Exogenous effect of gibberellins and jasmonate on tuber enlargement of *Dioscorea opposita*

S. K. Kim[1], J. T. Kim[2], S. W. Jang[3], S. C. Lee[2], B. H. Lee[1] and I. J. Lee[2]

[1]Institute for Bioresources Research, Gyeongbuk Provincial Agricultural Technology Administration, Andong 760-891, Korea
[2]Division of Plant Biosciences, Kyungpook National University, Daegu 702-701, Korea; e-mail: ijlee@knu.ac.kr
[3]Korea Tobacco and Ginseng Central Research Institute, Daejon 305-805, Korea
The authors (S. K. Kim and J. T. Kim) have equally contributed to this study.

Abstract. We have examined the single and combinational effect of gibberellins (GA_3, GA_{4+7}) and jasmonic acid (JA) on enlargement of Chinese yam tubers in field. In a single treatment, gibberellin promoted the tuber enlargement by one time application, whereas the lowest concentration (100ppm) led to the highest tuber yield rather than accumulative application. The effect of GA_{4+7} enhancing tuber yield was only recognised at the highest concentration by a single treatment. Tuber weight was decreased at the highest JA concentration, otherwise the lowest concentration of JA (5 ppm) significantly promoted the tuber weight by a single treatment (FS1). The combination of GA 50 ppm plus JA 5ppm enhanced remarkably the tuber weight by a single treatment (FS1). It is suggested that the combined treatment of yam plants with both gibberellic acid and jasmonic acid has promoted tuber yield.

Key words: *Dioscorea opposita, gibberellin, jasmonate, tuber yield*

INTRODUCTION

Chinese yam (*Dioscorea opposita* Thunb.) has been cultivated as a major medicinal crop and is also grown widely as a food plant in China, Japan, and Korea (Kim et al., 2003a). Mass production of reproductive organs such as tubers and bulbils is essential for reducing the propagation cost for yam farmers. Of the Chinese yams *Dioscorea. opposita* Thunb. var. Naga, Icho, and Tsukune, only two varieties, Naga and Icho, are able to produce high amounts of bulbils and enlarged tubers under natural conditions. Otherwise, the variety Tsukune has been shown to have the lowest bulbil production among the yam varieties in fields. Recently, for this reason, we found that certain plant growth retardants, such as mepiquat chloride and trinexapac-ethlyl, readily induced bulbil formation under field conditions (Kim et al., 2003b, 2003c). Application of plant growth regulators, particularly growth retardants, may maintain internal hormonal balances and efficient sink-source relationships and thus enhance crop productivity (Singh et al., 1987). It is one of the efficient methods for inducing bulbil formation and promoting enlarged bulbils in agricultural practices. However, bulbils produced by MC are needed for consumers and food processing utilisation at least for two years.

In practical application of plant hormones, the best practices in stable production of reproductive organs is to use rather tubers than bulbils of the variety Tsukune because the tubers can be used directly on propagation purposes by making multiple tuber pieces every year. Application of plant growth hormones is a promising agronomic benefit to enhance yields of tubers and bulbils of Chinese yam. It is also suggested that gibberellin treatment to Chinese yam plants increases the tuber yield at the higher concentration (Kim et al., 2003b).

Among plant growth hormones, jasmonic acid is also involved in the tuber enlargement of Chinese yam (Koda et al., 1991). It was reported that the endogenous jasmonic acid content in the leaf tissues of Chinese yam increased during the tuber enlargement. Until now, no attempts have been made by researchers to enhance the tuber yield of Chinese yam by using jasmonic acid and gibberellins in Chinese yam.
The aim of the present field experiment is to investigate the single and combinational effects of gibberellic acid (GA_3) and jasmonic acid (JA) on tuber yield reposes of Chinese yam plant.

