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POST INFESTATIONAL CHANGES IN THE NUTRITIVE ELEMENTS OF THRIPS (*PSEUDODENDROTHRIPS MORI*) ATTACKED MULBERRY (*MORUS* SP.) FOLIAGE

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Abstract: Mulberry, the sole food of silkworm, *Bombyx mori* L. is prone to various pests and diseases. The injury caused during the feeding behavior of insect pests may alter the physiological activities and leading to imbalances in the nutritive constituents of the host plants. An study has been made to know the level of six macro (nitrogen, phosphorus, potassium, calcium, magnesium and sulphur) and seven micro nutrients (zinc, iron, manganese, copper, boron, molybdenum and chloride) elements in the thrips (*Pseudodendrothrips mori* Niwa.) attacked leaves of six popularly cultivated mulberry varieties. The results revealed a large variation in the nitrogen, phosphorous, potassium, magnesium, sulphur and molybdenum content. The remaining elements were changed non-significantly. Feeding such leaves may cause a variation in growth and development of the silkworm, which results the low yield and poor quality of silk.

Key Words: Mulberry, Nutritive Elements, Silkworm, Thrips.

INTRODUCTION

Mulberry (*Morus alba* L.), a commercially important crop is grown extensively as food plant for the production of most valued silkworm (*Bombyx mori* L.) cocoons. The leaves are harvested for rearing domesticated silkworms. The quality and quantity of mulberry leaf yield directly affects the cocoon production. Being a perennial crop it is prone to various pests and diseases which in turn becomes a serious constraint for the production of quality leaf for feeding silkworm. *Pseudodendrothrips mori* Niwa (Thysanoptera: Thripidae) commonly known as thrips has become a dominant and regular pest of mulberry. About 21 species (46.67%) of thrips are identified as pest of agricultural crops of which five species under sub order Tubulifera have been reported to inflict damage to mulberry (Reddy and Narayanaswamy, 1999). *P. mori* cause loss in the leaf area and leaf weight resulting in yield reduction to the tune of 20 to 40 per cent (Muthuswami *et al.,* 2010). It feeds on fully expanded leaves and young tissue in the bud. Infested leaves dry out and have a stippled or silver flecked appearance. Small brownish specks of excrement are usually noticed on the underside of the leaves (Lewis, 1997). The nymphs and adults of the mulberry thrips lacerate the tissue and suck the oozing cell sap from the upper and lower surfaces of the leaves. So, the usual evaporation process of the leaves is quickened, especially during high temperature seasons, by additional evaporation through these wounds (Ye and Gu, 1990). Mulberry thrips reduces the leaf moisture by 3.57% and therefore has a negative impact on the quality of the leaves when consumed by silkworms (Etebari *et al.,* 1998). Due to the sucking nature of thrips, the nutritive elemental level may alter, which forms qualitative nature of the leaves. Hence in the present investigation, an attempt has been made to assess the level of macro and micro nutrients in the thrips infested leaves of commercially exploiting indigenous mulberry varieties.

MATERIALS AND METHODS

The healthy and thrips infested leaves of six popular indigenous mulberry varieties *viz.,* M_5, MR_2, Mysore local, S_{36}, S_{54} and V_1 were collected in butter paper bags from plantations in and around Tumkur district and Kanakapura taluk, Ramanagara district (Karnataka state, India). They were washed thoroughly in distilled water and blotted to dry. Later, they were dried in hot air oven a temperature of 60 – 65 °C for 48 hr. The dried leaf materials were ground to fine powder and later used for analyzing the total nitrogen and other mineral elements. The total nitrogen estimated by Micro-Kjeldahl flask by using the procedure of Piper (1966). For mineral analysis one gram of dried mulberry leaf powder was initially digested in 15 mL of nitric acid and then 10 mL of perchloric acid was added. This was digested over sand bath until a clear solution was obtained. It was cooled and the volume was made up to 100 ml with double distilled water. It was filtered through Whatman's No. 1 filter paper. Aliquots of 25 ml were taken from this solution and the mineral nutrients of phosphorus and potassium were estimated by using Elicol CL 360 Flame Photometer while calcium, magnesium, sulphur, zinc, iron, manganese, copper,

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boron, molybdenum and chloride were estimated by using Atomic Absorption Spectrophotometer (GBC 932 plus) (Martin *et al.*, 1987). The results were analysed statistically by applying Student's t-test.

