Journal of Plant Physiology and Breeding
2017, 7(1): 99-104 ISSN: 2008-5168

Applying Calcium Carbide Solution Affect Sex Expression and Increases Yield of Monoicous Cucumber

Kambiz Mashayekhi, Saeed Jafari, Aida Shomali and Seyyed Javad Mousavizadeh*

Received: March 12, 2016 Accepted: April 17, 2017
Department of Horticulture, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran
*Corresponding Author; Email: mousavizadeh@gau.ac.ir

Abstract
Sex expression in cucumber is influenced by hormonal and environmental factors such as day length and temperature. Increasing female flowers that will develop to fruit is a trick for increasing yield, hence it's importance. Likewise, it would help breeders through hybridizing process. Ethylene as a plant hormone is known to increase female flowers of most members of Cucurbitaceae family but as an exception increase in watermelon's female flowers reported under the effect of gibberlic acid. Ethylene is a gaseous ubiquitous phyto-hormone that is known to influence sex expression in cucumber. As acetylene's chemical structure with a minor difference is almost similar to gaseous hormone ethylene, in higher concentrations it is expected to retain the same physiological effects as ethylene. This experiment evaluated the effect of foliar application of different concentration of liquid solution of acetylene (0, 50, 250, 500, 750 and 1000 ppm) released from calcium carbide on cucumber sex expression and other physiological traits of cucumber. Results showed that number of female flowers and some vegetative traits of cucumber affected by different concentration of acetylene solution. Maximum number of female flowers obtained by applying 500 ppm of acetylene solution. The maximum leaf area and chlorophyll content of fruit achieved by application of 250 ppm and the maximum number of internodes obtained by 500 ppm acetylene solution. In conclusion, using acetylene as the solution form has not been reported until now. Foliar spraying of acetylene increased the female flowers in cucumber. The highest yield linked with 250 ppm of acetylene solution.

Keywords: Ethylene; Femaleness; Leaf area; Yield

Introduction

Cucumber (*Cucumis sativus* L.) belongs to Cucurbitaceae family, originated from India and South Asia (Bassett *et al.* 1986). In different environmental and physiological conditions, every type of sex expression including androecious (male flowers only), andromonoecious (staminate and bisexual flowers on the same plant), gynoecious (female flowers only), hermaphroditic (perfect flowers only), monoecious (both male and female flowers on the same plant) and trimonoecious (male, female and bisexual flowers on the same plant) (Kiełkowska 2013) can be expressed. Sex expression in cucumber is affected by three major loci. They are named as F, M and A; the F gene can stimulate femaleness of cucumber and is affected by environmental factors, while the M gene determines whether flowers are unisexual or not and induces formation of hermaphrodite flowers (Bassett 1986; Zhang *et al.* 2014). Furthermore, Tanurdzic and Banks (2004) in their study on *Marchantia polymorpha*, *Ceratopteris richardii* and maize founded that the A locus and the F locus show epistasis; so, the A gene can affect femaleness of cucumber.

Although sex expression is controlled genetically, but some hormonal factors such as ethylene could affect sex expression. Byers *et al.* (1972) measured endogenous ethylene content of apical tips and seeds of *Cucumis sartivus* L. and C*ucumis melo* during germination and showed that femaleness is associated with endogenous ethylene level. The effect of seven plant growth regulators on sex expression of in vitro cultured cucumber has been also reported previously; of all plant growth regulators, etherel (2-chloroethylphosphonic acid) as ethylene producing compound, was the most effective on inducing femaleness in cucumber. Cytokinin also promoted the production of pistillate organ and gibberellins showed a tendency to form male flowers (Matsubara 1977).

The positive effect of ethylene and ethylene producing compounds have been reported. Iwahori *et al.* (1970) indicated the increase in female flowers along with reduction of male flowers by using ethrel and gibberllic acid together and demonstrated that using 100 microliter ethylene decreased the number of nodes formed before the emergence of female flowers.

Application of ethylene as a gaseous structure is very difficult practically. Discovering ethylene releasing compounds such as ethephon (2-chloroethylphosphonic acid) in the 1960s solved this problem (Taiz and Ziger 2002; Akhter *et al.* 2004; Abbasi *et al.* 2012). However, ethephon is very expensive and is not economical for farmers. On the other hand, the amount of ethylene produced by this substance is not under control, so there is no confidence about the ability of this substance to retain the effects of ethylene in concentration sensitive cases (Zhang *et al.* 2010). Therefore, this study was conducted to evaluate the effect of acetylene solution released from calcium carbide on cucumber sex expression and yield.