MATERIALS AND METHODS

The experiment was performed in 2004 at the Institute for Bioresources Research at Gyeongbuk Provincial Agricultural Technology Administration to establish the effect of plant hormones on the tuber yield of Chinese yam. In the experiment there was used the Chinese yam variety 'Tsukune', cultivated widely in Korea, Japan and China as a medicinal or food crop. Tuber pieces (about 40–50 g fresh weight) were planted in fields (soil texture: sandy loam). The planting density was 30×30 cm with a tuber piece in a depth of 5 cm. The planting date was 5 April. A randomised block design with three replications was used for the experiment. Prior to the planting, 430-280–320 kg ha^{-1} of N-P_2O_5-K_2O was applied and incorporated as basal and top-dressing (7:3. w/w) to the experimental field. The collected data for tuber yield were analysed by using SAS package for the Dunkan's multiple range test.

For the application of four plant growth regulators, GA_3 and GA_{4+7} (Promalin) as gibberellin and prohydrojasmonic acid (PDJ) as jasmonic acid were applied to the foliage of Chinese yam. Benzylaminopurine (BA) was used to determine the single effect of Promalin (GA_{4+7}). The concentration of each compound was as follows: 100, 200 and 400 ppm for the two gibberellins and 5, 10 and 25 ppm for jasmonic acid. Finally, BA was also applied as 100, 200, 400 ppm. Plant growth regulators were foliar-sprayed twice on 15 July (97 days after planting) and on 15 Aug. (132 days after planting) at a rate of 1,004 l ha^{-1}. Cultural practices were those commonly used for the cultivation of Chinese yam plant.

RESULTS AND DISCUSSION

We have previously demonstrated that gibberellin treatment in Chinese yam promotes the tuber enlargement resulting in increase of the tuber yield (Kim et al., 2003b). It has been postulated that tuber enlargement might be triggered by enhancement of endogenous gibberellin during the growing seasons. In this study, we therefore firstly determined if single and accumulative treatments of exogenous gibberellin resulted in tuber enlargement.

Table 1. Effect of gibberellic acid on tuber yield (kg ha^{-1}) of Chinese yam grown in field.

Gibberellic acid (ppm)	Application times	
	FS1[2]	FS2[3]
Control[1]	11,850 c	11,850 b
100	19,720 a	6,480 c
200	15,930 b	12,410 b
400	14,350 b	15,740 a
Mean	16,667	11,543

[1]Control, Untreated control, [2]FS1, Foliar sprayed on 15 July, [3]FS2, Foliar sprayed on 15 July and 15 August accumulatively. Means with the same letter within the columns are not significantly different ($P < 0.05$).

When gibberellic acid (GA_3) was foliar-sprayed on 15 July as a single application, and on 15 August following 15 July as an accumulative treatment, respectively, it was observed that tubers were enlarged by the lowest concentration in the single treatment, otherwise, tubers were increased by the highest concentration of gibberellin in the accumulative treatment (Table 1).

In our previous results (Kim et al., 2003b), tuber weight was dramatically increased by an increased gibberellin concentration when it was applied accumulatively. However, when gibberellin was treated just one time on 15 July (an initial tuber formation stage), tuber enlargement was conversely promoted by the lowest gibberellin concentration. It is likely that the effect of exogenously applied gibberellin in relation to tuber enlargement in Chinese yam may have different responses depending on the developmental stages, application times, and diverse environmental conditions.

It was found that two different gibberellin biosynthetic pathways in Chinese yam are operated commonly in leaves and tubers (Kim et al., 2003). During tuber enlargement, in particular, non C-13 hydroxylation pathway (bioactive gibberellin A_4, GA_4) was more dominant than an early C-13 hydroxylation pathway (bioactive gibberellin A_1, GA_1) in the Chinese yam plants.

Table 2. Effect of promalin (gibberellin mixture) on tuber yield (kg ha^{-1}) of Chinese yam grown in field.

