Neth. J. Pl. Path. 77 (1971) 154–167

Some physiological effects of spider mite infestation on bean plants

J. J. H. STORMS

Institute of Phytopathological Research (IPO), Wageningen

Accepted 14 May 1971

Abstract

Using autoradiography it was shown that saliva of *T. urticae* injected into the plant was transported to the growing regions. Indications were found that the two-spotted spider mite has an active phosphate metabolism. A local mite infestation on a bean plant caused an increased transport of phosphates to the top leaves and the roots.

At the same time an increase of P transport towards the infested leaf was ascertained. It appeared that this was not caused by a wound reaction but by a physiological influence of the mites via their saliva secretion into the host plant. A mite population in bean interferes with the equilibrium of the growth promoting substances present in the plant. Under certain conditions a slight infestation of mites (1–4 ♀♀ per cm^2) causes a growth stimulation. A heavier infestation (more than 10 ♀♀ per cm^2) causes growth inhibition. Using thin layer chromatography an indole compound was found in the mites. In bean plants infested with mites the amount of gibberellin appeared to be markedly increased.

Introduction

In the past research on phytophagous mites and their host plants has been mainly restricted to the separate study of plant or animal. Less attention has been paid to the interrelationships between both. The influence of changes in the chemical composition of the plant on the population development of the mites, has been investigated more thoroughly (Rodriguez, 1958, Storms, 1969, Watson, 1964) but as yet very little is known about the influence of a mite population on physiological processes in the host plant.

Many phytophagous mites inject saliva into the host plant during feeding. (Miles, 1968, Kloft, 1960). The saliva of many gall-forming insects is known to contain growth substances while proteolytic enzymes and substances toxic to the plant are sometimes found in the saliva of aphids (Nuorteva, 1958, Miles, 1968).

The effects of mite saliva are unkown. In preliminary observations it was found that *Tetranychus urticae* (Koch) injects saliva not only into leaves but also through membranes into artificial diets (*Storms,* 1965 unpublished). The role of this secretion in the plant – parasite relationship is practically unknown. Although there are many data on the influence of a mite infestation on growth, bud formation and yield of apple trees, (van de Vrie, 1956, Avery and Briggs, 1968), the economic significance has not been thoroughly investigated. The damage to the crop might be caused by the decrease of assimilating capacity or by an interference with a number of chemical processes in the plant. Since the nature of the damaging effect is not yet understood, some aspects of phosphorus translocation and auxin relationships in the diseased plant were investigated. The purpose of this research was to gather some data on the physiological background of an infestation of the two spotted spider mite *T. urticae* on bean plants. *Phaseolus vulgaris.*

Materials and methods

1. *Plant material*

Beans of the variety 'Processor' were sown in soil of constant composition in plastics pots ans were kept in a glasshouse conditioned at a temperature of 21 °C (± 2 °) and with artificial light (1500 mW/m^2) if necessary.

In a number of experiments the plants were transferred to a mineral nutrient solution 14 days after sowing. A standard solution coded J6 was used as described by Storms (1969).

2. *Mite material*

The mites used in the experiments were taken from a mixed population of *T. urticae* living on bean plants in the glasshouse. A number of heavily infested leaves were put into a plastic container. After 24h young active full-grown females were collected from the rim of the container with a fine brush and put on the plants used for the experiments. Large quantities of mites, needed for chemical analysis, were collected with a brushing machine (Storms, 1965).

3. *Application of isotopes*

Radiophosphorus ^{32}P was used in the form of Na_2 HPO_4. The concentrations are mentioned in the discussion of each experiment. The radioactivity of plants or mites was determined with a Geiger Müller tube (Philips 18505) at the end of the experiments, with corrections for background and dead time and the radioactive plants and mites were autoradiographed on Kodak 'no screen' Röntgenfilm.

To estimate the exposure time required the radioactivity of the material was first established with a GM tube. Between plant and film a 3.5 μm thick plastic foil was placed to prevent the plants to exert any undesired influence on the film. In one experiment tryptophan ^{14}C with a specific activity of 271 μCi/mg was used. During exposure the films were stored at 4 °C.

4. *Thin layer chromatography*

The preparation of the auxin extracts was carried out following a modified method of Posthumus (1967). 100–500 mg of homogenized mites collected as described above, or a certain volume of leaf-sap was mixed with the same volume of ethanol at 4 °C. After centrifuging at 3000 g for 20 min at 4 °C the pH of the supernatant was adjusted to 8.0 with sodium bicarbonate in order to allow extraction of the non-acidic fractions with ether. After readjusting the aqueous phases to pH 3 with phosphoric acid, the acid fractions were shaken several times with ether. The extracts were concentrated to a volume of 1 ml and chromatographed. Extracts were run on ascending thin layer chromatograms (silica gel, 6) in a mixture of iso-propanol, 7N ammonia and water (8:1:1) for 3 h. After drying during 1 h at 110 °C, the chromatograms were sprayed with 1 % DMAC (4 dimethyl-aminocinnamaldehyde) in ethanol and 6N hydrochloric acid (1:1). An indole compound fluorescent under u.v. light became visible 24 h after spraying. A search for gibberellin was made by its fluorescence under UV light after spraying with 5% sulphuric acid in ethanol and heating for two h at 110°C (Cavell *et al.*, 1967).