Materials and Methods

A field experiment was conducted at the Research Field of Gorgan University of Agriculture Sciences and Natural Resources, Gorgan (36o51'N, 54o16'E) in the growing season of 2015. Meteorological information was recorded at a weather station located approximately 4 km from the experimental site (Table 1).

In this study, the seeds of Beth Alpha, a monoicous cucumber cultivar, were sown in 1.5×0.5 meter plots. Every plot consisted of 4 rows and 3 seeds were planted in 2-3 cm deep holes 50 cm far from each other. Every plot consists of 40 plants. Then, 20 days after germination and emergence of three true leaves only one vigorous seedling was kept and the rest were eliminated. In all treatments, no fertilizer was added to the soil before and after sowing the seeds and during plant growth. Plants were irrigated weekly (25-40 mm) at non-raining condition.

Different concentration of acetylene solution (0, 50, 250, 500, 750 and 1000 ppm) were preparde according to Mashayekhi *et al.* (2015) and were applied by weekly foliar spraying on seedling of cucumbers after emergence of the forth leaf.

Four weeks after planting, number of female flowers and number of total flowers of each plant were counted. Some other characteristics such as leaf area, number of internode, chlorophyll content of leaf and fruit, fruit length, fruit diameter and fruit weight (yield) were measured. Leaf area was measured by a digital leaf area meter, model

Table 1. Climactic data of cucumber growth season in 2015

Month	Minimum temperature (ºC)	Maximum temperature (ºC)	Average temperature (ºC)	Monthly rainfall (mm)
May	27.2	16.2	21.7	33
June	30.8	19.6	25.2	24
July	32.3	22.6	27.4	16

DELTA T, and the chlorophyll content was recorded by a digital chlorophyll meter.

Statistical differences among treatments were analyzed following the randomized complete block design with four replications using the SAS (2001) program. Means were compared by the least significant difference (LSD) test at 0.05 probability level.

Results and Discussion

Result showed that by using different concentration of acetylene solution, no significant difference observed in the number of total flowers by different treatments (Table 2), but acetylene solution significantly affected number of female flowers in a way that the maximum number of female flowers obtained by the foliar application of 500 ppm acetylene solution. Also, minimum number of female flowers obtained by using 0 and 50 ppm of acetylene solution (Table 3). Siddiq *et al*. (2009) reported significant increase in the number of total flowers in tomato by soil application of 15 mg/kg calcium carbide. This result clarifies the point that despite the total number of flowers remained constant, the female: male ratio increased. Thus, we may conclude that expression of some male flowers changed to female flowers under the effect of acetylene application. The effect of acetylene on sex expression hadn't been reported yet, but previous reports stated the effect of ethylene and ethylene producer substances on sex expression of Cucurbitacea family. Iwahori *et al.* (1970) evaluated the effect of ethylene, ethereal and growth regulators and retardants on a monoecious variety of cucumber and showed that by applying ethylene, the number of nodes at which the first female flower emerged were lower than the control. Also applying 100 microliter ethylene resulted in a significant increase in the number of nodes to the first male flower and also lowered the number of days to anthesis of female flowers. The effect of day length and endogenous ethylene content of flower bud apex on cucumber sex expression have been also determined; both short days and increased endogenous ethylene resulted in the increase of female flowers. The effect of short days associated with increase of endogenous ethylene in response to short days (Rudich *et al.* 1972). Yamasaki (2001) also reported the effectiveness of etephone on inducing femaleness in monoecious cucumber and the inability of this substance to induce femaleness in andromonoecious plants. Previous researchers also evaluated the rate of ethylene production by intact apical tips of *C. sativus* and *C. melo* and found that

ethylene production in gynoecious cucumber was more than hermaphrodite, monoecious and andromonoecious flowers which prove the positive role of ethylene in expression of femaleness (Bayers *et al.* 1972).

