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Effect of Concentration and Time of Giving Paclobutrazol on Lumbu Hijau-Garlic Seedling Bulbs

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Abstract

The farmer's interest in garlic planting is low because the yield is unsatisfied. One reason is the use of small cloves. Giving paclobutrazol is expected to increase the size of garlic cloves and bulbs. This research aims to determine the interaction between concentration and time of giving paclobutrazol, which produces the best size for cloves and bulbs. The research is a factorial, Completely Randomized Design. The first factor is the concentration of paclobutrazol:250 mg.L^{-1} and 500 mg.L^{-1} of water. The second factor is the time of applying paclobutrazol: 6 and 10, 8 and 12, 10 and 14 weeks after planting (w.a.p). Data were analyzed using variance, which will be continued with DNMRT at the 5% level. The results showed that giving paclobutrazol at 10 and 14 w.a.p resulted in the highest apparent stem diameter and yield, but even so, the weight of the largest and the smallest cloves was the lowest. Meanwhile, giving paclobutrazol at 6 and 10 w.a.p resulted in the highest weight of the largest cloves 1.95 g and the highest of the smallest cloves 0.55 g, even though the apparent stem diameter and yield were the lowest. Treatment of 250 mg.L^{-1} paclobutrazol resulted in the highest weight of the largest cloves 1.80 g.

Keywords: *Allium sativum, bulbs, cloves, retardant.*

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INTRODUCTION

Garlic (*Allium sativum* L.) production in Indonesia still needs to meet the needs of the community, causing people's dependence on imported garlic is very high. Around 80%-90% of garlic comes from imports such as China (Agustina, 2020). The people of Indonesia favor imported garlic from China because of the larger bulbs and cloves and the cheaper price than local garlic. The low price of imported garlic is caused by the high productivity of garlic in China, which is around 25.3 t.ha^{-1}, so the cost of garlic production in China has become cheap (Sandrakirana et al., 2018).

Local garlic productivity can be increased by paying attention to several important aspects of cultivation activities, including providing growth regulators. growth regulators are organic compounds that are exogenously given to plants to stimulate, inhibit, and modify physiological processes in plants but do not act as nutrients. Paclobutrazol is a growth regulator from the retardant group that affects plant growth and metabolism in the subapical meristem, which can block cell elongation, resulting in inhibited book elongation and stimulating bulb enlargement, new bud formation and plant flowering. Giving paclobutrazol to plants will result in the inhibition of gibberellin synthesis in these plants. The role of gibberellin was to promote the synthesis of a hydrolytic enzyme such as α-amylase that indirectly triggers shoot, root, and cell elongation by transporting the auxin, even though it could inhibit plant growth at higher concentrations (Hedden & Sponsel, 2015). Gibberellin is one of the important plant hormones that play a role in photoperiod and regulation of potato tuber formation (Javanmardi & Rasuli, 2017).

Syahputra, (2021) reported that the time of application of paclobutrazol can affect plant height, flag leaf area, and stem diameter. The best plant height and flag leaf area were produced by spraying paclobutrazol seven days after panicle initiation of paddy, but stem diameter at that time was lowest on IR64. In line with Atikabudi et al., (2022), 200 ppm of paclobutrazol can reduce plant height, leaves, and

internodes. It meets the requirements of cut *Chrysanthemum*. Paclobutrazol concentration and time of application need to be regulated. If the concentration is too low, it will cause the effect of Plant Growth Regulator (PGR) to disappear, while a high concentration will impact plant growth and make plants grow abnormally. The application of PGR must also be given at the right time because if given at the wrong planting age, it can affect the physiological function of the plant, and the effect of PGR will not be maximized.

Based on research conducted by Kamboj et al., (2017), differences in planting age and paclobutrazol concentration affected the yield and quality of shallot seeds. Shallot plants given paclobutrazol at a concentration of 500 ppm increased the weight of the bulbs from 3.49 g per plant to 3.65 g per plant. Salta et al., (2023) stated that applying a concentration of 30 ppm paclobutrazol on 40 w.a.p gave the best diameter of the Shallot bulb, and without paclobutrazol gave the lowest bulb diameter. Mubarok et al., (2022) reported the application of paclobutrazol and BAP improved the number, the weight of tuber, and its starch content. Even the application of paclobutrazol and BAP could be used to overcome an environmental problem for potato cultivation in both lowland and medium land. This study aims to determine the interaction of administration concentration and administration time of paclobutrazol on the growth and production of Lumbu Hijau garlic.