Results and conclusions

1. *Distribution of ^{32}P in the plant*

A. *Application of ^{32}P via the leaf.* In 1965 it was found (Storms, 1969), that the two-spotted spider mite injects saliva into plants while feeding. This saliva could be detected in leaves as well as in artificial diets using the colour reaction of Rawitzer (1934). *T. urticae* can produce several salivary sheaths from the point at which the stylets penetrate the leaf.

Probably they differ greatly from the sheaths of aphids as described by *van Hoof* (1958). To study transport of ^{32}P from saliva, radioactive mites were confined on 3-week-old bean plants. They had been made radioactive by feeding for one week on a bean plant which had taken up radioactivity via its roots from a standard feeding solution (Code J6) to which ^{32}P was added at a concentration of 500 μCi/200 ml, (Storms, 1969).

Fifty Young females were localized within a ring of a tree banding gum (area 2 cm^2) on a primary leaf of a bean plant. At the start of the experiment the total radioactivity of the mites was 2500 c/min. After 8 days the radioactive phosphate from the saliva was transported to the growing parts, that is the developing top leaves, the shoot tip and the roots. (Fig. 1). Before autoradiographing the infested part is punched from the leaf. This transport was found in old as well as in young plants. Films in these experiments were exposed during 7 days at 4°C. A similar effect was found by Avery and Briggs (1968b) with *Panonychus ulmi* (Koch) on plum tree. That this transport was

Fig. 1. Autoradiograph showing transport of ^{32}P from saliva of mites in bean. For details see text.

Fig. 1. Autoradiogram van een boneplant tonend het transport van ^{32}P uit het speeksel van mijten. Voor details zie tekst.

Fig. 2. Transport of ^{32} P in bean plants taken up by petiole of top leaf (A) and basal leaf (B); left originals, right autoradiographs. For details see text.

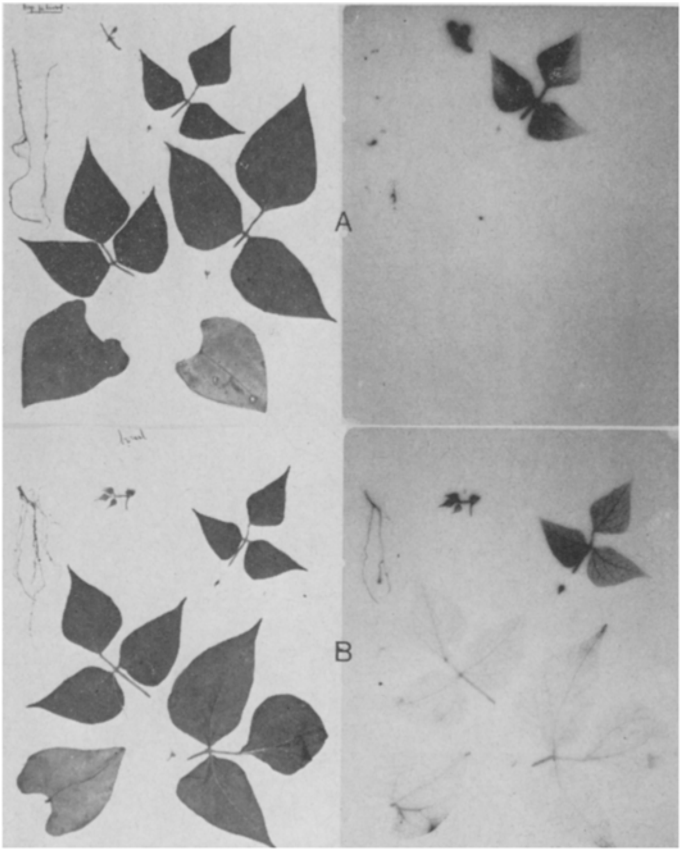

Fig. 2. Transport van ^{32}P opgenomen via de bladsteel van het topblad (boven) en primair blad (beneden) in boneplanten; links originelen, rechts autoradiogrammen. Voor details zie tekst.

indeed due to saliva secretion was proved by letting 20 radioactive females with a total activity of 300 c/min feed on an artificial diet through a parafilm membrane. Autoradiographs of the concentrated diet showed the presence of ^{32}P.

From August 1969 to January 1970 12 experiments with 3 replicates each on transport of ^{32}P in bean plants, under the influence of mite infestation, were carried out. In total more than 100 autographs were developed. When radioactive mites are placed on a primary leaf in a growing bean plant the distribution of ^{32}P is similar as if ^{32}P is taken up from an aqueous solution via the petiole of a primary leaf (Fig. 2B). If the radioactive phosphate is taken up via the petiole of the top leaf transport is much less polar and no lateral movement of ^{32}P occurs. Only the developing leaves at the shoot tip and the main root become radioactive. (Fig. 2A). When a primary leaf is treated superficially with a solution of ^{32}P with a total activity of 10 μCi the results are similar to those presented in Fig. 1 and 2B (Fig. 3A).

