January 2022

THE SECOND INTERNATIONAL CONFERENCE ON GENETIC RESOURCES AND BIOTECHNOLOGY: Harnessing Technology for Conservation and Sustainable Use of Genetic Resources for Food and Agriculture

Committees: The Second International Conference on Genetic Resources and Biotechnology

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Preface: The Second International Conference on Genetic Resources and Biotechnology

The Second International Conference on Genetic Resources and Biotechnology, which is the continuation of the first event held in 2018, focuses on topics related to advances in biotechnology to create more opportunities for effective conservation and sustainable utilization of genetic resources for food and agriculture. This year conference's theme is Harnessing Technology for Conservation and Sustainable Use of Genetic Resources for Food and Agriculture. The conference was organized by Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture, Indonesia, in collaboration with Indonesian Biotechnology Consortium and held on 24th-25th of May 2021virtually due to the pandemic of COVID-19.

The conference aims to share and exchange current scientific information and technological developments on biotechnology and their applications for conservation and sustainable use of genetic, to encourage and promote quality, efficiency, and modernization of management and utilization of genetic resources, and to facilitate national and international collaboration among participants. There are five scopes discussed in this conference. They are effective management of conservation and sustainable use of genetic resources for food and agriculture, application of genomics and molecular markers for genetic resource conservation and crop adaptation to climate change, application of innovative crop improvement techniques for conservation and sustainable use of plant genetic resources for food and agriculture, plant cell and tissue culture for conservation and effective utilization of genetic resources, and the use of microbial genetic resources as biological control agents of agricultural pests and diseases, and for soil bioremediation.

Five speakers from the United States of America, Japan, India and Indonesia were invited to discuss about their expertise and knowledge on relevant subjects in the plenary sessions. This conference was attended by more than 100 participants including 75 presenters and 44 listeners worldwide. They came from diverse governmental, private, or academic institutions and also scientific communities. The presented materials have undergone peer review processes and only qualified papers were selected. Furthermore, all papers were subjected to double blind peer-review and expected to meet the scientific criteria of significance and academic excellence to be published in a conference proceedings indexed in a well-known, reputable service.

We would like to express our sincere gratitude to our speakers, presenters and all participants for their contributions in this conference. We would also like to express our appreciation for the generosity of our sponsors that support this conference: PT CropLife, PT ITS Science Indonesia, PT Fajar Mas Murni and PT Prima Instrument Analitika. Lastly, special thanks to all committee members for their exceptional work and contributions in the conference and publication.

Chair of Organizing Committee

Dr. Toto Hadiarto

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The growth of garlic internal sprout on different storage condition

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Chotimatul Azmi, Imas Rita Saadah, Nazly Aswani, et al.

The Growth of Garlic Internal Sprout on Different Storage Condition

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Abstract. Garlic is one of Indonesia main spices. However, garlic bulb needs a long period of dormancy (4–6 months) before sprouting. Garlic dormancy ends as the shoot emerges from the clove. This research was aimed to examine the internal sprout growth of different garlic cultivars. A factorial completely randomized block design with two replications was applied to the combination between four garlic varieties, i.e. Lumbu Hijau, Lumbu Putih, Lumbu Kuning, and Tawangmangu Baru, and three different storage condition, i.e. garlic storeroom, seed drying room, and cold storage. Observed parameters included bulb weight, number of cloves, clove diameter, clove length, internal sprout length, and ratio between internal sprout length and clove length. The results showed that the internal sprout length was affected by varietal difference and storage condition. There was an interaction between varieties and storage condition to the growth of garlic internal sprout. It also showed that cold storage method was approved to accelerate the internal sprout emergence of garlic cloves. Meanwhile, drying room method apparently hindered garlic dormancy compared to garlic storeroom.

INTRODUCTION

Garlic (*Allium sativum* L.) is one of Indonesia's main spices besides shallot and chili. Garlic has also been used as herbal medicine [1–5] or biopesticide. Indonesia has been China's largest garlic importer by 95% to fulfill national garlic demand [6]. Some other imported garlic is from India, USA, Malaysia, Switzerland, Germany, and Australia [7, 8]. Indonesia Agency of Agricultural Research Development (IAARD) has released four national garlic varieties, i.e. Lumbu Putih, Lumbu Hijau, Lumbu Kuning, and Tawangmangu Baru. These varieties have been produced mainly for vegetative seed production under the national certification standards. One of these standards is the requirement of dormancy state of garlic seed that is indicated by the internal sprout length has reached 75% of clove length [9], which means the vegetative seed is ready to be planted. On average, dormancy in garlic needs 4–6 months after harvest. This condition is troublesome for farmers who need either to sell garlic seed earlier in high market demand or, vice versa, to prolong the shelf life of the seed in low market demand situation.

There are numerous studies related to garlic dormancy, some of them mentioned that dormancy in garlic is affected by the storage temperature [10–22]. The five-week storage condition in 5°C caused garlic breaking dormancy [10]. Meanwhile, breaking dormancy of *in vitro* garlic bulbils occurred when kept in 4°C for three weeks [14]. In addition, pre-planting treatment in 10–15°C for 15–30 days was proven to accelerate the growth of garlic internal sprout by more than 70% depending on the observed varieties [23].