MATERIAL AND METHODS

Experiment Site

This research was conducted from July until Desember 2023, in the experimental field of the Faculty of Agricultural, Andalas University, Padang City.

Materials and Tools

The ingredients used in this study include cloves of garlic (Lumbu Hijau variety), chicken manure, SP36, NPK Wasp Pillar®, DGW®, Korn Kali®, paclobutrazol, dolomite lime, Wokozim® liquid organic fertilizer, pesticides with active ingedients 75% acephate, abamectin 18 $g.L^{-1}$ emamectin benzoate, tebuconazole, and mancozeb. The tools are hoe, spray equipment, buckets, ruller and vernier calipers

Research Desain

The research method is a factorial, Completely Randomized Design (CRD). The first factor is the concentration of paclobutrazol 250 $mg.L^{-1}$ and 500 $mg.L^{-1}$ of water. The second factor is the time of giving paclobutrazol, namely 6 and 10 w.a.p; 8 and 12 w.a.p; and 10 and 14 w.a.p. Data were analyzed using variance through the F test at the 5% level. If the calculated F of the treatments is significantly different, then it will be continued with Duncan's New Multiple Range Test (DNMRT) at the 5% level.

Research Procedure

Fertilization carried out in garlic cultivation includes basic fertilization and advanced fertilization. The basic fertilizer used is chicken manure compost. Chicken manure compost is applied simultaneously with land processing by spreading and stirring evenly in bed as much as 20 $t.ha^{-1}$. Furthermore, further fertilization consisted of 400 $kg.ha^{-1}$ SP36 + 420 $kg.ha^{-1}$ NPK BASF + 420 $kg.ha^{-1}$DGW Daun + 280 $kg.ha^{-1}$ Korn Kali. The whole fertilizer is mixed until evenly distributed and given as much as 10 g/planting hole.

The garlic bulbs used are Lumbu Hijau varieties originating from the Vegetable Crops Research Institute (BALITSA) Lembang and have experienced a shelf life of 12 months after harvest. Before planting, the cloves must be separated. The cloves used as seeds are those of uniform size with an average weight of 1.5 g. After mowing, the seeds are soaked with Wokozim for 30 min to stimulate the growth of garlic roots. The planting distance used is 20 cm x 20 cm with a depth of 3 cm.

The concentration of paclobutrazol was given according to the treatment, namely 250 mg/L and 500 mg/L. When paclobutrazol was given, it was at 6 and 10 w.a.p; 8 and 12 w.a.p; and 10 and 14 w.a.p. Paclobutrazol is given in the morning because the leaf stomata are open then. Paclobutrazol is applied by spraying with a sprayer. The volume of Paclobutrazol spray given is the same each time it is applied and adjusted to the age of the plant. Garlic are ready for harvesting approximately 16 w.a.p, the foliage turns yellowing and flops over. Lift the bulbs before the foliage dies down completely.

Observation parameters in this research are plant height, number of leaves, pseudo stem diameter, the diameter of the bulb, number of cloves per bulb, the weight of the biggest cloves, the weight of the smallest cloves, dry weight of the bulb, and yield.

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RESULT AND DISCUSSION

Vegetative Growth

Based on the results of the F test at a real level of 5%, there is no interaction between the concentration and the time of application of paclobutrazol on the growth of garlic plants. The concentration and the time of application of paclobutrazol singly had no significant effect on plant height and leaf count. In contrast, paclobutrazol treatment had a significantly different effect on the diameter of the pseudo-stem of garlic (**Error! Reference source not found.**).