Table 2. Analysis of variance of the effect of different concentrations of acetylene solution on cucumber traits

SOV	df	Total flower number	Female flower	Number of internodes	Leaf area	Leaf chlorophyll	Fruit chlorophyll	Fruit length	Fruit diameter	Yield (fruit weight)
Treat.	5	0.005 ^{ns}	0.007 **	11.81 **	6084.8 **	222.35 ^{ns}	0.0021 *	36.4 ^{ns}	1.84 ^{ns}	0.0053 **
Error	18	0.009	0.004	7.66	2795.3	592.87	0.0025	132.6	9.001	0.0028
Total	23	0.014	0.011	18.98	8880.1	518.22	0.0046	169.11	10.85	0.0082
CV%		2.01	1.4	15.36	14.6	14.24	0.99	24.89	25.74	1.01

^{ns}p>0.05; *p≤ 0.05); **p≤ 0.01

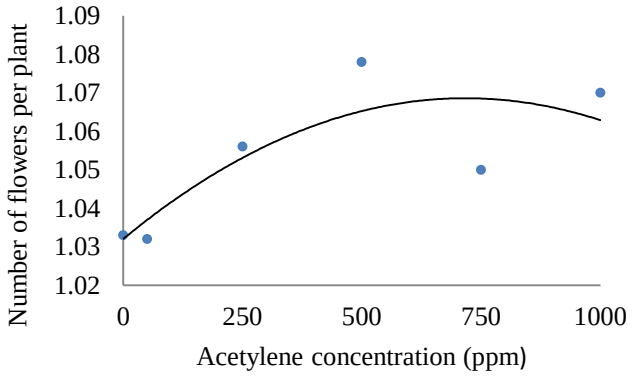

Figure 1. Number of female flowers under the effect of acetylene solution

Analysis of variance revealed that different concentrations of acetylene solution affected number of internodes, fruit chlorophyll and leaf area but didn't influence other characteristics (Table 2). The maximum number of internodes related to the leaf application of 500 ppm acetylene solution and the maximum leaf area and fruit chlorophyll were obtained when 250 ppm of acetylene was applied (Table 3).

Acetylene mimics the role of ethylene in the plant growth regulation, so the effect of foliar application of acetylene can be similar to ethylene treatments (Mashayekhi *et al.* 2015). Up to day, there was not any report on the effect of ethylene

Table 3. Comparison of different acetylene treatments means for cucumber characteristics

Concentration of acetylene solution	Number of internodes	Number of female flowers	Leaf area (m^2)	Fruit chlorophyll (mg/g/FW)	Yield (fruit weight) (kg per plot)
0	3.72bc	1.033c	6.09d	1.19abc	1.231c
50	3.51c	1.032c	86.19bc	1.18c	1.211c
250	3.96bc	1.056ab	112.08a	1.21a	1.27a
500	5.06a	1.078a	88.45bc	1.20ab	1.24bc
750	4.07bc	1.050a	72.78c	1.18bc	1.25ab
1000	4.67ab	1.07a	91.7b	1.19abc	1.25ab

Means followed by the same letter in each column are not significantly different at 0.05 probability level by LSD method

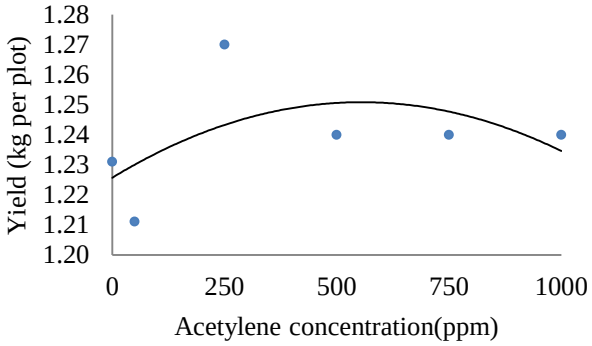

Figure 2. Yield of cucumber affected by acetylene solution

or acetylene on increasing the number of female internodes and the results obtained in this study can be attributed to the faster growth rate of treated plants as compared to the control. Indeed, at 30th day of planting, more internodes were formed in the treated plants compared with the control.

Considering the effect of acetylene on leaf area, a regular trend was not observed. In fact, plant growth regulators are known to interact and crosstalk with other hormones, thereby, ethylene cannot exert its effects without involvement of other hormonal pathways (Dugardeyn and van Der Straeten 2008). Tholen *et al.* (2004) also investigated the effect of ethylene on leaf area and growth rate for ethylene- sensitive and ethylene-insensitive mutants of *Arabidopsis*. By exposure of plants to ethylene, leaf area of the ethylene-sensitive Arabidopsis was smaller as compared to the ethylene-insensitive plants.