Concentration (ppm)	Application times					
	FS1[2]			FS2[3]		
	GA_{4+7}	BA	Promalin	GA_{4+7}	BA	Promalin
Control[1]	11,850 a	11,850 a	11,850 b	11,850 a	11,850 a	11,850 b
100	3,430 b	6,200 b	9,630 c	3,280 d	8,290 b	11,570 b
200	4,170 b	6,480 b	10,650 b	4,210 c	6,250 c	10,460 c
400	11,950 a	6,250 b	15,560 a	8,840 b	3,380 d	12,220 a
Mean	6,517	6,310	11,947	5,443	5,973	11,412

[1]Control, Untreated control, [2]FS1, Foliar sprayed on 15 July, [3]FS2, Foliar sprayed on 15 July and 15 August accumulatively. Promalin was treated as gibberellin (GA_{4+7}) including BA (benzyladenine) with an equal ingredient volume (1.8%). Means with the same letter within the columns are not significantly different ($P < 0.05$).

Table 2 shows the effect of promalin, benzylaminopurine and real GA_{4+7} on tuber yield of Chinese yam grown in greenhouse. Promalin has been used to increase the length of apples and to improve the fruit weight in horticultural fields. The ingredients of promalin consist of two compounds named benzylaminopurine and $GA_{4+7,}$ in the same volume 1.8%. Promalin did not affect the increase of tuber weight at the lower concentration by a single treatment. It was only increased at the highest concentration (400 ppm). This tendency was also similar to the result of the accumulative treatment. Tuber yield was more decreased in the accumulative treatment than in the single treatment. Table 2 shows the effect of real GA_{4+7} treatment subtracted data of BA (benzylaminopurine) from that of promalin. Benzylamonopurine has been known for cytokinins. The physiological effects caused by cytokinins are stimulatation of cell division, the growth of lateral buds, release of apical dominance, and leaf expansion resulting from cell enlargement (Davies, 1995). Pure effect of $GA_{4+7,}$ enhancing tuber yield, was only recognised at the highest concentration by a single treatment (FS1), In addition, it showed negatively that the GA_{4+7} treatment is more decreased in an accumulative treatment (FS2) than that in a single treatment. Compared to the effect of gibberellic acid (Table 1), the treatment of gibberellic acid was much more effective in promoting the tuber weight than the promalin (GA_{4+7}) treatment. It suggests strongly that the gibberellins play different roles in tuber enlargement in Chinese yam.

Among plant growth hormones, jasmonic acid is also involved in tuber enlargement of Chinese yam (Koda et al., 1991). In particular, as jasmonic acid (JA) content in leaf tissues was increased, tuber weight was also enhanced in Chinese yam.

Table 3. Effect of jasmonic acid on tuber yield (kg ha^{-1}) of Chinese yam grown in field.

Jasmonic acid	Application times	
(ppm)	FS1[2]	FS2[3]
Control[1]	11,850 c	11,850 c
5	15,830 a	14,630 b
10	13,610 b	16,670 a
25	9,170 d	11,480 c
Mean	12,870	14,260

[1]Control, Untreated control, [2]FS1, Foliar sprayed on 15 July, [3]FS2, Foliar sprayed on 15 July and 15 August accumulatively. Prohydrojasmonic acid (PDJ) was applied as jasmonic acid. Means with the same letter within the columns are not significantly different ($P < 0.05$).

Table 3 shows the effects of jasmonic acid on tuber yield in Chinese yam grown under greenhouse conditions. Tuber weight was decreased at the highest JA concentration, otherwise the lowest concentration of JA (5 ppm) promoted significantly the tuber weight by a single treatment (FS1). In an accumulative treatment (FS2), tuber weight is decreased only at the highest JA concentration. Finally, the accumulative JA treatment was more effective in promoting the tuber yield than the single JA treatment.

We also examined the interactive effect of jasmonic acid and gibberellic acid on the tuber yield of Chinese yam (Table 4). In a single treatment including gibberellic acid (GA_3) and jasmonic acid (JA), these compounds were useful to increase the tuber weight in Chinese yam grown in greenhouse.

