HORTSCIENCE 35(5):868–870. 2000.

CPPU and BA, with and without Pollination, Affect Set, Growth, and Quality of Muskmelon Fruit

Y. Hayata[1], Y. Niimi, K. Inoue, and S. Kondo
School of Bioresources, Hiroshima Prefectural University Shobara, Hiroshima 727-0023, Japan

Additional index words. *Cucumis melo,* sugar, fruit size, parthenocarpy, growth regulators

Abstract. **Solutions of CPPU and BA were applied to ovaries of melon (*Cucumis melo*) flowers with or without pollination, and the effects on fruit set, growth, and sugar content were investigated. Treatment with CPPU increased fruit set in both seeded and seedless melons. Even at low concentrations, CPPU had a strong effect on fruit set in the seeded melons. In seedless melons, CPPU induced 100% parthenocarpic fruit set when applied with 10 mg·L^{-1}; lower concentrations were much less effective. Treatment with BA increased fruit set in seeded melons, but was not particularly effective in the absence of pollination. During the first 10 days after anthesis, CPPU promoted fruit growth, but between 8 and 13 days after anthesis, the growth rate was lower than in the controls. Treatment with CPPU had little effect upon soluble solids (SS) levels in seeded fruit. SS content was significantly lower in seedless than in seeded fruit; this difference was larger in the placenta than in the mesocarp. Sucrose levels of both seeded and seedless fruits were consistently higher than glucose and fructose levels. High concentrations of CPPU reduced sucrose levels in the placenta of seedless fruit. These results indicate that seeds play an important role in sugar accumulation and melon fruit growth during later stages of development. Chemical names used: [1-(2-chloro-4-pyridyl)-3-phenylurea] (CPPU); 6-benzylaminopurine (BA).**

The size and quality of melon fruit is greatly influenced by position on the plant (Kamiya, 1969). Fruits on the lower position of the stem were smaller and sweeter than those on the upper portion. The optimum position for fruit set is between the 9th and 13th nodes of a vine. To encourage fruit set on a suitable node, flowers are often pollinated by hand and insects. Melon fruit set is inconsistent at low temperatures and under cloudy or rainy conditions, which inhibit the activity of pollen-carrying insects (Tsukahara, 1988). Under such conditions, particularly in semi-forcing cultures, low fruit set is a serious problem.

The following plant growth regulators have been used in attempts to improve fruit set: indole-3-acetic acid (IAA) (Burrell and Whitaker, 1939), naphthaleneacetic acid (NAA) (Iiyama, 1972; Takayama, 1970), para-chlorophenoxyacetic acid (4-CPA) (Kondo and Murozono, 1974), BA (Jones, 1965; Takayama, 1970), gibberellic acid (GA) (Kondo and Murozono, 1974), ethephon (Batal, 1983), and 2,4-dichlorophenoxyacetic acid (2,4-D) (Masuda et al., 1990). NAA, 4-CPA, and BA were most effective. However, NAA is not used because of harmful side-effects. Thus, 4-CPA and BA are usually used, although they are not effective at low temperatures. The newly developed plant growth regulator, CPPU, a urea-derivative cytokinin, promotes fruit growth in grape (*Vitis vinifera* L.) (Nickell, 1986; Ogata et al., 1988), pears (*Pyrus* sp.) (Banno et al., 1986), and kiwifruit (*Actinidia chinensis* Planch) (Iwahori et al., 1988), as well as increasing fruit set in melon (Tanakamaru, 1989).

In this study we compared the effects of CPPU vs. BA on fruit set and quality of pollinated and nonpollinated muskmelon flowers.

Materials and Methods

Plant material. The cultivar used was 'Tokyo Earl's 55'. Seedlings (140) were transplanted 45 cm apart in two rows in each of two beds (1.2 m wide × 18 m long) in a greenhouse at Hiroshima Prefectural Univ. Fertilizer was applied at two stages, a preplant broadcast application of 900 kg·ha^{-1} of 14N–14P–36K, followed by a sidedress application of 150 kg·ha^{-1} N at flowering. The vines (main shoots) were trained vertically and topped at the 23rd node. All lateral shoots were cut above the 2nd node.