RESULTS AND DISUSSION

The nutrients of six macro (nitrogen, phosphorus, potassium, calcium, magnesium and sulphur) and seven micro (zinc, iron, manganese, copper, boron, molybdenum and chloride) elements showed variation in the thrips infested leaves of six popular indigenous mulberry varieties compared to healthy ones.

Macro nutrients **(Table I)**

Nitrogen (N) is vitally associated with the activity of all living cells of mulberry. It is involved in the synthesis of low molecular weight organic nitrogenous compounds such as amino acids, amides, peptides, amines and urides which are directly participate in the synthesis of proteins, nucleic acids and co-enzymes and various energy metabolism. The quality of mulberry foliage is dependent on their N content (Shankar 1997). In the present investigation, the thrips infested mulberry showed a little variation in their nutrient content. The nitrogen was reduced in the leaves of M_5, MR_2, S_{36} and S_{54} varieties. The decrease was in the range of 0.24 to 0.64 % in the leaves of M_5 and S_{54} varieties respectively. The N content was remained unaltered in the leaves of Mysore local and V_1 varieties. Satya Prasad *et al.*, (2002) observed a decrease in the N content in the thrips, infested tender and medium leaves of K_2, S_{13}, S_{34} and S_{36} mulberry varieties. Narayanaswamy *et al.*, (1999) recorded 35.22 % decrease in the N content due to spiralling whitefly attack on mulberry leaves (M_5 var.). The decrease in the N content may be attributed to damage caused by the insect through sucking of the leaf sap thus altering the metabolic functions leading to either decline in protein synthesis or mobilization of proteins for repair of the damaged tissues in order to develop resistance to insect bite (Satya Prasad *et al.*, 2002). Proteins are the most important constituents in living tissues and account for a large proportion of the total N content. Reduced N level leads to stunted growth of mulberry shoot and root. Leaf area is reduced, bud dormancy is prolonged and flowering is delayed (Manuel Sanchez 2006). Leaf proteins form an important source for silkworms to biosynthesise of silk which comprises two proteins i.e., fibroin and sericin (Rangaswami *et al.*, 1976). A highly significant correlation was found between the N content of leaf and silkworm body weight, cocoon and shell (Subbarayappa and Bongale 1997). Derangement in the N level of mulberry leaves due to pest - injury obviously causes reduction in the amino acids and protein content. Such leaves when fed to silkworms adversely affect their growth and development.

Phosphorus (P) is an important major nutrient in mulberry plant. It is a component of nucleotides, nucleic acids, phosphatides and number of co-enzymes. In addition, it has a close relation with the synthesis of proteins, metabolism of fat and carbohydrates, respiration, photosynthesis and other metabolic activities (Shree *et al.*, 2005). In the present work, the phosphorus was decreased significantly in the Mysore local and S_{36} varieties and non-significantly in MR_2 variety. The reduction was maximum (9.52%) in Mysore local and minimum (2.00%) in the leaves of MR_2 varieties respectively. The phosphorus remains unaltered in the leaves of M_5, S_{54} and V_1 varieties even after *P. mori* infestation. Narayanaswamy *et al.*, (1999) observed a decrease (26.53 %) in the P content in the spiralling whitefly infested mulberry leaves (M_5 var.) compared to healthy ones. The P content was decreased (43.14 %) in the leaf roller infested mulberry (M_5 var.) foliage (Naryanaswamy 2003). Variation in the P level affects the uptake of other elements in mulberry leaves, which in turn hampers the growth, and economic characters of silkworm (Ito and Nimura, 1966; Chakrabarti *et al.*, 1997).

Table I: Changes in the macro nutritive elements in the thrips infested mulberry foliage.

