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DURATION OF LOW TEMPERATURE STORAGE, CLOVE TOPPING AND GIBBERELLIC ACID ON GARLIC SPROUTING AND SEEDLING VIGOR

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ABSTRACT

Dormancy of garlic (*Allium sativum* L.) creates a problem in use of freshly harvested garlic bulbs. Thus, pre-planting treatment of garlic cloves is an important agronomic concern for inducing and improving sprouting behavior of garlic. Glasshouse experiment was conducted at Haramaya University to evaluate the effect of cold storage (7°C) durations (10, 20, 30 days and one stored at room temperature that is 21°C for 30 days), clove topping (whole and cut) and gibberellic acid concentrations (0, 125, 250 and 375 mg/l) and distilled water treatment as second control on sprouting behavior of improved garlic variety ('Tseday'). The treatments were laid out in factorial arrangement with three replications using completely randomized design (CRD). For cloves stored at ambient temperature (0 day) and non-topped, gibberellic acid application (250 and 375 mg/l) showed a significant increase in sprouting percentage, speed of sprouting and shoot dry mass of garlic as compared to 125mg/l GA_3 treated and the controls. On the other hand, for topped cloves stored at ambient temperature (0 day), 10 and 20 days cold storage, gibberellic acid treatment did not show a significant influence on these characteristics as compared to the controls. The interaction effect of 30 days cold stored and topped cloves significantly increased pseudo-stem height (40.51%) compared to the lowest values recorded for the non-cold treated and non-topped cloves. The 30 days cold stored and topped cloves soaked in water significantly increased sprouting percentage over the period of 19 days after planting, speed of sprouting (four fold) and above ground shoot dry mass (79.41%) compared to the lowest values recorded for the non-cold treated and non-topped cloves not soaked in water and gibberellic acid (GA_3). Hence, it can be concluded that 30 days cold storage, topping and soaking in water could enhance early sprouting of the garlic variety tested under glasshouse condition.

Key words: Clove topping, Dormancy, Garlic, Gibberellic acid, Sprouting percentage, Storage conditions

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INTRODUCTION

Garlic (*Allium sativum* L.) is conventionally propagated by its cloves. However, the garlic seed cloves cannot be planted immediately after harvesting because garlic needs a period of dormancy before resuming growth. This dormancy varies depending on the kind of variety and storage temperature [1]. Dormancy of garlic creates a problem in use of fresh bulbs for planting. Treatments of cloves with different low temperature, cutting and GA_3 have been reported to have potential to break dormancy and accelerate sprouting [2, 3, 4].

Plant growth regulators have been known to play a vital role in sprouting of garlic [2]. Gibberellins play a major role in diverse growth processes including seed development, organ elongation, senescence and control of flowering time [5]. Treatment of seed bulbs (cloves) in GA_3 solution stimulate sprouting and bulbing as well as its development [2].

The optimum storage temperature for sprouting of garlic is in the range of 5 to 10^{o}C [6]. According to Rosa *et al*. [4], low temperature affects enzymes involved in regulation of sucrose/starch ratio in plants. Sucrose is the free sugar in plants, which changes at low temperatures [7]. In such conditions, sucrose is catabolized to simple sugars for energy production [8].

Arifin *et al*. [3] reported that the bulbs received cutting treatments sprouted earlier than whole bulbs in all the accessions of shallot and *Allium wakegi.* Rabinowitch and Kamenetesky [9] reported that for easy and quick sprouting, the growing portion of the bulb is topped one-fourth to one-third of the height. Peter [10] also reported that bulbs are topped to break bud dormancy and enhance uniform sprouting prior to planting. This is due to removal of some sprout inhibiting substances contained in the removed scale portion of Easter lily as suggested by Lin and Roberts [11] and Wang and Roberts [12]. The substance inhibiting sprouting in the bulbs of *Allium wakegi* has been proved to be abscisic acid [13].

