12 (2): 223-227.
Tropical ecology (1971) 12 (2): 223-227

PRIMARY PRODUCTIVITY OF THREE VEGETABLE CROPS AS INFLUENCED BY VIRUS INFECTION

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(Accepted for Publication on April 14, 1971)

INTRODUCTION

The production of fruit-vegetables depends to a great extent on the accumulation of assimilates in them, which in turn is determined by the magnitude of difference between the gross photosynthesis and respiration of leaves. Various processes which could upset this balance would cause an adverse effect on the productivity of vegetable crops. Infection by pathogens is one such phenomenon. In the Kurukshetra area three important vegetable crops heavily infected by viruses are: *Hibiscus esculentus*, *Luffa aegyptiaca* and *Cucurbita moschata*. Out of these, *H. esculentus* is infected by Yellow Vein Mosaic Virus and the other two by Cucumber Mosaic Virus. In the present paper an attempt has been made to determine the loss in primary productivity of the leaves of the above crops and to seek the relation of this loss with pigment destruction on account of virus infection.

MATERIAL AND METHODS

Intact leaves from healthy and infected plants were collected during the last week of July from vegetable plots at Kurukshetra in the early morning. Care was taken to sample leaves of uniform size and in the case of infected leaves only those were collected which showed 50% chlorotic area. From these leaves discs of 1 cm^2 size were obtained with the help of a cork borer. Immediately afterwards eight samples, each containing twenty discs were placed in Petri dishes fitted with wet cotton and filter paper. Four such Petridishes were kept in full sunlight for five hours and the other four Petridishes were placed in light-proof card board boxes for the same duration of time. An equal number of samples was dried in an oven at 80°C for recording initial dry weight. After five hours the samples exposed to sunlight and those kept in dark were dried in an oven at 80°C, to record the gain (net production) or loss (respiration) in dry weight in accordance with the method described by Misra *et al.* (1968). In the beginning three samples, each containing twenty discs, were placed in a refrigerator for pigment analysis. Pigments were extracted in 80% acetone and the optical density of extract was determined in a

spectro-colorimeter at desired wavelengths. The following expressions were used for the estimation of various pigments following Arnon (1949) and Duxbury and Yentsch (1956).

$$\text{Chlorophyll } a \text{ (mg/l)} = 15.6\ OD_{665} - 2.0\ OD_{645} - 0.8\ OD_{630}$$

$$\text{Total chlorophyll } (a + b), \text{ (mg /l)} = \frac{OD_{652} \times 1000}{34.5}$$

$$\text{Chlorophyll } b \text{ (mg /l)} = \text{Total chlorophyll} - \text{chlorophyll } a$$

$$\text{Carotenoids (mg /l)} = 7.6\ (OD_{480} - 1.49\ OD_{510}).$$

Gross production was estimated by adding the value for respiration to the value for net production.

RESULTS AND DISCUSSION

From the data presented below, it is apparent that the primary productivity of the infected leaves is greatly reduced, so much so that in *C. moschata* the gain in weight due to photosynthesis is negative (Table 1). Apparently in this species the infection is so severe that respiration out balances photosynthesis. Virus

TABLE 1. *Productivity of healthy and virus infected leaves of* Hibiscus esculentus, Luffa aegyptiaca *and* Cucurbita moschata

	H. esculentus		L. aegyptiaca		C. moschata	
	Healthy leaf	Diseased leaf	Healthy leaf	Diseased leaf	Healthy leaf	Diseased leaf
INITIAL AND FINAL WEIGHT OF LEAF DISCS (mg/20cm²)						
Initial	51.60± 0.52	51.90± 0.47	51.10± 0.63	74.60± 2.08	53.80± 3.12	54.25± 0.50
5 hrs in Sun	53.50± 0.50	52.10± 0.47	52.25± 0.26	75.25± 4.05	55.50± 0.67	50.75± 0.50
5 hrs in dark	50.40± 0.47	50.60± 0.22	50.25± 0.50	73.25± 0.36	50.50± 0.0	50.25± 0.86
PRODUCTIVITY (mg/m²/hr)						
Net production	190	20	125	65	170	—350
Respiration	120	130	75	135	330	400
Gross production	310	150	200	200	500	—

infection is reported to suppress the rate of photosynthesis in a number of other species also. For example, both Tobacco etch virus and Tobacco mosaic virus cause a decrease in photosynthesis of *Nicotiana tabacum* and *N. glutinosa* (Owen 1957 a, b, 1958). Similarly, Orlob and Arny (1961) found that the rate of photosynthesis in barley is reduced to a little more than 50% due to the infection by barley yellow dwarf virus.