Error! Reference source not found. showed that plant height in paclobutrazol concentration t reatment of 250 mg.L^{-1} and 500 mg.L^{-1} was 42.68 cm and 40.92 cm, respectively. Plant height at different times of application of paclobutrazol ranges from 37.70 cm - 45.99 cm. The research found that the height of the plants obtained was lower than the description by Menteri Pertanian (1984), which can reach a height of 63-75 cm. Paclobutrazol is a growth inhibitor, so that plant height growth becomes inhibited. This statement is in line with the statement of Gautam et al., (2014), which states that garlic plants that are not given retardant substances produce better plant height compared to plants given paclobutrazol treatment 500 mg.L^{-1} and cycocel 500-1,000 mg.L^{-1}.

Table 1. Vegetative Growth of Garlic on 16 W.A.P Observation

Paclobutrazol Treatment	Plant Height (cm)	Number of Leaves	Pseudo Stem Diameter (cm)
Concentration (mg.L^{-1})			
250	42.68	6.58	0.86
500	40.92	6.47	0.82
Application Times (w.a.p)			
6 and 10	37.70	6.47	0.77 b
8 and 12	41.72	6.54	0.83 ab
10 and 14	45.99	6.57	0.93 a
Concentration x Aplication Time of Paclo	ns	ns	ns
Concentration of paclo	ns	ns	ns
Time of paclo	ns	ns	*
CV	13.85%	11.20%	12.03%

Note: * was significantly different; ns was not significantly different. The numbers in each column followed by the same letter were not significantly different based on the DNMRT at the 5% level.

The number of leaves produced at 250 mg.L^{-1} and 500 mg.L^{-1} paclobutrazol concentration ranged from 6.58 - 6.47 strands. The number of leaves produced at different paclobutrazol application times ranged from 6.47 - 6.57 strands. The Ministry of Agriculture Decree No. 894 of 1984 stated that the description of the Lumbu Hijau variety garlic plant has a number of leaves of 7-9 strands. However, in the results of research that has been carried out, the number of leaves of garlic plants obtained only ranges from 6.47 - 6.57 leaves. Research conducted by Kristina et al., (2023) on the Lumbu Hijau variety garlic also obtained the number of leaves around 5.20 strands, which was relatively low compared to the description of the Lumbu Hijau variety and this experiment.

Application time of paclobutrazol on 6 and 10 w.a.p resulted in the lowest pseudo-rod diameter of only about 0.77 cm. Application on 10 and 14 w.a.p resulted in a larger pseudo-stem diameter (0.93 cm) than other treatments. That means that at the age of 10 and 14 w.a.p, garlic plants have entered the bulb ripening phase and have completed the vegetative phase so that when given paclobutrazol, no longer inhibits the growth of pseudo-stems of plants as a result of which the diameter of pseudo-stems becomes larger. At the age of 6 w.a.p, garlic plants are in the vegetative phase, where the vegetative parts of plants, such as stems and leaves, experience growth. Reduction in vegetative growth of plants at the beginning of growth due to the application of paclobutrazol will cause plant growth to be not optimal, causing the diameter of the pseudo-stem of garlic plants to be smaller. The research of Widaryanto et al., (2011) states that the earlier paclobutrazol was given to plants, the greater the inhibitory properties. On the contrary, the longer paclobutrazol was given to plants, the smaller the inhibitory properties caused.

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Garlic plants given paclobutrazol with concentrations of 250 mg.L^{-1} and 500 mg.L^{-1} produce pseudostem diameters ranging from 0.82 cm - 0.86 cm. Marshel et al., (2015) said that paclobutrazol affects the anatomy inside the trunk so that a high retardant concentration can increase the stem's thickness and diameter. Widaryanto et al., (2011) reports that adding paclobutrazol can suppress plant stem growth so that the diameter of the plant stem increases thicker. The thickening of the stem by paclobutrazol administration is caused by an increased volume of parenchyma cells in the cortex area and increased cell production in the cambium area. According to Suhadi et al., (2017), paclobutrazol is one of the retardant growth regulators that can be used to modify the physical structure of plants. The working principle of paclobutrazol in plants is to inhibit gibberellin biosynthesis by suppressing kaurene so that carbonate formation does not occur, thereby reducing the size and rate of cell division.

Bulb and Cloves Performance

The ANOVA test shows no interaction between paclobutrazol concentration and application time on the performance of garlic bulbs and cloves. The concentration of paclobutrazol has no significantly different effect on bulb diameter, number of cloves per bulb, and weight of the smallest cloves. Still, it significantly affects the weight of the biggest cloves. The application time of paclobutrazol treatment has a significantly different effect on the performance of garlic bulbs and cloves (Table 2).