Timely availability of ready-to-sprout seed cloves at the onset of rain as well as for irrigation during the dry season is a prerequisite for attaining proper planting materials, which leads to high yields. To achieve this, use of freshly harvested garlic clove seed as a planting material after treating with low temperature storage, clove topping and gibberellic acid would be imperative. However, there is scarce information regarding the effects of these treatments on sprouting behavior of garlic varieties. Thus, the objective of this study was to evaluate the effectiveness of low temperature storage, clove topping and gibberellic acid on sprouting behavior of improved garlic variety, 'Tseday'.

MATERIALS AND METHODS

The experiment was conducted in a glasshouse at Haramaya University, Ethiopia, to evaluate the effect of cold storage, clove topping and gibberellic acid on sprouting behavior of garlic variety, 'Tseday', which has extended dormancy period of more than

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three months. The treatments were laid out in factorial arrangement with three replications using completely randomized design (CRD).

Plant material: Freshly harvested garlic bulbs were cured for 10 days (under ambient condition by thinly spreading them on wooden shelves in a diffused light store house, constructed from wood and having walls netted with a wire mesh and roofed with corrugated iron sheets) and separated into cloves. Medium sized cloves (3.0-3.50g) were sorted and placed in a refrigerator {MPR-311D (H)} at 7^0C such that different samples received 10, 20 and 30 days of cold storage before planting them in pot placed in a glasshouse. Another set of clove samples were stored at ambient temperature (21^0C) to be planted and serve as the control.

Clove preparation and planting: After cold storage, cloves from each storage treatment were grouped into two groups, one group topped at ¾ length and the second kept whole. The GA_3 solution at different concentrations {0 (non-treated), 0 (soaked in distilled water), 125, 250 and 375mg/l} was prepared by dissolving in a small amount of 70% ethanol (grain alcohol) until enough to wet before it was mixed with distilled water. Cloves were soaked for 24 hours. The treated and untreated cloves were then planted in pots (12 cloves per pot) filled with top soil, compost and sand (3:2:1, respectively).

Measurement of percent and speed of sprouting: The number of sprouted cloves was recorded starting from 7^{th} day of planting until the 49^{th}day. Speed of sprouting was estimated with slight modification of the procedure established for estimation of speed of germination by Maguire [14]. The numbers of sprouted cloves were counted daily until there was no further sprouting of cloves. An index was calculated by dividing the number of sprouted cloves each day by the number of days in which they have been sprouted, using the following formula.

$$\text{Speed of Sprouting} = \frac{N1}{C1} + \frac{N2}{C2} + \ldots + \frac{NF}{CF}$$

Where
N1 = number of normal sprouts at first count
N2 = number of normal sprouts at the second count
NF = number of normal sprouts at the final count
C1 = days to the first count
C2 = days to the second count
CF = days to the final count

To determine the sprouting percentage in number bases on predetermined days after treatments, the following formula was used:

$$\text{Sprouting percentage} = \frac{\text{Number of sprouted cloves}}{\text{Total number of cloves}} \times 100$$

Measurement of pseudo stem height and shoot dry mass: Five sprouted cloves were randomly taken and pseudo stem height was measured at 49^{th}day after planting. Shoot dry mass (g) was determined at 60^{th}day after planting. After measuring the fresh weight,

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the above ground part was dried at 70°C to constant mass in an oven and the dry mass was recorded.

Data analysis: Data obtained were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of the SAS statistical package version 9.2. All significant pairs of treatment means were compared using the Duncan's Multiple Range Test (DMRT) at 5% level of significance.

RESULT AND DISCUSSION

Effect of Pre-Planting Treatments on Sprouting Percentage

The analysis of variance revealed that the two main factors viz. clove topping and cold storage significantly influenced sprouting percentage ($P<0.01$) of garlic cloves starting from 7th to 49th day after planting. Gibberellic acid treatment did not significantly influence this characteristic. The two factors (clove topping x cold storage and clove topping x gibberellic acid) and the three factors (clove topping x cold storage x gibberellic acid) interacted to significantly influence sprouting percentage of garlic cloves until 49th day after planting, while cold storage and gibberellic acid interacted significantly only up to 31st day after planting (Table 1).