Paradoxially, however, the reduced photosynthesis does not affect the dry weight per unit area in *H. esculentus* and *C. moschata* ; rather the dry weight of leaves on area basis increases conspicuously in the infected leaves of *L. aegyptiaca* as compared to healthy leaves (Table 1). Ordinarily this could be possible only if there is a corresponding reduction in the rate of respiration resulting in increased net photosynthesis. This possibility, however, is completely ruled out in the present cases because instead of a decline, the respiration is considerably enhanced (Table 1). Several workers have earlier reported the enhanced rate of respiration of virus infected tissues in advanced infections (Goodman *et al.* 1967) and probably some of this excess energy is wasted as heat (Yarwood 1953). The only possible explanation for the increased dry weight per unit area of infected leaves of *L. aegyptiaca* and also for the unaffected weight in the other two cases could be advanced on the basis of abnormal translocation of assimilates. It appears that the photosynthetically inefficient and at the same time catabolically overactive infected leaves work as metabolic sinks, and draw the assimilates for their sustenance from healthy leaves of the plant. In other words, the diseased leaves act like parasites. This must be an additional factor for the reduction of fruit production in the infected plants because the assimilates are channelized in a different direction. The abnormal transport of nutrients induced by rust infection has already been reported by Pozsar and Kiraly (1964).

A word of explanation is required for the value of gross production which does not appear to be affected by infection in *L. aegyptiaca* (Table 1). In this case there is a proportional increase in respiration with the decrease in net production in the diseased leaves. Obviously, the total amount of organic matter respired is not synthesized *in situ*. The gross production value therefore appears to be inflated to the extent of the amount of reserve material respired. In *H. esculentus* and *L. aegyptiaca* the healthy leaves exhibit more net photosynthesis than respiration. This is quite normal. But the healthy leaves of *C. moschata* exhibit an opposite relation in the two attributes. This behaviour indicates a probable decrease in photosynthesis on account of latent infection because the leaves showed no visual symptom. Owen (1957b) found an inhibition in photosynthesis of *Nicotiana tabacum* only half an hour after inoculation with tobacco mosaic virus and before visual symptoms appeared.

Pigment analysis of the healthy and infected leaves indicates a destruction of chlorophylls and carotenoids on account of infection (Table 2). Peterson and McKinny (1938) found that virus infection in tobacco results in a loss of chlorophyll and in an increase in the activity of the enzyme chlorophyllase which is involved in the destruction of chlorophyll. The present study indicates that there is a disproportional destruction of chlorophyll *a* and chlorophyll *b*. The minimum loss in chlorophyll *a* occurs in *C. moschata* (22%) and maximum in *L. aegyptiaca* (63%), the value (46%) being intermediate for *H. esculentus*. On the other hand, maximum loss in chlorophyll *b* is exhibited by *H. esculentus* (89%) followed by *C. moschata* (83%) and minimum by *L. aegyptiaca* (66%). There is greater loss in the carotenoid content in *C. moschata* (70%) and *H. esculentus* (53%) than in *L. aegyptiaca* (40%).

There does not seem to be any apparent relation between net production

and chlorophyll content in healthy leaves, but carotenoids seem to be directly related. Both net production and carotenoid content vary in the same direction: *H. esculentus* > *C. moschata* > *L. aegyptiaca*.