Table 2. Bulb and Cloves Performance

Paclobutrazol Treatments	Bulb Diameter (cm)	Number of cloves per bulb	Weight of the biggest cloves (g)	Weight of the smallest cloves (g)
Concentration (mg.L^{-1})				
250	3.71	14.91	1.80 a	0.40
500	3.62	15.37	1.56 b	0.39
Application Times (w.a.p)				
6 and 10	3.34 b	10.13 b	1.95 a	0.55 a
8 and 12	3.68 ab	15.97 a	1.59 b	0.33 b
10 and 14	3.98 a	19.33 a	1.49 b	0.31 b
Concentration x Aplication Time of Paclo	ns	ns	ns	ns
Concentration of paclo	ns	ns	*	ns
Time of paclo	*	*	*	*
CV	10.42%	23.29%	12.03%	20.23%

Note: * was significantly different; ns was not significantly different. The numbers in each column followed by the same letter were not significantly different based on the DNMRT at the 5% level.

Table 2 above it can be seen that the application of paclobutrazol at 10 and 14 w.a.p resulted in a larger bulb diameter when compared to other treatments around 3.98 cm. While the smallest bulb diameter was found in the treatment of paclobutrazol at weeks 6 and 10 w.a.p with an average of 3.34 cm. The diameter of garlic bulbs resulting from the administration of paclobutrazol concentrations of 250 mg.L^{-1} - 500 mg.L^{-1} did not differ around 3.62 cm -3.71 cm. These results are higher than Kristina et al., (2023) that gets bulb diameter of Lumbu Hijau around 3.28 cm. The diameter of the bulb is related to the diameter of the pseudo-stem of the garlic plant, where the larger the diameter of the pseudo stem of garlic, the larger the diameter of the bulb as well. Vice versa, the smaller the diameter of the pseudo-stem of the plant, the smaller the diameter of the bulb produced. This is in accordance with the observations of Atif et al., (2019) who found a significant correlation between bulb characteristics, bulb index, pseudo stem diameter, fresh weight and total flavonoids. Diameter bulbs are also affected by plant height. Plant stems can store assimilate so the higher the plant, the more assimilate there will be in the stem that can be diverted for bulb formation.

The diameter of the bulbs of garlic plants obtained is close to the potential yield of garlic plants released by Kementrian Pertanian Decree No. 894 of 1984, with the size of the bulb diameter ranging from 3.3 cm to 3.9 cm (Menteri Pertanian, 1984). Giving paclobutrazol can control vegetative growth by

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inhibiting the formation of gibberellins in plant cell elongation so that the transfer of assimilate used initially in vegetative growth will be allocated more to the building and development of bulbs. Wijana et al., (2015) shows that adding paclobutrazol really affects the number of bulbs and the diameter of onion bulbs.

The inhibition of gibberellin works as an effect of paclobutrazol administration, which will result in no cell stretching in bulbs, so cells that accumulate at the base of the bulb will result in sideways growth, such as bulb circumference or bulb diameter becoming larger. Harjadi (2009) states that bulbs or plants given paclobutrazol growth inhibitors experience long inhibitions, but the diameter of the bulbs will enlarge. In addition to paclobutrazol, the size of the diameter of plant bulbs was influenced by environmental factors, one of which was temperature. The temperature at the location ranges from 16 - 18°C. Low soil temperatures can reduce the rate of root respiration, so the accumulation of assimilates to food reserves is higher. Bulbs on onion plants are one of the organs hoarding food reserve materials.

The potential number of cloves per Lumbu Hijau bulb ranges from 13-20 cloves per bulb (Menteri Pertanian, 1984). The result of this research aligns with research conducted by Firmawini, (2018) showing that the Lumbu Hijau variety planted in the highlands can produce 19.50-26.50 cloves. The altitude factor dramatically influences the formation of garlic cloves. The 8 and 12 w.a.p, 10 and 14 w.a.p treatments produced the cloves per bulb at 15.97 and 19.33, respectively. Giving paclobutrazol 6 and 10 resulted in the lowest number of cloves 10.13. The low number of cloves obtained because of at the age of 6 w.ap garlic plants are experiencing a phase of vegetative development, so when given paclobutrazol, it directly suppresses the vegetative growth of plants, in line with the results of observations of vegetative variables obtained, such as plant height at 6 and 10 w.a.p is low. The application of paclobutrazol, which is an inhibitor, can inhibit gibberellin synthesis and inhibit cell elongation, thereby causing stunted shoot growth.