Mulberry varieties	Nitrogen (%)		Phosporous (%)		Potassium (%)		Calcium (%)		Magnesium (%)		Sulphur (%)	
	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested
M_5	4.13	4.12	0.26	0.26	3.21	3.19	3.20	3.20	0.56	0.56	0.47	0.47
	(-0.24)		(---)		(-0.62)		(---)		(---)		(---)	
MR_2	4.17	4.15	0.15	0.12	4.06	4.06	2.66	2.66	0.61	0.60*	0.31	0.31
	(-0.48)		(-2.00)		(---)		(---)		(-1.64)		(---)	
Mysore local	4.12	4.12	0.21	0.19*	4.12	4.10	2.69	2.67	0.76	0.74*	0.39	0.38
	(---)		(-9.52)		(-0.49)		(-0.74)		(-2.36)		(-2.56)	
S_{36}	4.78	4.76	0.26	0.24*	2.84	2.82	2.10	2.10	0.50	0.48*	0.23	0.22
	(-0.42)		(-7.69)		(-0.70)		(---)		(-4.00)		(-4.35)	
S_{54}	4.70	4.67	0.30	0.30	3.16	3.14	3.02	3.02	0.47	0.45*	0.42	0.43
	(-0.64)		(---)		(-0.63)		(---)		(-4.26)		(+2.38)	
V_1	2.90	2.90	0.19	0.19	3.10	3.08	2.88	2.87	0.89	0.87*	0.39	0.39
	(---)		(---)		(-0.65)		(-0.35)		(-2.27)		(---)	

Values in the brackets ( ) indicate % difference over healthy (+ = more than; - = less than; ---- = not altered). * Significant @ 5%.

The potassium (K) was reduced in the leaves of M_5, Mysore local, S_{36}, S_{54} and V_1 varieties. The reduction was in the range of 0.49 % in Mysore local to 0.70 % in S_{36} variety. It was not changed in the leaves of MR_2 variety. Narayanaswamy *et al.,* (1999) noticed a increased (19.41 %) K content in the spiralling whitefly infested mulberry (M_5 var.) leaves. Narayanaswamy (2003) observed reduction (5.61 %) in the K content of leaf roller infested mulberry (M_5 var.) foliage. K has a role in carbon assimilation and N metabolism; activates several kinds of enzymes and controls respiration. It also plays a significant role in high yield (productivity) and quality of leaf (Shree *et al.,* 2005). It is involved in the translocation of carbohydrates and protein metabolism. K improves the thickness and colour of leaves and also disease tolerance particularly to a fungal disease, powdery mildew in mulberry. It has relationship with the occurrence of viral diseases in mulberry. The deficiency leads to accumulation of hydrogen peroxide in plants which is toxic and results in abnormal respiration and catalase activity (Manuel Sanchez 2006). In the silkworm body, strong alkalinity of the gastric juice originates from potassium and sodium compounds present in the blood. The high alkaline condition of digestive fluid has a strong germicidal power against pathogens. K is a unique element which contributes for the growth of silkworms to maximum extent. In addition, K has a stimulating effect on protein synthesis including silk protein in the silk glands and on the function of ovary (Shankar *et al.,* 1990).

Calcium (Ca) plays an important role in the synthesis of pectin in the middle lamella which provides firmness and rigidity to cell walls. Its deficiency causes incomplete cell division or mitosis, without formation of new cell wall resulting in multi-nucleatic cells (Bidwell 1979). It is considered essential for the growth of meristematic tissues and for the functioning of root tips. It acts as detoxifying agent by neutralizing organic acids such as oxalic acid which helps in membrane stability and maintenance of chromosome structure, activity of enzymes and translocation of carbohydrates. It is also involved in the differential permeability of membranes (Shankar 1997). The thrips infested leaves of Mysore local (0.74 %) and V_1 (0.35 %) varieties showed reduced calcium content. The calcium was not altered in the leaves of M_5, MR_2, S_{36} and S_{54} varieties. Narayanaswamy *et al.,* (1999) noticed a decrease (35.31 %) in the Ca content of spiralling whitefly infested mulberry (M_5 var.) leaves. There was decrease (39.52 %) in the leaf roller infested mulberry (M_5 var.) foliage over healthy with respect to Ca content (Narayanaswamy 2003).

