Philipp. Ent. 3(3-4): 201-224 *April-October* 1976

EFFECTS OF NUTRITION ON LARVAL COLORATION OF HELICOVERPA ARMIGERA (HUBNER)[1]

V. E. Ramos and B. Morallo-Rejesus[2]

Laboratory rearing of corn earworm on various natural and artificial media revealed that larval coloration is closely associated with nutrition. The larvae exhibited distinct colors and markings when reared on corn, cotton, tomato, and tobacco. The addition of B-carotene in the artificial diets intensified the dorsal and stigmatal coloration or caused the earlier appearance of the various larval color forms. Carotenoids strongly influence larval coloration in H. armigera.

The corn earworm, *Helicoverpa armigera* (Hubner), is one of the most destructive pests of agricultural crops. It is especially injurious to corn, sorghum, cotton, tomato, tobacco, legumes, and crucifers. Because of the extensive damage caused by this species, the corn earworm has been the subject of considerable study by entomologists. The full-grown larvae have been observed and reported to vary greatly in color, which ranged from green to almost black, with the body sometimes marked with longitudinal stripes of various color combinations. Field observations conducted in the Philippines indicate the occurrence of these various color patterns (Otanes and Karganilla 1940, Catan 1958, Deang 1971). However, no conclusive evidence has yet been presented to explain the cause(s) of this phenomenon.

A possible correlation between nutrition and insect coloration was hypothesized in the course of studying the nutritional requirements of a number of insect species and of developing artificial diets for mass rearing insects in the laboratory. Dadd (1961), Dahlman (1969), and Clark (1971) found variations in the degree of coloration among insects fed with various preparations. Macular patterns characteristic of the insects reared on their natural hosts were absent in those reared on artificial diets devoid of carotene. However, Clark (1971) succeeded in returning blue larvae of *Hyalophora cecropia* to their normal green pigmentation by adding commercial vegetable lutein to the artificial diet. The absence of this carotenoid had evidently induced the blue color. He further observed that the addition of B-carotene only induced pale yellow and pink coloration to the dorsal and abdominal

[1] Contribution No. 94; received for publication 15 October 1976. Portion of a thesis presented by the senior author in partial fulfillment of the requirement for the degree of Master of Science in Entomology under the direction of the junior author, University of the Philippines at Los Baños.

[2] Instructor and Associate Professor, respectively, Department of Entomology, UPLB-CA, College, Laguna.

tubercles, but did not affect the color of the cuticle and hemolymph. Dadd (1961) also found that with carotene in the diet, hoppers of *Schistocerca gregaria* developed the colors of those fed with grass although rarely with normal intensity. Purified lutein added to the food of dietary-induced blue pupae restored the wild-type coloration of *Pieris brassicae* (Rothschild *et al.* 1975). The physiological functioning of the insects did not appear to be upset in other aspects.

This paper reports on the possible effects of several natural and artificial diets on the larval coloration of *H. armigera* and the role played by B-carotene in larval coloration.

MATERIALS AND METHODS

Collection and Mass Rearing. Larvae of *Helicoverpa armigera* (Hubner) feeding on corn, cotton, tomato, and tobacco were used as test insects. The larvae were collected from cotton at Central Luzon State University, Muñoz, Nueva Ecija, from tobacco in San Fernando, La Union, and from corn and tomato at the University of the Philippines Central Experiment Station, College, Laguna and Batangas. The insects were reared on the original hosts under Los Baños conditions until pupation. The colors and morphological changes were noted. Pupae were sexed and placed in separate cages of emergence and oviposition. Eggs were collected daily. Larvae that hatched from these eggs were used in the succeeding experiments.

Larval Hosts. Four natural hosts, tobacco (*Nicotiana tabacum* L., Virginia variety), corn (*Zea mays* L.), tomato (*Lycopersicon esculentum* Mill.), and cotton (*Gossypium barbadense*), and Deang's formulated diet (1971) using green mungo seeds (*Phaseolus aureaus* Roxb.) were used in this study. Batches of each host plant were grown from time to time to provide a continuous supply of plants during the exepriments.

Larval Coloration Study. To determine the effects of several hosts on the larval coloration of *H. armigera,* 60 newly-hatched larvae were used in each diet.

In the case of tobacco, tomato, and cotton, the insects were placed singly on the preferred portion of the plant and enclosed with rearing cages following the method used by Novero (1972). For corn ears and formulated diet, the larvae were transferred individually to covered 'Gerber' bottles containing the medium. The bottles were cleaned daily and old diets were replaced with fresh slices. Simultaneous rearing of insects taken from eggs laid by field-collected earworms originally found feeding on the said plants were also conducted.

Larval coloration for each instar was observed and recorded. The insects were viewed under the dissecting microscope illuminated by a 50-watt incandescent lamp. Descriptions were based on the work of Hardwick (1965).

Effects of B-carotene Additives Contained in the Diets. Using published data, it was originally intended to prepare artificial diets simulating the pigment contents of the four natural hosts (Table 1). This part of the study was omitted because only B-carotene was available. However, since this carotenoid is abundant in leaves and green parts of the plant, the effect of this carotenoid on larval coloration was therefore determined. Three sets of diets were prepared and modified by the addition of 333 mg/1, 1000 mg/1, and

TABLE 1. **The different carotenoids present in the various natural hosts of** H. armigera **(Hubner)**[a]

Carotenoids	HOSTS[b]			
	Corn[c]	Tomato[d]	Tobacco[e]	Mongo[f]
B-carotene	0.80	0.0069	3.40	0.564
B-zeacarotene				0.008
Monoepoxy-B-carotene				0.076
Diepoxy-B-carotene				0.197
Neo-B-carotene	X	0.51	X	
-carotene		1.24		
-carotene		0.13		
-carotene		0.60		
-carotene	X			
Monohydroxy - carotene	X			
Lutein	X	0.41	X	1.442
Monoepoxy lutein				0.019
Flavoxanthin				0.322
Auroxanthin				traces
Lycoxanthin		0.20		
Violaxanthin	X		X	
Neoxanthin	X			
Neoviolaxanthin	X		X	
Antheraxanthin			X	
Cryptoxanthin	X			
Zeaxanthin	X			
Phytofluene		2.09		traces
Phytoene		8.15		
Prolycopene		0.48		
Neolycopene		8.57		
Lycopene		88.33		
Total carotene	67.3-145.0 fresh wt.	118.2 fresh pulp	10.0 wet wt.	2.628 ug/g dry wt.

[a] Values are in ug/g wt. Carotenoids with unknown quantities are designated with letter X.
[b] No published data were found for the carotenoids present in cotton.
[c] Mosher *et al.* 1952.
[d] Mallia *et al.* 1967.
[e] Whitfield and Rowan 1974.
[f] Valadon and Mummery 1969.

2,000 mg/1 B-carotene. This pigment was added when the dissolved agar was mixed with the preparation. Deang's formulated diet served as control.

Newly-hatched larvae were reared on each diet. Each larva was placed in a rearing bottle containing the medium. Larval coloration was recorded for each instar until pupation.

For each part of the experiment, 60 insects were reared, with 30 cultures maintained at one time. The experiments were conducted in the laboratory at 24-26°C and at a relative humidity of 75 percent, at the Department of Entomology, University of the Philippines at Los Baños.

RESULTS AND DISCUSSION

Larval Coloration Study. When corn earworms were reared on a variety of food — corn, cotton, tomato, tobacco, and artificial diet, the larvae exhibited variable colors even within a single host plant. Many were marked with conspicuous stripes of varying shades of yellow, brown, red, and green interspersed with black and white markings. A few were without stripes and may be pink, green, or yellow. Similar findings were observed by several workers (Quaintance and Brues 1905, Isely 1935, Mummery *et al.* 1975). They reported that the concentration of the various carotenoids can differ greatly even in leaves from the same plant, which in due course may be reflected on the larvae feeding on them. Thus, even within the same host, color variations occurred.

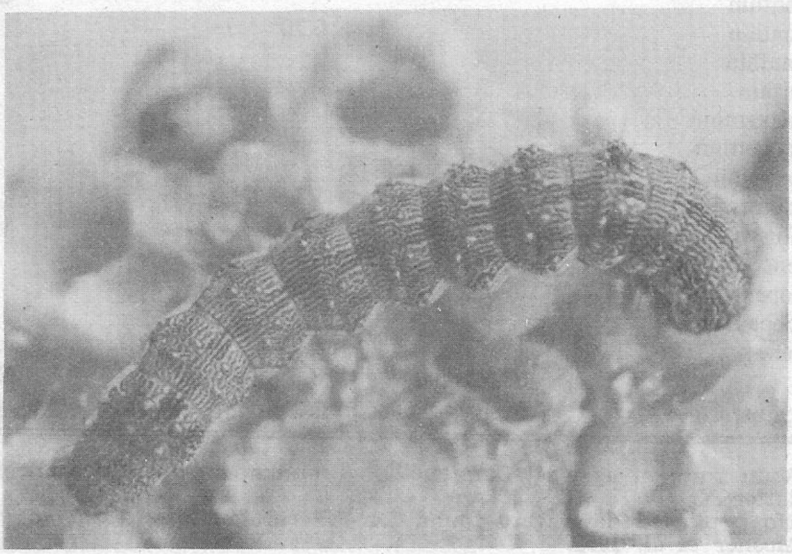

Fig. 1. Sixth instar corn-reared larva which served as source of eggs used in the larval coloration study.