Treatment. Solutions of 1, 5, and 10 mg·L^{-1} CPPU, and 1, 5, 10, and 100 mg·L^{-1} BA were applied at anthesis to the ovaries of the flowers on the first nodes of lateral shoots between the 11–12th nodes of the vines. The nonpollinated flowers were covered with paper bags from the day before until 3 d after anthesis. A 2 × 2 × 4 factorial arrangement of treatments in a randomized block design was used, consisting of pollination vs. nonpollination and CPPU vs. BA, each at 0, 1, 5, and 10 mg·L^{-1}, and a nonpollination + 100 mg·L^{-1} BA. In each plot there were 10 seedlings.

Fruit set and growth data. Fruit set was recorded 10 d after treatment and the fruit were thinned to leave one per plant. In BA-treated plants, only fruit set was measured, since the effects of BA on the growth and sugar accumulation of seeded melon fruit were reported in a previous paper (Hayata, 1988). Using a caliper, fruit length was measured at 2-d intervals from anthesis to harvest.

Analysis of soluble solids (SS) and sugar contents. The fruit were halved and SS in samples from the placental and pericarp regions were measured with a hand refractometer (N 1; Atago Co., Tokyo). Placental and mesocarp tissue (5 g each) were prepared by cutting with a razor and crushing with a mortar. The soluble sugars contained in aliquots of the juice were passed through a membrane filter (0.45 μm) and 10 μL was injected into a high-performance liquid chromatography system (model TRIROTAR-VI system controller, 830 RI refractive index detector, and 807-IT integrator; Japan Spectroscopic Co., Tokyo). Sugars were separated on a Shodex sugar SC1011 column (Showadenko Co., Tokyo) at 80 °C using distilled water (1 mL·min^{-1}) for elution.

Results

The percentage of fruit set for the pollinated control plants was 50%, whereas treatment with CPPU increased this to 85% to 100%, depending upon concentration (Table 1). The application of 1 mg·L^{-1} CPPU to nonpollinated ovaries induced 14% fruit set; however, 5 and 10 mg·L^{-1} CPPU increased set to 97% and 100%, respectively. Nonpollinated ovaries not treated with CPPU or BA began to wilt within 3 d after anthesis. In pollinated ovaries, 1 mg·L^{-1} BA had no effect on fruit set; however, 5 and 10 mg·L^{-1} BA increased set to 80% and 84%, respectively (data not shown). Fruit set in nonpollinated ovaries treated with 10 and 100 mg·L^{-1} BA was very low (7% and 11%, respectively), and growth of the fruits was not recorded. No fruit set occurred following treatment with 1 or 5 mg·L^{-1} BA (data not shown). The number of normal seeds in the pollinated control fruit was 463 (71.9% of the total number); however, 1, 5, and 10 mg·L^{-1} CPPU reduced the number of normal seeds to 327 (58.8%), 292 (51.7%), and 159 (29.4%), respectively. Application of CPPU to nonpollinated ovaries induced parthenocarpy, as all seedcoats were empty.

During the first 10 d after anthesis, fruit length was enhanced by CPPU treatment; thereafter the growth rate of the control (nontreated, pollinated fruit) exceeded that of the CPPU-treated fruit (Fig. 1). Final weight of fruit from nonpollinated ovaries treated with 10 mg·L^{-1} CPPU was equivalent to that of control pollinated fruit, whereas 5 mg·L^{-1} CPPU was less effective (Table 1). No growth occurred in nonpollinated ovaries treated with 1 mg·L^{-1} CPPU.

Received for publication 1 Feb. 1999. Accepted for publication 6 Oct. 1999. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]To whom reprint requests should be addressed. E-mail address: yhayata@bio.hiroshima-pu.ac.jp

Table 1. Effects of pollination and CPPU treatment on fruit set and size, and seed development of melon fruit.

