark condition was also helpful to preserve soil moisture and keep the soil loose that assists in increasing root.

Seedling length

Application of GA_3 significantly influenced seedling length (Table 2). Higher seedling length was obtained from 10 ppm GA_3 (16.68 cm in 2019 and 17.47 cm in 2020) while lower from the control (without GA_3) (15.27 cm in 2019 and 15.53 cm in 2020). Noor *et al*. (2017) obtained higher plant height using GA_3 than control treatment. Seedling length was significantly influenced by different growing conditions (Table 2). Maximum seedling length was recorded from G_1 (17.17 cm in 2019 and 19.65 cm in 2020) followed by G_4 (15.89 cm in 2019) and by G_2 (18.36 cm in 2020) and G_2 (15.86 cm in 2019) and the lowest from G_3 (14.98 cm in 2019), but from G_4 (11.98 cm) in 2020. The combination of GA_3 and growing condition had a significant effect on seedling length (Table 2). The highest seedling length was obtained from T_2 x G_2 combination (17.58 cm in 2019 and 19.01 cm in 2020) closely followed by T_1 x G_1 combination (17.38 cm) in 2019 and its minimum value was recorded from T_1 x G_3 combination (13.50 cm) in 2019. But in 2020, the combination T_2 x G_1 recorded maximum seedling length (20.37 cm) which was followed by T_2 x G_2 combination (19.01 cm) and T_1 x G_1 combination (18.93 cm). Application of gibberellic acid increased shoot length as well as root length that resulted in seedling length. Low light condition created in G_1 and G_2 treatments which made such environment for the seedlings that helped increase seedling length. Ultimately, GA_3 application in combination with low light condition increased seedling length.

Table. 2. Effect of GA_3 and growing condition on shoot length, root length and seedling length of lettuce

Treatment	Shoot length (cm)		Root length (cm)		Seedling length (cm)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
GA_3 (T)						
T_1	7.06	5.06	8.21	10.47	15.27	15.53
T_2	7.86	5.58	8.82	11.89	16.68	17.47
LSD (0.05)	0.35	0.33	0.47	0.45	0.39	0.54
Growing condition (G)						
G_1	7.53	5.17	9.65	14.48	17.17	19.65
G_2	6.31	5.36	9.54	13.00	15.86	18.36
G_3	7.43	5.04	7.55	9.35	14.98	14.39
G_4	8.56	5.70	7.33	6.28	15.89	11.98
LSD (0.05)	0.32	0.31	0.37	0.37	0.38	0.51
CV (%)	3.93	4.05	3.49	5.43	3.10	4.87
Interaction (TxG)						
T_1 x G_1	7.68	4.93	9.70	14.00	17.38	18.93
T_1 x G_2	5.82	5.10	8.30	12.60	14.12	17.70
T_1 x G_3	6.90	4.80	6.60	9.13	13.50	13.93
T_1 x G_4	7.82	5.41	8.25	6.13	16.07	11.54
T_2 x G_1	7.37	5.42	9.60	14.95	16.97	20.37
T_2 x G_2	6.80	5.61	10.78	13.40	17.58	19.01
T_2 x G_3	7.95	5.28	8.50	9.57	16.45	14.85
T_2 x G_4	9.38	6.00	6.40	6.43	15.70	12.43
LSD (0.05)	0.45	0.41	0.53	0.51	0.54	0.53
CV (%)	3.93	4.05	3.49	5.43	3.10	4.87

T_1= 0.00 ppm GA_3 (distilled water), T_2 = 10 ppm GA_3, G_1 = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; G_2 = Seeding in polythene bag placed in bright light keeping open; G_3 = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; G_4 = Seeding in seed bed placed under bright light place keeping open; Y_1 = 2019, Y_2 = 2020

Shoot dry weight

Application of GA_3 significantly influenced shoot dry weight (Table 3). Higher shoot dry weight was obtained from 10 ppm GA_3 (1.67 g in 2019 and 1.56 g in 2020) while lower from the control (without GA_3) (1.58 g in 2019 and 1.49 g in 2020). Shoot dry weight was significantly influenced by different growing conditions (Table 3). Maximum shoot dry weight was recorded from G_4 (2.04 g in 2019 and 1.65 g in 2020) followed by G_2 and G_3 in 2019, but by G_3 in 2020 and the lowest from G_1. The combination of GA_3 and growing condition had a significant effect on shoot dry weight (Table 3). Maximum shoot dry weight was obtained from T_2 x G_4 combination (2.24 g in 2019 and 1.86 g in 2020) followed by T_1 x G_4 combination (1.84 g in 2019 g and 1.76 g in 2024) and its minimum value was recorded from T_1 x G_2 combination (1.49 g in 2019 and 1.26 g in 2020). Seedling dry weight was increased due to higher chlorophyll synthesis and net photosynthates under bright light condition and GA_3 application which helps in growth of seedlings. Under bright light place (open condition), chlorophyll was synthesized more and greater photo-assimilates was produced (Fan *et al*., 2023).