Topped cloves stored at ambient temperature (0 day) and treated as controls showed a comparable result in percentage of sprouting from 7th to 49th day after planting with cloves non-topped and 10 days cold stored cloves (treated as controls). Similarly, on these days, topped cloves stored for 10 days and treated as controls showed a comparable result with cloves non-topped and cold stored for 20 days (treated as controls). This could be due to the effect of cutting to break the bud dormancy. In agreement with this, Peter [10] reported that bulbs are topped to break bud dormancy and enhance uniform sprouting prior to planting. Arifin *et al*. [3] also reported that the bulbs received cutting treatments sprouted earlier than whole bulbs in all the accessions of shallot and *Allium wakegi.* This is due to removal of some sprout inhibiting substances contained in the removed scale portion as suggested by Lin and Roberts [11] and Wang and Roberts [12] in Easter lily. The substance inhibiting sprouting in the bulbs of *Allium wakegi* has been proved to be abscisic acid [13]. Similarly, Yamazaki *et al*. [15] and Teaster *et al*. [16] reported that the decrease in endogenous ABA content led to early sprouting.

Planting 30 days cold stored and topped cloves soaked in water significantly produced sprouts with highest percent (50%) after 7th day of planting. This was higher than whole cloves stored for same days in cold storage (36.11%) by about 38.46%. The interaction effect of 30 days cold storage, topping and soaking in water produced significantly highest percent of sprouts starting from 7th to 19th day after planting. However, cloves that received neither cold storage nor clove topping treatments and treated as controls gave the lowest sprouting percentage.

This could be due to the breaking of garlic dormancy by low temperature [17] and cutting [3]. In agreement with this, Youssef [18] reported that storage of cloves at 10°C for 30 days increased sprouting of cloves. This is presumably due to carbohydrates mobilization after starch hydrolysis during cold temperature exposure [19]. The mobilization of

carbohydrate reserves provides energy for development of leaves and photosynthetic apparatus in bulbous plants. It also shortens the sprouting time [20]. Soluble carbohydrate such as sucrose has been reported as the major associated factor for bulb development [21] and carbohydrates in general have shown a positive association in dormancy breaking of lily bulbs [22]. Takagi [23] also reported early sprouting of seed cloves stored at 7°C and attributed this to the effect of low temperature in reducing the proportion of growth inhibitors and increase of growth promoting hormones, especially gibberellins.

Application of GA_3 at a rate of 250 and 375mg/l on non-topped cloves stored at ambient temperature (0 day) resulted in a significant increase in sprouting percentage from 7th to 49th day after planting as compared to the controls. This could be due to dormancy breaking by GA_3. In agreement with this, Niimi *et al*. [24] reported that improved sprouting of bulbs could be achieved by a short treatment with gibberellins that can be used with or without exposing the plants to low temperatures.

Gibberellic acid application at a rate of 375 mg/l on ambient temperature stored (0 day) and non-topped cloves showed a comparable sprouting percentage from 7th to 43th day after planting with 10 days cold stored and non-topped cloves treated as controls. Moreover, GA_3 application at a rate of 375 mg/l on 10 days cold stored and non-topped cloves showed a comparable result from 7th to 49thday after planting with 20 days cold stored and non-topped cloves. Similarly, gibberellic acid application at a rate of 250 mg/l on 20 days cold stored and non-topped cloves showed a comparable result from 7th to 49thday after planting with 30 days cold stored and non-topped cloves except cloves treated with water at 13th and 25thday after planting. Rahman *et al.* [25] reported sprouting percentage of *Allium sativum* increased in bulbs treated with gibberelllic acid, where the highest percentage of germination was achieved at the concentration of 250 ppm.

The application of gibberellic acid on 20 days cold stored and non-topped cloves did not show significant influence on sprouting percentage from 7th to 49thday after planting as compared to the controls. Similarly, during the same time (days), this treatment did not show significant influence on sprouting percentage of topped cloves stored at ambient temperature (0 day) and cold stored for 10 days as compared to the controls. This could be due to the higher duration of cold storage and clove topping, respectively, which resulted in earlier release of clove dormancy. Petric *et al*. [26] also reported that GA_3 can compensate the lack of low-temperature for specific time period, but not completely and Arifin *et al*. [3] also reported the earlier dormancy breaking by cutting of bulbs.