The clove weight on 250 $mg.L^{-1}$ paclobutrazol is 1.80 g, while the clove weight on 500 $mg.L^{-1}$ paclobutrazol is lower at only about 1.56 g per clove. Giving paclobutrazol at a concentration of 250 $mg.L^{-1}$ has produced a large clove even though the number of cloves obtained is less than 500 $mg.L^{-1}$. Giving paclobutrazol at 6 and 10 w.a.p makes a 1.95 g clove weight, while at the age of 8 and 12 w.a.p, 10 and 14 w.a.p are greater than 8 and 12 w.a.p and 10 and 14 w.a.p. In addition, the 6 and 10 w.a.p treatment can produce a more prominent clove because the number of cloves formed is less, so the assimilate produced can maximize the cloves' development.

Table 2 shows that the cloves obtained were mostly large. This could be due to the use of large seed bulbs. The seed bulbs used as propagation material are chosen to have a size of 1.5 g per clove. Efendi et al., (2020) states that the size of the cloves used as planting material positively correlates with the bulbs harvested. The use of large sized cloves increased plant height, number of leaves, plant dry weight and yield of garlic var. Lumbu Hijau. El-Mesirry & Radi, (2019) research also states that the larger the cloves used as planting material, the taller the plant. The large size of cloves will encourage plant growth because larger cloves contain food reserves that are more supportive in the early stages of plant growth. Garlic plants given paclobutrazol treatment at weeks 6 and 10 w.a.p showed the smallest clove weight with an average of 0.55 g per clove, while the clove weight on 10 and 14 w.a.p treatments only had an average of 0.31 g per clove. The small cloves on 8 and 12 w.a.p, 10 and 14 w.a.p treatments were thought to be due to the more significant number of cloves in one bulb from the treatment. This means the assimilation obtained is needed to encourage the development of all the cloves of garlic plants. Smaller cloves are usually produced by the clove in the center of the bulb.

Wind-Dry Weight of The Bulb and Yield

Table 3. shows that the time treatment of paclobutrazol application had a markedly different impact on the wind-dry weight of the bulb and per hectare (Table 3).

Giving paclobutrazol at 6 and 10 w.a.p resulted in the lowest dry weight of bulb winds with an average of 11.01 g. The low wind-dry weight of the bulb obtained in the treatment of 6 and 10 w.a.p is caused by plants experiencing an early vegetative development phase, so when given paclobutrazol, it directly suppresses plant vegetative growth. In comparison, the highest wind-dry weight of the bulb was found in the treatment of paclobutrazol at the time of application 10 and 14 w.a.p with an average of 16.44 g. That is in line with the highest pseudo stem diameter, highest number of cloves, and highest bulb diameter.

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Table 3. Dry Weight of Bulbs and Garlic Yield

Paclobutrazol Treatments	Dry weight of the bulb (g)	Yield (t.ha^{-1})
Concentration (mg.L^{-1})		
250	14.53	3.63
500	12.91	3.23
Application Times (w.a.p)		
6 and 10	11.01 b	2.75 b
8 and 12	13.72 ab	3.43 ab
10 and 14	16.44 a	4.11 a
Concentration x Aplication Time of Paclo	ns	ns
Concentration of paclo	ns	ns
Time of paclo	*	*
CV	24.46%	24.44%

Note: * was significantly different; ns was not significantly different. The numbers in each column followed by the same letter were not significantly different based on the DNMRT at the 5% level.