TABLE 2. *Pigment content of healthy and virus infected leaves* (mg/m^2)

Species	Chloro-phyll *a*	Chloro-phyll *b*	Carote-noids
Hibiscus esculentus			
Healthy	107.5	66.0	55.1
Diseased	57.3	7.2	25.7
Luffa aegyptiaca			
Healthy	108.1	137.0	34.2
Diseased	39.4	47.1	10.5
Cucurbita moschata			
Healthy	33.0	227.5	40.0
Diseased	25.7	39.3	11.8

The reduction in photosynthesis due to infection seems to be related to the destruction in pigments. In the advanced stages of virus disease, the Hill reaction and photosynthetic phosphorylation have been reported to be impaired (Spikes and Stout 1955, Zaitin and Jagendorf 1960). In the present observations it is obvious that the loss in accessory pigments, *viz.*, chlorophyll *b* and carotenoids is more directly responsible for a decrease in net production. Thus the loss in these two types of pigments is more in *C. moschata* and *H. esculentus* and least in *L. aegyptiaca* accompanied with greater reduction in net production of the former two species (apparent total inhibition and 89% reduction, respectively) and lesser in the latter species (48% reduction). Since pigment system II is characterised by an abundance of chlorophyll *b* and xanthophylls (san Pietro 1967), the photosystem II is apparently most affected by virus infection which would naturally lead to an inhibition of Hill reaction.

ACKNOWLEDGEMENT

Thanks are due to Dr. R. K. Nigam, Chemistry Department, Kurukshetra University, for kindly permitting the use of Spectro-Colorimeter.

SUMMARY

Primary productivity and respiration of leaf discs sampled from healthy and virus infected plants of *Hibiscus esculentus*, *Luffa aegyptiaca* and *Cucurbita moschata* have been investigated in the present paper with a view to asses the loss in production in the above vegetable crops due to virus infection. It is observed that infection by virus greatly reduces net production and enhances respiration. Further, there is enough indication that the infected leaves draw assimilates from healthy leaves for their sustenance acting almost as parasites. The loss in net photosynthesis is directly related with the destruction of chlorophyll *b* and carotenoids, although chlorophyll *a* is also destroyed to a considerable extent.

REFERENCES

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts. (1) Polyphenol oxidase in *Beta vulgaris*. *Plant Physiol.* **24**: 1–15.

Duxbury, A.C. and C.S. Yentsch. 1956. Plankton pigment nomographs. *J. Marine Res.* **15**: 92–101.

Goodman, R.N., Z. Kiraly and M. Zaitlin. 1967. *The biochemistry and physiology of infectious plant disease*. D. Van Nostrand Co. Inc., Princeton, New Jersey.

Misra, R., J.S. Singh and K.P. Singh. 1968. Dry matter production in sun and shade leaves and a simple method for the measurement of primary productivity. *Curr. Sci.* **37**: 306-307.

Orlob, G.B. and D.C. Arny. 1961. Some metabolic changes accompanying infection by barley yellow dwarf virus. *Phytopathology* **51**: 768–775.

Owen, P.C. 1957a. The effect of infection with tobacco etch virus on the rates of respiration and photosynthesis of tobacco leaves. *Ann. Appl. Biol.* **45**: 327–331.

Owen, P.C. 1957b. The effects of infection with tobacco mosaic virus on the photosynthesis of tobacco leaves. *Ibid.* **45**: 456–461.

Owen, P.C. 1958. Photosynthesis and respiration rates of leaves of *Nicotiana glutinosa* infected with tobacco mosaic virus and of *N. tabacum* infected with potato virus. *Ibid.* **46**: 198–204.

Peterson, P.D. and H.H. McKinney. 1938. The infuence of four mosaic diseases on the plastid pigments and chlorophyllase in tobacco leaves. *Phytopathology* **28**: 329–342.

Pozsar, B. and Z. Kiraly. 1964. Abnormal transport of nutrients induced by rust infection and the removal of the terminal bud in bean plants. Symp. on *Host-Parasite Relations in Plant Pathology*. Budapest. (Abstract).

San Pietro, A. 1967. Electron transport in chloroplasts. p. 49–68. *In* A. San Pietro, F.A. Greer and T.J. Army (Eds.). *Harvesting The Sun*. Academic Press, New York.

Spikes, J.D. and M. Stout 1955. Photochemical activity of chloroplasts isolated from sugar beet infected with virus yellows. *Science* **122**: 375-376.

Yarwood, C.E. 1953. Heat of respiration of injured and diseased leaves. *Phytopathology* **43**: 675–681.

Zaitlin, M. and A.T. Jagendorf. 1960. Photosynthetic phosphorylation and Hill Reaction activities of chloroplasts isolated from plants infected with tobacco mosaic virus. *Virology* **12**: 477–480.