The low sprouting percentage of non-cooled cloves suggests that the effect of gibberellic acid on these characteristics is weak unless the cloves were stored for a specific period of time at low temperatures. GA_3 can compensate the lack of low-temperature for specific period of time, but not completely [26]. Certain amount of hydrolyzed sugar must be stored in the bulb during the minimum period of low temperatures, which in the case of *Fritillaria meleagris* L. bulb is 4 weeks, to have enough energy to sprout and grow after a dormancy break [26].

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Effect of Pre-planting Treatments on Speed of Sprouting

Analysis of variance revealed that the two main factors viz. clove topping and cold storage significantly influenced speed of sprouting of garlic cloves ($P<0.01$) while gibberellic acid treatment did not significantly influence this characteristic. The two factors (clove topping x cold storage, clove topping x gibberellic acid and cold storage x gibberellic acid) and the three factors (clove topping x cold storage x gibberellic acid) interacted to influence significantly speed of sprouting of garlic cloves (Table 3).

Topped cloves, which were stored at ambient temperature (0 day), showed a higher speed of sprouting as compared to same days cold stored and non-topped cloves except at 250 and 375 mg/l GA_3 concentration. Similarly, topped cloves stored for 10 days and treated as controls showed a higher result as compared to same days cold stored and non-topped cloves except at 250 and 375 mg/l GA_3 concentration. This could be due to removal of some sprout inhibiting substances contained in the removed portion of cloves. In agreement with this, Rabinowitch and Kamenetesky [9] reported that for easy and quick sprouting, the growing portion of the bulb is topped one-fourth to one-third of the height. Arifin *et al*. [3] also reported that the bulbs received cutting treatments sprouted earlier than whole bulbs in all accessions of shallot and *Allium wakegi*.

Planting of 30 days cold stored cloves, (topped and non-topped) soaked in water resulted in a significant increase in speed of sprouting as compared to gibberellic acid treated cloves. However, cloves that received neither cold storage nor clove topping treatments and treated as controls gave the lowest speed of sprouting. This could be due to the ending of dormancy by low temperature [17, 18]. Cantwell *et al*. [27] also showed that storage of garlic at temperatures of 5-10°C than 25°C promoted respiration rate during storage and the emergence of seedlings.

Application of GA_3 at a rate of 375 mg/l on ambient temperature stored (0 day) and non-topped cloves showed a significant increase in speed of sprouting as compared to the controls and 125mg/l GA_3 treated cloves. In addition, this treatment has a comparable result with 10 days cold stored and non-topped cloves treated as controls. This could be due to stimulation of sprouting by GA_3 [24, 25].

Gibberellic acid application at a rate of 250 and 375 mg/l on 10 days cold stored and non-topped cloves showed comparable speed of sprouting with 20 days cold stored and non-topped cloves except at 250 mg/l GA_3 concentration. Similarly, gibberellic acid application at a rate of 250 mg/l on 20 days cold stored and non-topped cloves showed a comparable result with 30 days cold stored and non-topped cloves except water soaked cloves. This study finding agreed with Petric *et al*. [26] who reported that GA_3 application compensates the lack of low-temperature for specific time period.

The application of gibberellic acid on 20 days cold stored and non-topped cloves did not show significant influence on speed of sprouting as compared to the controls. Similarly, this treatment did not show significant influence on speed of sprouting of topped cloves in each of the storage duration except 30 days cold stored and topped cloves. This could

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be due to the higher duration of cold storage and clove topping, respectively, which resulted in earlier initiation of sprouting [3, 26].

Effect of Pre-Planting Treatments on Pseudo-stem Height

Analysis of variance revealed that the three main factors viz. clove topping, gibberellic acid and cold storage significantly influenced pseudo-stem height of garlic cloves ($P<0.01$). The two factors (clove topping x gibberellic acid and cold storage x gibberellic acid) and the three factors (clove topping x cold storage x gibberellic acid) did not significantly influence pseudo-stem height of garlic cloves while clove topping x cold storage interacted to influence significantly this characteristic (Table 3).

