urinary excretion of serotonin and tryptamine is considerably diminished in untreated phenylketonurics. The excretion of normetanephrine (the major metabolite of norepinephrine) and of *p*-tyramine tends to be lower in phenylketonurics, but there is overlapping with the values obtained in normal children and control mental defectives. Children with mongolism excreted as much serotonin as normal subjects. Phenylethylamine was found only in the urine of phenylketonurics, and in smaller amount than previously reported (*2*), while *o*-tyramine could not be detected in the urine of any subject even during monoamine oxidase blockade. Experiments in which authentic amines were added to urine indicated that approximately 30 percent of *p*-tyramine and normetanephrine, 40 percent of *o*-tyramine and phenylethylamine, 50 percent of serotonin, and 70 percent of tryptamine were recovered by the technique used. The sensitivity of the method was sufficient to detect as little as 1.5 μg of *o*-tyramine and 3 μg of phenylethylamine per 100 mg of creatinine in the original urine.

Failure to find *o*-tyramine in the urine of phenylketonurics during monoamine oxidase blockade and the low excretion of phenylethylamine, together with an earlier finding that neither amine is detectable in cerebrospinal fluid of phenylketonurics (*10*), make it appear unlikely that either of these substances produces mental defect by a direct neurotoxic action on brain. On the other hand, the results support the possibility that the mental defect of phenylketonuria is due to underproduction of serotonin and catecholamines in brain as a result of competitive inhibition by phenylalanine of aromatic L-amino acid decarboxylase (*11*). The results do not indicate any defect in serotonin production in mongolism (*12*).

THOMAS L. PERRY

Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, and *Pacific State Hospital, Pomona, California*

References and Notes

1. C. Mitoma, H. S. Posner, D. F. Bogdanski, S. Udenfriend, *J. Pharmacol. Exptl. Therap.* **120**, 188 (1957).
2. J. B. Jepson, W. Lovenberg, P. Zaltzman, J. A. Oates, A Sjoerdsma, S. Udenfriend, *Biochem. J.* **74**, 5P (1960).
3. A. N. Davison and M. Sandler, *Nature* **181**, 186 (1958).
4. J. B. Boylen and J. H. Quastel, *Biochem. J.* **80**, 644 (1961).
5. C. M. B. Pare, M. Sandler, R. S. Stacey, *Arch. Disease Childhood* **34**, 422 (1959).
6. H. L. Nadler and D. Y.-Y. Hsia, *Proc. Soc. Exptl. Biol. Med.* **107**, 721 (1961).
7. M. A. Chirigos, P. Greengard, S. Udenfriend, *J. Biol. Chem.* **235**, 2075 (1960).
8. H. Jerome, J. Lejeune, R. Turpin, *Compt. rend.* **251**, 474 (1960).
9. T. L. Perry, K. N. F. Shaw, D. Walker, D. Redlich, *Pediatrics*, in press.
10. T. L. Perry, K. N. F. Shaw, D. Walker, *Nature* **189**, 926 (1961).
11. S. Udenfriend, W. M. Lovenberg, H. Weissbach, *Federation Proc.* **19**, 7 (1960).
12. I am grateful to Dr. Dorothy Redlich for valuable assistance, and to Dr. Kenneth N. F. Shaw for helpful advice. This research was supported by grants from the Ford Foundation and from the National Institutes of Health. This report is contribution No. 2794 of California Institute of Technology, Pasadena.

22 December 1961

Chemical Regulation of Flower Sex Expression and Vegetative Growth in Cucumis sativus L.

Abstract. Pistillate flower formation in monoecious cucumber plants is increased when allyl trimethylammonium bromide is added to aerated solution cultures used as the root medium. By contrast, gibberellin induces staminate flower formation on gynoecious cucumber plants. The two chemicals also have diametrically opposite effects in tendril formation and vegetative extension.

During the development of a monoecious cucumber plant there is a changing nodal array of flowers of the two sex types—staminate (male) and pistillate (female). The usual spatial pattern is staminate flower formation exclusively at the basal nodes with a gradual shift in flower sex expression to ultimately only pistillate flowers in the upper nodes. Thus, staminate, monoecious, and pistillate phases in sex expression progressively occur. These phases may be identified by the nodes at which the first pistillate and last staminate flowers appear. It has been shown that the nodal location of the first pistillate flower can be a constant varietal characteristic (*1*), but this position may be modified by nutrition, light, and temperature (*2*). Treatment of monoecious cucumber plants with a variety of auxins and other growth substances may shorten the duration of the staminate phase and hasten the pistillate phase of flowering (*3*). Conversely, gibberellin enhances staminate flower production and delays the appearance of pistillate flowers (*4*). Gibberellin has been used to induce staminate flowers on gynoecious cucumbers; this has resulted in an inbred line (MSU 713-5) that, independent of natural photoperiods, temperature, and nutrient status, forms only pistillate flowers (*5*). In the meantime, antigibberellin properties of 2-chloroethyl trimethylammonium chloride and related compounds on the gross morphology of certain plants have been emphasized (*6*). This report (*7*) summarizes the effects of one of these derivatives, allyl trimethylammonium bromide (AMAB), and gibberellin A_3 (GA_3) on flower sex expression, tendril formation, and internode elongation when added to aerated solution cultures (*8*) used as the root growth medium for a monoecious (Marketer) and gynoecious (MSU 713-5) cucumber (*9*).