Magnesium (Mg), the central atom of chlorophyll, with its specific electron resonance properties to which the organic components of chlorophyll is responsible for photo-reduction and photochemical breakdown of water are attuned, is vital for the process of photosynthesis (Bergmann 1992). Apart from this, Mg is of importance mainly as a co-factor and activator for many enzymes and substrate transfer reactions (Gunther 1981). In the present investigation, the magnesium was decreased significantly in the leaves of MR_2, Mysore local, S_{36}, S_{54} and V_1 varieties. The reduction was minimum (1.64 %) in MR_2 and maximum (4.26 %) in S_{54} varieties. Magnesium content remained same in the leaves of M_5 variety even after they were infested by *P. mori*. The Mg content was reduced (23.59 %) in the spiralling whitefly infested mulberry (M_5 var.) leaves (Narayanaswamy *et al.,* 1999). Narayanaswamy (2003) observed reduced (27.11 %) Mg content in the leaf roller infested mulberry (M_5 var.) foliage. When Mg is passed on to the silkworms, it accelerates their growth and increases the oviposition rate in the adult (Thangavelu and Bania 1990). Ca and Mg accelerated the growth of silkworms and reduced the larval duration; decrease in the intake of these elements reduced the body weight of silkworms (Chakrabarti *et al.,* 1997).

Sulphur (S) is known to have an important role in the synthesis of proteins, oils and vitamins (Epstein, 1972). It plays a vital role in the N metabolism and proper development of mulberry plant tissues (Munirathnam Reddy *et al.,* 1990). It is a constituent of amino acid, cysteine (contains 27 % of S) and methionine (contains 21 % of S). In the present study, the sulphur was reduced significantly in the leaves of Mysore local (2.56 %) and S_{36} (4.35 %) varieties. It was increased in the leaves of S_{54} (2.38 %) variety. The sulphur was not altered in the leaves of M_5, MR_2 and V_1 varieties due to thrips infestation. The S content was increased (11.11 %) in the spiralling whitefly infested mulberry (M_5 var.) leaves (Narayanaswamy *et al.,* 1999) and it decreased (47.76 %) in the leaf roller infested mulberry (M_5 var.) leaves (Narayanaswamy 2003). This is because of the association of sulphur - amino acid *viz.,* methionine and cystine, methionine forms one of the ten essential amino acids for silk formation in silkworms. Cystine and cysteine are among the non-essential amino acids, the quantitative presence of which influences the formation of fibroin over sericin (Mahadevappa *et al.,* 2001). Deficiency of S level leads to low level of S containing amino acids, thus reducing protein synthesis. As a result, amino acids without S and amides of nitrate ions accumulate in the plant tissue and lead to decrease in sugar as well as insoluble N (protein) in plants (Munirathnam Reddy *et al.,* 1990).

Micro - nutrients **(Table II)**

Mulberry needs micronutrients like zinc, iron, manganese, copper, boron, molybdenum and chloride in very small quantities. Their adequate amount and in proper proportion is one of the main factors which govern the growth, development and yield of mulberry, wherein they play an important role in enzymatic reactions. The metal activators in enzymes are nothing but micronutrients (Shankar 1997).

Thrips attacked mulberry leaves also showed variation in their micro nutrient level. The zinc (Zn) was increased in the leaves of MR_2 (0.57 %) and Mysore local (0.69 %) varieties. The zinc content remained same in the thrips infested tender leaves of M_5, S_{36}, S_{54} and V_1 varieties. Shree and Ravi Kumar (2002) observed a significantly increased Zn content in the tender and medium maturity leaves and decrease in the coarse leaves compared to healthy ones when mulberry plants were infested by giant African snails. The assimilation of Zn in V instar silkworm is about 50 % of total nutrients among the several elements and is the only micronutrient element which is passed on to the silkworm seed. In addition, Zn is known to increase the pupal weight and filament length (Chakrabarti *et al.*, 1997). Lokanath *et al.*, (1986) have reported that excess of Zn content in mulberry leaf leads to reduction in cocoon yield.

The iron (Fe) content was decreased in the leaves Mysore local and S_{36} (0.54 %) and V_1 (0.32 %) varieties. It was increased in the M_5 (1.04 %) variety. Iron content was remains same in the thrips infested leaves of MR_2 and S_{54} varieties compared to healthy ones. Fe is present in the chloroplast proteins and several enzymes. It plays a dominant role in protein metabolism and N fixation (Shankar 1997). Shree and Ravi Kumar (2002) noticed a decrease in the Fe content of mulberry (M_5 var.) leaves of all the three maturity levels (tender, medium and coarse) due to giant African snails attack. The reduction in the Fe level may be due to its competition with other iron-binding compounds (Karande 1984). The increase may be due to failure in its translocation to the physiologically active site (Nagaraja 1987). The altered Fe content in mulberry foliage resulted in the reduced larval weight, cocoon weight and silk filament length (Shankar 1997).