There are limited studies that evaluate this case on Indonesian varieties. A previous study on Lumbu Kuning has shown that the highest sprouting percentage occurred on low-temperature storage with 7°C temperature and 50–70% relative humidity [23]. Another similar study was also done for the Sangga Sembalun variety which concluded that thermal shock could be alternative way to shorten garlic dormancy [24]. Meanwhile, the storage condition in 4°C for 30 days was shown to break garlic variety of Lumbu Hijau [12]. Another study [13] showed that Corona Fluorescent Plasma Radiation treatment for 30 min can induce the growth of garlic internal sprout of Lumbu Kuning variety by 74%. Similar experiments using cold conditioning studied that Lumbu Kuning bulbs which were stored in 5°C for

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4 months only reached 1% sprouting, whereas none of Lumbu Hijau bulbs showed any sign of sprouting [15]. Another experiment showed that 25% of Lumbu Kuning bulbs sprouted when treated with cold conditioning in 7°C for 6 months, yet became dormant in 0°C [24]. Meanwhile, a study using higher temperature (38–42°C) continued with lower temperature (12–14°C) without GA3 for 2 weeks, respectively, was shown to increase sprouting percentage in Sangga Sembalun bulbs by 4.67% [24]. Thus, this research was aimed to evaluate the growth of internal sprouts of garlic cloves as the indication of dormancy state that is regulated in garlic seed certification standards.

MATERIALS AND METHODS

The research was conducted at IVEGRI's Lembang Experimental Station, West Java, Indonesia using three different storage conditions as the given treatment from December 2020 until April 2021. Factorial completely randomized design with two replications was applied on a combination of varieties (Lumbu Putih, Lumbu Hijau, Lumbu Kuning, and Tawangmangu Baru) and storage conditions, i.e. garlic storeroom (24°C, RH ±70%), seed drying room (30°C, RH ±50%), and cold storage (18°C, RH ±55%).

Preceding the treatments, freshly harvested garlic bulbs were air-dried and stored in a garlic storeroom (24°C, RH ±70%) for a total of 11–12 weeks. Each treatment used 2 bulbs as its replication. Bulbs of each variety were kept in three conditions, i.e. cold storage, drying room, and garlic storeroom. After 0, 1, 2, 3, 4 months, the bulbs were observed for the following parameters. Bulb weight both with (BWPS) and without pseudostem (BWWPS), number of bulbils per bulb (NBB), total weight of bulbils per bulb (TWBB), bulb diameter (BD), bulb length (BL), clove length (CL), clove diameter (CD), internal sprout (ISL), ratio between internal sprout length with clove length (RISCL), minimum clove length (MCL), maximum clove length (XCL), minimum clove diameter (MCD), maximum clove diameter (XCD), minimum internal sprout length (MISL), maximum internal sprout length (XISL), minimum ratio internal sprout length and clove length (MRISCL), maximum ratio between internal sprout length and clove length (XRISCL), weight loss, and number of cloves and clove weight.

The whole dried plant was weighed using a digital scale to measure bulb weight with pseudostem. The bulb weight was again measured by removing its pseudostem. Bulb diameter was measured at the largest part of the bulb using a digital caliper. The length of the clove was measured using a digital caliper from the tip of the clove to the base of the clove. The clove diameter was measured using a digital caliper at the widest part of the clove. The minimum or maximum value for each clove diameter, clove or bulb height, and internal sprout is the lowest or highest value taken from data on a group of cloves from the same bulb. Internal sprout length is measured from the base of the clove to the top of the internal sprout. Data obtained were analyzed using PKBT-STAT ver. 3.1 software that automatically executes the comparison between significant treatments using Tukey's Test.

RESULTS AND DISCUSSIONS

Analysis of Varian on Table 1 showed that varieties caused significant differences in most of the observed characters. Meanwhile, the interaction between variety and storage condition only affected on the growth of internal sprout (average internal sprout length and its minimum value, average ratio between internal sprout length, and clove length and its minimum value).

Table 2 showed that internal sprout length was significantly different within varieties in three different conditions from 4–5 weeks after treatment (WAT) until the end of observation (18–19 WAT). Consistent value from low to high on growth of internal sprout was observed from the seed drying room, garlic storeroom, dan cold storage, respectively. Garlic seeds stored in cold storage experienced the highest growth rate compared to the garlic storeroom and seed drying room conditions, starting 4–18 WAT. Different varieties have different responses to the growth of the buds. The storage temperature and variety affect the internal sprouting of garlic [25]. It was suggested that different variety needs different temperature and storage period. For example, storage condition of 10–15°C for 15–30 days induced the internal sprout growth of Egyptian garlic for more than 90% [23]. Cold temperatures can speed up the emergence of garlic sprouts. The inductive stage of garlic needs low temperature to trigger differentiation process of its axillary bud since a low temperature can affect sugar accumulation [26] and sprout proteome [10]. In the molecular level, 14 significantly upregulated DEGs contributing to calcium signal transduction have been found only from cold conditioned bulbs [14]. Furthermore, it was suggested that cold temperature increases gibberellin and reversely decreases abscisic acid. It activates gibberellin expressing genes and inactivates

abscisic acid expressing genes. Gibberellin is a growth hormone that induces the hydrolytic enzymes to break down carbohydrates for embryo development in shoot differentiation process.

TABLE 1. Effect of varieties and storage conditions on some garlic seed characters.