Fig. 3. Autoradiographs showing the effects of a local mite infestation on the distribution of ^{32}P in bean. The figures near the leaves are the counts per minute established with a Geiger Müller tube, just before the plants were autoradiographed.

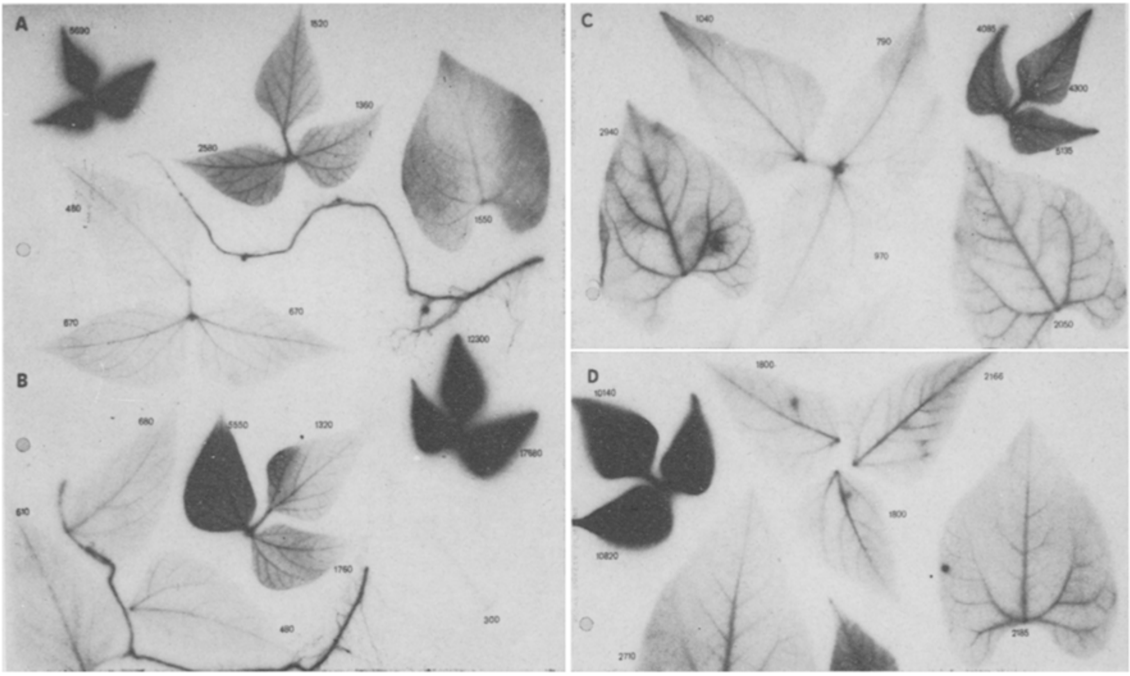

Fig. 3. Autoradiogrammen de effecten tonend van een lokale mijtenaantasting op de verdeling van ^{32}P in boneplanten. De cijfers bij de bladeren zijn het aantal tikken per minuut gemeten met een Geiger Müller teller, voordat de planten werden geautoradiografeerd.

To establish the effects of a mite infestation on the transport of ^{32}P the following experiments were carried out. If 100 adult non-radioactive females of *T. urticae* are confined for 3 days on the first trifoliate leaf of a 3-week-old bean plant and one primary leaf is superficially treated with 10 μCi ^{32}P, a marked increase of ^{32}P transport through the plant occurs as compared with a control (Fig. 3B). The top leaves are twice as radioactive and the roots are clearly more radioactive too. The transport to top and roots, however, increased at the expense of that to the primary leaf of the infested plant. The unfolded leaves were not autoradiographed because their high activity would only show as big black spots. One half of the trifoliate leaf is more radioactive than the other half. This is only apparent if the ^{32}P is applied via a primary leaf instead via the roots. Both primary leaves apparently contribute equally to the nutrition of all other leaves. The same increased transport of ^{32}P occurred if the ^{32}P treated leaf was infested with mites. If the opposite, untreated leaf, was infested, the effect was most clear. A marked increase of radioactivity in the top leaves and the roots, was observed 24 h after the mites were put on the leaf. Moreover the infested leaf also becomes heavily labelled. In this case a lateral transport occurs which is not observed if mite infestation is anywhere also on the plant.

To find out whether this effect was caused by the influence of the mite population on the physiology of the plant or to a wound reaction caused by mechanical damage of the leaf stylet insertion, the leaves were rubbed with carborundum powder. This powder consists of fine needles with an average length of 32 μm. Damage to the leaf epidermis caused by carborundum-needles is somewhat comparable to that caused by a heavy infestation of mites. The stylets of adult females of *T. urticae* penetrate the leaf for about 70 μm (*Liesering*, 1960) and the thickness of the bean leaves is about 170 μm.