The low temperature treatment efficiently elongated stem of garlic plantlets for both types of cloves. The longest pseudo-stem height was found in cloves treated with 30 days cold storage and topping followed by 20 days cold storage and topping. This result agreed with a study by Satin and Lopez [28], which indicated that bulbs that received low temperature storage had increased plant growth compared to non-treated counterparts. The increase in pseudo-stem height with increase in duration of cold temperature could possibly be due to its effect on early breaking of dormancy thus enabling emerging seedlings to utilize reserve food in the cloves for easy establishment and further growth and development [28,29].

Siddique and Rabbani [30] also found that plantlet height was influenced by low temperature treatments that enhanced tallness of garlic plants. The tallest plantlets of the cold treated cloves could be due to early production of GA_3 and other growth substances ascribed to the cold treatment. In addition, Kurtar and Ayan [31] also reported that exposure of tulips to low temperature increased the production of gibberellins and auxins, which were necessary for stalk elongation.

The increase in pseudo-stem height by clove topping could possibly be due to removal of some sprout inhibiting substance, abscisic acid (ABA) contained in the removed portion which led to early sprouting of cloves and enabled proper stalk elongation. This result agreed with findings in a study by Singha and Powell [32], who used apple *(Malus domestica* Borkh cv Northern Spy) buds and found that ABA inhibited bud break and shoot elongation.

Effect of Pre-Planting Treatments on Shoot Dry Mass

Results from analysis of variance revealed that the two main factors viz. clove topping and cold storage significantly influence shoot dry mass of garlic cloves while gibberellic acid treatment did not significantly influence this characteristic ($P<0.01$). The two factors (clove topping x cold storage, clove topping x gibberellic acid and cold storage x gibberellic acid) and the three factors (clove topping x cold storage x gibberellic acid) interacted to influence significantly shoot dry mass of garlic cloves (Table 3).

Topped cloves, which were stored at ambient temperature (0 day) showed a higher shoot dry mass as compared to same days cold stored and non-topped cloves except at 250 and 375 mg/l GA_3 concentration. Similarly, topped cloves stored for 10 days showed a higher result as compared to same days cold stored, non-topped and treated as controls. The

increase in shoot dry mass by clove topping might be due to removal of ABA contained in the removed portion that enabled proper growth in vegetative parts. In agreement with this, Watts *et al*. [33], and Munns and Cramer [34] reported that ABA is generally regarded as inhibitor of shoot growth.

Planting of 30 days cold stored cloves (topped and non-topped), soaked in water resulted in a significant increase in shoot dry mass as compared to gibberellic acid treated cloves. However, cloves that received neither cold storage nor clove topping treatments and treated as controls gave the lowest shoot dry mass. This could be due to cold treatment that dramatically accelerated the rate of shoot extension due to GA-like substances, which induces the production of hydrolytic enzymes. Bhuiya *et al*. [35] and Ade-Ademilua *et al.* [36] reported that cool temperature storage helps to enhance shoot growth, indicating that garlic cloves treated with cold temperature could have enhanced vegetative growth, which increased shoot dry mass of the plant.

Application of GA_3 on ambient temperature stored (0 day) and 10 days cold stored and non-topped cloves showed a significant increase in shoot dry mass as compared to the controls. The increase in shoot dry mass by gibberellic acid could possibly be due to early breakdown of clove dormancy, which enabled proper shoot growth.

Ouzounidou *et al*. [37] reported that either shoot biomass of garlic expressed in fresh or dry weight significantly increased with GA_3 treatment at 100 ppm when applied three weeks after germination. Similarly, Marie *et al*. [38] showed that GA_3 increased the fresh and dry weight of okra as compared with the control.

Gibberellic acid application at a rate of 375 mg/l on ambient temperature stored (0 day) and non-topped cloves showed a comparable shoot dry mass with 10 days cold stored and non-topped cloves treated as controls. Additionally, GA_3 application at a rate of 375 mg/l on 10 days cold stored and non-topped cloves showed a comparable result with 20 days cold stored and non-topped cloves except at 250 mg/l GA_3 concentration. Similarly, gibberellic acid application at a rate of 250 mg/l on 20 days cold stored and non-topped cloves showed a comparable result with 30 days cold stored and non-topped cloves except water soaked cloves. This could be due to early sprouting of cloves and proper growth of vegetative parts by gibberellic acid application that lack sufficient amount of cold temperature exposure [27,37].