Table 3. Effect of GA_3 and growing condition on shoot dry weight, root dry weight, total dry weight and seedling vigour index of lettuce seedling

Treatment	Shoot dry weight (g)		Root dry weight (g)		Seedling dry weight (g)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
GA_3 (T)						
T_1	1.58	1.49	0.27	0.31	1.85b	1.80b
T_2	1.67	1.56	0.30	0.33	1.97a	1.90a
LSD (0.05)	0.06	0.04	NS	NS	0.10	0.09
Growing condition (G)						
G_1	1.43	1.33	0.29	0. 39	1.72	1.72
G_2	1.53	1.48	0.27	0.32	1.80	1.80
G_3	1.51	1.54	0.22	0.31	1.73	1.79
G_4	2.04	1.65	0.36	0.27	2.40	2.08
LSD (0.05)	0.04	0.03	0.04	0.02	0.07	0.08
CV (%)	4.64	4.67	12.11	6.76	3.99	5.43
Combined effect (TxG)						
T_1 x G_1	1.49	1.26	0.31	0.38	1.79	1.64
T_1 x G_2	1.41	1.53	0.25	0.30	1.66	1.83
T_1 x G_3	1.58	1.42	0.21	0.30	1.79	1.72
T_1 x G_4	1.84	1.76	0.33	0.27	2.17	2.03
T_2 x G_1	1.37	1.39	0.28	0.40	1.64	1.79
T_2 x G_2	1.66	1.43	0.29	0.34	1.95	1.77
T_2 x G_3	1.43	1.65	0.22	0.32	1.66	1.87
T_2 x G_4	2.24	1.86	0.39	0.27	2.63	2.13
LSD (0.05)	0.06	0.07	0.03	0.05	0.13	0.10
CV (%)	4.64	4.67	12.11	6.76	3.99	5.43

T_1= 0.00 ppm GA_3 (distilled water), T_2 = 10 ppm GA_3, G_1 = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; G_2 = Seeding in polythene bag placed in bright light keeping open; G_3 = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; G_4 = Seeding in seed bed placed under bright light place keeping open; Y_1 = 2019, Y_2 = 2020

Root dry weight

Root dry weight was not significantly influenced by GA_3 application and growing condition (Table 3). Numerically higher root fresh weight was obtained from GA_3

application. Root dry weight was significantly influenced by different growing conditions (Table 3). In 2019, maximum root dry weight was recorded from G_4 treatment (0.36 g) followed by G_1 and G_2 conditions, but in 2020, maximum root dry weight was recorded from G_1 condition (0.39 g) followed by G_2 condition. GA_3 application and growing conditions in combination significantly influenced root dry weight (Table 3). In 2019, maximum root dry weight was recorded from T_2 x G_4 combination (0.39 g) closely followed by T_1 x G_4 (0.33 g) and T_1 x G_1 (0.31 g) combinations. While, in 2020, maximum root dry weight was obtained from T_2 x G_1 condition (0.40 g) which was closely followed by T_1 x G_1 combination (0.38 g) and followed by T_2 x G_2 combination (0.34 g).