Treatment with carborundum powder was effected by dusting the leaves with the powder, rubbing them with a wet cotton-wool pad and by washing excess powder from the leaves with tap water. It appeared that in plants of which a primary leaf or trifoliate leaf was treated with carborundum, no increase of ^{32}P-transport could be found. If, however, the primary leaf which was treated with carborundum also received a quantity of ^{32}P an increased uptake and a subsequent increase of transport of the isotope in the plant to the growing regions occurred.

From these experiments it was concluded that a strong physiological influence by the mite population is responsible for the increase of ^{32}P transport in the plant.

B. *Application of* ^{32}P *via the roots*. In order to find out whether the xylem transport is influenced by the mite infestation, 14-day-old bean plants were placed for 24 h on a J6 nutrient solution (Storms, 1969) to which 20 μCi ^{32}P per plant was added. The control plants showed the same image on the films as in the experiments in which the primary leaf was treated with ^{32}P. Films in these experiments were exposed 24 h at 4 °C (Fig. 3C). A light infestation of mites for 3 days on the whole plant or restricted to the primary leaves did not result in an increased ^{32}P uptake via the roots.

If, however, the infestation took place on the first trifoliate leaf after 3 days a marked increase of ^{32}P uptake via the roots to the growing parts occurred (Fig. 3D). In these experiments the effects of mechanical leaf damage by carborundum powder on the uptake of ^{32}P was also studied. The effect of treating a bean leaf with carborundum powder in the manner described, showed in the autoradiographs as somewhat dark spots on the leaves. If a disc (2 cm^2) was punched from the leaf no wound reaction was visible on the films. These experiments also showed under certain conditions a strong influence on the uptake of phosphate by the roots caused by a local infestation of mites.

2. *Turn-over of* ^{32}*P in mites*

In the experiments described above, ^{32}P was used as an indication of phosphate transport in the plant. As the plant reacts to the mite infestation by increased phosphate transport and as phosphorus is an important nutrient element for the plant as well as for the mite and also keeping in view the effect a change of host plants has on the metabolism of the mites, it was interesting to know how fast phosphate from a feeding substrate is made available to the progeny.

Two 14-day-old bean plants were put on a nutrient solution to which ^{32}P was added at a concentration of 250 μCi per 100 ml. During a period of 24 h every 2 h all eggs laid were collected, mounted on filter paper and autoradiographed. It appeared that 6 h after the transfer of the mites, the eggs began to show radioactivity (Fig. 4A) Rodriguez (1954) also reports on an active phosphate metabolism in the two-spotted spider mite. When the radioactive mites were put back on a non-radioactive plant, the

Fig. 4. Autoradiographs of mite eggs showing speed of ^{32}P turn-over.
A. Radioactivity of eggs laid by mites which had fed on ^{32}P containing bean plants
B. Radioactivity of eggs laid by mites which were transformed to non-radioactive bean plants