CPPU ($mg \cdot L^{-1}$)	Fruit set (%)	Wt/fruit (kg)	No. seed/fruit Normal	No. seed/fruit Empty
Not pollinated				
0	---	---	---	---
1	14	---	---	---
5	97	1.56 ± 0.28[z]	0	565 ± 88
10	100	2.00 ± 0.25	0	532 ± 95
Pollinated				
0	50	2.33 ± 0.26	436 ± 98	170 ± 56
1	85	2.44 ± 0.38	327 ± 87	229 ± 79
5	95	2.55 ± 0.44	292 ± 102	272 ± 96
10	100	2.40 ± 0.21	159 ± 68	381 ± 105

[z]Mean ± SD.

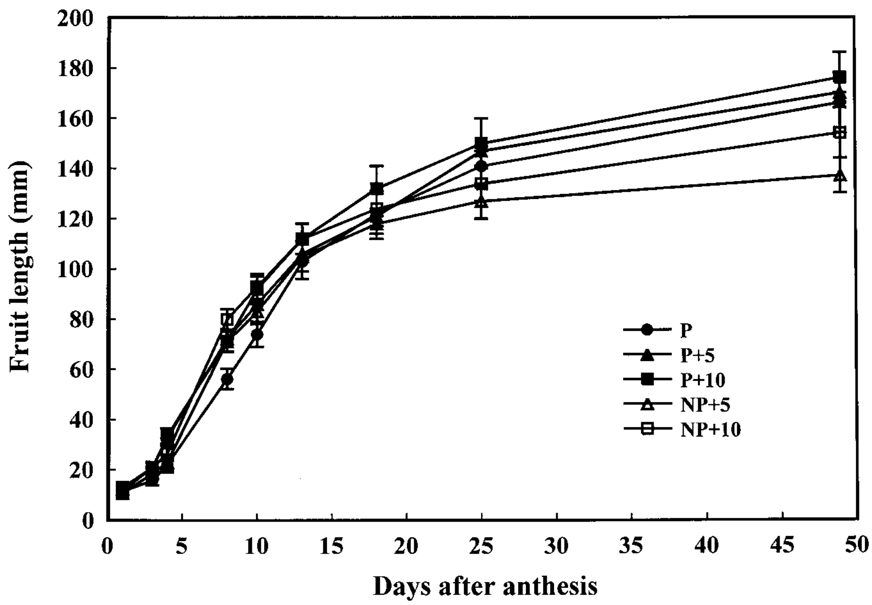

Fig. 1. Effects of pollination and CPPU on the growth of melon fruit. P = pollinated; NP = not pollinated; Number = concentration of CPPU in $mg \cdot L^{-1}$. Bars represent ± SD.

Table 2. Effect of pollination and CPPU treatment on the sugar content of the mesocarp and placenta of melon fruit.

Pollination	CPPU ($mg \cdot L^{-1}$)	SS[z] (%)	Sucrose (%)	Fructose (%)	Glucose (%)
		Mesocarp			
+	0	12.4 ± 0.85[y]	6.76 ± 0.63	2.01 ± 0.20	2.20 ± 0.13
	1	12.4 ± 1.30	6.60 ± 2.02	1.53 ± 0.15	1.83 ± 0.12
	5	12.2 ± 0.80	5.75 ± 0.94	2.02 ± 0.30	2.30 ± 0.14
	10	12.9 ± 1.20	5.88 ± 0.84	1.80 ± 0.21	2.08 ± 0.13
–	0	---	---	---	---
	1	---	---	---	---
	5	11.1 ± 1.30	5.24 ± 1.09	1.74 ± 0.55	2.04 ± 0.35
	10	11.3 ± 1.10	5.29 ± 1.01	1.60 ± 0.42	2.30 ± 0.29
		Placenta			
+	0	14.4 ± 1.30	6.10 ± 0.91	1.26 ± 0.13	1.47 ± 0.08
	1	15.8 ± 0.50	5.95 ± 0.21	1.13 ± 0.06	1.53 ± 0.40
	5	13.8 ± 0.30	5.55 ± 0.18	1.10 ± 0.18	1.32 ± 0.19
	10	14.8 ± 0.90	6.26 ± 0.49	0.92 ± 0.37	1.20 ± 0.32
–	0	---	---	---	---
	1	---	---	---	---
	5	8.8 ± 1.40	2.30 ± 0.45	0.82 ± 0.44	1.26 ± 0.45
	10	6.8 ± 0.80	1.37 ± 1.06	0.33 ± 0.23	0.76 ± 0.15