Characters	December			January			February			March			April		
	V	V×L	CV (%)	V	VxL	CV (%)	V	V×L	CV (%)	V	V×L	CV (%)	V	V×L	CV (%)
BWPS	*	ns	30.29	**	ns	22.98	**	ns	20.26	**	ns	17.79	**	ns	19.85
BWWPS	ns	ns	32.56	**	ns	23.41	**	ns	22.42	**	ns	17.09	**	ns	19.65
NBB	-	-	-	**	ns	59.88	ns	ns	103.94	**	ns	41.46	**	ns	59.16
TWBB	-	-	-	**	ns	54.25	ns	ns	136.01	ns	ns	116.99	**	ns	86.59
BD	-	-	-	**	ns	8.97	**	ns	9.62	**	ns	7.31	**	ns	8.05
BL	-	-	-	*	ns	14.84				**	ns	9.04	**	ns	10.59
CL	ns	ns	12.91	*	ns	9.30	*	ns	10.28	*	ns	10.19	**	ns	7.41
CD	*	ns	18.44	**	ns	10.78	**	ns	15.45	ns	ns	19.11	**	ns	13.00
ISL	ns	ns	18.80	*	*	18.46	ns	ns	14.23	ns	ns	18.23	ns	ns	20.52
RISCL	*	*	11.50	*	ns	18.80	**	**	9.14	**	**	8.18	*	ns	15.45
MCL	*	ns	17.86	*	ns	12.95	ns	ns	15.62	*	ns	21.50	**	ns	10.10
XCL	ns	ns	13.38	**	ns	8.68	ns	ns	13.00	ns	ns	16.13	**	ns	7.34
MCD	*	ns	26.20	**	ns	15.07	ns	ns	32.87	ns	ns	30.78	**	ns	19.56
XCD	ns	ns	19.93	**	ns	12.69	**	ns	15.79	*	ns	19.30	**	ns	17.99
MISL	ns	ns	26.80	**	*	21.42	*	ns	13.48	ns	ns	29.91	ns	ns	16.87
XISL	**	ns	14.96	ns	ns	31.37	ns	ns	16.91	ns	*	15.61	ns	ns	23.36
MRISCL	ns	*	20.40	**	ns	20.09	*	ns	16.43	**	ns	16.70	ns	ns	25.98
XRISCL	**	ns	18.30	ns	ns	24.95	ns	ns	35.63	**	**	8.44	**	ns	20.18

V = variety, L = location, CoV = coefficient of variance, BWPS = bulb weight with pseudo stem, BWWPS = bulb weight without pseudo stem, NBB = number of bulbils per bulb, TWBB = total weight of bulbils per bulb, BD = bulb diameter, BL = bulb length, CL = clove length, CD = clove diameter, ISL = internal sprout length, RISCL = ratio between internal sprout length with clove length, MCL = minimum clove length, XCL = maximum clove length, MCD = minimum clove diameter, XCD = maximum clove diameter, MISL = minimum internal sprout length, XISL = maximum internal sprout length, MRISCL = minimum ratio between internal sprout length and clove length, XRISCL = maximum ratio between internal sprout length and clove length, ns = nonsignificant at 5% level of significance. *Significant different at 5% level of significance. **Highly significant different at 1 % level of significant.

In this study, breaking dormancy within Lumbu Putih variety was the fastest among other three varieties. It is because this variety was released as a variety adapted to lowland. Thus, it is more sensitive to the cold conditioning treatment.

Percentage of ratio between internal sprout length with clove length was significantly different among varieties on the three storage conditions from 4–5 WAT until the end of observation as shown in Table 3. Consistent value from low to high percentage of ratio between internal sprout length with clove length was observed from seed drying room, garlic storeroom, dan cold storage, respectively. After being stored for 4–5 weeks in cold storage, the ratio percentage of internal sprout length to clove length increased by 78.75%, 28.48% in seed drying room, and 60.67% in garlic storeroom. Bulbs stored in cold storage (18°C, RH ±55%) showed accelerated sprouting up to 75%. This condition is the requirement in inspection for garlic seed certification in the warehouse. It is likely that if the temperature is lowered, internal sprout needs shorter period to reach 75% of the clove length. A temperature of 7°C provides faster shoot growth than a temperature of 0°C and a temperature of 29–30°C [23]. Conclusively, for all treated varieties, the status of 75% sprouting can be reached by storing garlic bulbs in cold storage for 4–5 weeks. The result [23] was in accordance with the previous study which found that bulbs which were treated with 10–15°C temperature for 15–30 days had grown internal sprout to more than 70% depending on garlic varieties [25].

TABLE 2. Internal sprout length (ISL; mm) of Indonesia garlic varieties on three different storage conditions.