Table 4. Interactive effects of gibberellic acid (GA) and jasmonic acid (JA) on tuber yield (kg ha^{-1}) of Chinese yam grown in field.

Treatment (ppm)	Application times	
	FS1[2]	FS2[3]
Control[1]	11,850 e	11,850 e
GA 50 + JA 5	19,170 a	12,130 d
+ JA 10	17,410 b	16,760 a
+ JA 25	12,590 d	14,540 c
Mean	16,390	14,477
GA 100 + JA 5	11,020 e	15,190 b
+ JA 10	11,570 e	14,450 c
+ JA 25	15,740 c	12,870 d
Mean	12,777	14,170
GA 200 + JA 5	18,980 a	11,670 e
+ JA 10	14,260 d	8,430 f
+ JA 25	11,570 e	16,020 a
Mean	14,937	12,040
Total mean	14,701	13,562

[1]Control, Untreated control, [2]FS1, Foliar sprayed on 15 July, [3]FS2, Foliar sprayed on 15 July and 15 August accumulatively, [4]JA, jasmonic acid. Jasmonic acid was applied to prohydrojasmonic acid. Means with the same letter within the columns are not significantly different (P < 0.05).

The tuber weight was enhanced significantly by a combination of two compounds in single and accumulative treatments. The combination of GA 50 ppm plus JA 5ppm enhanced remarkably the tuber weight by a single treatment (FS1). Secondly, the combination of GA 200 ppm plus JA 5ppm remarkably enhanced the tuber weight by a single treatment (FS1). In these cases, the lowest treatment of jasmonic acid is believed to be the optimum concentration for increasing the tuber weight of Chinese yam. Comparing the application times, tuber weight was much higher with a single treatment (FS1) than with the accumulative treatment (FS2). Finally, it is suggested that promalin does not affect dramatically the increase of tuber weight, whereas gibberellic acid does promote the tuber enlargement by showing high yield. It is also demonstrated that the direct relationship between gibberellic acid and an increase of tuber weight requires a further study under diverse environmental conditions.

CONCLUSIONS

It is suggested that combined application with gibberellic acid and jasmonic acid to Chinese yam has a beneficial effect on promoting the tuber enlargement.

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REFERENCES

Karalus, W. & Rauber, R. 1997. Effect of presprouting on yield of maincrop potatoes (*Solanum tuberosum*L.) in organic farming. *J. Agron. Crop Sci.* **179**, 241–249.

Kim, S.K., Lee, S.C., Lee, B.H., Shin, D.H., Jang, S.W., Nam, J.W., Park, T.S. & Lee, I.J. 2003a. Quantification of endogenous gibberellin in leaves and tubers of Chinese yam, Dioscorea opposite Thunb. cv. Tsukune during tuber enlargement. *Plant Growth Regul.* **39**, 125–130.

Kim, S.K., Lee, S.C., Choi, H.J., Kim, K.U. & Lee, I.J. 2003b. Bulbil formation and yield responses of Chinese yam to application of gibberellic acid, mepiquat chloride and trinexapac-ethyl. *J. Agron. Crop Sci.***189**, 255–260.

Kim, S.K., Lee, S.C., Choi, H.J., Kim, K.U. & Lee, I.J. 2003c. Possible residual effects of gibberellic acid and gibberellin biosynthesis inhibitors on sprouting, early bulbil formation, tuber yield in Chinese yam. *J. Agron. Crop Sci.* **189**, 428–432.

Koda, Y., Kikuta, Y., Tazaki, H., Tsujino, Y., Sakamura, S. & Yoshihara, 1991. Possible involvement of jasmonic acid in tuberization. *Physiol Plant.* **100**, 639–646.

Singh, H., Chandra, S. C. & Jolly, R. S. 1987. Effect of growth regulators in relation to time of sown and yield of soybean cultivars. *Ann. Biol.* **3**, 36–43.