The larvae used in our experiment came from three pairs of moths that showed the same color pattern in the larval stage (Fig. 1). They were collected and subsequently reared on corn ears. The color pattern is described below:

> The head is pale, usually mottled with orange or orange-brown and commonly reticulated with white. Shields and setal bases blend with the colors of surrounding areas. Trunk pale and showed a variety of colors — brown, orange, white, and orange-brown. The yellowish-white spiracular bands were provided with bright orange or orange-brown at the center. Prior to pupation, red and orange became prominent.

Variations in larval coloration consisted of a change in body color, in the color of the fine lines on the dorsum, or in that of the lateral stripe. These began to appear in stages IV and V usually at the time of molting. Sometimes, however, these colors suddenly appeared during an earlier instar.

Figs. 2, 3, and 4 show the development of general body color of larvae reared on the different hosts. When soft corn ears were used as food, the predominating form (Fig. 5A) had the following description:

> Body pale ochre-yellow; the upperside brownish and marked with fine longitudinal lines of yellow-brown or orange-brown alternating with white stripes. As the larvae matured, the lines became more pronounced. Brown or black stripes were usually found along the median and lower parts of the dorsum. The stigmatal band was broadest and most prominent; made up of white and yellow to orange-brown stripes. Head was cream or fawn and invariably mottled with black or dark brown and reticulated with white. During the first stadium, the head was entirely black. The prothoracic shield, suranal shield, proleg shields, setal bases, setae, and rims of spiracles were black.

This color type was constant in all the larvae through the first four instars. On the fifth stadium, orange and yellow lines became more prominent and the tubercles assumed the colors of the surrounding areas. The anal shield became obsolete (Fig. 5B). As the larvae increased in size, several changes were noted (Fig. 5C):

> Head pale with red-brown mottling and white reticulation. The trunk marked with fine longitudinal lines of red and orange. Median line was black and bordered with black stripes. Upper side lines were red and orange-red and numerous with yellow to orange spots while the stigmatal bands were white, red, and conspicuous. Setae were reddish and transparent. As the larvae approached pupation, body turned greenish and the trunk showed greenish stripes.

Only a few larvae (15.5%) showed the green phase (Fig. 2, 5D). This conforms with the report of Isely (1935) that very little green tinge appeared when corn was used as food.

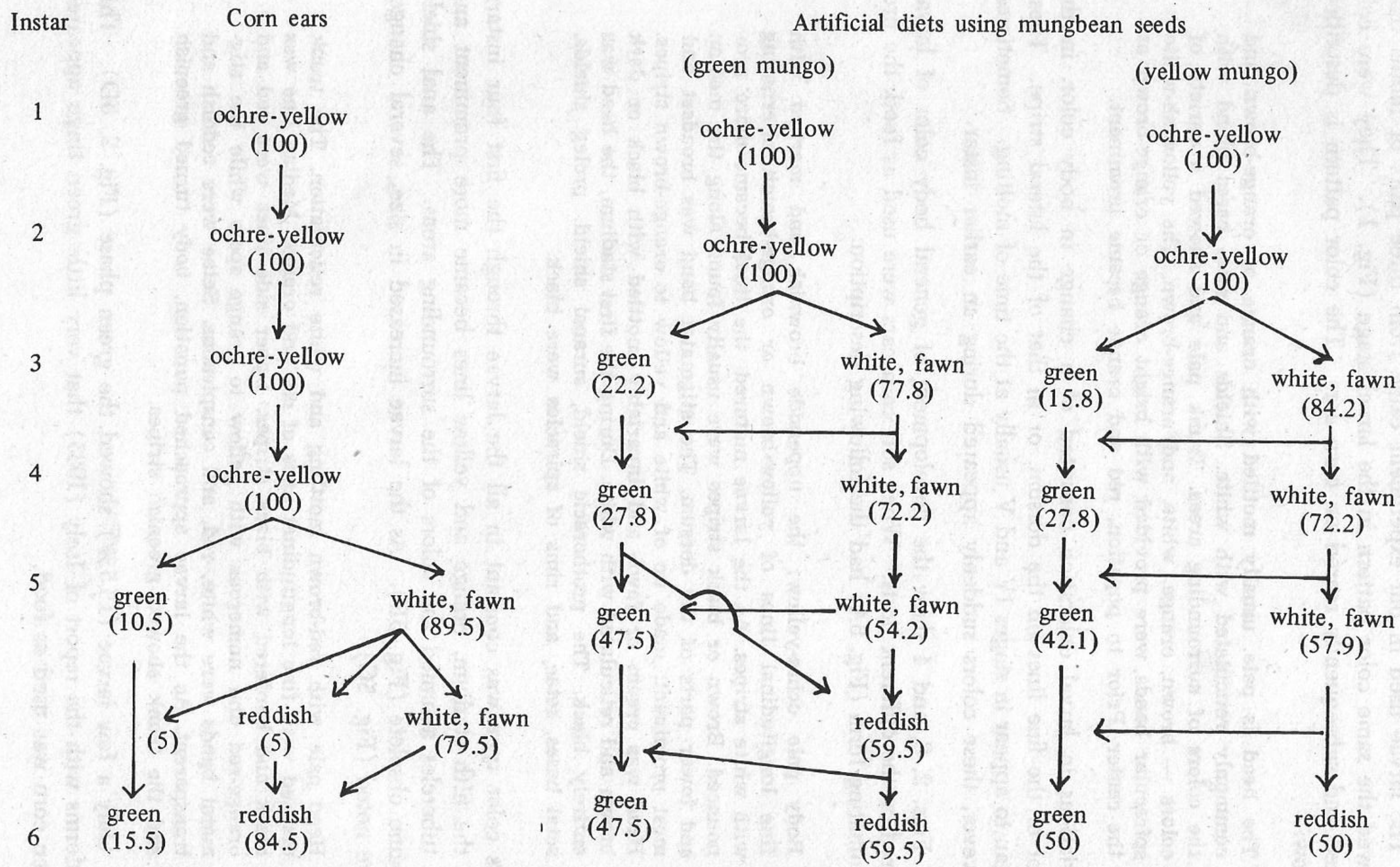

Fig. 2. Development of general body color of corn earworm larvae reared on corn ears and artificial diets using mungbean seeds. (Numbers in parenthesis refer to percentages of insects of the given color phase.)

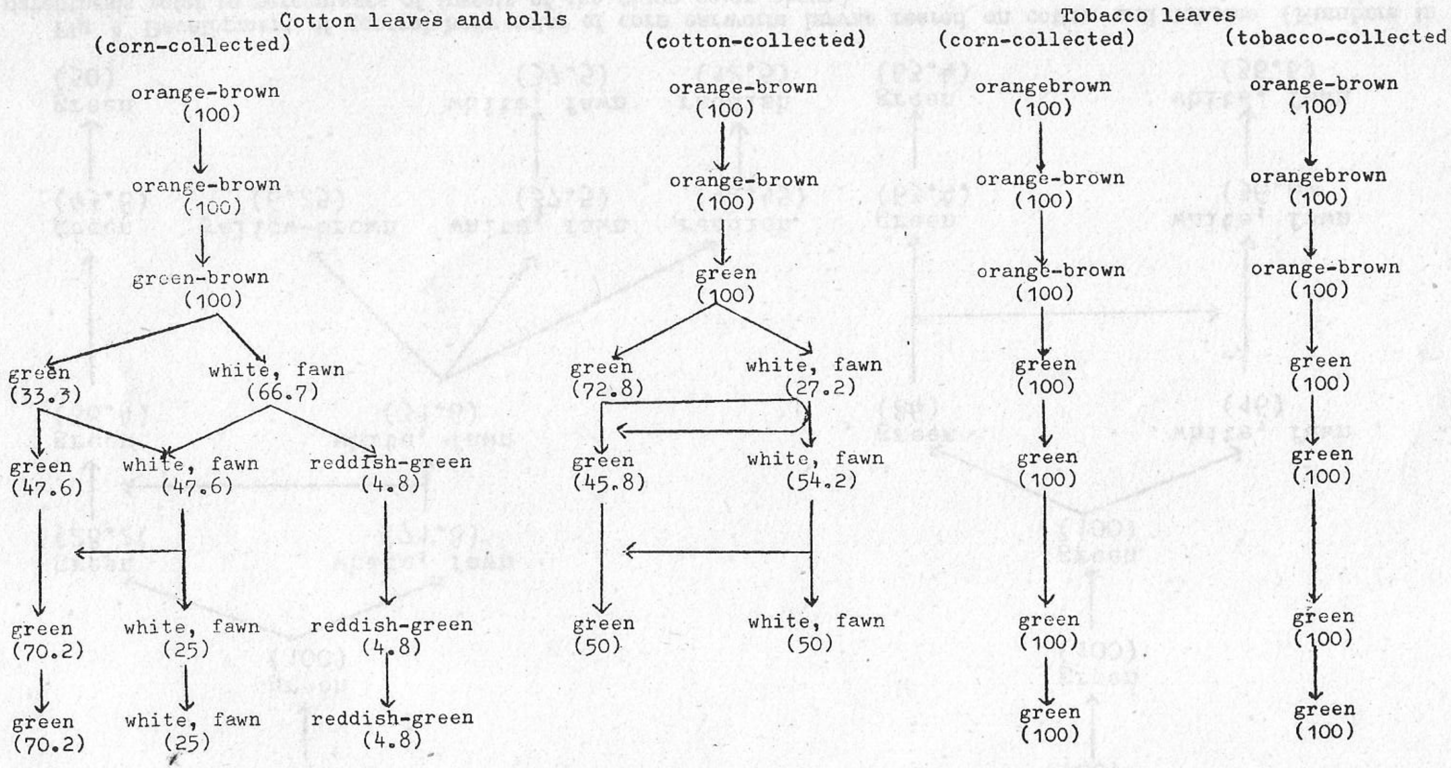

Fig. 3. Development of general body color of corn earworm larvae reared on tomato leaves and fruits. (Numbers in parenthesis refer to percentages of insects of the given color phase.)