Variety	Garlic storeroom	Seed drying room	Cold storage	Average
December (0 WAT)				
Tawangmangu Baru	4.33 a	4.81 a	5.28 a	4.80 a
Lumbu Putih	5.55 a	5.74 a	5.94 a	5.74 a
Lumbu Hijau	3.98 a	4.93 a	4.53 a	4.48 a
Lumbu Kuning	6.51 a	4.59 a	5.53 a	5.54 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	5.09 a	5.02 a	5.32 a	
January (4–5 WAT)				
Tawangmangu Baru	9.68 a	4.83 b	14.07 b	9.52 a
Lumbu Putih	11.40 a	11.60 a	14.92 ab	12.64 a
Lumbu Hijau	7.10 a	4.66 b	16.96 ab	9.58 a
Lumbu Kuning	9.99 a	5.91 ab	20.76 a	12.22 a
Tukey's HSD 5% level of significance	6.36	6.36	6.36	3.67
Average	9.54 b	6.75 b	16.68 a	
February (9–10 WAT)				
Tawangmangu Baru	11.17 b	5.46 c	16.25 a	10.96 a
Lumbu Putih	16.71 b	5.67 c	18.55 a	13.64 a
Lumbu Hijau	9.17 b	5.21 c	18.09 a	10.82 a
Lumbu Kuning	12.62 b	5.65 c	19.50 a	12.59 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	12.42 b	5.50 c	18.10 a	
March (13–14 WAT)				
Tawangmangu Baru	13.30 b	5.97 c	20.09 a	13.12 a
Lumbu Putih	17.49 b	13.27 c	17.25 a	16.00 a
Lumbu Hijau	15.47 b	5.69 c	20.46 a	13.87 a
Lumbu Kuning	13.81 b	7.01 c	21.54 a	14.12 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	15.02 b	7.98 c	19.83 a	
April (18–19 WAT)				
Tawangmangu Baru	17.63 a	6.93 b	21.45 a	15.33 a
Lumbu Putih	18.69 a	13.28 b	17.12 a	16.36 a
Lumbu Hijau	15.14 a	6.75 b	17.65 a	13.18 a
Lumbu Kuning	20.54 a	6.72 b	22.18 a	16.48 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	18.00 a	8.42 b	19.60 a	

WAT = weeks after treatment. Different letters indicate significant differences between means within columns at Tukey's 5% level of significance.

To slow the growth of shoots, garlic bulbs can be stored in a seed drying room with a temperature of 30°C and RH ±50%. This treatment can be applied for storing garlic in certain period.

TABLE 3. Ratio between internal sprout length with clove length (RISCL; %) among garlic varieties on three different storage conditions.

Variety	Garlic storeroom	Seed drying room	Cold storage	Average
December (0 WAT)				
Tawangmangu Baru	21.21 b	26.71 ab	27.21 a	25.04 ab
Lumbu Putih	29.20 ab	30.66 a	30.94 a	30.27 a
Lumbu Hijau	20.21 b	26.61 ab	23.86 a	23.56 b
Lumbu Kuning	31.90 a	19.06 b	24.77 a	25.24 ab
Tukey's HSD 5% level of significance	9.38	9.38	9.38	5.42
Average	25.63 ab	25.76 ab	26.69 ab	
January (4–5 WAT)				
Tawangmangu Baru	42.49 b	24.55 c	71.48 a	46.17 b
Lumbu Putih	64.44 a	58.12 ab	79.82 a	67.46 a
Lumbu Hijau	33.03 c	24.09 c	78.68 a	45.26 b
Lumbu Kuning	39.61 c	27.03 c	85.02 a	50.56 ab
Tukey's HSD 5% level of significance	-	-	-	17.81
Average	44.89 b	33.45 c	78.75 a	
February (9–10 WAT)				
Tawangmangu Baru	52.95 b	30.42 a	81.40 a	54.93 b
Lumbu Putih	87.44 a	31.93 a	90.29 a	69.89 a
Lumbu Hijau	53.07 b	26.98 a	83.03 a	54.36 b
Lumbu Kuning	49.23 b	24.58 a	88.40 a	54.07 b
Tukey's HSD 5% level of significance	16.69	16.69	16.69	9.64
Average	60.67 b	28.48 c	85.78 a	
March (13–14 WAT)				
Tawangmangu Baru	66.56 b	29.50 b	94.61 a	63.56 b
Lumbu Putih	84.75 a	69.06 a	93.62 a	82.48 a
Lumbu Hijau	61.57 b	27.23 b	93.58 a	60.79 b
Lumbu Kuning	54.80 b	28.77 b	89.68 a	57.75 b
Tukey's HSD 5% level of significance	16.96	16.96	16.96	9.79
Average	66.92 b	38.64 c	92.87 a	
April (18–19 WAT)				
Tawangmangu Baru	87.18 a	34.87 b	103.26 a	75.10 ab
Lumbu Putih	97.75 a	76.09 ab	109.73 a	94.52 a
Lumbu Hijau	84.58 a	33.98 b	91.91 a	70.16 b
Lumbu Kuning	78.8 ab	26.31 b	95.62 a	66.91 b
Tukey's HSD 5% level of significance	-	-	-	21.43
Average	87.07 a	42.81 b	100.13 a	

WAT = weeks after treatment. Different letters indicate significant differences between means within columns at Tukey's 5% level of significance.

The shortest internal sprout (minimum internal sprout length) was significantly different among garlic varieties on three different storage conditions observed from 4–5 WAT until the end of observation (Table 4). Consistent value from low to high number of minimum internal sprout was observed from seed drying room, garlic storeroom, dan cold storage, respectively. However, the growth of garlic internal sprout during storage treatment is not evenly distributed between the cloves within the same bulbs. It was found that there were cloves sprouting more slowly than other cloves in one bulb. This indicates that the checking for 75% dormancy status in garlic seed certification must be done to all cloves in one bulb to ensure the majority or average internal sprout length. We found that this 75% sprouting condition occurred on the 4^{th}–5^{th} week in the cold storage treatment of all varieties; 18^{th}–19^{th} week in the garlic storeroom treatment of all varieties, except Lumbu Putih, which already 75% sprouted in its 9^{th}–10^{th} week.

TABLE 4. Minimum internal sprout length (MISL; mm) among garlic varieties on three different storage condition.