CONCLUSION

The results of the study showed significant improvement in sprouting percentage, speed of sprouting, pseudo stem height and shoot dry mass of garlic as a result of pre-planting clove treatments. Thus, it can be concluded that combination of cold storage (7^{o}C) duration for 30 days, clove topping and soaking in water could be used to treat fresh garlic cloves for higher sprouting percentage, speed of sprouting and shoot dry mass of garlic. Such seedling performance is indicative of further growth and yield success in a field and also it would be imperative for production of garlic twice in a year, under rain fed and irrigated conditions.

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Table 1: Mean square from analysis of variance for sprouting percentage of garlic cloves as influenced by clove topping, cold storage and gibberellic acid

Treatment	Clove topping A (1)	Cold storage B (3)	Gibberellic acid C (4)	A x B (3)	A x C (4)	B x C (12)	A x B x C (12)	Error (39)	CV (%)
7 DAP	3431.134**	4327.739**	16.493ns	134.838**	84.780**	40.027*	38.870*	18.934	15.62
13 DAP	5113.425**	6841.820**	19.386 ns	323.302**	216.145**	94.618**	88.445*	37.823	14.15
19 DAP	3255.243**	5955.878**	80.450ns	102.441*	283.571**	116.708**	78.326*	34.069	10.21
25 DAP	2675.926**	4951.389**	8.678ns	118.827**	158.567**	71.951**	62.886**	24.573	7.21
31 DAP	2445.053**	3978.997**	7.812ns	90.085**	88.255**	49.095**	34.624*	17.702	5.41
37 DAP	835.648**	2377.315**	40.509ns	130.401**	100.694**	31.636ns	49.383*	22.836	5.25
43 DAP	280.092**	1266.204**	17.940 ns	99.537**	63.079**	13.310ns	25.270*	11.737	3.61
49 DAP	148.148**	562.500**	8.102ns	174.383**	20.833*	6.944ns	18.133*	7.552	2.83

ns, * and **, non significant, significant at P<0.05 and P<0.01, respectively. Numbers in parenthesis represent degree of freedom, 7-49 DAP = 7-49 days after planting, and CV (%) = coefficient of variation in percent

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Table 2: The effect of clove topping, cold storage and gibberellic acid interaction on sprouting percentage of garlic cloves

CT	DLTS (days)	GA_3 (mg/l)	7DAP	13DAP	19DAP	25DAP	31DAP	37DAP	43DAP	49DAP
whole	0 (ambient)	0	0.00i	0.00n	11.11j	30.56m	47.22l	61.11g	72.22e	77.78f
		0(dw)	0.00i	2.78n	16.67j	36.11m	50.00l	63.89g	75.00e	83.33e
		125	0.00i	25.00m	41.67i	50.00l	61.11k	80.56f	86.11d	88.89d
		250	16.67h	25.00m	41.67i	52.78kl	61.11k	80.56f	86.11d	88.89d
		375	16.67h	27.78lm	44.44i	55.56jkl	66.67jk	83.33ef	88.89cd	91.67cd
	10	0	19.44gh	33.33j-m	47.22hi	61.11j-l	69.44ij	86.11d-f	91.67b-d	97.22ab
		0(dw)	19.44gh	33.33j-m	47.22hi	61.11h-j	69.44ij	86.11d-f	91.67 b-d	97.22ab
		125	22.22f-h	36.11i-l	50.00g-i	63.89g-i	72.22h-j	88.89c-e	94.44a-c	100.00a
		250	25.00e-g	38.89h-k	55.56f-h	66.67f-h	75.00g-i	88.89c-e	94.44a-c	97.22ab
		375	25.00e-g	41.67g-j	55.56f-h	69.44e-g	77.78f-h	91.67b-d	94.44a-c	97.22ab
	20	0	27.78ef	44.44g-i	55.56f-h	69.44e-g	77.78f-h	91.67 b-d	97.22ab	100.00a
		0(dw)	27.78ef	44.44g-i	58.33e-g	69.44e-g	77.78f-h	91.67 b-d	97.22ab	100.00a
		125	27.78ef	44.44g-i	61.11d-f	72.22d-f	80.56e-g	94.44a-c	100.00a	100.00a
		250	30.56de	47.22f-h	63.89c-f	75.00c-e	83.33d-f	97.22ab	100.00a	100.00a
		375	27.78ef	44.44g-i	61.11d-f	69.44e-g	77.78f-h	91.67 b-d	97.22ab	100.00a
	30	0	36.11cd	50.00e-g	66.67b-e	77.78b-d	86.11c-e	97.22ab	100.00a	100.00a
		0(dw)	36.11cd	58.33c-e	69.44b-d	83.33ab	88.89b-d	100.00a	100.00a	100.00a
		125	30.56de	47.22f-h	63.89c-f	72.22d-f	80.56e-g	97.22ab	100.00a	100.00a
		250	30.56de	47.22f-h	63.89c-f	72.22d-f	80.56e-g	97.22ab	100.00a	100.00a
		375	30.56de	47.22f-h	63.89c-f	72.22d-f	80.56e-g	97.22ab	100.00a	100.00a