[z]Soluble solids.
[y]Mean ± SD.

The treatments had little effect on mesocarp SS (values from 11.1% to 12.9%), but SS readings were low in the placenta of nonpollinated fruit following treatment with CPPU at 5 or 10 $mg \cdot L^{-1}$ (Table 2). Sucrose, glucose, and fructose are the three major sugars in melon fruit. Of these, sucrose content was almost three times as great as that of glucose or fructose. There was little difference in the sucrose content in the mesocarp for the various treatments; levels ranged from 5.29% to 6.76%. However, sucrose levels in the placenta were particularly low (1.37% to 2.3% vs. 6.17% in the control) following treatment of nonpollinated ovaries with 5 or 10 $mg \cdot L^{-1}$ CPPU. Differences in fructose and glucose content were nonsignificant for all treatments, with the exception of the lower levels in the placenta of fruit following treatment with 10 $mg \cdot L^{-1}$ CPPU.

Discussion

Both CPPU and BA greatly increased fruit set of pollinated flowers. Mori (1975) reported that BA treatment to flowers had a limited effect on fruit set, even at concentrations above 1000 $mg \cdot L^{-1}$. However, we previously observed that lower concentrations of BA dramatically increase fruit set of artificially pollinated flowers. Moreover, fruit size and sugar content equaled those of the control (Hayata, 1988). Application of BA to nonpollinated flowers had little effect. In muskmelon, BA may increase the competitive ability of the treated fruit by improving transportation of assimilation products and prolonging the period during which pollination and fertilization can occur (Hayata, 1988).

Treatment with CPPU promoted fruit set in seedless fruit, and induced parthenocarpy, whereas BA did not. This has also been observed in watermelon [*Citrullis panatus* (Thunb.) Matsum. & Nak.] (Hayata et al., 1995). Therefore, under conditions that limit pollination, such as low temperature, CPPU may enhance fruit set.

Fruit growth in grapes (Nickell, 1986) and kiwifruit (Iwahori et al., 1988; Ogata et al., 1988) is markedly stimulated by CPPU. However, in our experiment, although CPPU promoted growth of seeded melon for 10 d following treatment, growth then slowed, resulting in fruits the same size as the controls. Fruits from CPPU-treated, nonpollinated flowers were smaller than the controls at harvest. The same growth pattern was observed in watermelon (Hayata et al., 1995). Nitsch (1952) suggested that fruit size and shape are closely correlated with seed number and seed distribution in many species, and Kurata (1983) reported that fruit development is related to seed number in watermelon. We found lower proportions of normal seeds in CPPU-treated fruit than in control fruit. Therefore, the number of seeds appears to be one of the factors affecting fruit growth in melon.

Treatment with CPPU did not affect the SS of the placenta or mesocarp of seeded fruit, but markedly reduced SS in the placenta of seedless fruit. This is consistent with the findings of Tanakamaru (1989), who reported that CPPU treatment reduced the SS of melon fruit when pollination was limited. Sucrose is the main nonreducing sugar in the melon fruit, and its content in both the placenta and mesocarp was consistently higher than that of either glucose or fructose in our experiment; however, CPPU treatment also dramatically reduced SS in the placenta of nonpollinated fruit. Seeds are thought to play an important role in promoting sink activity of fruit, thereby enhancing the accumulation of sugars. Therefore, our data suggest that this reduction in sugar content cannot be attributed to CPPU treatment, but is probably a result of the absence of seeds.

