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The Hormonal Basis of Tendril Coiling

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Summary

UMRATH K. & WATANABE S 1983. The hormonal basis of tendrill coiling. — Phyton (Austria) 23 (2): 307—312. — English with German summary.

Tendril coiling is induced by leaf extracts of plants from the same family or subfamily, but much less or not by leaf extracts of other plants. The same is known from releasing of leaf movements in sensitive plants and the specifity is attributed to different excitatory substances in different plant families.

It is known from the literature, that the excitatory substance is an antagonist of auxin and inhibts auxin accelerated growth. We found that in *Pisum sativum* (*Fabaceae*), the trans-forms of *liberating* substances related to cinnamic acid are more effective in inducing coiling of tendrills and they are also the more effective in growth inhibition in seedlings of the fabaceous plant *Lupinus albus,* as will be shown in a subsequent paper. On the other hand, on *Vitis* tendrils compounds without a double bound are more effective in inducing coiling as the respective trans- or cis-forms.

The second step in induction of tendril coiling in light seems to be, that the excitatory substance at the inner side of the tendril makes auxin available. This is suggested by the fact, that leaf extracts and most liberating substances induce coiling only in the light, but the auxins induce it also in the dark.

In *Pisum* and in *Vitis* tendrils stimulation of the outer side inhibits coiling. It is suggested that the excitatory substance liberated thereby conteracts auxin on the outer side.

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Zusammenfassung

UMRATH K. & WATANÄBE S. 1983. Die hormonale Grundlage der Rankenkrümmung. — Phyton (Austria) 23 (2) 307—312. — Englisch mit deutscher Zusammenfassung.

Die Einkrümmung von Ranken wird durch Blattextrakte von Pflanzen derselben Familie oder Unterfamilie ausgelöst, aber viel weniger oder gar nicht durch Blattextrakte anderer Pflanzen. Dasselbe ist für die Auslösung der Blattbewegungen sensitiver Pflanzen bekannt und die Spezifität wird der Verschiedenheit der Erregungssubstanzen verschiedener Pflanzenfamilien zugeschrieben.

Es ist aus der Literatur bekannt, daß die Erregungssubstanz ein Antagonist des Auxins ist und auxingefördertes Wachstum hemmt. Wir fanden, daß bei *Pisum sativum,* einer Fabacee, die trans-Formen freisetzender mit Zimtsäure verwandter Substanzen bei der Auflösung von Rankenkrümmungen die wirksameren sind und sie sind auch die wirksameren bei der Wachstumshemmung von Keimlingen der Fabacee *Lupinus albus,* was in einer folgenden Arbeit gezeigt werden wird. Andererseits sind an *Vitis*-Ranken Verbindungen ohne Doppelbindung wirksamer als die betreffenden trans- oder cis-Formen.

Der zweite Schritt bei der Auslösung von Rankenkrümmungen im Licht scheint zu sein, daß die an der inneren Seite der Ranke befindliche Erregungssubstanz Auxin verfügbar macht. Das wird durch den Befund nahegelegt, daß Blattextrakte und die meisten freisetzenden Substanzen die Einkrümmungen nur im Licht bewirken, Auxine aber auch im Dunkeln.

Bei Ranken von *Pisum* und von *Vitis* hemmt Reizung der Außenseite die Einkrümmung. Das weist darauf hin, daß die dabei freigesetzte Erregungssubstanz dem Auxin an der Außenseite entgegenwirkt.

Introduction

We investigated the coiling of cut tendrils of pea, *Pisum sativum* L. and of vine, *Vitis vinifera* L. in extracts of leaves of different plants, hoping to find a test for the excitatory substance of plant families with members having tendrils.

Methods

Tendrils were cut with scissors, pea tendrils near the distal leaflets. The shape of the tendrils was sketched. In most experiments the tendrils were then put into Petri dishes, 9 cm in diameter with 1 ml solution. The dishes were put slantwise on a table, so that the cut ends of the tendrils and some length of them dipped into the fluid. In some experiments Petri dishes of 6,5 cm diameter with 5 ml solution were used. The dishes were put evenly on a table and the tendrils lied in the fluid. Three sorts of solutions were used. Leaf extracts in the proportion of 1 g of fresh weight in 10 ml of destilled water, extracted by short boiling, standing half an hour or more and then decanted. Liberating substances were dissolved in destilled water and neutralized

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with sodium bicarbonate. Auxins were dissolved in tap water. Tap water was used as a control. The tendrils were sketched again one and two hours later. In later experiments 3 to 5 tendrils were put in a dish with at least 10 ml fluid. The 9 cm dishes contained mostly 20 ml. In every experiment one dish contained water and the others solutions in different concentrations. After one and two hours the coilings in the dishes were compared. The experiments were performed in day light and in the dark.