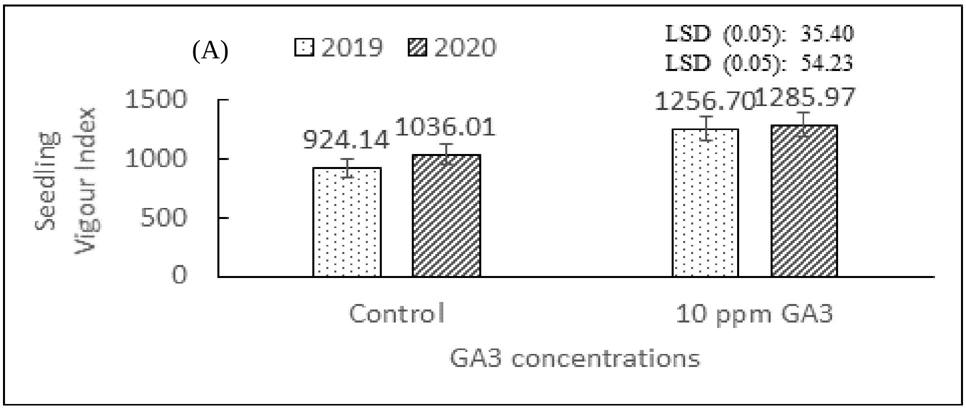
It is observed that there was a different result from two years in respect root dry weight. Dark condition (low light condition) helped more to increase root fresh weight in 2020, but in 2019, the bright sun light. There was also influence of GA_3 for increasing root dry weight.

Seedling dry weight

The application of GA_3 significantly influenced seedling dry weight (Table 3). Higher seedling dry weight was obtained from 10 ppm GA_3 (1.97 g in 2019 and 1.90 g in 2020), while lower from the control (without GA_3) (1.85 g in 2019 and 1.80 g in 2020). Abdullah *et al*. (2023) reported that GA_3 treed seeds of barley gave higher seedling dry weight than without GA_3. Seedling dry weight was significantly influenced by different growing conditions (Table 3). Maximum seedling dry weight was recorded from G_4 (2.40 g in 2019 and 2.08 g in 2020) followed by G_2 (1.80 in both 2019 and 2020) and the lowest from G_1 (1.72 g in both years). The combination of GA_3 and growing condition had a significant effect on seedling dry weight (Table 3). The highest seedling dry weight was obtained from T_2 x G_4 combination (2.63 g in 2019 and 2.13 g in 2020) followed by T_1 x G_4 combination (2.17 g in 2019 and 2.03 g in 2020) and its minimum value was recorded from T_2 x G_1 combination (1.64 g) in 2019, but from T_1 x G_1 combination in 2024. Seedling dry weight was increased due to maximum shoot fresh weight that might be happened for higher chlorophyll synthesis and photosynthates under bright sun light and due to the positive influence of GA_3.

Seedling vigour index

Application of GA_3 significantly influenced seedling vigour index (SVI) (Fig. 3A). Higher SVI was obtained from 10 ppm GA_3 (1256.7 in 2019 and 1285.97 in 2020) while lower from control (without GA_3) (924.14 in 2019 and 1036.01 in 2020). SVI was significantly influenced by different growing conditions (Fig 3 B). Maximum SVI was recorded from G_1 (1362.0 in 2019 and 1675.75 in 2020) and the lowest from G_4 (876.10 in 2019 and 689.57 in 2020). The combination of GA_3 and growing condition had a significant effect on SVI (Fig. 4). The highest SVI was obtained from T_2 x G_1 combination (1461.0 in 2019 and 1921.71 in 2020) followed by T_2 x G_3 combination (1290.0) in 2019 and T_2 x G_2 combination (1669.88) in 2020 and its minimum value was recorded from T_1 x G_4 combination (714.30 in 2019 and 602.60 in 2020). The seedling vigour index was calculated by multiplying the seed emergence percent and seedling length. A higher emergence percentage was recorded from GA_3 application and by the influence of low light condition. GA_3 helps break seed dormancy that gave higher emergence percentage. On the other hand, low light condition preserved soil moister and maintained the soil in loose condition that resulted in higher emergence percentage. Both GA_3 and low light condition gave the higher seedling length and ultimately maximum seedling vigour index was obtained. Abdullah *et al*. (2023) reported that GA_3 treated seeds of barley recorded maximum seedling vigour.