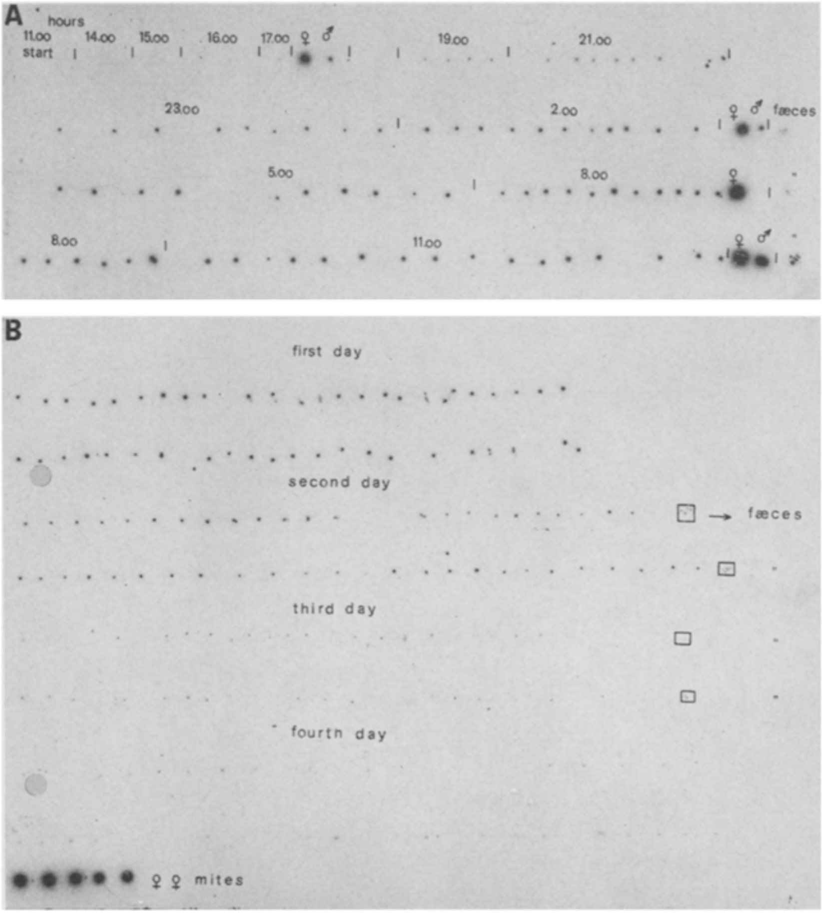

Fig. 4. Autoradiogrammen van mijteneieren tonend de incorporatie van ^{32}P.
A. Radioactiviteit van eieren gelegd door mijten die zich hadden gevoed op ^{32}P*-bevattende boneplanten.*
B. Radioactiviteit van eieren gelegd door mijten die waren overgezet op niet-radioactieve boneplanten.

eggs gradually lost their activity and after 4 or 5 days it had almost disappeared, (Fig. 4B). The mites which laid these eggs, however, were still quite radioactive, which indicates that the mites have a reservoir of phosphate which is not used for egg production. The radioactive phosphate in the mite disappears gradually through egg-laying, faeces, urine, web formation and saliva secretion. If mites are transferred from one plant to another or to an artificial diet it seems that the egg production is in a short period of time a function of the nutritive value of the new feeding substrate.

3. *Effect of a mite infestation on the growth of been plants*

A. *Biological experiments.* In a preliminary experiment an increase in root weight of a bean plant infested with a certain number of mites had been observed. Therefore it was also investigated whether mite saliva contained growth-regulating substances. It is known that many insects produce growth-regulating substances, like gall-forming insects. With mites Avery and Lacey (1968) found alterations in the quantity of gibberellin and auxin-like substances in plum trees, caused by an infestation by the fruit tree red spider mite, *P. ulmi*. In the years 1968, 1969 and 1970 experiments were carried out to establish the influence of mite density on the growth of bean plants. In these experiments 3 groups of 10 plants each were compared. The first group was not infested with mites (A), the second one (B) was infested with 20 or 25 adult females per plant and the third group (C) with 60 or 100 adult females. The experiments were carried out in a glasshouse with extra light during winter and spring and a temperature of 22 °C ± 2 °C (Fig. 5).

Forteen-day-old bean plants were used of which the first composite leaf was incompletely developed. They were selected from a group of seedlings grown under the same conditions of light and temperature. The plants were grown and afterwards potted in sterilized vegetable mould. From 60 selected plants of the same size 30 were chosen at random. The mites were collected as described above.

Every 2 days the total length of the plants and the length of the main vein of the middle leaf of all composite leaves were measured. The experiments lasted 3 weeks and 14 experiments were carried out. The mites were transferred to leaf-discs which were put on the plants to be infested. Even the plants which initially had 20 or 25 females were badly damaged at the end of the experiment and showed a marked yellowing.

Table 1 shows the results of these experiments expressed in relative growth of plants and leaves. The effects (E) of a mite infestation on first the B group was calculated using the equation $E = Be/Ae \times Ab/Bb$ in which Ab is the total length of the plant or leaf at the beginning of the plant or leaf at the beginning of the experiments and Ae is the end of the experiment. The same goes for B. The effect in group C is calculated in the same way. Differences of less than 0.03 were excluded. In Table 1 the number of experiments is given, showing the difference in effect on plant growth due to mite-infestation. In the experiments in which E equals 1 it can be noted that in spite of the heavy infestation at the end of the experiment no growth reduction occurred. It can be

Fig. 5. Effect of a mite infestation on the growth of bean plants after a period of two weeks.

Fig. 5. Effect van een mijtenaantasting op de groei van boneplanten na een proefperiode van twee weken

supposed that any growth-stimulating effect caused by mites was nullified by the growth reduction due to a decrease of the assimilating capacity. The largest stimulating effects were observed in the apical growth of the plant and the first trifoliate leaf. Stimulating effects diminished in the course of the experiment while damage increased. Stimulating effects were mostly found with an initial density of 20 or 25 females per plant; with an initial density of 60 or 100 females per plant only in 16% of the experiments a positive effect was observed.

In some cases the mites were weighed at the beginning and end of the experiments. It appeared that after 3 weeks the mite population in groups B and C increased 85 and 70 times in weight respectively. The leaf surface showed a twelvefold increase during this period. At the beginning of the experiment the density of mites in the B group was 0.7 females per cm^2 and 2–3 females per cm^2 in group C. At the end these densities were 4 and 12 females per cm^2, respectively .The total multiplication rate for mites in group C was lower than that of group B which means that in group C density dependent inhibition of the population development occurs probably because of lack of food.

To explain the results given in Table 1, the plants grow much less in winter, from November to March, than in the remaining months of the year. In winter the plants grew an average of 6.7 mm per day as compared to 7.9 mm per day during the other months. It may be supposed that, apart from differences in population development of mites in the various seasons, the growth-stimulating effects of a mite infestation is much less apparent in plants with a suboptimal growth than in plants with a high growth rate.