Manganese (Mn) is essential for the synthesis of chlorophyll. It is not mobile and its principal function is to activate some of the enzyme systems in plant physiology and to some extent regulation of Fe metabolism. In addition, it has a close relation with N metabolism (protein), assimilation of carbohydrates and formation of vitamin C. It is involved in oxidation - reduction processes and electron transport system (Shankar 1997). In the current study, The manganese was reduced in the leaves of MR_2 (0.58 %) variety. It was increased in the leaves of Mysore local (0.37 %) and S_{36} (0.38%) varieties. The manganese was remained unaltered in the leaves of M_5, S_{54} and V_1 varieties. Both increase as well as decrease in the Mn content was observed in the mulberry (M_5 var.) leaves due to giant African snails infestation i.e., it caused significant increase in the Mn content of medium and coarse leaves, while it was significantly decreased in the tender leaves when compared to healthy ones (Shree and Ravi Kumar 2002). Fe and Mn have a potentiality to enhance the larval (silkworm) development, filament length of single cocoon, cocoon weight and yield (Lokanath *et al.*, 1986).

A number of enzymes with diverse properties and functions are dependent on copper (Cu) and the metal is strongly found in many proteins especially chloroplast proteins (Shankar 1997). In the present investigation, the copper content was decreased in the leaves of S_{54} (0.10 %) variety. It was increased in the leaves of Mysore local (0.11 %) and S_{36} (0.21 %) varieties. The copper was not changed in the *P. mori* infested tender leaves M_5, MR_2 and V_1 varieties. Shree and Ravi Kumar (2002) noticed a decrease in the copper content of tender, medium and coarse leaves of giant African snails infested leaves of M_5 mulberry cultivar.

Table II: Changes in the micro nutritive elements in the thrips infested mulberry foliage.

Mulberry varieties	Zinc (ppm)		Iron (ppm)		Manganese (ppm)		Copper (ppm)		Boron (ppm)		Molybdenum (ppm)		Chloride (%)	
	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested	Healthy	Infested
M_5	189	189 (---)	96	97 (+1.04)	169	169 (---)	8.10	8.10 (---)	18	17 (-5.56)	0.13	0.13 (---)	0.92	0.92 (---)
MR_2	176	177 (+0.57)	265	265 (---)	172	171 (-0.58)	11.10	11.10 (---)	38	38 (---)	0.29	0.29 (---)	1.64	1.64 (---)
Mysore local	145	146 (+0.69)	290	289 (-0.34)	270	271 (+0.37)	9.12	9.13 (+0.11)	41	41 (---)	0.32	0.30* (-6.25)	1.39	1.39 (---)
S_{36}	138	138 (---)	186	185 (-0.54)	263	264 (+0.38)	9.60	9.62 (+0.21)	41	41 (---)	0.42	0.42 (---)	1.63	1.63 (---)
S_{54}	220	220 (---)	138	138 (----)	210	210 (---)	10.11	10.10 (-0.10)	36	35 (-2.78)	0.56	0.55* (-1.79)	1.08	1.08 (---)
V_1	215	215 (---)	310	309 (-0.32)	186	186 (---)	8.09	8.09 (---)	17	16 (-5.88)	0.50	0.51* (-2.00)	1.66	1.66 (---)

Values in the brackets ( ) indicate % difference over healthy (+ = more than; - = less than; ---- = not altered). * Significant @ 5%.

The boron (B) content was decreased in the leaves of M_5, S_{54} (2.78 %) and V_1 (5.80 %) varieties. The boron content remains same in the thrips infested leaves of MR_2, Mysore local and S_{36} varieties. Boron (B) plays an essential role in the growth and development of new cells in plant meristems. This element bears close relation with the translocation of carbohydrates and protein synthesis. In addition, the phenol metabolism and auxin activity is also regulated by B. It is associated with the uptake of Ca and its utilization. It also regulates K and Ca ratio in plants (Shankar 1997).