Variety	Garlic storeroom	Seed drying room	Cold storage	Average
December (0 WAT)				
Tawangmangu Baru	3.47 a	4.05 a	3.64 a	3.72 a
Lumbu Putih	3.57 a	4.15 a	2.88 a	3.53 a
Lumbu Hijau	2.47 a	3.32 a	2.37 a	2.72 a
Lumbu Kuning	5.33 a	2.70 a	4.86 a	4.29 a
Tukey's HSD 5% level of significance	3.47	4.05	3.64	3.72
Average	3.57 a	4.15 a	2.88 a	3.53 a
January (4–5 WAT)				
Tawangmangu Baru	3.41 a	3.31 a	9.85 b	5.52 b
Lumbu Putih	6.89 a	8.35 a	12.56 b	9.27 a
Lumbu Hijau	4.23 a	3.54 a	10.88 b	6.22 b
Lumbu Kuning	8.08 a	4.07 a	18.57 a	10.24 a
Tukey's HSD 5% level of significance	5.24	5.24	5.24	3.03
Average	5.65 b	4.82 b	12.96 a	
February (9–10 WAT)				
Tawangmangu Baru	9.25 ab	4.08 b	13.34 a	8.89 ab
Lumbu Putih	13.21 a	3.83 b	14.95 a	10.66 a
Lumbu Hijau	6.23 b	3.43 b	13.48 a	7.71 b
Lumbu Kuning	8.97 ab	3.65 b	14.33 a	8.98 ab
Tukey's HSD 5% level of significance	-	-	-	2.21
Average	9.41 ab	3.75 b	14.02 a	
March (13–14 WAT)				
Tawangmangu Baru	9.30 b	4.91 c	14.78 a	9.66 b
Lumbu Putih	14.99 b	9.45 b	15.21 a	13.22 b
Lumbu Hijau	12.68 b	4.39 c	16.22 a	11.10 b
Lumbu Kuning	7.87 b	5.02 c	18.91 a	10.60 b
Tukey's HSD 5% level of significance	-	-	-	-
Average	11.21 b	5.94 c	16.28 a	
April (18–19 WAT)				
Tawangmangu Baru	13.94 a	4.85 b	18.21 a	12.33 a
Lumbu Putih	15.70 a	7.12 b	11.91 a	11.58 a
Lumbu Hijau	10.09 a	5.70 b	14.23 a	10.01 a
Lumbu Kuning	15.85 a	5.23 b	13.83 a	11.64 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	13.90 a	5.72 b	14.54 a	

WAT = weeks after treatment. Different letters indicate significant differences between means within columns at Tukey's 5% level of significance.

Table 5 showed that minimum ratio between internal sprout length and clove length (%) was significantly different among varieties on three different storage condition from 4–5 WAT until the end of observation. Consistent ratio value from low to high of minimum internal sprout length to clove length was observed from seed drying room, garlic storeroom, dan cold storage, respectively. It also showed that the ratio of minimum length of internal sprout to clove length in cold storage treatment reached to 75% for 13–14 WAT.

TABLE 5. Minimum ratio between internal sprout length and clove (MRISCL; %) among garlic varieties on three different storage conditions.

Variety	Garlic storeroom	Seed drying room	Cold storage	Average
December (0 WAT)				
Tawangmangu Baru	15.95 ab	20.95 ab	21.94 a	19.61 a
Lumbu Putih	18.64 ab	24.53 a	19.27 a	20.82 a
Lumbu Hijau	12.01 b	22.64 a	12.87 a	15.84 a
Lumbu Kuning	24.49 a	10.47 b	21.87 a	18.94 a
Tukey's HSD 5% level of significance	12.02	12.02	12.02	-
Average	17.77	19.65	18.99	
January (4–5 WAT)				
Tawangmangu Baru	15.50 b	13.66 b	55.86 a	28.34 b
Lumbu Putih	42.61 ab	40.77 ab	67.93 a	50.44 a
Lumbu Hijau	22.71 b	17.08 b	62.04 a	33.94 b
Lumbu Kuning	26.86 b	18.70 b	75.42 a	40.33 ab
Tukey's HSD 5% level of significance	-	-	-	13.91
Average	26.92 b	22.55 b	65.31 a	
February (9–10 WAT)				
Tawangmangu Baru	49.76 b	23.17 c	66.05 a	46.33 ab
Lumbu Putih	66.90 a	22.57 c	81.17 a	56.88 a
Lumbu Hijau	39.10 b	19.68 c	60.00 a	39.59 b
Lumbu Kuning	39.16 b	18.62 c	80.80 a	46.19 ab
Tukey's HSD 5% level of significance	-	-	-	14.05
Average	48.73 b	21.01 c	72.01 a	
March (13–14 WAT)				
Tawangmangu Baru	48.68 b	22.50 c	87.85 a	53.01 b
Lumbu Putih	74.58 a	52.04 b	86.86 a	71.16 a
Lumbu Hijau	54.37 b	22.48 c	80.63 a	52.49 b
Lumbu Kuning	36.62 c	19.70 c	81.10 a	45.81 b
Tukey's HSD 5% level of significance	-	-	-	16.81
Average	53.56 b	29.18 c	84.11 a	
April (18–19 WAT)				
Tawangmangu Baru	67.17 ab	25.41 b	86.10 a	59.56 ab
Lumbu Putih	86.07 a	49.44 b	75.24 a	70.25 ab
Lumbu Hijau	60.09 ab	29.64 b	95.43 a	61.72 ab
Lumbu Kuning	61.62 ab	21.25 b	71.22 a	51.37 ab
Tukey's HSD 5% level of significance	-	-	-	-
Average	68.74 ab	31.44 b	82.00 a	

WAT = weeks after treatment. Different letters indicate significant differences between means within columns at Tukey's 5% level of significance.