The effects as given in Table 1 are subdivided into experiments in summer (March to September) and winter time. It appears that the results are mainly negative in winter contrasting to the positive results in summer.

Besides the positive effect on the length of the plant and leaves in the B groups an accelearted breaking of the side buds was observed as well as stimulation of the root growth.

Table 1. Effect of mite infestation on plant growth.

	Total plant		1st trifol. leaf		2nd trifol. leaf		3rd trifol. leaf		4th tirfol. leaf	
	summer	winter	summer	winter	summer	winter	summer	winter	summer	winter
Increase of plant growth	4[1]	0	5	2	5	2	4	1	4	4
No effect on plant growth	5	3	3	1	1	1	3	1	0	0
Decrease of plant growth	0	2	1	2	3	2	2	3	2	3

[1] The figures indicate the number of experiments in which an effect (or no effect) on the growth was found.

Tabel 1. Het effect van mijtenaantasting op plantengroei.

B. *Chemical analysis.* The results of the biological experiments indicated changes in the action of auxin or indole derivatives in the plant directly or indirectly caused by a mite infestation.

To support the above conclusions the presence of growth-promoting substances in the saliva and the infested plant material was investigated. An artificial chemically defined diet for *T. urticae* (Storms, 1970) on which 100 young female mites had fed through a parafilm membrane for 24 h, was examined for the presence of indole acetic acid (IAA) or other indole compounds by means of thin layer chromatography. In these diets traces of these derivatives were found just within the limits of the technique.

In concentrated extracts of mites a probable derivative of indole acetic acid was detected. Instead of IAA (Rf = 44) a compound with Rf = 66 was found which fluoresced under UV light. Also in the supernatant of homogenized mites, after centrifuging at 200.000 g a similar spot on the chromatograms was observed. The compound did not react with ninhydrin.

The biological activity was not tested.

Using tryptophan – $^{14}C^1$ as precursor the compound which was probably active was shown to be an indole derivative. In this experiment 2000 full-grown female mites were fed during three days on 1 ml of an artificial diet, (P-diet- Storms, 1970). In this diet the normal tryptophan was replaced by 50 μCi of the radioactive one. Half of the mites were placed in 1 ml of ethanol. The other half were allowed to feed for 3 days on a non – radioactive diet. The diets and the mite extracts were chromatographed. The chromatograms were exposed on a Röntgenfilm for 10 days. In the original radioactive diet after 3 days one radioactive compound could be detected at Rf = 66. This compound was also found in the mites to a lesser degree. In the non radioactive diet on which the second 1000 mites had fed no radioactivity was found. However, in extracts of these mites the compound could be detected. The presence of this compound in the original diet after the mites had fed on it for 3 days must be ascribed to the injection of this compound by the mites into the diet. The mites are capable of transforming tryptophan into this compound.

The role of gibberellin in the growth promotion of bean plants infested with mites was also tested 10 g bean leaves, derived from heavily (A), moderately (B) and uninfested plants (C), homogenized as described above, extracted and chromatographed. Gibberellin GA 3[2] was run as a reference. In contrast to the control, spots with the same Rf value as gibberellin were found in the A group and to a lesser extent in the B group. This gives a first indication that an auxin-like substance and a gibberellin play a role in growth regulation in the plant, after damage by mites. This was also found by Avery and Lacey (1968) with *P. ulmi* on plum trees. In contrast to the method used by these autors, in the present experiments the plant material was cleared of mites and debris by means of a brushing machine and washed carefully before homogenizing.

Discussion

A high population density of the two-spotted spider mite can exert a strong negative influence in the yield of fruit trees. Premature leaf drop, decreased shoot and root

---

[1] D. L. Tryptophan – methylene – ^{14}C Radiochemical Centre

[2] Berelex – ICI – England.

growth and a decrease in the number of buds can also occur (van de Vrie, 1956 and Briggs and Avery, 1968).

According to Avery and Lacey (1968) in the case of damage to a host plant two phases can be distinguished: a) shoot and root growth are influenced and b) photosynthetic capacity decreases. Liesering (1960) also found an inhibition of photosynthetic capacity in bean plants infested with *T. urticae*. In plants damaged by mites he found an increased uptake and evaporation of water. Loss of water in particular can increase in such a way it would lead to a rapid dehydration of the leaves. The oxygen requirement of damaged leaves appeared to be 20–60% higher than usual. Many gaps remain in our knowledge of the physiological influence a mite infestation has on a plant. A marked change was found in the distribution of phosphate in the plant after mite damage. There is not only an increased rate of transport of phosphate to the growing parts of the plant after the infestation but also to the parts occupied by the mites. It was found that this was not a normal wound reaction, but caused by the injection of certain salivary components of the mites which can influence some physiological processes in the plant to a great extent. The observed increase of phosphate transport to the growing parts of the plant caused by a local mite infestation could be connected with the growth stimulation effect as was found in plants infested with a small number of mites. It is likely that growth-stimulating substances from the mite saliva are transported by the plant to top and roots. This growth stimulation could influence the transport of substances in the plant.