Comparison of traits means showed that the maximum fruit weight was obtained by foliar application of 250 ppm acetylene solution. Positive effect of soil application of calcium carbide has been reported in previous studies. Ahmad *et al.* (2004) showed the increase in dry matter of wheat by application of 60 kg/ha calcium carbide. Number of fruits per plant and weight of each fruit increased in different genotypes of tomato by application of 300 mg calcium carbide in a pot trial (Siddiq *et al.* 2012; Siddiq *et al.* 2009).

In conclusion, water dissolved acetylene released from calcium carbide influenced the sex expression and other vegetative traits of cucumber. By foliar spraying of 500 ppm acetylene solution the maximum number of female flowers obtained. However, the highest yield and leaf area was linked with 250 ppm of acetylene solution which is preferred economically.

References

Abbasi NA, Zahoor M, Khan HA and Qureshi AA, 2012. Effect of encapsulated calcium carbide application at different growth stage on potato (*Solanum tubersum* L.) growth, yield and tuber quality. Pakistan Journal of Botany 44 (5): 1543-1550.

Ahmad Z, Azam F, Mahmood T, Arshad M and Nadeem S, 2004. Use of plant growth regulators (PGRs) in enhancing crop productivity: effect of CaC2 as a source of ethylene on some agronomic parameters of wheat (*Triticum aestivum* L.). Journal of Agronomy 3 (1): 68-71.

Akhter MJ, Arshad M, Khalid A and Yaseen M, 2004. Effect of calcium carbide derived ethylene on growth and yield of rice. Pakistan Journal of Life and Social Sciences 2 (1): 85-88.

Bassett MJ, 1986. Breeding Vegetable Crops. AVI Publisher Company, Westport.

Byers RE, Baker LR, Sell HM, Herner RC and Dilley DR, 1972. Ethylene: a natural regulator of sex expression of *Cucumis melo*. Proceedings of the National Academy of Sciences 69 (3): 717-720.

Dugardeyn J and van Der Straeten D, 2008. Ethylene: fine-tuning plant growth and development by stimulation and inhibition of elongation. Plant Science 175 (1): 59-70.

Iwahori S, Lyons JM and Smith OE, 1970. Sex expression in cucumber plants as affected by 2 chloroethyl phosphonic acid, ethylene and growth regulators. Plant Physiology 46 (3): 412-415.

Kiełkowska A, 2013. Sex expression in monoecious cucumbers micro propagated in vitro. Biologia Plantarum 57 (4): 725-731.

Mashayekhi K, Shomali A and Mousavizadeh SJ, 2015. Acetylene resembling effect of ethylene on seed germination: evaluating the effect of acetylene released from calcium carbide. Notulae Scientia Biologicae 7 (3): 334-337.

Matsubara S, 1977. *In vitro* modification of sex expression of cucumber by plant growth regulators. Scientific Reports of the Faculty of Agriculture, Okayama University, Okayama, Japan, 15-23.

Rudich J, Halevy AH and Kedar N, 1972. Ethylene evolution from cucumber plants as related to sex expression. Plant Physiology 49 (6): 998-999.

Siddiq S, Yaseen M, Arshad M and Ahmed N, 2012. Effect of calcium carbide on photosynthetic characteristics, growth and yield of tomato cultivars. Pakistan Journal of Agricultural Sciences 49 (4): 505-510.

Siddiq S, Yaseen M, Mehdi SAR, Khalid A and Kashif S, 2009. Growth and yield response of tomato (*Lycopersicon esculentum* Mill.) to soil applied calcium carbide and L-methionine. Pakistan Journal of Botany 41 (5): 2455-2464.

Taiz L and Zeiger E, 2002. Plant Physiology. 3rd edition. Sinauer Associates, 690 pages.

Tanurdzic M and Banks JA, 2004. Sex-determining mechanisms in land plants. The Plant Cell 16 (suppl. 1): S61-S71.

Tholen D, Voesenek LA and Poorter H, 2004. Ethylene insensitivity does not increase leaf area or relative growth rate in Arabidopsis, *Nicotiana tabacum* and Petunia x hybrida. Plant Physiology 134 (4): 1803-1812.

Yamasaki S, Fujii N, Matsuura S, Mizusawa H and Takahashi H, 2001. The M locus and ethylene controlled sex determination in andromonoecious cucumber plants. Plant and Cell Physiology 42 (6): 608-619.

Zhang J, Boualem A, Bendahmane A and Ming R, 2014. Genomics of sex determination. Current Opinion in Plant Biology 18: 110-116.

Zhang W, Hu W and Wen CK, 2010. Ethylene preparation and its application to physiological experiments. Plant Signaling and Behavior 5 (4): 453-457.