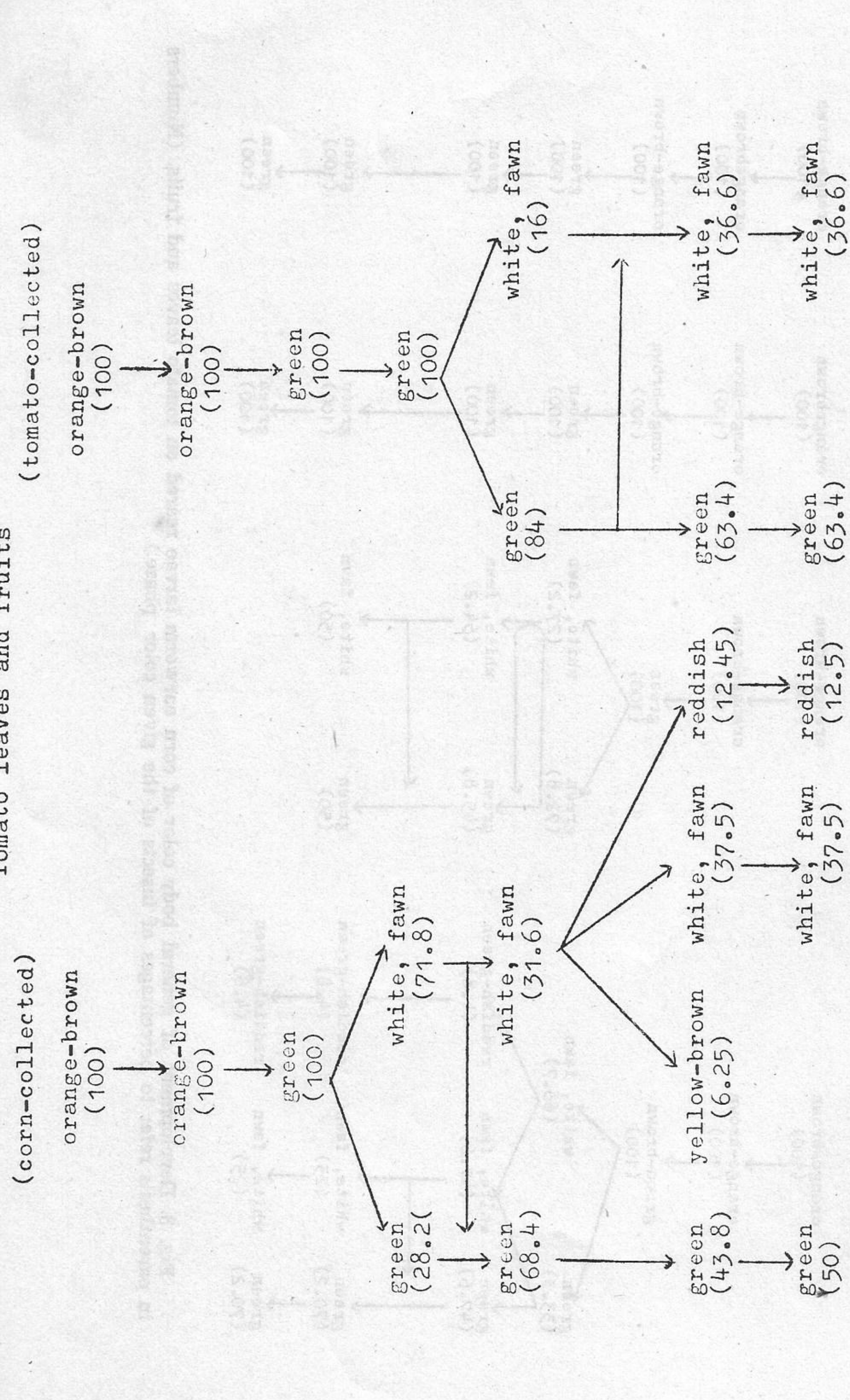

Fig. 4. Development of general body color of corn earworm larvae reared on cotton and tobacco. (Numbers in parenthesis refer to percentages of insects of the given color phase.)

Body marked with green, white, and black stripes. Tubercles along the lateral part of the trunk were black while the rest were concolorous with surrounding areas. During the sixth instar, this macular pattern was maintained and became more defined.

The larvae reared on artificial diets were very much similar in coloration and exhibited the same macular pattern as that of corn-reared insects (Fig. 5A). However, as early as the third instar, some larvae (22.2%) began to

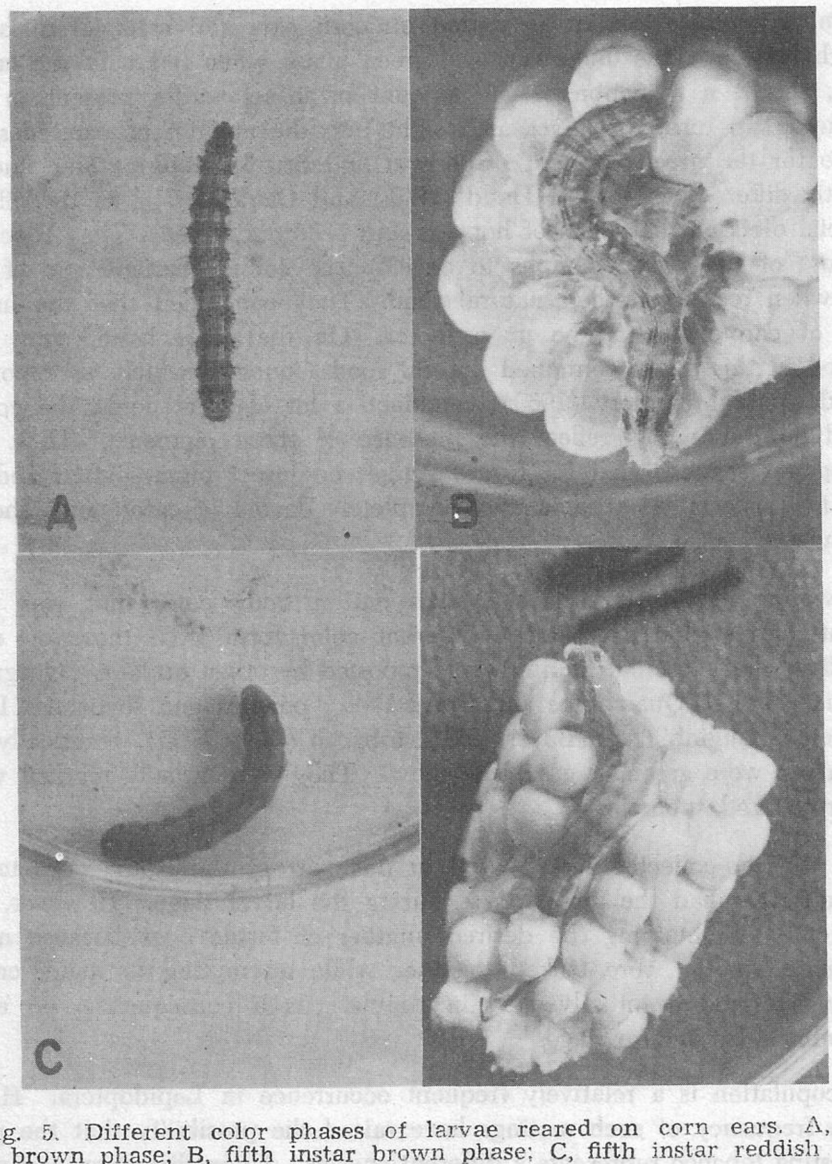

Fig. 5. Different color phases of larvae reared on corn ears. A, third instar brown phase; B, fifth instar brown phase; C, fifth instar reddish phase; D, fifth instar green phase.

show the green phase. This increased in number in the succeeding stadia. On the fifth stadium, newly-molted larvae exhibited the macular pattern of the previous instars. However, most of the tubercles and setae were still black in green mungo, brown in yellow mungo, in contrast to reddish tinge in corn. The larvae exhibited the same macular pattern of those in corn as they matured. Some changed body color from green to reddish-orange with the yellow spiracular bands sprinkled with orange specks. Larvae reaching the sixth instar retained the same macular pattern. However, they assumed the colors of pupating larvae on corn ears as they matured.