It may be concluded from Tables 2–5 that cold storage condition (18°C, RH ±55%) can accelerate the growth of garlic internal sprout. On the contrary, seed drying room (30°C, RH ±50%) can hinder the growth of garlic internal sprout.

Observation made on 10^{th}–11^{th} week after harvest showed that Lumbu Kuning had the highest bulb weight (with pseudo stem), bulb weight without pseudo stem, average number and weight of bulbils per bulb, average bulb diameter and length, average clove length and diameter, whereas Lumbu Putih had the lowest number (Table 6). At 18–19 WAT or about 32–33 weeks after harvesting, the weight of the garlic bulbs of Tawangmangu Baru, Lumbu Putih, Lumbu Hijau, and Lumbu Kuning were 21.78 g, 12.49 g, 25.93 g, and 27.96 g, respectively. While bulb diameter was 40.01 mm, 29.59 mm, 42.60 mm, and 43 mm, respectively. This study resulted in a larger bulb size when compared to the results of the study by Sandrakirana *et al*. [27] which described diameter of Lumbu Putih

3.44 cm, Lumbu Kuning 3.36 cm, Tawangmangu Baru 3.07 cm, and Lumbu Hijau 2.97 cm. The bulb length in this study were Tawangmangu Baru 24.46 mm, Lumbu Putih 16.22 mm, Lumbu Hijau 25.06 mm, and Lumbu Kuning 26.62 mm, respectively. The bulb length is lower than the description described by Sandrakirana *et al*. [27], which resulted in Tawangmangu Baru 3.54 cm, Lumbu Hijau 3.31 cm, Lumbu Kuning 2.97 cm, and Lumbu Putih 2.77 cm. The clove length in this study were Tawangmangu Baru 23.10 mm, Lumbu Putih 20.63 mm, Lumbu Hijau 22.27 mm, and Lumbu Kuning 28.41 mm, respectively. This number is higher than the study carried out by Sandrakirana *et al*. [27] which resulted Tawangmangu Baru 2.19 cm, Lumbu Hijau 1.45 cm, Lumbu Kuning 2.97 cm, and Lumbu Putih 0.9 cm. This may be caused by different planting locations or cultivation techniques. The bulbs used in this study were bulbs from garlic harvested in the Ciwidey area, West Java. Meanwhile, Sandrakirana *et. al*. studied several garlic varieties taken from different garlic centers [27]. So, it is possible that the age of harvest, type of soil and cultivation are not the same.

TABLE 6. Average garlic seed characters among varieties in three different storage conditions.

Variety	Characters				
	0 WAT	**4–5 WAT**	**9–10 WAT**	**13–14 WAT**	**18–19 WAT**
Bulb weight with pseudo stem (BWPS)					
Tawangmangu Baru	23.52 ab	27.46 a	22.74 bc	22.25 b	21.78 a
Lumbu Putih	14.81 b	13.98 b	15.92 c	13.35 c	12.49 b
Lumbu Hijau	23.92 ab	28.62 a	29.36 ab	26.32 ab	25.93 a
Lumbu Kuning	28.14 a	33.54 a	34.56 a	30.92 a	27.96 a
Bulb weight without pseudo stem (BWWPS)					
Tawangmangu Baru	20.80 a	25.22 a	20.80 bc	20.49 b	19.64 a
Lumbu Putih	13.62 a	13.17 b	14.96 c	12.54 c	11.49 b
Lumbu Hijau	20.96 a	26.14 a	26.87 ab	23.68 ab	23.54 a
Lumbu Kuning	25.20 a	30.86 a	31.66 a	28.50 a	25.06 a
Number of bulbils per bulb (NBB)					
Tawangmangu Baru		1.00 b	1.67 bc	2.67 ab	1.50 bc
Lumbu Putih		0.50 b	0.00 c	0.00 c	0.00 c
Lumbu Hijau		1.50 b	1.83 ab	4.17 a	1.83 ab
Lumbu Kuning		4.83 a	3.33 a	2.33 b	3.33 a
Total weight of bulbils per bulb (TWBB)					
Tawangmangu Baru		0.12 b	0.25 b	0.31 b	0.20 b
Lumbu Putih		0.13 b	0.00 b	0.00 b	0.00 b
Lumbu Hijau		0.32 b	0.34 b	0.97 a	0.23 b
Lumbu Kuning		1.04 a	0.93 a	0.48 b	0.70 a
Bulb diameter (BD)					
Tawangmangu Baru		46.01 a	43.59 ab	43.43 b	40.01 a
Lumbu Putih		35.07 b	37.73 b	33.92 c	29.59 b
Lumbu Hijau		47.45 a	47.98 a	44.37 ab	42.60 a
Lumbu Kuning		48.62 a	49.56 a	49.09 a	43.43 a
Bulb length (BL)					
Tawangmangu Baru		30.93 a		31.66 a	24.46 a
Lumbu Putih		22.55 b		26.19 b	16.22 b
Lumbu Hijau		31.93 a		32.67 a	25.06 a
Lumbu Kuning		32.09 a		36.28 a	26.62 a
Clove length (CL)					
Tawangmangu Baru	19.24	21.08 ab	19.97 ab	20.76 ab	20.42 b
Lumbu Putih	18.8	18.94 b	19.66 b	19.41 b	17.42 c
Lumbu Hijau	19.13	20.79 ab	19.60 b	22.54 ab	19.12 bc
Lumbu Kuning	22.56	24.00 a	23.55 a	24.59 a	24.93 a