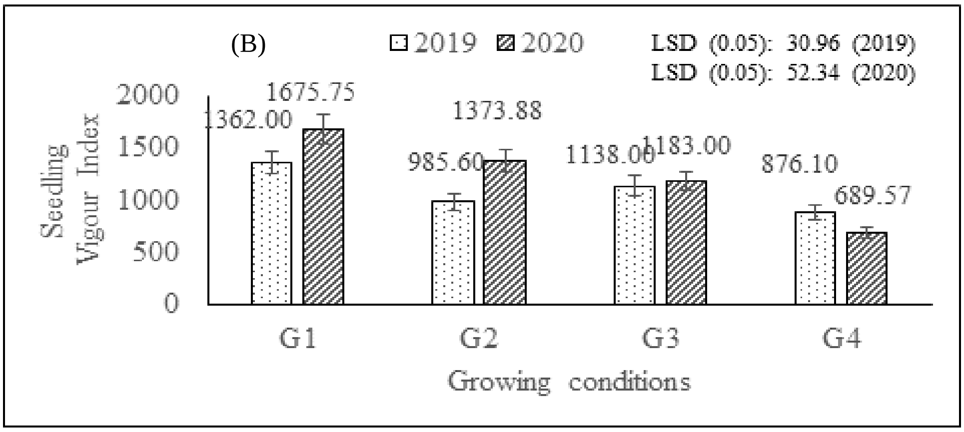


Fig. 3. Effect of GA_3 (A) and growing conditions (B) on seedling vigour index of lettuce seeds.

T_1= 0.00 ppm GA_3 (distilled water), T_2 = 10 ppm GA_3, G_1 = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; G_2 = Seeding in polythene bag placed in bright light keeping open; G_3 = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; G_4 = Seeding in seed bed placed under bright light place keeping open; Y_1 = 2019, Y_2 = 2020.

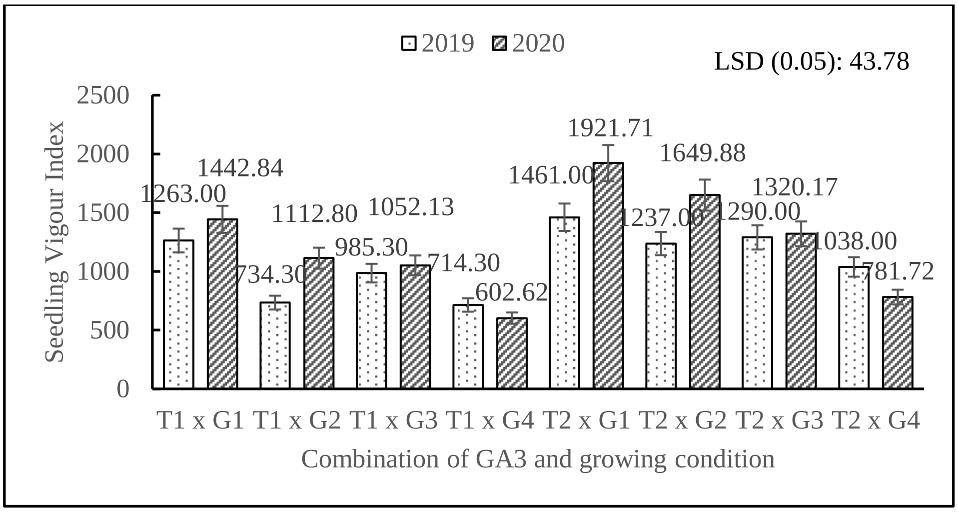


Fig. 4. Combined effect of GA_3 and growing conditions on seedling vigour Index of lettuce seeds

T_1= 0.00 ppm GA_3 (distilled water), T_2 = 10 ppm GA_3, G_1 = Seeding in polythene bag placed under diffused light created by bamboo chatai with black polythene; G_2 = Seeding in polythene bag placed in bright light keeping open; G_3 = Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene; G_4 = Seeding in seed bed placed under bright light place keeping open; Y_1 = 2019, Y_2 = 2020, Y_2 = 2020

Conclusion

The experimental results revealed that application of 10 ppm GA_3 (T_2) positively influenced seed emergence percent, seedling fresh weight, seedling dry weight, seedling length and seedling dry weight and seedling vigour index. Seed growing condition (G_1) (Seeding in polybag placed under diffused created by bamboo-chatai and black polythene) or G_3 (Seeding in seed bed placed under diffused light created by bamboo chatai with black polythene) recorded maximum seed emergence per cent, seedling length and seedling vigour index. Thus, the T_2 x G_1 or T_2 x G_3 combinations gave maximum seed emergence percent, seedling length and seedling vigour index. It is concluded that, for raising good and healthy lettuce seedlings diffused light condition created by bamboo chatai with black polythene cover in combination with 10 ppm GA_3 might be suggested.

References

Abdul-Baki, A. A. and J. D. Anderson. 1973. Vigour determination in soybean seed and by multiple criteria. *J. Crop Sci*. **13**: 630-633.