Comparison between larvae reared on corn ears and artificial diets revealed that more larvae underwent the green phase when fed with the latter. Perhaps, this is a reflection of the amount of insectoverdin present in the hemolymph. In turn, this gives an insight into the amount of carotenes responsible for the green pigment (Goodwin and Srisukh 1951). This finding apparently differs from that of Dadd (1961) and Clark (1971) on the effects of artificial diets on the colors of hoppers and *cecropia* larvae. They reported the failure of the larvae/nymphs to develop the colors characteristic of the species when reared on their natural food. They concluded that the insufficiency of carotenoids is the main factor. On the other hand, since the diets used in this study contained natural food (mungo) which, as reported by Valadon and Mummery (1969), contained a lot of carotenoids, the colors observed on the insects reflect the presence of these pigments. Thus, the present paper suggests that for future studies on insect pigmentation and its biochemical aspects, an artificial diet completely devoid of carotenoids should be formulated.

Earworms reared on tobacco leaves had a body color that was predominantly green and exhibited a different color form from those on corn and artificial diet. Similar findings were reported by other workers. On green foliage like alfalfa (Quaintance and Brues 1905), cowpea and soybeans (Isely 1935), vetch (Luginbill and Beyer 1921), tobacco (Isely 1935), practically all of the larvae were green or greenish-yellow. They were usually marked with black stripes and tubercles.

The tobacco-collected larvae used in this part of the study were taken from adults that had the green phase during the larval stage. However, we had difficulty in obtaining the desired number of fertile eggs because most of the mated moths were locked together while attempting to mate, could not disengage and eventually died in copula. As a consequence, no eggs were produced by such matings.

Miscopulation is a relatively frequent occurrence in Lepidoptera. However, the frequency of such matings have raised the possibility that the pest now infesting tobacco represents a different species. Upon dissection and sub-

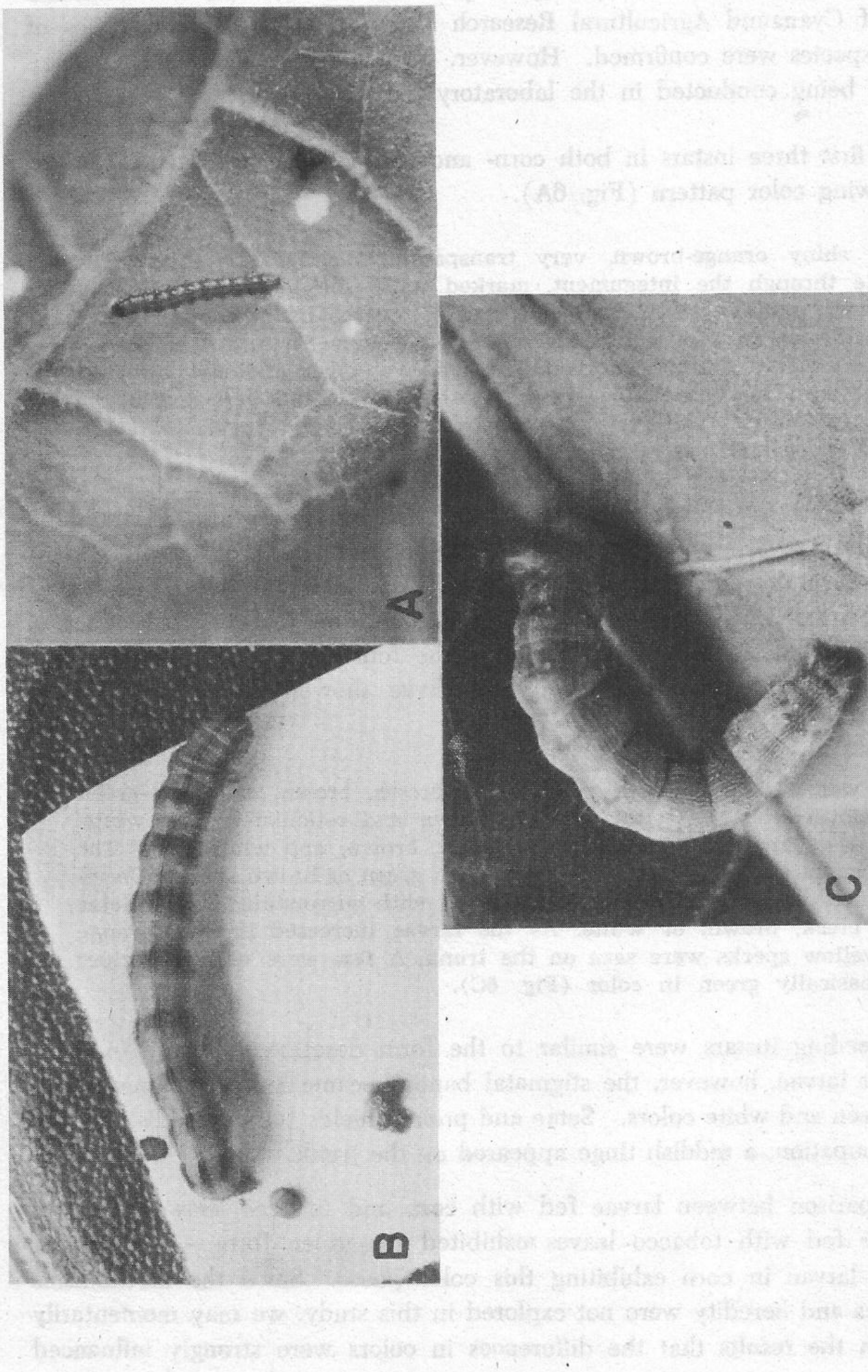

Fig. 6. Variations of green phase larvae reared on tobacco leaves. A, third instar; B, sixth instar; C, all-green sixth instar with reddish-orange specks.

sequent study of the genitalia of the moths, two distinct types of genitalia were observed. One is identified as *H. armigera* and the other *H. assulta*, based on the description of Hardwick (1965). Upon consultation with Dr. Feliciano Calora of Cyanamid Agricultural Research Foundation Inc., the identities of the two species were confirmed. However, further studies along this line are presently being conducted in the laboratory.

The first three instars in both corn- and tobacco-collected larvae showed the following color pattern (Fig. 6A).

> Body shiny orange-brown, very transparent, making the green guts visible through the integument, marked with fine longitudinal stripes of brown or orange in corn while that on tobacco had white-green and yellow-brown in addition to the other two colors. These stripes turned brown, green, and white later on. The head was black at first but turned brown with black mottling. In some, the black head persisted up to the third instar. The cervical shield, suranal shield, tubercles, setae, and rims of spiracles were black.

The persistence of a black head up to the third instar was also observed by Quaintance and Brues (1905) but they attributed this to cold weather conditions. Since those reared on corn and artificial diet had black head only during the first instar in contrast to those found on tobacco, the effect of temperature could be eliminated. During the fourth instar, the transparency of the integument disappeared and the larvae showed the following form (Fig. 6B):

> Head was variably colored green, green-brown, brown, or yellow-green and mottled heavily with black or brown and reticulated with white. Body was green and marked with green, brown, and white lines. The conspicuous stigmatal band was white with green or brown specks. Cervical shield and tubercles were concolorous with surrounding areas. Setae were black, brown, or white. As the larvae increased in size, orange and yellow specks were seen on the trunk. A few were without stripes and basically green in color (Fig. 6C).

The succeeding instars were similar to the form described above. In some fifth-instar larvae, however, the stigmatal bands became more prominent with yellow-green and white colors. Setae and proleg shields turned reddish brown. Prior to pupation, a reddish tinge appeared on the trunk.

Comparison between larvae fed with corn and tobacco showed that all the larvae fed with tobacco leaves exhibited the green form — a contrast to a few larvae in corn exhibiting this color phase. Since the mechanisms of genetics and heredity were not explored in this study, we may momentarily infer from the results that the differences in colors were strongly influenced