Variety	Characters				
	0 WAT	4–5 WAT	9–10 WAT	13–14 WAT	18–19 WAT
Clove diameter (CD)					
Tawangmangu Baru	12.46 ab	11.34 b	12.36 ab	12.17	12.64 ab
Lumbu Putih	9.15 b	8.24 c	9.28 b	9.38	7.49 c
Lumbu Hijau	10.99 ab	11.78 b	10.70 b	12.65	10.51 b
Lumbu Kuning	14.64 a	14.80 a	14.59 a	13.15	14.32 a
Minimum clove length (MCL)					
Tawangmangu Baru	15.82 a	17.20 ab	15.89	15.40 b	17.36 b
Lumbu Putih	15.13 a	16.21 b	15.03	16.68 ab	14.25 b
Lumbu Hijau	14.77 a	15.62 b	14.86	19.10 ab	15.15 b
Lumbu Kuning	19.88 a	20.94 a	18.91	23.82 a	21.90 a
Maximum clove length (XCL)					
Tawangmangu Baru	22.37 ab	25.76 ab	23.53 ab	25.24 ab	23.10 b
Lumbu Putih	22.27 ab	21.91 b	23.48 ab	21.79 ab	20.63 b
Lumbu Hijau	24.16 ab	24.82 ab	24.22 ab	26.71 ab	22.27 b
Lumbu Kuning	26.25 ab	28.24 a	27.49 ab	25.71 ab	28.41 a
Minimum clove diameter (MCD)					
Tawangmangu Baru	9.54 ab	8.89 b	9.04 ab	9.39 ab	9.93 ab
Lumbu Putih	6.42 b	6.40 b	7.01 ab	7.81 ab	5.32 c
Lumbu Hijau	7.70 b	8.71 b	6.95 ab	9.21 ab	7.90 bc
Lumbu Kuning	12.03 a	12.52 a	10.27 ab	10.00 ab	12.36 a
Maximum clove diameter (XCD)					
Tawangmangu Baru	14.59 ab	13.93 b	14.77 ab	14.92 ab	15.73 a
Lumbu Putih	12.26 ab	10.37 c	11.79 b	10.97 b	9.20 b
Lumbu Hijau	14.81 ab	14.75 ab	14.20 ab	15.86 ab	12.64 ab
Lumbu Kuning	17.18 ab	17.20 a	18.05 a	16.85 a	16.96 a
Maximum internal sprout length (XISL)					
Tawangmangu Baru	6.01 b	13.41 a	13.35 a	15.67 a	17.96 a
Lumbu Putih	8.66 a	16.04 a	16.63 a	18.79 a	21.26 a
Lumbu Hijau	6.01 b	13.15 a	14.65 a	17.83 a	16.70 a
Lumbu Kuning	6.84 ab	14.65 a	15.04 a	16.64 a	20.03 a
Maximal ratio between internal sprout length and clove length (XRISCL)					
Tawangmangu Baru	33.21 b	63.46 b	73.74 b	78.90 b	92.07 b
Lumbu Putih	44.81 a	84.82 b	101.18 b	93.16 a	126.85 a
Lumbu Hijau	29.13 b	59.32 b	65.27 b	72.83 b	79.71 b
Lumbu Kuning	30.64 b	59.17 b	60.63 b	69.96 b	77.70 b

WAT = weeks after treatment. Different letters indicate significant differences between means within columns at Tukey's 5% level of significance.

ANOVA of bulb weight loss during treatment, number of cloves per bulb, and clove weight are recapitulated in Table 7. Weight loss was measured by comparing bulb weight before and after treatment, not from freshly harvested bulbs. There was a tendency that the lower storage temperature we used, the smaller bulb weight loss we observed [17]. However, in our experiment, weight loss occurred after 2–20 weeks was not significantly different both within varieties and storage condition treatment. This possibly because bulbs had already reached their stability when stored at 10^{th}–11^{th} week after harvest, thus, all bulbs from different varieties had the similar weight loss in all storage conditions. Hence, we suggested that storage treatment should be carried out sooner after harvest or at least, after curing (1 month after harvest). On the other hand, number of cloves per bulb and average clove weight were affected by varieties.

TABLE 7. ANOVA of bulb weight loss, number of cloves per bulb, and clove weight in three different storage condition.

Characters	Variety	Variety×Location	CoV (%)
Weight loss after stored for:			
20 weeks	ns	ns	48.94
16 weeks	ns	ns	31.58
12 weeks	ns	ns	37.41
7 weeks	ns	ns	42.51
2 weeks	ns	ns	83.43
Average number of cloves per bulb	*	ns	15.99
Average weight per clove	**	ns	17.49

ns = nonsignificant at 5% level of significance. *Significantly different at 5% level of significance. **Highly significant different at 1 % level of significance.

TABLE 8. Average weight loss among garlic varieties on three different storage conditions.