Germinated seedlings, immediately following cotyledon expansion, were transferred to solution cultures. AMAB and GA_3 were added to the solution cultures in a logarithmic series of molar concentrations, each of which was replicated (Table 1). There were two plants of each variety in each replicate. The evaporated and transpired solutions were replaced periodically with nutrient solution only. Thus, the roots were in constant contact with a diminishing pool of the chemical stimuli. Vegetative and flowering responses were recorded over an interval of 50 and 60 days for the GA_3- and AMAB-treated plants, respectively. Plants were grown in a greenhouse maintained at 70° to 75°F night temperature and at a seasonal photoperiod of 9 to 11 hours with no supplemental lighting.

The two chemicals in the root media induced opposite responses in flower sex expression, tendril formation, and vegetative extension (Table 1). In the control monoecious cucumber plants, staminate flowers were produced exclusively on the first 17 nodes. Only one pistillate flower occurred among the first 20 nodes, and this was at the 18th. Similar plants subjected to $5 \times 10^{-4}M$ AMAB formed pistillate flowers at 9 of the first 20 nodes with the first at the second node above the cotyledons. Twelve of the 20 nodes on such plants produced staminate flowers in contrast to 19 of the 20 for the controls. Some plants treated with $5 \times 10^{-4}M$ AMAB produced exclusively pistillate flowers after the ninth node, and there was an abrupt change from the staminate to the pistillate phase without the transitory monoecious phase. Tendril formation was delayed to the 11th node. Tendril emergence also occurred at a higher node when the plants were exposed to high temperatures and long photoperiods (*10*).

Gibberellin A_3, at $10^{-3}M$, caused reversion from pistillate to staminate

Table 1. Response of *Cucumis sativus* L. to allyl trimethylammonium bromide and gibberellin A_3 added to aerated solution cultures used as the root growth medium.

Concentration of AMAB or GA_3 (molar)	Flower sex responses			Vegetative responses	
	Node of first pistillate flower above cotyledons	No. of nodes producing*		Position of first tendril	Plant heights (monoecious cucumber) or lengths of first internode (gynoecious cucumber) (cm)
		Pistillate flowers	Staminate flowers		
Effects of allyl trimethylammonium bromide on a monoecious cucumber (var. Marketer)					
0 (control)	18 c†	1a	19 b	6a	302 d
10^{-6}	10 b	2a	18 b	7 b	256 c
10^{-5}	7 b	2a	18 b	9 c	207 b
10^{-4}	6 b	9 b	11a	10 c	108a
5×10^{-4}	2a	9 b	12a	11 d	79a
Effects of gibberellin A_3 on a gynoecious cucumber (var. MSU 713-5)					
0 (control)	1a	10 c	0a	3 b	2.1a
10^{-7}	2a	10 c	0a	3 b	2.4a
10^{-6}	2a	10 c	0a	3 b	2.6a
10^{-5}	2 b	9 c	1a	2a	2.6a
10^{-4}	6 c	5 b	4 b	2a	5.5 b
10^{-3}	11 d	0a	9 c	2a	13.0 c

* Number of nodes confined to first 20 in the monoecious cucumber and to 10 in the gynoecious cucumber.
† Means not containing a common letter are significantly different at the 5-percent level [see D. B. Duncan, *Biometrics* **11**, 1 (1955)].

flowers in the gynoecious cucumber up to the tenth node (Table 1). While no flowers were usually formed at the first node, there was an uninterrupted sequence of staminate flowers from the second through the ninth nodes. At $10^{-4}M$ GA_3 staminate flowers were continuous through the second to fourth nodes with some additional nodes that produced staminate flowers before the tenth. A few plants produced both staminate and pistillate flowers at the same node. Such "mixed nodes" immediately preceded the reversion to the pistillate phase. Gibberellin at $10^{-5}M$, or higher, changed the position of the first tendril from the third to the second node. Similarly, the promotive effects of GA_3 on staminate flower formation paralleled the increase in elongation of the first internode.