Results

In the light on *Pisum* tendrils the extract of *Pisum* leaves induced very intensive coiling, also in higher dilution. An extract of *Neptunia plena* leaves was less effective and that of *Vitis* leaves was ineffective. On *Vitis* tendrils an extract of *Vitis* leaves induced coiling in dilutions of 1 g fresh wight in 30 to 100 ml water, that of *Neptunia* leaves in the dilution of 1 g fresh wight in 10 ml water and that of *Pisum* leaves was ineffective. In the dark with all extracts any coiling did not occur.

On cut sprouts of *Mimosa pudica,* as used by Umrath & Thaler 1980, the extract of *Pisum* was scarcely effective in inducing leaf movements, the extract of *Vitis* was somewhat effective in the dilution of 1 g of fresh weight in 100 ml water and that of *Neptunia* in the dilution of 1 g of fresh weight in 1000 ml water. These results show, that induction of leaf movements in *Mimosa* and induction of coiling of tendrils are effectively done by extracts of plants of the own family or subfamily and are mostly done with highest efficiency.

We next extracted leaves of *Gleditsia triacanthos (Caesalpiniaceae).* These extracts, 1 g of fresh weight in 10 ml water, brought *Pisum* tendrils to coiling in a manner like *Pisum* extract did. We extracted in the same way leaves of *Astragalus glycyphyllos, Robinia pseudacacia* and *Mimosa pudica.* Leaves of *A. glycyphyllos* are a little sensitive to mechanical stimulation and to extracts. Leaves were cut and put into water which afterwards was changed to an extract, 1 g of fresh weight in 10 ml water. Extracts of *Astragalus* induced closing movements, extracts of *Robinia* and of *Gleditsia* induced closing in most cases, extracts of *Mimosa* were mostly ineffective. On sprouts of *Mimosa* the *Astragalus* extracts were ineffective, the extracts of *Robinia* and of *Gleditsia* were both effective in dilutions of 1 g of fresh weight in 100 to 200 ml water and the extract of *Mimosa* in a dilution of 1 g of fresh weight in 1000 ml water.

These experiments indicate, that the *Caesalpiniaceae* have the same excitatory substance as the *Fabaceae.*

The following experiments with different solutions were made on *Pisum* tendrils.

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Indolyl-3-acetic acid (IAA) in the light induced coiling of *Pisum* tendrils in 0,5 to 0,001 mM solutions and in the dark in 1 mM solution. 1 and 0,1 mM IAA seemed at first to be ineffective in the light and in the dark.

1 mM 5-hydroxyindolyl-3-acetic acid (OH-IAA) induced coiling in *Pisum* tendrils in the light and in the dark. 4 mM solutions seemd to be mostly ineffective.

Later experiments showed, that some times with 1 mM IAA and as well with 1 mM OH-IAA there was no difference to the control in water in the first two hours, but it developed a positive difference after 14 to 16 hours. Either the coilings in the auxin solution developed late or the coilings in the water controls disappeared and these in the auxin solutions persisted.

The reason that high auxin concentrations are ineffective or effective only after a long time may be, that they effect not only the inner surface of the tendrils, as lower concentrations do, but also the outher surface, what hinders or delays the coiling.

Table 1

Coiling of tendrils of *Pisum* treated with certain liberating substances in neutralized solution

Substance	Concentration mM	effective in
mandelic acid	10 to 1	light, dark
hydrocinnamic acid	5	light, dark
trans-cinnamic acid	1 to 0,05	light
trans-cinnamic acid	5	ineffective
trans-4-hydroxycinnamic acid	10 and 5	light
cis-4-hydroxycinnamic acid	40 to 10	ineffective
trans-2-methoxycinnamic acid	5	light
trans-2-methoxycinnamic acid	20	light = dark
cis-2-methoxycinnamic acid	50 to 10	ineffective
IAA	0,5 to 0,001	light
IAA	1	dark
OH-IAA	1	light = dark

In *Vitis vinifera* tendrils the coiling was intensified considerably in 1 to 0,001 mM neutralized IAA solutions, whereas OH-IAA was effective only in 3 to 0,1 mM solutions in the light and in the dark. Narrow coiling occured chiefly in the dark, but this is valid also for the rare coiling in water.