Abdullah, H. Mohammed and B. S. Baldwin. 2023. Effect of seed priming with gibberellic acid (GA_3) on seed germination and seedling growth of some barley varieties

(*Hordeum vulgare* L.). *Tikrit J. Agricul. Sci*. **23** (2):190-200 DOI: https :// doi. org/10. 25130/tjas .23.2.16

Butler, W. L., K. H. Norris, H. W. Siegelman, S. B. Hendricks. 1959. Detection, assay, and preliminary purification of the pigment controlling photoresponsive development of plants. Proceedings of the National Academy of Sciences, USA. **45**:1703–1708. doi: 10.1073/pnas.45.12.1703.

Crynos, M. 2015. Effects of retention period on field emergence, seed vigour and genetic purity of soybeans (*Glycine max* L). A dissertation submitted in partial fulfilment of the requirements of Bsc Natural Resources Management and Agriculture General Degree. Department of Agronomy. Midlands State University.52pp. https://cris .library .msu ac.zw /bitstream /11408/2535 /1 /final% 20marked%20project.pdf

Fan, X. X., J. Zang, Z.G. Xu, S.R. Guo, X. L. Jiao, X.Y. Liu and Y. Gao. 2023. Effect of different light quality on growth, chlorophyll concentration and chlorophyll biosynthesis precursors of non-heading Chinese cabbage (*Brassica campestris* L.). *Acta Physiogiae Plantarum*. **35**: 2721-2726. https :// link.springer.com/article/10. 1007/ s11738-013-1304-z.

Jaskani, M.J., S.W. Kwon, D.H. Kim, and H. Abbas. 2006. Seed treatments and orientation affects germination and seedling emergence in tetraploid watermelon. *Pak. J. Bot.* **38**(1): 89-98.

Kahn, A and J. A. Goss. 1978. Effect of gibberellins on germination of lettuce seed. *Science.* **125**:645-646.

Korobova, A., R. Ivanov , L. Timergalina , L. Vysotskaya , T. Nuzhnaya, G. Akhiyarova , V. Kusnetsov , D. Veselov , G. Kudoyarova. 2023. Effect of low light stress on distribution of auxin (Indole-3-acetic Acid) between shoot and roots and development of lateral Roots in barley Plants. 2023. *Biology (basel*). **12**(6):787. doi: 10.3390/biology12060787.

Lewak, S and A. A. Khan. 1977. Mode of action of gibberellic acid and light on lettuce seed germination. *Plant Physiol*. **60**: 575-577.http:/www.researchgate.net/publication / 7121175 _Mode _of _Action_ of_ Gibberellic _Acid_ and_ Light_ on_ Lettuce_ Seed_ Germination.

Maboko, M. M. 2007. "Leafy lettuce grown in a hydroponics system." *Undercover Farming Magazine. Pretoria, South Africa*. **3** (6): 8.

Mohammed, A. 2023. Effect of gibberellic acid on germination and seedling growth of Soybean (*Glycine max* L. Merrill). *Revis Bionatura*. **8** (2) 41. http://dx. doi. org/ 10.21931 /RB/2023.08.02.41

Noor, F., F. Hossain and U. Ara. 2017. Effects of gibberellic acid (GA_3) on growth and yield parameters of French bean (*Phaseolus vulgaris* L.). *J. Asiat. Soc. Bangladesh, Sci.* **43**(1): 49-60.

Quamruzzaman, A. K. M. 2019. Personal communication. Principal Scientific Officer, Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701.

Saimbhi, M. S. 1993. Growth regulators on vegetable crops. *In*: K. L. Chadha and G. Kallo (eds.). *Advances in Horticulture*, vol. **6** (I). Malhotra Publishing House, New Delhi, India. pp. 619-642.

Sawada, Y., T. Katsumata, J. Kitamura, H. Kawaide, M. Nakajima, T. Asami, K. Nakaminami, T. Kurahashi, W. Mitsuhashi, Y. Inoue and T. Toyomasu. 2008. Germination of photoblastic lettuce seeds is regulated via the control of endogenous physiologically active gibberellin content, rather than of gibberellin responsiveness. *J. Exper. Bot.* **59** (12) pp. 3383–3393. doi:10.1093/jxb/ern192

Schuller, J. and J. Colquhoun. 2022. Influence of gibberellic acid on vegetables crop and weed emergence. *Weed Tech*. **36** (6): 808-813. Doi: 10.1017/wet2022 83.

Thomas, T.H., D. Pallvitch, N.L Biddington, R. B. Austin 1975. Growth regulators and the phytochrome mediated dormancy of celery seeds. *Physiol. Plant*. **35**: 101-106.