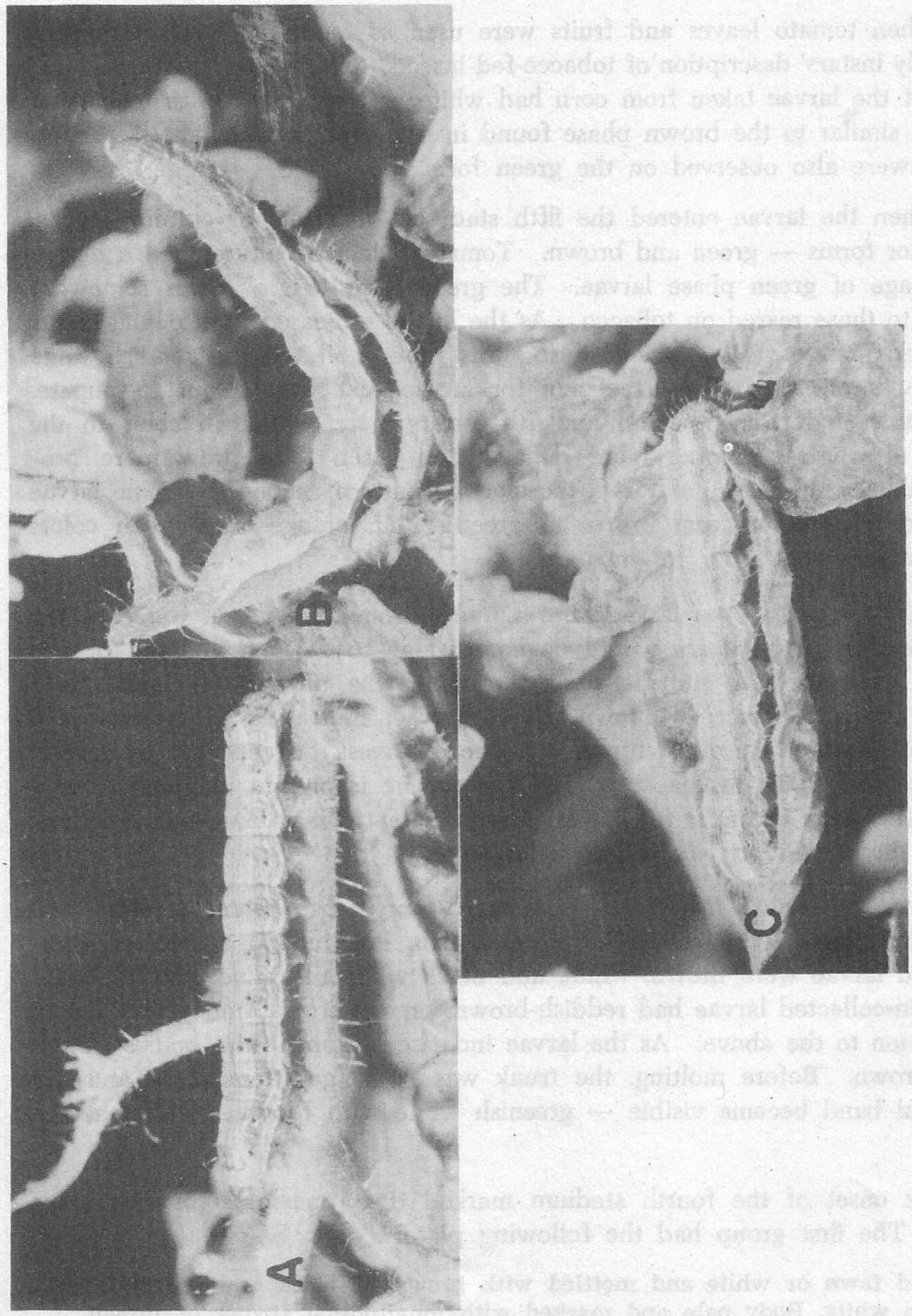

Fig. 7. Green phase larvae reared on tomato leaves and fruits A, sixth instar; B, seventh instar; C, seventh instar.

by nutrition. We suggest, however, that a similar study of the genetic effects on color pattern be conducted precisely to assess the role of genetics and nutrition on body color variation.

When tomato leaves and fruits were used as food, the larvae exhibited the early instars' description of tobacco-fed insects. During the fourth stadium, some of the larvae taken from corn had white or fawn trunk with a macular pattern similar to the brown phase found in corn and artificial diets. Yellow stripes were also observed on the green form.

When the larvae entered the fifth stadium, both sets of culture showed two color forms — green and brown. Tomato-collected cultures had a higher percentage of green phase larvae. The green form (Fig. 7) was somewhat similar to those reared on tobacco. As the larvae increased in size, the colors deepened; larvae that pupated during this time exhibited the reddish tinge which was observed to be the sign for larvae that were about to pupate. Those that underwent the 6th and 7th instars were similar in color to the above, although becoming more defined; the green form grew more pronounced. As the larvae matured, the macular pattern deepened. Some larvae changed body color from brown to green. Red, orange, and green colors were very evident prior to pupation.

Since the early-instar larvae were reared on tomato leaves, it was expected that their macular pattern would be comparable to those reared on tobacco leaves. However, the shift to tomato fruits in the third instar might have caused the appearance of brown-colored larvae, indicating the presence of carotenoids which were not found in tobacco leaves. As reported by several workers (Curl 1961, Mallia *et al.* 1967), lycopene is present in green to ripe red tomatoes but absent in the leaves. This carotenoid may have been responsible for the appearance of the brown larvae.

The early instar's description of tobacco- and tomato-reared insects fitted the description of the cotton-fed instars. The longitudinal stripes of corn-collected larvae were brown, white, and black while the more colorful batch of cotton-collected larvae had reddish-brown, orange-brown, and yellow colors in addition to the above. As the larvae increased in size, their bodies turned green-brown. Before molting, the trunk was no longer transparent and the stigmatal band became visible — greenish white with brown mottling at the center.

The onset of the fourth stadium marked the appearance of two color forms. The first group had the following pattern (Fig. 8A):

> Head fawn or white and mottled with brown or black and reticulated with white. Body pale and marked with longitudinal stripes of brown, black, and white. The shields, tubercles, and setae black. Stigmatal band white and mottled with brown.

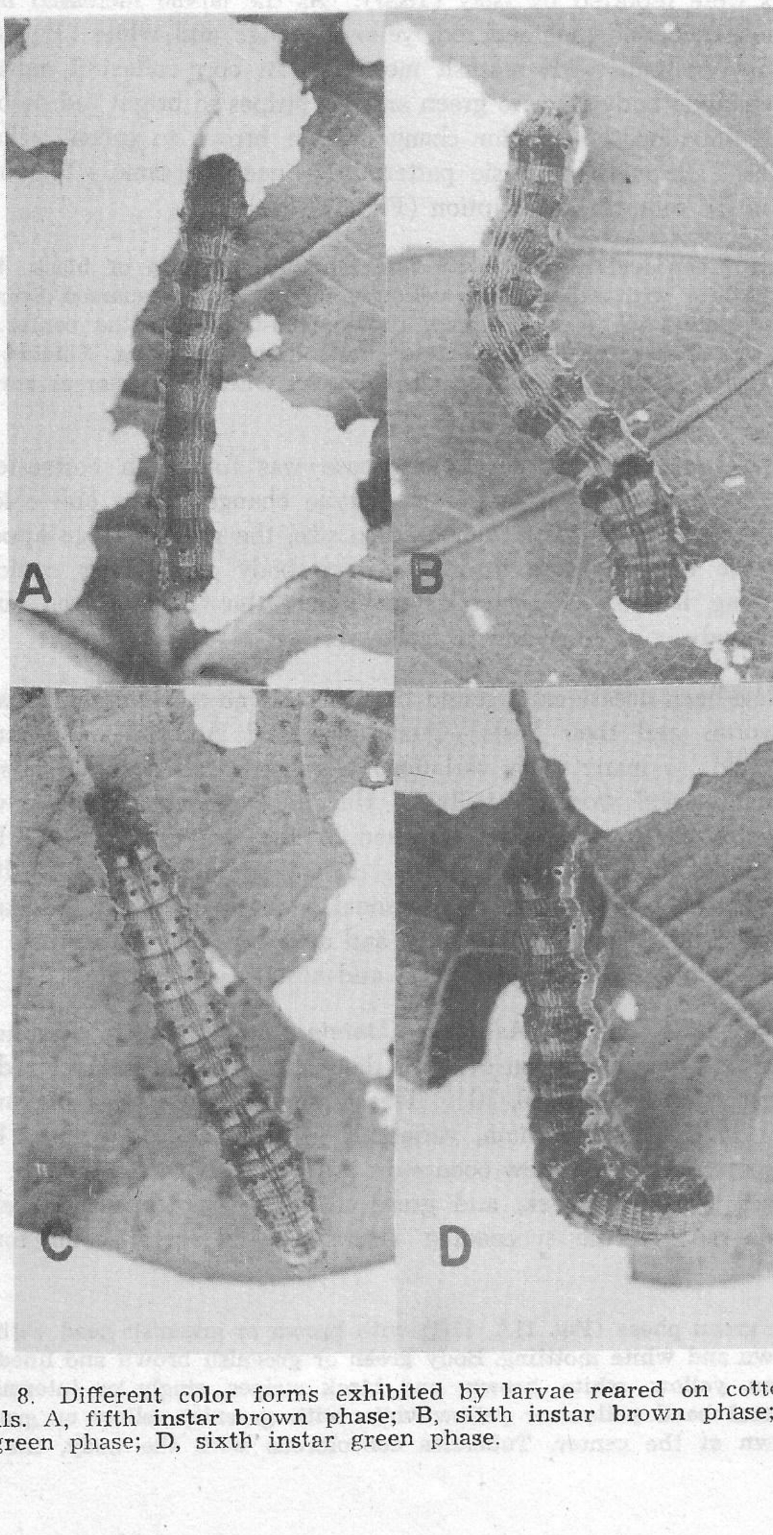

Fig. 8. Different color forms exhibited by larvae reared on cotton leaves and bolls. A, fifth instar brown phase; B, sixth instar brown phase; C, fifth instar green phase; D, sixth instar green phase.

This macular pattern was darker than those found on the other diets. Similar findings were reported by Isely (1935). As the larvae increased in size, the color deepened and included red, yellow, orange and white (Fig. 8B). The head may be pale with reddish mottling. In corn-collected cultures, some larvae changed body color to green and the stripes to bright red or orange-red. Prior to pupation, body color changed from brown to green, yellow-brown, or reddish, although the basic pattern remained the same. The other color form had the following description (Fig. 8C, 8D):

> Body green and marked with fine longitudinal lines of black, brown, and white, with either green, yellow-green or red interspersed. Spiracular band yellow-white with green, brown, red-brown at the center. Head brown or greenish with black or dark brown mottling. Shields, setae, and rims of spiracles black, some tubercles with same color as surrounding areas.