Variety	Garlic storeroom	Seed drying room	Cold storage	Average
20 weeks				
Tawangmangu Baru	34.08 a	28.52 a	23.76 a	28.79 a
Lumbu Putih	34.58 a	16.87 a	15.49 a	22.31 a
Lumbu Hijau	26.98 a	12.41 a	20.12 a	19.83 a
Lumbu Kuning	28.62 a	52.58 a	21.94 a	34.38 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	31.06 a	27.59 a	20.33 a	
16 weeks				
Tawangmangu Baru	21.02 a	22.78 a	14.10 a	19.30 a
Lumbu Putih	17.53 a	10.64 a	15.87 a	14.68 a
Lumbu Hijau	33.60 a	15.67 a	19.60 a	22.96 a
Lumbu Kuning	24.81 a	22.80 a	18.17 a	21.93 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	24.24 a	17.97 a	16.94 a	
12 weeks				
Tawangmangu Baru	10.53 a	30.93 a	13.46 a	18.30 a
Lumbu Putih	10.91 a	11.57 a	9.36 a	10.62 a
Lumbu Hijau	17.81 a	25.47 a	11.53 a	18.27 a
Lumbu Kuning	16.50 a	18.49 a	15.23 a	16.74 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	13.94 a	21.62 a	12.39 a	
7 weeks				
Tawangmangu Baru	13.10 a	10.19 a	6.76 a	10.02 a
Lumbu Putih	22.73 a	6.30 a	3.61 a	10.88 a
Lumbu Hijau	23.53 a	13.73 a	7.07 a	14.78 a
Lumbu Kuning	9.24 a	17.21 a	11.04 a	12.49 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	17.15 a	11.86 a	7.12 a	
2 weeks				
Tawangmangu Baru	4.18 a	2.20 a	6.04 a	4.14 a
Lumbu Putih	2.15 a	3.17 a	4.14 a	3.15 a
Lumbu Hijau	3.71 a	3.21 a	3.40 a	3.44 a
Lumbu Kuning	2.13 a	2.72 a	3.13 a	2.66 a
Tukey's HSD 5% level of significance	-	-	-	-
Average	3.04 a	2.83 a	4.18 a	

Different letters indicate significant differences between means within columns at Tukey's 5% level of significance.

From storage treatment point of view, the highest to lowest weight loss respectively were garlic storeroom (24°C, RH ±70%), seed drying (30°C, RH ±50%), and cold storage (18°C, RH ±55%) (Table 8). The longer it is stored, the greater weight loss of bulbs (Table 8). Up to 20 weeks, the lowest weight loss was shown in garlic stored in cold storage (21.94%), followed by seed drying room (27.59%) and garlic storeroom (31.06%). Storage of garlic bulbs in cold temperatures (7°C) can reduce weight loss compared to higher temperatures (29–30°C) [17]. However, it is different from [15] which obtained a higher cold temperature weight loss (5°C) than the weight loss of garlic tubers stored at a higher temperature. The weight loss of Lumbu Kuning (38.38%) was the highest compared to other varieties at the end of the observation. Followed by varieties of Tawangmangu Baru 28.79%, Lumbu Putih (22.31%), and Lumbu Hijau (19.83%). This different percentage of weight loss also occurred in the study by Nurmalia *et al*. [15].

From all observed varieties, Lumbu Kuning had the lowest number of cloves (13.83 cloves per bulb) compared to other varieties (16.97–20.40 cloves) (Table 9). Average of biggest cloves in a row were Lumbu Kuning 2.19 g, Tawangmangu Baru 1.39 g, Lumbu Hijau 1.29 g, and the smallest clove from Lumbu Putih 0.71 g (Table 10). Compared to Sandrakirana *et al*. [27] which described the weight of Tawangmangu Baru cloves of 4.89 g, Lumbu Kuning 2.46 g, Lumbu Hijau 1.03 g, and Lumbu Putih 0.77 g, the weight of cloves in this study was higher, except for Tawangmangu Baru cloves. This result was different from previous study [27] which observed bulbs from different location. In our study, observed bulbs were harvested in the same time and from the same locations.

TABLE 9. Average number of cloves among garlic varieties on three different storage conditions.

Variety	Garlic storeroom	Seed drying room	Cold storage	Average
Tawangmangu Baru	18.5 a	14.2 b	18.2 a	16.97 ab
Lumbu Putih	22.0 a	16.1 ab	19.8 a	19.30 a
Lumbu Hijau	22.6 a	18.4 a	20.2 a	20.40 a
Lumbu Kuning	14.4 b	12.9 b	14.2 b	13.83 b
Tukey's HSD 5% level of significance	-	-	-	5.10
Average	19.38 a	15.4 a	18.1 a	

Different letters indicate significant differences between means within columns at Tukey's 5% level of significance.

TABLE 10. Average clove weight per bulb among garlic varieties on three different storage conditions.

Variety	Garlic storeroom	Seed drying room	Cold storage	Average
Tawangmangu Baru	1.41 b	1.51 b	1.22 b	1.38 b
Lumbu Putih	0.63 c	0.82 c	0.66 c	0.71 c
Lumbu Hijau	1.27 b	1.34 b	1.25 b	1.29 b
Lumbu Kuning	2.25 a	2.48 a	1.85 a	2.19 a
Tukey's HSD 5% level of significance	-	-	-	0.44
Average	1.39 b	1.54 b	1.25 b	

Different letters indicate significant differences between means within columns at Tukey's 5% level of significance.

CONCLUSION

Cold storage method was approved to accelerate the internal sprout emergence of garlic cloves. Meanwhile, drying room method apparently hindered garlic dormancy compared to garlic storeroom. We suggested another comparable study using freshly harvested garlic bulbs and analysis related to metabolic process or physiological hormone for explanatory information about the phases of garlic breaking dormancy.

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