It is assumed that neither the plant nor the mites can discriminate between radioactive ^{32}P and non-radioactive ^{31}P. An increased ^{32}P transport is linked to an increased ^{31}P transport in the plant. ^{32}P is used in our experiments as a tracer in general transport problems.

The experiments on transport of radioactive mite saliva in the plant (Fig. 1) are very difficult to reproduce in winter time. Old bean plants are more suitable than young ones for these experiments.

T. urticae has an unpaired salivary gland. This runs out into the top of the stylets. By a movement of the mandibular front piece the stylets are rapidly moved up and downward (± 20 times per sec). In this way relatively large amounts of saliva can be injected into the leaf. Haemolysis experiments indicated that *T. urticae* can also inject one or more proteolytic enzymes into the leaf with its saliva. As the adult mite is capable to empty approximatively 100 cells from one part of the leaf epidermis it can be assumed that the saliva of the mites plays a role in the digestion of food in the leaf, an activity analogous to that of aphid saliva (van Hoof, 1958).

The growth experiments, (Fig. 5) gave an indication that a slight mite infestation can influence the equilibrium of growth hormones in the plant. Whether the interference with this equilibrium is caused by certain phytohormones or their precursors which are injected into the plant via mite saliva or by a secondary reaction of the plant to these substances by way of a subsequently increased manufacture of auxins and gibberellins could not be determined. An accelerated breaking of the side buds was observed, after a slight mite infestation, and the correlative inhibition of the breaking of the side buds is neutralized. Not much is known about the cause of this phenomenon.

Ishaaya and Sternlight (1969) found no stimulating effect of *Aceria* mites in lemon trees. The greater the density of the mite population the more growth inhibition was found. They reported a higher concentration of phenols in the infested buds. It is generally assumed that phenolic compounds play a role, either stimulating or inhibiting the production of indol-acetic acid. Avery and Lacey (1968), also explain the decrease in auxin content in plant parts of plum trees infested by *P. ulmi* by action of some phenolic compounds. In infested leaves, however, an increased amount of auxins was found.

In bean plants a growth stimulation by *T. urticae* was found at densities between 1 and 4 females per cm^2. If the density exceeded 10 females per cm^2 growth inhibition occurred. Avery and Briggs (1968b) found a growth stimulation by *P. ulmi* in plum trees at a density of 0.5 female per cm^2. Inhibition of growth was found with densities of 1–2 females per cm^2. So the bean plants can tolerate a higher population density of *T. urticae* compared to plum trees infested with *P. ulmi.*

The effect of mite infestation on the growth of the host plant depends on the growth intensity of the plant and the reproductive capacity of the mites.

A better understanding of the physiological changes in the plant caused by mite infestation is important in evaluating the real damage. At the same time it would enable a prediction of the probable damage caused by a certain mite population.

Knowledge of the physiological reaction mechanism of the plant to a mite infestation could also make a valuable contribution to research on the nature of resistance of plants to phytophagous mites.

Acknowledgments

This work was sponsored by the National Council for Agricultural Research, TNO, in the Netherlands. I thank Mr W. H. M. Mosch and especially J. Ph. W. Noordink ing., Institute of Phytopathological Research and Ir F. L. Dieleman, Department of Entomology of the Agricultural University of Wageningen for their help and advice and Dr J. M. S. Forrest for correcting the manuscript.

Samenvatting

Enkele fysiologische effecten van spintaantasting op boneplanten.

Met behulp van autoradiografie werd aangetoond dat speeksel van de bonespintmijt of bepaalde componenten van dat speeksel, welke tijdens de voedselopname in de plant (boon) worden gebracht, getransporteerd worden naar de sterk groeiende delen van de plant te weten de zich ontwikkelende bladeren en de wortel, (Fig. 1). Eenzelfde verdelingspatroon werd verkregen door autoradiografie van boneplanten die radioactief fosfaat hadden opgenomen via de bladsteel van een primair blad, (Fig. 2B). Het bleek dat reeds zes uur na het opnemen van voedsel, fosfaat, afkomstig van dat voedsel, in nieuw gevormde eieren kon worden teruggevonden, (Fig. 4). Een lokale mijtenaantasting van de boon veroorzaakt een toename van het fosfaattransport naar de top en de wortels, (Fig. 3).

Tevens ontstaat er een fosfaattransport naar het aangetaste blad. Met behulp van behandeling van bladeren met carborundumpoeder kon aannemelijk worden gemaakt dat het hier geen wondreactie betreft maar er sprake is van een fysiologische reactie van de plant op een mijtenaantasting. Een mijtenpopulatie verstoort het groeistoffenevenwicht in de plant. Een geringe aantasting (1–4 ♀♀ per cm^2 bladoppervlak) veroor-

zaakt onder bepaalde omstandigheden een stimulering van de lengtegroei van de plant en van de bladeren, (Fig. 5). Tevens wordt de wortelgroei gestimuleerd en wordt door het versneld uitlopen van de zijknoppen, de apicale dominantie doorbroken.