Based on Table 3 above, it can be seen that the administration of paclobutrazol with a concentration of 250 mg.L^{-1} until 500 mg.L^{-1} produces a wind-dry bulb weight ranging from 12.91 g to 14.53 g. The highest wind-dry weight of bulb per hectare was found in the paclobutrazol treatment at an application time of 10 and 14 w.a.p with an average of 4.11 t.ha-1, while the lowest wind-dry weight of bulb per hectare was found on 6 and 10 w.a.p with an average of 2.75 t.ha^{-1}. That result is in line with bulb diameter, where the 10 and 14 w.a.p treatments produced the largest bulb diameter with an average of 3.98 cm and the dry weight of bulbs per plant with an average weight of 16.44 g per plant. Giving paclobutrazol in the early phase of vegetative growth reduced yield, but offering paclobutrazol in the final stage did not have a negative effect; the number of cloves and the weight of the bulb were still high. This is because administering paclobutrazol more quickly causes the inhibitor to impact the plant sooner, thereby suppressing the plant's vegetative growth rate. growth that is not optimal in the vegetative phase will affect the amount of assimilate produced, so the bulbs formed will also be lower. Mir et al., (2015), who found that the results of the present study revealed that paclobutrazol significantly reduced the vegetative growth of plants, enhanced the fruit quality and increased the yield of apricot during both the years of study. Syaputra et al., (2017) also mentioned that the administration of paclobutrazol at specific concentrations in tomato plants needs to be done for an inhibited height of the plant, and the photosynthates are maximally allocated to the formation of generative developments.

The results of research conducted by Firmawini (2018) on the Lumbu Hijau variety of garlic showed that the dry weight of wind bulbs per hectare reached 8.5 t.ha^{-1}. This result is very high compared to the results obtained in research, which only ranged from 2.71 to 4.13 t.ha^{-1}. The high yield obtained by Firmawini (2018) was due to the fulfillment of the nutrients needed for vegetative growth, so the assimilate produced was geater and caused more bulbs to form. Table 3 shows that administering paclobutrazol at various concentrations has not been able to increase the yield of garlic bulbs. The bulb yield obtained only ranged from 2.71 t.ha^{-1} to 4.11 t.ha^{-1}, while the potential yield of the Lumbu Hijau garlic variety ranged from 8 – 10 t.ha^{-1}. The low yield of bulbs is thought to be caused by the intensity of frequent rains, resulting in a lack of sunlight for the plants during the bulb formation phase. Leaves play a role in capturing more sunlight for photosynthesis, greater photosynthate allows the formation of greater plant biomass.

The paclo application significantly affected the Chlorophyll Content Index (CCI). The application of paclobutrazol caused a significantly higher CCI than without using paclobutrazol and BAP, and it caused an increasing shoot and root ratio, number of tubers per plant, and weight of tuber per plant than control (Mubarok et al., 2022). In this research, the photosynthates obtained from photosynthesis will first encourage an increase in the size of the cloves on the outside to produce a larger size than the cloves in the center of the bulb. In addition, the age of the seed bulbs can also affect the results of the cloves obtained. Seed bulbs used as propagation material are seed bulbs stored for one year. The duration of the storage process can affect the bulbs' yield, which will impact the size of the cloves.

The low dry weight yield per bulb is also thought to be caused by the low soil pH, namely 5.32 in the acid category. Low soil pH can affect the availability of nutrients in the soil, where the more acidic the

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soil pH is, plants cannot absorb the more nutrients in the soil. Although the bulb yield per plant and hectare on 6 w.a.p and 10 w.a.p application paclobutrazol was lower, the size of cloves was larger. The size of the clove is essential as a seed source. The size of cloves used as planting material correlates with the yield. Using a large clove as a seed will produce larger bulbs (Badura et al., 2013). Commonly, the large bulbs of garlic have a clove largest too (Neeraj et al., 2014).

CONCLUSION

Giving paclobutrazol at 10 w.a.p and 14 w.a.p resulted in the highest apparent stem diameter and yield. Still, the weight of the largest and the smallest cloves was the lowest. Meanwhile, giving paclobutrazol at 6 w.a.p and 10 w.a.p resulted in the highest weights of the largest cloves 1.95 g and the highest of the smallest cloves 0.55 g, even though the apparent stem diameter and yield were the lowest. Treatment of 250 $mg.L^{-1}$ paclobutrazol resulted in the highest weight of the largest cloves 1.80 g

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