Literature Cited

Banno, K., S. Hayashi, and K. Tanabe. 1986. Effect of KT-30 spray on the growth and quality of pear fruit (in Japanese). Abstr. Jpn. Soc. Hort. Sci., Autumn Mtg. 55:521–522.

Batal, K.M. 1983. Effects of ethephon–gibberellin combinations on yield, size, and quality of muskmelon. J. Amer. Soc. Hort. Sci. 108:77–80.

Burrell, P.C. and T.W. Whitaker. 1939. The effect of indole-acetic acid on fruit setting in muskmelons. Proc. Amer. Soc. Hort. Sci. 37:829–830.

Hayata, Y. 1988. The effect of BA treatment on the setting and development of melon (*Cucumis melo* L.) fruit (in Japanese with English summary). Bul. Hiroshima Agr. Coll. 8:11–22.

Hayata, Y., Y. Niimi, and N. Iwasaki. 1995. Synthetic cytokinin—1-(2-chloro-4-pyridyl)-3-phenylurea (CPPU)—promotes fruit set and induces parthenocarpy in watermelon. J. Amer. Soc. Hort. Sci. 120:997–1000.

Iiyama, T. 1972. Melon and NAA (in Japanese). Protected Hort. 14:35–38.

Iwahori, S., S. Tominaga, and T. Yamasaki. 1988. Stimulation of fruit growth kiwifruit, *Actinidia chinensis* Planch., by N-(2-chloro-4-pyridyl)-N´-phenylurea, a diphenylurea-derivative-cytokinin. Scientia Hort. 35:109–115.

Jones, C.M. 1965. Effects of benzyladenine on fruit set in muskmelon. Proc. Amer. Soc. Hort. Sci. 87:335–340.

Kamiya, E. 1969. Culture and management of melon in greenhouse (in Japanese), p. 56–62. Seibundo Shinkosha Press, Tokyo.

Kondo, Y. and M. Murozono. 1974. Study on the method of artificial fruit set in melon (in Japanese). Abstr. Jpn. Soc. Hort. Sci., Autumn Mtg. 43:167–169.

Kurata, H. 1983. Physiology and ecology of fruit-set in watermelon, p. 57–58. In: N. Fujishita, E. Suzuki, and H. Kurata (eds.). The system of agricultural technology, melon and watermelon (in Japanese). Soc. Cult. Agr. Vill. Press, Tokyo.

Masuda, M., H. Nagao, and S. Matsubara. 1990. Growth and sugar contents of 2,4-D-induced parthenocarpic melon fruits cv. 'Earl's Favourite' (in Japanese with English summary). Bul. Okayama. Agr. Coll. 75:15-21.

Mori, Y., T. Okuda, and M. Kosuge. 1975. Study on the stability of bearing and the elevation of quality (sugar degree) in netted melons grown in the plastic greenhouse (in Japanese with English summary). Bul. Fukui Agr. Expt. Sta. 12:11–22.

Nickell, L.G. 1986. The effect of N-(2-chloro-4-pyridyl)-N´-phenylurea on grapes and other crops. Proc. Plant Growth Regulat. Soc. Amer. 13:236–241.

Nitsch, J.P. 1952. Plant hormones in the development of fruits. Quart. Rev. Biol. 27:33–57.

Ogata, R., T. Saito, and K. Oshima. 1988. Effect of N-phenyl-N´-(4-pyridyl) urea (4-pu) on fruit size: Apple, Japanese pear, grapevine, and kiwi fruit. Acta. Hort. 239:395–398.

Takayama, G. 1970. Promoting fruit set of melon (in Japanese). Agr. and Hort. 45:839–840.

Tanakamaru, K. 1989. Development and characteristics of new plant growth regulator [Fulmett solution] (in Japanese). Agr. Chem. 36:40–46.

Tsukahara, A. 1988. Semi-forcing culture in watermelon, p. 194–196. In: The system of agricultural technology, melon and watermelon (in Japanese). Soc. Cult. Agr. Vill. Press, Tokyo.