Deze effecten treden vooral op in voorjaar en zomer wanneer de groei van de plant relatief het sterkst is. Het stimulerend effect kwam vooral tot uiting in de lengtegroei van de plant en de groei van het eerste samengestelde blad, (Tabel 1). Een zwaarder aantasting (meer dan 10 ♀♀ per cm^2 bladoppervlak) veroorzaakt een remming van de groei.

Op dunne-laag chromatogrammen van gezuiverde extracten van mijten werd een indolverbinding aangetoond met een hogere Rf-waarde dan die van auxine.

In bladeren van boneplanten, welke door mijten waren aangetast werd een verhoging gevonden van het gehalte aan gibberelline.

References

Avery, D. J. & Briggs, J. B.,1968a. Damage to leaves caused by fruit tree red spider mite, *Panonychus ulmi* (Koch). J. hort. Sci. 43: 463–473.

Avery, D. J. & Briggs, J. B., 1968b. The aetiology and development of damage in young fruit trees infested with fruit tree red spider mite, *Panonychus ulmi* (Koch). Ann. appl. Biol. 61: 277–288.

Avery, D. J. & Lacey, H. T., 1968. Changes in the growth-regulator content of plum infested with Fruit Tree Red Spider Mite, *Panonychus* (Koch). J. exp. Bot. 19: 760–769.

Briggs, J. B. & Avery, D. J., 1968. Effects of infestation with fruit tree red spider mite, *Panonychus ulmi* (Kch), on the growth and cropping of young fruit trees. Ann. appl. Biol. 61: 269–276.

Cavell, J., Mac Millan, R. J. Price & Sheppard, A. C., 1967. Plant hormones V. Thin layer gas liquid chromatography of the gibberellins, direct indentification of the gibberellin in a crude plant extract by gas liquid chromatography. Phytochemistry 6: 867–874.

Hoof, H. A. van, 1958. An investigation of the biological transmission of a non-persistent virus. Diss. Agricultural University Wageningen.

Ishaaya, I. & Sternlicht, M., 1969. Growth accelerators and inhibitors in lemon buds infested by *Aceria sheldoni* (Euring) (*Acerina: Eriophydae*). J. exp. Bot. 20: 796–804.

Kloft, W., 1960. Wechselwirkungen zwischen Pflanzensaugenden Insecten und der von ihnen besogenen Pflanzengeweben, I und II. Z. angew. Ent. 45: 337–381; 46: 42–70.

Liesering, R., 1960. Beitrag zum phytopathologischen Wirkungsmechanismus von *Tetranychus urticae* Koch (*Tetranychidae, Acari*). Z. Pflkrankh. PflSchutz. 67: 524–543.

Miles, P. W., 1968. Studies on the salivary Physiology of plant-bugs; experimental induction of galls. J. Insect Physiol. 14: 97–106.

Nuorteva, P., 1958. Die Rolle der Speichselsekrete im Wechselverhältnis zwischen Tier und Nahrungspflanze bei Homopteren und Heteropteren. Entomologia exp. appl. 1: 41–49.

Posthumus, A. C., 1967. Crown-gall en indolazijnzuur. Diss. Leiden University.

Rawitzer, G., 1934. Wohin stecken die Pflanzenläuse? Z. Bot. 26: 144–168.

Rodriguez, J. G., 1954. Radiophosphorus in metalbolism studies in the two-spotted spider mite. J. econ. Ent. 47: 514–517.

Rodriguez, J. G., 1958. The comparative NPK nutrition of *Panonychus ulmi* (Koch) and *Tetranychus* telarius (L.) on apple trees. J. econ. Ent. 51: 369–373.

Stahl, E., 1969. Thin-layer chromatography. Springer-Verlag. Berlin, Heidelberg, New York.

Storms, J. J. H., 1965. Rearing methods for studying the effect of the physiological condition of the host plant on the population development of *Panonychus ulmi* (Koch). Boll. Zool. agr. Bachic. 2: 79–85.

Storms, J. J. H., 1969. Observations on the relationship between mineral nutrition of apple rootstocks in gravel culture and the reproduction rate of *Tetranychus urticae* (*Acarina: Tetranychidae*). Entomologia exp. appl. 12: 297–311.

Storms, J. J. H., & Noordink, J. Ph. W., 1970. Nutritional requirements of the two-spotted spider mite *Tetranychus urticae* (*Acarina: Tetranychidae*) Polska Akademia, in press.

Vrie, M. van de, 1956. The effect of fruit tree red spider mite infestation on yield and growth of fruit

trees. Neth. J. Pl. Path. 62: 243–257.
Watson, T. F., 1964. Influence of host plant condition on population increase of *Tetranychus telarius* (L.) (*Acarina: Tetranychidae*). Hilgardia 35: 273–323.

Address

Instituut voor Plantenziektenkundig Onderzoek (IPO), Binnenhaven 12, Wageningen, the Netherlands