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Table 3: Continued…

Cut	0 (ambient)	0	19.44gh	36.11i-l	47.22hi	61.11h-j	69.44ij	86.11d-f	91.67b-d	97.22ab
		0(dw)	19.44gh	36.11i-l	47.22hi	61.11h-j	69.44ij	86.11d-f	91.67b-d	97.22ab
		125	19.44gh	33.33j-m	47.22hi	58.33i-k	69.44ij	83.33ef	88.89cd	94.44bc
		250	16.67h	30.56k-m	44.44i	55.56j-l	66.67jk	83.33ef	88.89cd	94.44bc
		375	16.67h	30.56k-m	44.44i	55.56j-l	66.67jk	83.33ef	88.89cd	94.44bc
	10	0	27.78ef	41.67g-j	58.33e-g	69.44e-g	77.78f-h	91.67b-d	97.22ab	97.22ab
		0(dw)	27.78ef	41.67g-j	58.33e-g	69.44e-g	77.78f-h	91.67b-d	97.22ab	97.22ab
		125	27.78ef	41.67g-j	58.33e-g	69.44e-g	77.78f-h	88.89c-e	94.44a-c	97.22ab
		250	25.00e-g	38.89 h-k	55.56f-h	66.67f-h	75.00g-i	88.89c-e	94.44a-c	97.22ab
		375	25.00e-g	38.89 h-k	55.56f-h	66.67f-h	75.00g-i	88.89c-e	94.44a-c	97.22ab
	20	0	41.67bc	61.11b-d	72.22bc	83.33ab	91.67a-c	100.00a	100.00a	100.00a
		0(dw)	41.67bc	61.11 b-d	72.22bc	83.33ab	91.67a-c	100.00a	100.00a	100.00a
		125	41.67bc	61.11 b-d	72.22bc	83.33ab	91.67a-c	100.00a	100.00a	100.00a
		250	41.67bc	55.56d-f	69.44 b-d	80.56bc	88.89b-d	100.00a	100.00a	100.00a
		375	41.67bc	50.00e-g	69.44 b-d	77.78b-d	88.89b-d	100.00a	100.00a	100.00a
	30	0	47.22ab	69.44ab	75.00ab	88.89a	94.44ab	100.00a	100.00a	100.00a
		0(dw)	50.00a	72.22a	83.33a	88.89a	97.22a	100.00a	100.00a	100.00a
		125	44.44ab	66.67a-c	72.22bc	83.33ab	91.67a-c	100.00a	100.00a	100.00a
		250	44.44ab	66.67a-c	72.22bc	83.33ab	91.67a-c	100.00a	100.00a	100.00a
		375	44.44ab	66.67a-c	72.22bc	83.33ab	91.67a-c	100.00a	100.00a	100.00a