Molybdenum (Mo) has a close association with N utilization and metabolism in plants by regulating two important enzymes *viz*., nitrate reductase and nitrogenase. In addition, it also reduces protein metabolism in combination with other micronutrients especially Fe (Shankar 1997). In the present investigation, the molybdenum was reduced significantly in the leaves of Mysore local, S_{54} and V_1 varieties. The decrease was maximum (6.25 %) and minimum (1.79 %) in the leaves of MR_2 and S_{54} varieties respectively. It was not altered in the leaves of M_5, MR_2 and S_{36} varieties even after *P. mori* infestation.

The chloride content remained same in all the varieties in M_5, MR_2, Mysore local, S_{36}, S_{54} and V_1 varieties in the *P. mori* infested leaves compare to healthy ones. Chloride (Cl) is involved in photosynthesis, synthesis of starch, cellulose and lignin. It influences water holding capacity of plant tissues. It stimulates the activities of some enzymes. It is not readily mobile in plants (Shankar 1997).

Mineral nutrition of the host is known to be impaired by pest - infestation. This may be due to direct plundering by the pest or indirect effects of the pest on absorption, mobilization, etc., (Vamseedhar *et al.*, 1999). Most sap sucking insects use a specialized mouth part, the stylet, to locate, penetrate and drain sap from the phloem sieve elements of the plants vascular tissue. Heavy infestation by sap sucking insects cause chronic shortages of photosynthates and thus severely reduces the growth potential of the plant (Kim Hammond-Kosack and Jonathan Jones 2000). The spiralling whitefly is a phloem sap feeder and its direct consumption of transportable carbohydrate and other nutrients carried in phloem reduces productivity of host plants by competing for available nutrients and causing premature leaf shedding (Bryne *et al.*, 1990). Similar results of variation in mineral nutrition were observed in other cases when the leaves were infested by mealy bugs (Mahadeva and Shree 2006) and jassids (Mahadeva *et al.*, 2006).

The quality of mulberry silk is directly dependent on the nutrition of leaf, which influences the healthy growth of silkworm larvae and thereby a good cocoon crop (Bongale *et al.*, 1996). Decrease in the intake of potassium, calcium, magnesium and phosphorus causes decrease in the body weight of silkworm. Magnesium, iron and manganese are reported to have favourable effect on the cocoon yield and shell percentage. Magnesium and calcium accelerates the growth of silkworm and reduce the larval duration. Zinc is known to increase the pupal weight and filament length. It is important for reproduction and hence, is much useful in grainage centers for increasing seed production (Chakrabarti *et al.*, 1997). Thus, mineral nutrition has a decisive role in good quality cocoon production. The variation in the nutrient contents may be attributed to damage caused by the insect altering the metabolic functions leading to either decline in protein synthesis of mobilization of proteins for repair of the damaged tissues in order to develop resistance to insect bite (Satya Prasad *et al.*, 2002).

If the mineral content is increased due to infestation/infection, it induces toxicity symptoms not only in mulberry plants, but also in silkworms when they are fed on such leaves. Similarly, if an element is decreased due to infestation/infection, it causes deficiency or physiological disorders in leaves and they become malformed, deformed, chlorotic and nutritionally inferior. Obviously, the increase or decrease in the mineral content(s), affects the growth and development of silkworms, which consequently alters the quality of silk produced (Ito and Nimura 1966; Lokanath *et al.*, 1986; Shankar *et al.*, 1990; Chakrabarti *et al.*, 1997; Shree *et al.*, 2005). Growth and development of silkworms depend on the nutritive status of leaves. If there is an imbalance in elemental contents (mineral nutrition), the leaf quality is severely deteriorated. This could be detrimental to silkworms. Mahadeva and Shree (2005) fed the silkworm with spiralling whitefly infested mulberry leaves and observed its negative effects on them in respect of growth and cocoon parameters. The pest infested mulberry leaves are quantitatively and qualitatively very poor Narayanaswamy *et al.*, (1999). Therefore, farmers must reject them as silkworm "feed" and try to protect mulberry plants from the fly attack by following suitable IPM methods.

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