A higher percentage of this color phase was found on cotton-fed insects. During the succeeding instars, some larvae changed from one color pattern to the other. As the larvae increased in size, the reddish tinge appeared and the pattern became more distinct. Green body and stripes could be seen in pupating larvae. Cotton-collected insects that reached the sixth instar changed body color to yellow or yellow-brown.

It has been occasionally stated that there is no relationship between color of earworms and their hosts (Quaintance and Brues 1905, Deang 1971). In the field, so many color variations were observed even on a single host plant that several workers attributed this to the effect of the environment. The relationship may even be confused by the fact that a single larva may feed on more than one plant species. Chamberlain and Tenhet (1926) contended that the change was not seasonal. Moreover, when the larvae were reared on a single host or plant part and at a constant temperature as in this study, the relationship between colors and hosts became obvious.

Effects of B-Carotene Additives Contained in the Diets. Results revealed that all the larvae reared on the four diets showed the same color description in the early instars (Figs. 9, 10). This mascular pattern was similar to corn-larvae. On the third stadium, variations in body color to green, brown, or white from pale ochre-yellow occurred. In diet II, however, shields, tubercles, and setae were still black, and green-brown stripes appeared even on the brown larvae. In the succeeding instars, several larval color forms were observed:

> The green phase (Fig. 11A, 11B) with brown or greenish head with dark brown and white mottling. Body green or greenish brown and lined with green, yellow, white, brown, and black stripes, singly or interminged. Lateral band yellow or yellow-white with greenish-yellow or greenish-brown at the center. Tubercles concolorous with the body, the setae

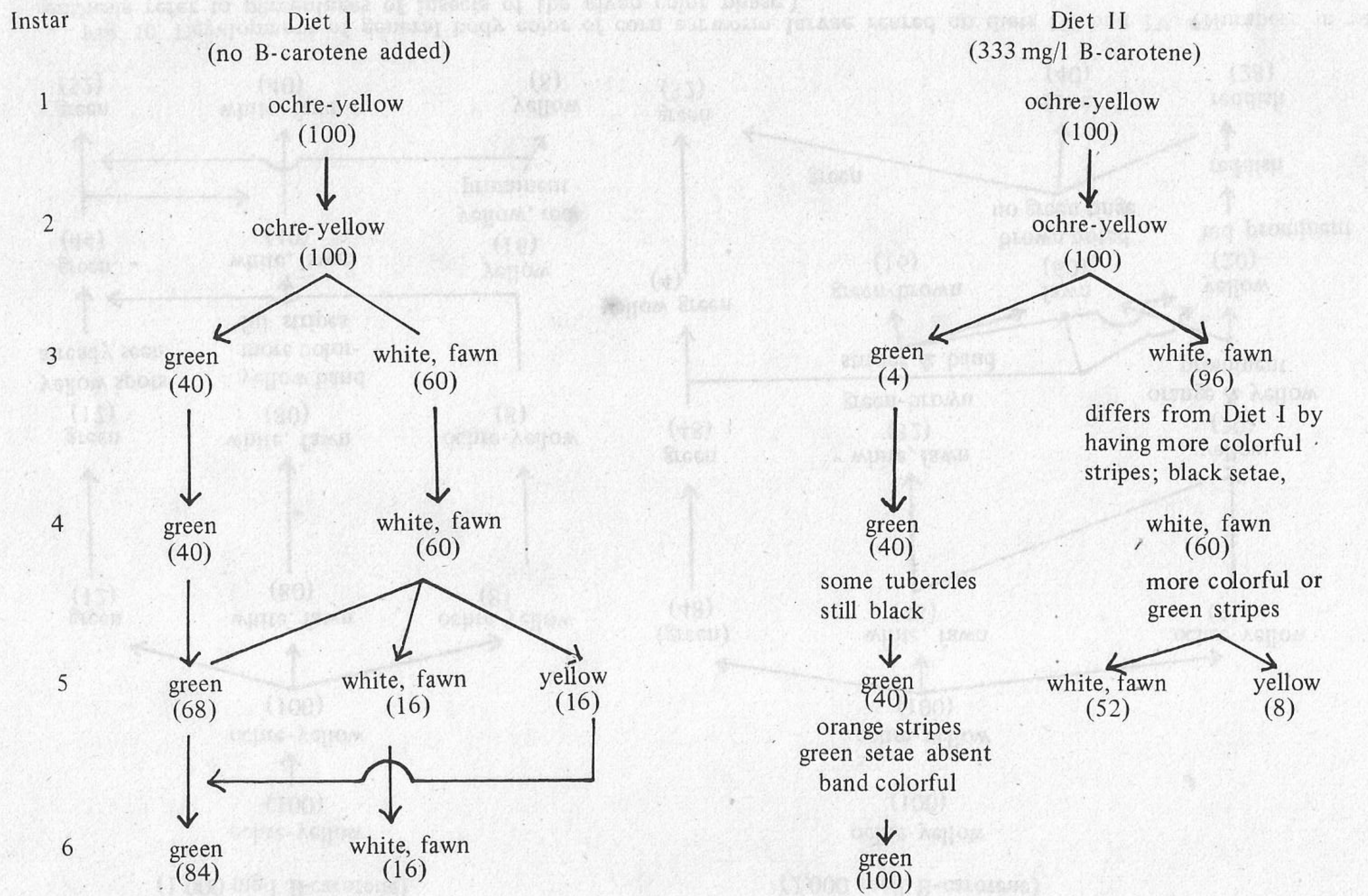

Fig. 9. Development of general body color of corn earworm larvae reared on diets I and II. (Numbers in parenthesis refer to percentages of insects of the given color phase.)

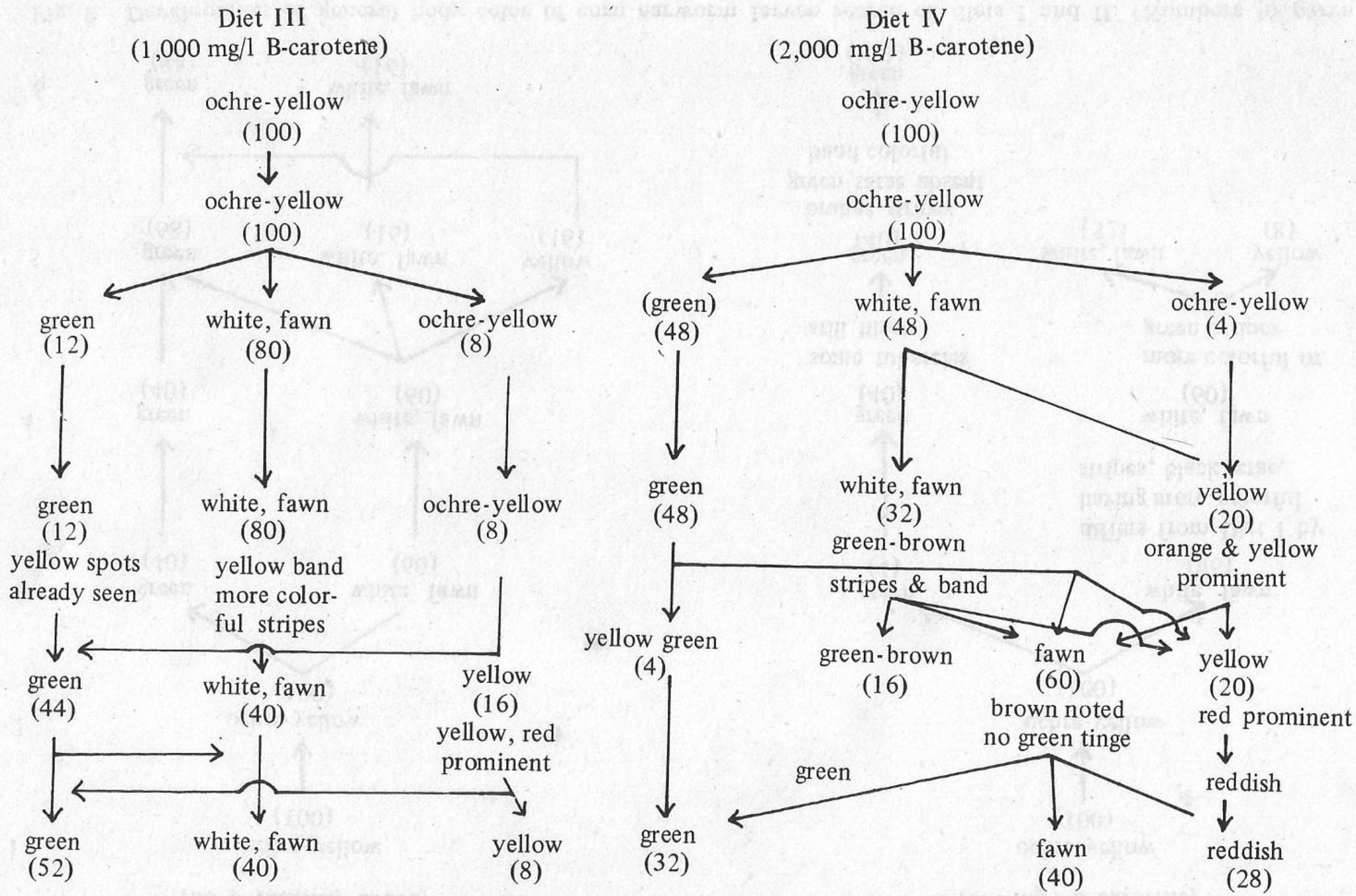

Fig. 10. Development of general body color of corn earworm larvae reared on diets III and IV. (Numbers in parenthesis refer to percentages of insects of the given color phase.)

black, brown, and white. On the fifth stadium, orange and yellow stripes became prominent. Yellow to orange spots present and greenish setae apparent.