Means designated with different letter(s) in columns and rows have significant differences according to DMRT at 5% probability level. Dw=distilled water

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Table 4: Mean square from analysis of variance for speed of sprouting, pseudostem height and shoot dry mass of garlic cloves as influenced by clove topping, cold storage and gibberellic acid

Treatment	Clove topping A (1)	Cold storage B (3)	Gibberellic acid C (4)	A x B (3)	A x C (4)	B x C (12)	A x B x C (12)	Error (39)	CV (%)
Speed of sprouting	6.940**	10.686**	0.032^{ns}	0.289**	0.292**	0.118**	0.106**	0.022	5.59
Pseudostem height	13.790**	17.172**	0.447**	2.469**	0.092^{ns}	0.055^{ns}	0.030^{ns}	0.066	3.61
Shoot dry mass	0.297**	0.615**	0.002^{ns}	0.016**	0.012**	0.002**	0.002*	0.001	2.69

ns, * and **, non-significant, significant at P<0.05 and P<0.01, respectively

Table 5: The effect of clove topping, cold storage and gibberellic acid interaction on speed of sprouting of garlic cloves

Clove type	Duration of low temperature (days)	Gibberellic acid (mg/l)				
		0	0(DW)	125	250	375
Whole	0	0.99^{o}	1.12^{o}	1.69^{n}	1.99^{m}	2.09^{lm}
	10	2.27^{kl}	2.27^{kl}	2.41^{i-k}	2.54^{h-j}	2.60^{hi}
	20	2.68^{gh}	2.70^{gh}	2.76^{gh}	2.88^{fg}	2.72^{gh}
	30	3.05^{ef}	3.19^{de}	2.86^{fg}	2.86^{fg}	2.86^{fg}
Cut	0	2.30^{j-l}	2.30^{j-l}	2.24^{kl}	2.12^{lm}	2.12^{lm}
	10	2.67^{gh}	2.67^{gh}	2.65^{g-i}	2.54^{h-j}	2.54^{h-j}
	20	3.34^{b-d}	3.34^{b-d}	3.34^{b-d}	3.24^{c-e}	3.18^{de}
	30	3.56^{ab}	3.70^{a}	3.44^{bc}	3.44^{bc}	3.44^{bc}

Means designated with different letter(s) in columns and rows have significant differences according to DMRT at 5% probability level

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Table 6: The effect of cold storage duration and clove topping interaction on pseudo-stem height of garlic cloves

Clove topping	Duration (days) of low temperature (7^0C) storage	Pseudo-stem height
Whole	0	6.22^{g}
	10	6.57^{f}
	20	7.07^{d}
	30	7.29^{c}
Cut	0	6.43^{f}
	10	6.84^{e}
	20	7.86^{b}
	30	8.74^{a}

Means designated with different letter(s) in columns have significant differences according to DMRT at 5% probability level

Table 7: The effect of clove topping, cold storage and gibberellic acid interaction on shoot dry mass of garlic cloves

Clove type	Duration of low temperature (days)	Gibberellic acid (mg/l)				
		0	0(DW)	125	250	375
Whole	0	0.68^{o}	0.69^{o}	0.75^{n}	0.79^{m}	0.82^{lm}
	10	0.85^{l}	0.86^{l}	0.91^{k}	0.94^{i-k}	0.95^{h-j}
	20	0.96^{h-j}	0.97^{hi}	0.99^{gh}	1.02^{fg}	0.99^{gh}
	30	1.04^{ef}	1.08^{de}	1.03^{f}	1.03^{f}	1.03^{f}
Cut	0	0.84^{l}	0.85^{l}	0.83^{lm}	0.82^{lm}	0.82^{lm}
	10	0.95^{h-k}	0.97^{h-j}	0.95^{h-k}	0.93^{i-k}	0.92^{jk}
	20	1.12^{c}	1.13^{c}	1.11^{cd}	1.10^{cd}	1.09^{cd}
	30	1.19^{ab}	1.22^{a}	1.18^{b}	1.18^{b}	1.17^{b}

Means designated with different letter(s) in columns and rows have significant differences according to DMRT at 5% probability level

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