Vitis tendrils coiled in neutralized 20 mM mandelic acid and in 10 mM 3-phenylpropionic acid (hydrocinnamic acid) about equally well and distinctly better as in water. The coiling in neutralized 20 mM trans-cinnamic acid was just discernible from that in water, whereas neutralized 20 mM hydrocinnamic acid induced good coiling. In another

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experiment neutralized 20 mM trans-2-methoxycinnamic acid and 20 mM cis-2-methoxycinnamic acid induced both the same medium coiling and water was ineffective.

On tendrils of *Cucumis melo* IAA induced in neutralized 1 mM solution intensive, narrow coiling, in 0,3 and 0,1 mM solutions the coiling was good and down to 0,0003 mM it seemed to be a small difference to water.

OH-IAA in neutralized 1 mM and 0,3 mM solutions induced coiling of tendrils in the light and in the dark.

Leaf extracts of *C. melo* induce tendril coiling even in the dilution 1 g of fresh weight in 100 ml of water in the light. In the dark a leaf extract of 1 g fresh weight in 40 ml water had not much more effect as water. 0,01 mM OH-IAA had the same effect as water, whereas a combination of both induced intensive coiling.

This shows that 0,01 mM OH-IAA has enough auxin activity to enable coiling in the dark, if sufficient excitatory substance is present in a leaf extract.

Conclusions

Umrath (1930) found that the ability of leaf extracts to induce movements on cut leaves of sensitive plants is specific in so far as extracts from the same group, family or subfamily, are effective and extracts from other groups are generelly less effective or ineffective. This means, the excitatory substance is specific for families or subfamilies of plants to this we can add for the family of the *Leguminoseae* that from the three subfamilies two, the *Fabaceae* and the *Caesalpiniaceae,* have the same excitatory substance. That of the *Mimosaceae* is different. Umrath & Soltys 1936 found, that the excitatory substances of the *Fabaceae* and of the *Mimosaceae* are chemically similar to each other.

Our experiments show, that from cinnamic acid and its derivatives only the trans-forms induce coiling of *Pisum* tendrils and most effectively trans-cinnamic acid, hydroxylation and methylation reduces the effect on tendrils. Substances without a trans position, as 3-phenylpropionic acid, mandelic acid or cis-forms are less active in inducing coiling of *Pisum* tendrils. These findings suggest a carboxylic acid group in trans position on the excitatory substance of the *Fabaceae* and the occurrence of OH-groups on it, as OH-groups on corresponding places on the liberating substance and on the substance to be liberated hinder the liberation. These assumptions about the mode of liberation will be better demonstrated in a subsequent paper.

The excitatory substance of the *Vitaceae* seems to have no double bound and no trans- or cis-position.

Our results on tendrils are in agreement with the view, that different plant families have different excitatory substances.

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In all families investigated IAA in very low concentrations liberates the respective excitatory substance. SOLTYS, UMRATH & UMRATH 1938 found an antagonism between the excitatory substance and IAA. This may have physiological importance and brought about by naturals selection chemical similarities of these two substances, being responsible for the liberating power.

Leaf extracts and most of the liberating substances induce coiling of tendrils only in the light. The auxins do it also in the dark. This suggests, that the second step in bringing about coiling of tendrils is to make auxin available. UMRATH & THALER 1981 found for IAA and for OH-IAA the same high auxin activity and we found in the dark both effective in 1 mM solution. The same authors found the power of liberating the excitatory substance of the *Fabaceae* much greater in the former substance and we found in the light 0,001 mM IAA and 1 mM OH-IAA effective in inducing coiling in pea tendrils.

JAFFE & SHOTWELL 1980 found that tendrils mechanically stimulated in the dark coil if brought in the light within 60 min after stimulation. According to our findings the reason may be, that the excitatory substance produced by the mechanical stimulation is retained 60 min on the inner side of the tendril in a concentration high enough to make auxin available for coiling if brought into light.

In tendrils of *Pisum* and of *Vitis* stimulation on the inner side initiated coiling, stimulation on the outer side diminished the effect of subsequent stimulation of the inner side. This can be explained by the antagonism between the excitatory substance and auxin. The excitatory substance produced by the stimulation of the outer side is supposed to conteract there the auxin activity. The inefficincy of high concentrations of liberating substances may be do to liberation of the excitatory substance also on the outer side.

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