These results indicate that flower sex expression in *Cucumis sativus* L. may be subject to control through adequate levels of certain chemical stimuli continuously available to the roots through the solution culture technique. While many plant growth substances will increase the number of pistillate flowers on monoecious cucumbers, as well as the ratio of pistillate to staminate flowers, and cause pistillate flowers to form at somewhat earlier nodes, in no instance have these effects approached the magnitude of those indicated for AMAB, nor were they associated with a delay in tendril formation and reduced vegetative extension. Similarly GA_3, at heroic dosages to the foliage, has induced some staminate flowers to form on two to five nodes on the gynoecious cucumber (*3, 5*), but when applied at appropriate concentrations in the root medium it causes a complete reversion in flower sex expression for an extended period. Thus, the mutually competitive inhibition of AMAB and GA_3 in vegetative responses (*6, 11*) applies also in sex expression. These results emphasize the significance of the apparent endogenous gibberellin level in modifying inherent flower sex types in the cucumber.

WM. D. MITCHELL
S. H. WITTWER
Department of Horticulture, Michigan State University, East Lansing

References and Notes

1. O. Shifriss and E. Galun, *Proc. Am. Soc. Hort. Sci.* **67**, 479 (1956).
2. J. P. Nitsch, E. Kurtz, Jr., J. Liverman, F. W. Went, *Am. J. Botany* **39**, 32 (1952).
3. M. J. Bukovac and S. H. Wittwer, *Advances in Chem. Ser.* **28**, 80 (1961); P. Laibach and F. J. Kribben, *Ber. deut. botan. Ges.* **62**, 53 (1950).
4. S. H. Wittwer and M. J. Bukovac, *Econ. Botany* **12**, 213 (1958).
5. C. E. Peterson, *Mich. State Univ. Agr. Expt. Sta. Quart. Bull.* **43**, (1960), p. 40; ——— and L. D. Anhder, *Science* **131**, 1673 (1960).
6. N. E. Tolbert, *Advances in Chem. Ser.* **28**, 145 (1961).
7. Journal Article No. 2900 of the Michigan Agricultural Experiment Station.
8. D. R. Hoagland and D. I. Arnon, *Calif. Agr. Expt. Sta. Circular No. 347* (1950); S. Asen, S. H. Wittwer, F. G. Teubner, *Proc. Am. Soc. Hort. Sci.* **64**, 471 (1954).
9. The gibberellin consisted of the potassium salt of gibberellin A_3, and was supplied by Merck and Company, Rahway, N.J.; allyl trimethylammonium bromide was generously provided by Dr. N. E. Tolbert, and seed of the gynoecious cucumber (MSU 713-5) by Dr. C. E. Peterson.
10. W. D. Mitchell, Ph.D. thesis, Michigan State University (1961).
11. H. M. Conrad and P. Saltman, *Plant Physiol.* **36**, 685 (1962).

18 January 1962

Rainfall and Deposition of Strontium-90 in Clallam County, Washington

Abstract. A linear relationship between cumulative strontium-90 deposition and rainfall has been observed from measurements made at five sites on the Olympic Peninsula. When an estimated contribution from dry deposition is subtracted from the measured total, the strontium-90 concentration in precipitation is seen to be independent of the amount of precipitation.

It has been known for some time that rainfall is the primary process by which fission products in the atmosphere are deposited on the earth's surface. From an extensive monthly rain collection network in the United States in 1956, linear relationships between strontium-90 deposition and amount of rainfall were observed within limited geographical areas (*1*). Other studies in the United States (*2*) and the United Kingdom (*3*) with open vessel collectors and soil analyses (*4*) have borne out this relationship. In those studies where only rainfall was measured, the strontium-90 concentration (activity per unit volume of rain), over a period of a month or more, was independent of the amount of rainfall.

Although the importance of the contribution of dry deposition has been considered as a possible reason for calculated high strontium-90 concentrations in areas of low precipitation, when debris deposited during both wet and dry periods was measured, there have been few attempts to determine the amount of strontium-90 that deposits in the dry state. Recent information from Norway, a country of comparatively heavy precipitation, suggests that at the end of June 1959, as much as 30 percent of the estimated strontium-90 deposited may have been dry fallout (*5*).

In addition to the U.S. Atomic Energy Commission's world-wide soil sampling program, a study was made of the strontium-90 deposition in a limited geographical area where the yearly amount of rainfall varies markedly from site to site. In 1957, four sites in Clallam County, Washington, on the Olympic Peninsula were selected (Sequim, Port Angeles, Joyce, and Forks) where the mean annual amount of rainfall varies from 15 inches to 110 inches as one proceeds in a westerly direction. The sites were resampled in 1959 and 1960 with the addition of one more location, Clallam