The brown form (Fig. 11C, 11D) had pale head with dark brown or orange-brown mottling and white reticulation. Body white or fawn and marked with longitudinal stripes of white, black, and brown, the lateral band white with brown, yellow-brown, or orange-brown at the center. Tubercles black or concolorous with surrounding areas. Setae black or brown. As the larvae grew in size, the macular pattern became more distinct and splashes of orange and red prominent. The band conspicuous with yellow and orange stripes. Orange to yellow spots present.

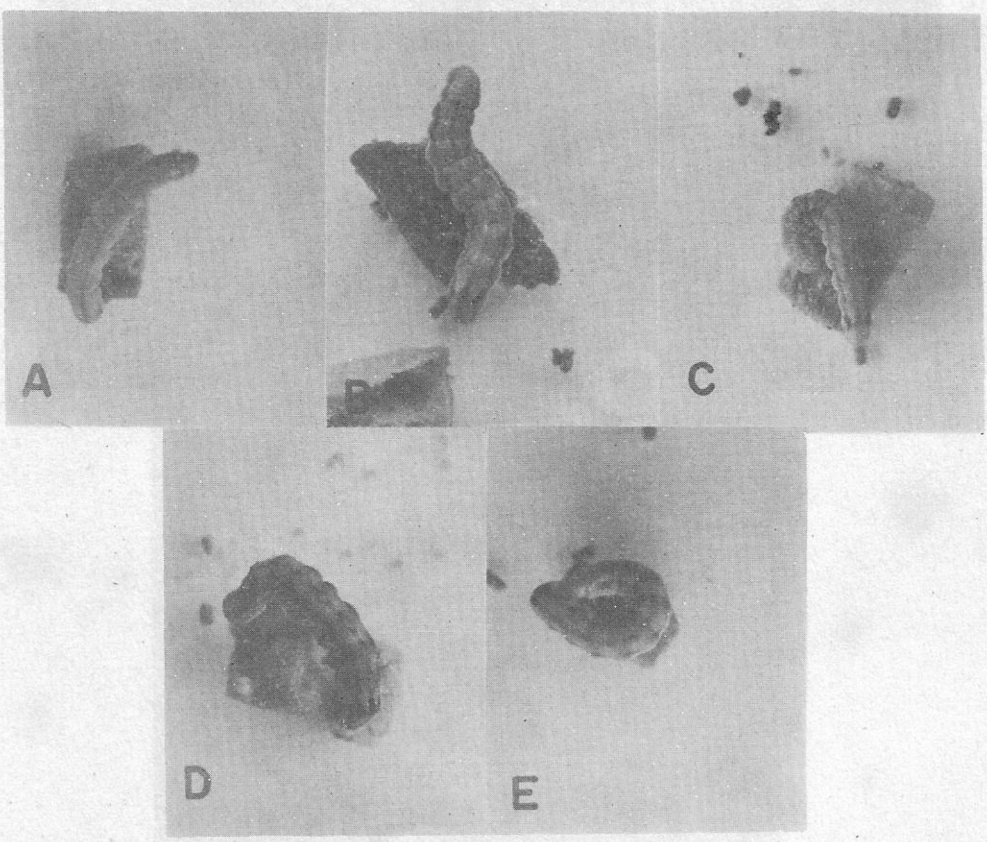

Fig. 11. Color variations of larvae reared on diet I. A, fifth instar green phase; B, sixth instar green phase; C, fifth instar brown phase; D, sixth instar brown phase; E, sixth instar yellow phase.

The yellow larva (Fig. 11E) marked with black, white, yellow, and orange stripes. Tubercles reddish or concolorous with the body. Setae red, brown, black, and white. Stigmatal band yellow with yellow-brown, orange, or orange-brown specks.

During the fourth stadium, the green and brown forms were found in diets I and II. The brown phase of the latter had more colorful stripes — yellow, orange-brown, brown, green. The green forms were basically the same except that some tubercles were still black on larvae fed with diet II. In contrast, diets III and IV had three color forms. The brown phase was similar to diet II but for the absence of green stripes on larvae fed with diet III. The green phase of diet III showed yellow spots on the trunk. Yellow larvae of diet III had the macular pattern of diet I but those on diet IV had prominent orange and yellow stripes. Just before molting, the yellow phase of diet III turned green.

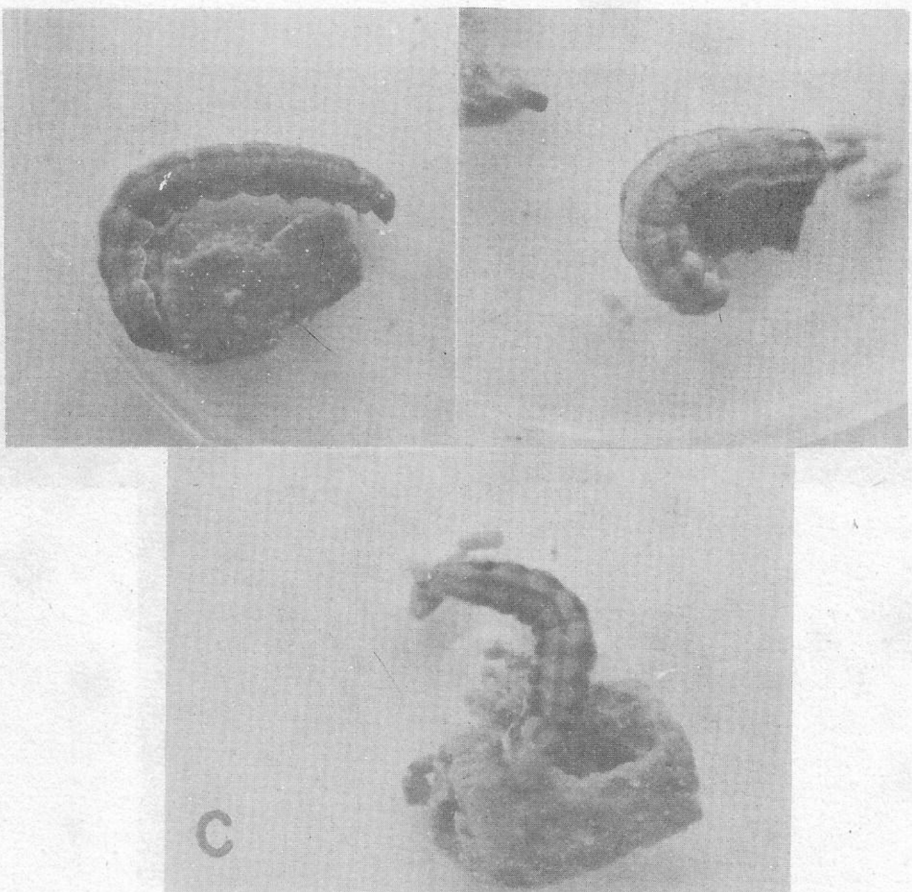

Fig. 12. Variations of green phase by sixth-instar larvae reared on diets II and III.

The basic diet used in this study already contained different pigments (Valadon and Mummery 1969) because of the presence of mungbean seeds. Thus, diet I already exhibited different color forms. The addition of B-carotene at different concentrations, however, either precipitated the earlier appearance of these colors or caused intensification of both dorsal and stigmatal coloration. This is in contrast to the findings of Clark (1971) on *cecropia* larvae. He reported that B-carotene did not affect the hemolymph and cuticle but only gave pink to yellow coloration to the dorsal and thoracic tubercles.

During the fifth stadium, all the diets had three color forms. The green phase (Fig. 12) of diets II and III had more colorful spiracular bands than diet I. In diet II, however, the larvae had no orange stripes and green setae. Later in this stadium, the color phase changed color to white or fawn or completely changed into the brown phase. The brown larvae were similar in macular pattern but green stripes were present in diet III. As the larvae matured the color of the body changed to green, some underwent a complete change in color phase. The yellow larvae were basically the same in the three diets but yellow and red seemed more prominent on larvae reared on diet III. The yellow phase came from brown forms. Just before molting, these transformed to the green phase in diet I but only a few did so in diets II and III.

It should also be noted that a very high concentration of B-carotene in diet IV caused the appearance of color forms different from the above. These other color patterns were offshoots of the three previously mentioned color phases. The yellow, brown, and green-brown larvae had the macular pattern of the brown phase but red was very prominent on the yellow larvae (Fig. 13A), and the brown stripes were very distinct on the brown larvae (Fig. 13B). Yellow-green larvae (Fig. 13C) had the green macular pattern. As the larvae matured, some transformed to the green color phase (Fig. 13D). Most yellow larvae pupated as such or became transformed to the reddish color pattern (Fig. 13E).

In other insect species, several workers (Dadd 1961, Clark 1971, Rothschild *et al.* 1975) were able to obtain normally colored larvae from diets supplemented with lutein and/or carotene. They concluded that the color aberrations of hoppers (Dadd 1961), *cecropia* larvae (Clark 1971), and cabbage moth (Rothschild *et al.* 1975) were mainly due to the absence of these pigments from the diets.

Our investigations, on the other hand, revealed that B-carotene may have been responsible for the intensification of the colors of the longitudinal stripes as well as the appearance of several color forms in the earworm. However, even with a high concentration of this pigment, the all-green phase noted on larvae reared on tobacco leaves was never obtained. Thus, although B-caro-

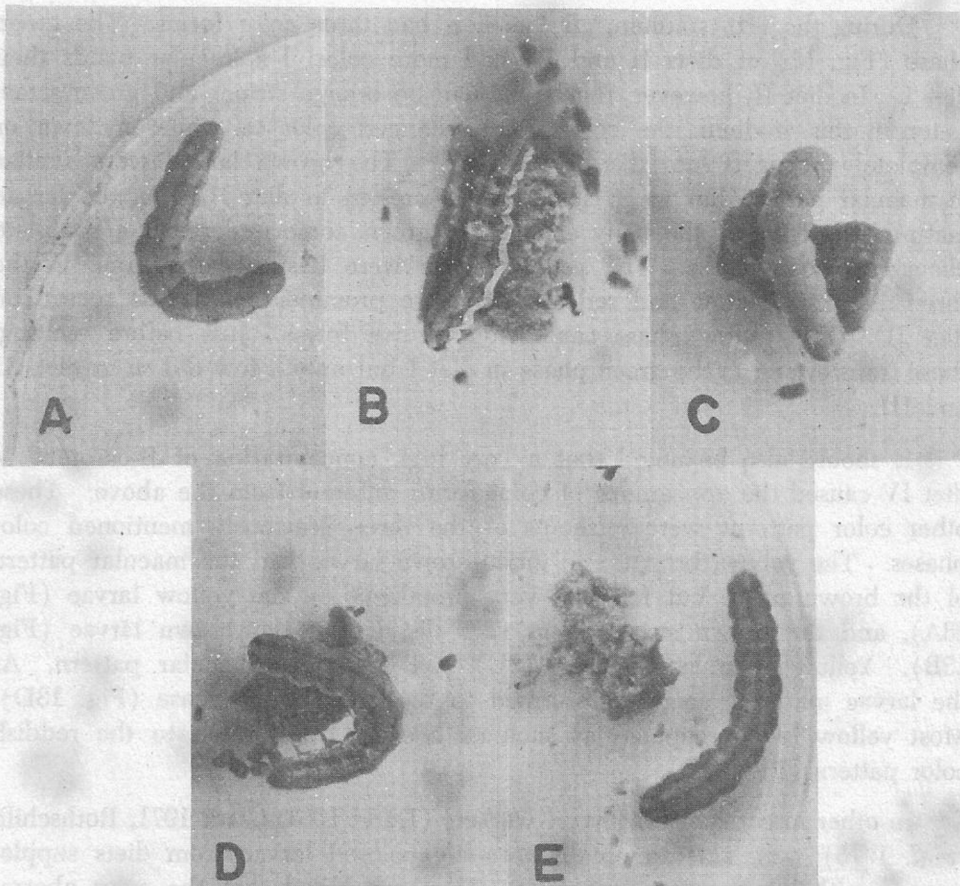

Fig. 13. Different color forms of sixth-instar larvae reared on diet IV, A, yellow; B, brown; C, reddish; D, yellow-green; E, greenish-brown.

tene was abundant in leaves, the appearance of the green phase was possibly not dependent on this pigment alone but probably caused by the interaction of the different pigments ingested by the larvae. Its effects, on the other hand, may have been masked by the pigments present in mungo.

SUMMARY AND CONCLUSION

Studies were undertaken to determine the effects of four host plant species (corn, cotton, tomato, and tobacco) and Deang's formulated diet using green mungo bean seeds on the coloration of *Helicoverpa armigera* (Hubner). The role of B-carotene on larval pigmentation was also investigated. Distinct color differences were exhibited by the larvae reared on the various natural hosts. Those fed with artificial diets were basically similar in color to corn-reared larvae. The addition of different concentrations of B-carotene in the diets either precipitated the earlier appearance of the various larval color forms or caused intensification of both dorsal and stigmatal pigmentation. These results, strongly suggest that the color of caterpillars was largely due to plant pigments derived from food. When the larvae were reared on the various plants under controlled conditions, the relationship between larval coloration and nutrition became obvious.

Incidental to our study was the finding that apart from *H. armigera,* tobacco was also attacked by *H. assulta.* Hence, the previously identified tobacco budworm, *H. armigera,* consists of two distinct species, further confirming the presence of *H. assulta* in the country.

LITERATURE CITED

CAPCO, S.R. 1957. A list of plant pests of the Philippines with special reference to field crops, fruit trees and vegetables. Philipp. Jour. Agr. 1: 7-80.

CATAN, G.O. 1958. The biology of the corn earworm, *Heliothis armigera* (Hubner) (Agrotidae, Lepidoptera) with a consideration of its natural enemies in the Philippines. (Unpublished B.S. thesis, University of the Philippines, College of Agriculture).

CHAMBERLAIN, F.S. and J.H. TENHET. 1926. The seasonal history and food habits of the tobacco budworm, *Heliothis virescens* Fab., in the southern tobacco growing region. J. Econ. Entomol. 19: 611-614.

CLARK, R.M. 1971. Pigmentation of *Hyalophora cecropia* larvae fed artificial diets containing carotenoid additivies. J. Insect. Physiol. 17: 1593-1598.

CURL, A.L. 1961. The xanthophylls of tomatoes. J. Food Sci. 20: 106.

DADD, R.H. 1961. Observations on the effects of carotene on the growth and pigmentation of locusts. Bull. ent. Res. 52: 63-81.

DAHLMAN, D.L. 1969. Cuticular pigments of tobacco hornworm, (*Manduca sextra*) larvae: effects of diets and genetic differences. J. Insect Physiol. 15: 807-814.

DEANG, R.T. 1971. Life history and morphology of *Helicoverpa armigera* (Hbn) reared on synthetic diet and topical toxicity of five organic insecticides to the insects. (Unpublished M.S. thesis, University of the Philippines, College of Agriculture).

GOODWIN, T.S. and S. SRISUKH. 1951. Biochemistry of locusts. 5. The green pigment of the hemolymph and integument of solitary locusts. (*Locusta migratoria migratoides*). Biochem .J. 48: 199-203.

HARDWICK, D.F. 1965. The corn earworm complex. Mem. ent. soc. Can. 40, 247 pp.

ISELEY, D. 1935. Relation of hosts to abundance of the cotton bollworm. Arkansas agr. Expt. Sta. Bull. 320.

LUGINBILL, P. and A.H. BEYER. 1921. Corn earworm as an enemy of vetch. USDA Farmers' Bull. 1206.

MALLIA, K., C. SUBBARAYAN and H. R. CAMA. 1967. Carotenoids in *Lycopersicon esculentum* (tomatoes). J. Nutr. Dietet. 4: 277.

MOSHER, J.B., F.W. QUACKENBUSH and J.W. PORTER. 1952. The carotenoids of corn seedlings. Arch. Biochem. Biophysics. 35: 287-296.

MUMMERY, R.S. and L.R.G. VALADON. 1974. Carotenoids of the lily beetle (*Lilioceris lilii*) and of its food plants. J. Insect Physiol. 20(2): 429-434.

———, M. ROTHSCHILD and L.R.G. VALADON. 1975. Carotenoids in two silk moths, *Saturnia pavonia* and *Actia luna*. Comp. Biochem. Biophysics 50B: 23-28.

NOVERO, I.P. 1972. Biotypes of *Aphis craccivora* Koch based on the biological and morphological differences among the bean aphids on five host plant species (Unpublished M.S. thesis, UPCA, College, Laguna).

OTANES, F.Q. and L.T. KARGANILLA. 1940. Insects and other pests of corn. Philipp. Jour. Agr. 11(4): 403-430.

QUAINTANCE, A.L. and C.T. BRUES. 1905. The cotton bollworm. USDA Bur. Ent. Bull. 50.

ROTHSCHILD, M., B GARDINER, G. VALADON and R. MUMMERY. 1975. Lack of response to background color in *Pieris brassicae* pupae reared on carotenoid-free diet. Nature 254: 592-594.

SILAYAN, H.S. 1938. Annual report of the Director of Plant Industry for the fiscal year ending Dec. 31, 1937. 182 pp. 23 pls. Manila, Philipp. Dept. Agric. Comm. 1938. (Abstracted in RAE 27A: 451).

UICHANCO, L.B. 1959. Philippine Agriculture. Field Crops. Vol. I. 922 p. College, Laguna, University of the Philippines, College, Laguna.

VALADON, L.R.G. and R.S. MUMMERY. 1969. The effect of light on carotenoids of etiolated mungbean seedlings. J .exp. Bot. 20: 732-742.

WHITFIELD, D.M. and K.S. ROWAN. 1974. Changes in the chlorophyll and carotenoids of leaves of *Nicotiana tabacum* during senescence. Phytochemistry 13(1): 77-83.